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## Ex ante assessment of the returns to livestock disease control in Indonesia

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### Abstract

Agriculture's importance in the process of economic growth highlights the role of sustained advances in farm production practices by improving the quantity and quality of farm products. In this context, investment in improved agricultural technology continues to be an important avenue of assistance to the developing countries. However, the increased resource pressures facing both aid donors and recipients have emphasised the need for the prior assessment of the potential benefits of aid projects to assist effective aid planning and management. Here, the main requirements are to establish viable project goals for translation into effective programmes, to predict the likely project impacts, and to evaluate the potential benefits and costs of adopting the project's outcomes. An ex ante assessment of assistance in controlling a major livestock disease in Indonesia's eastern islands is described in this paper. The annual net benefits from controlling this disease ranged between \$A0.45 and \$A2.5 million according to the mortality rate reduction achieved. The benefits were shared between beef producers and consumers according to the market elasticity conditions assumed.

### 1. Introduction

Investment in agricultural research and development is a major form of assistance to the developing countries. Where this investment results in increased agricultural productivity, it is likely to have national implications because of agriculture's central role in economic development and its importance as a determinant of long-term economic growth (Mellor, 1986). The

growth in funding for this purpose has introduced a donor demand for complementary economic assessments (Davis, Oram and Ryan, 1987). Hardaker, Anderson and Dillon (1984) identified a requirement of aid donors and recipients for estimates of the returns from such investment and the need for the prior demonstration of its likely benefits to facilitate resource allocation. They made the distinction between the roles of ex ante analysis in guiding technology planning and management and of ex post evaluations of past investment to facilitate future policy formulation. This distinction is important because the end uses of these applications differ, and they also have

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different assessment and data requirements. Because the need for *ex ante* assessment is largely attributed to increasing demands on a limited aid budget, it assists the process of maximising aid effectiveness (Australian Government, 1985).

New production technology adoption may improve a farm's productivity by either reducing its unit output costs or increasing its production capacity. These gains are likely to be sustainable where technology adoption results in the maintenance of improved production practices. Productivity improvements in livestock production can have significant economic benefits in the developing countries because their income elasticities of demand for livestock products are high relative to other major food groups. Sarma and Yeung (1985) have reported income elasticities of demand for livestock and cereal products of 0.63 and 0.16 over all developing countries. Because these countries are anticipated to face future meat supply–demand imbalances as incomes rise, an annual 5.1% growth in domestic meat production was required to meet southern Asia's projected annual per capita meat demand of 8.7 kg by the year 2000. By comparison, the annual growth rate for meat production in this region was 1.8% in 1977. These trends reflect the increased assistance to improving the performance of the livestock sectors in the developing countries, which remain relatively under-developed and offer considerable scope for effecting productivity gains.

The livestock sector in the eastern islands of Indonesia has become a focus of government attention because it is an important source of breeding stock and meat into the rapidly expanding urban markets. National per capita meat consumption has doubled over the last 20 years to 5.5 kg per annum. The eastern islands region<sup>1</sup> is important for livestock production because the dry climate makes it generally unsuited to cropping. About 30% of the Indonesian cattle and buffalo populations are in this region. Livestock

(particularly cattle) are regarded as a means of improving the living standards of the predominantly subsistence farmers in the drier areas. However, livestock productivity is significantly affected by many major animal diseases including Haemorrhagic Septicaemia, Malignant Catarrhal Fever and Brucellosis in cattle and buffalo, Newcastle Disease in poultry, and parasitism in all livestock species. Major productivity losses result from animal mortality but these are exceeded by morbidity-induced losses from the non-fatal diseases. With certain diseases, economic costs also result from the government restrictions on the transfer of breeding stock from disease-affected areas, while other costs include the reductions in the social and religious values of animals, and in their importance as store capital (Winrock, 1986).

Haemorrhagic Septicaemia (HS) is a highly infectious respiratory disease of cattle, buffalo and goats, and results in the rapid death of approximately 80% of affected animals. While survivors develop a strong immunity, a high HS mortality rate in village systems in which farmers own only five to six breeding animals on average makes HS a most economically important disease. Apart from being a major income source, these livestock provide breeding stock for government redistribution programmes throughout Indonesia. HS has a high disease status in the eastern islands region for these reasons and its control is considered by the Government of Indonesia (GOI) to be essential from both the individual farmer and social welfare standpoints. Official records indicate a low incidence of HS but specialist opinion suggests that these data do not reflect the true status of the disease since precise disease identification is difficult and the lack of laboratory diagnosis results in many cases not being reported. Experts consider that on average, 5% of young animals die every year from HS, but mortality is increased to between 10% and 30% in an outbreak. Young animals are more susceptible than old animals and buffaloes are more affected than cattle.

In 1991, the GOI allocated funds for a three-year HS mass vaccination programme on Sumbawa following the success of a similar programme on Lombok. The GOI's involvement

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<sup>1</sup> This region comprises Nusa Tenggara Barat (NTB) which incorporates Lombok and Sumbawa islands, and Nusa Tenggara Timur (NTT) which includes the islands of Flores, Sumba and West Timor.

arose because farmers were considered to be undertaking a socially deficient level of HS control because of the relatively high cost and a general lack of experience in disease recognition and prevention. Further, there were other national disease control policies whose implementation depended on the outcome of the HS programme. This programme aims to vaccinate some 350 000 animals over six months old, of which 70% are cattle and buffalo. An economic analysis of this programme estimated benefit–cost ratios between 0.7:1 and 3.5:1 and corresponding net present values of \$A0.1 and \$A0.652 million (at 10% discount) for various mortality rate reductions (Patrick and Vere, 1992). Because HS presents a similar problem to the beef production systems throughout the region, the GOI is likely to consider extending this programme after the Sumbawa experience.

The following sections describe an *ex ante* assessment of the potential economic impacts an expanded HS control programme throughout the eastern islands of Indonesia which include the Bali and Sulawesi regions. The main objective of this assessment is to determine the levels and distribution of potential benefits from the expanded control programme.

## 2. Methods

Anderson and Parton (1983) considered that the *ex ante* assessment of agricultural research and technology was analogous to an investment analysis in which the future flows of diverse and uncertain benefits and costs had to be projected. Complexities were introduced by the need to elicit potential outcomes and adoption levels, the public good nature of the programme, and in identifying its eventual beneficiaries. Of the various *ex ante* assessment techniques (such as scoring models, mathematical programming models, production function and system approaches, and benefit–cost methods), benefit–cost analysis was considered to be the most practical. Where the main concern of this type of assessment is to evaluate the social benefit changes from technology adoption, a value measure is required. In

benefit–cost analysis, Randall (1980) suggested that economic surplus was the most appropriate measure. Norton and Davis (1981) regarded the *ex ante* estimation of benefit–cost ratios and rates of return to proposed research as being conceptually similar to technology impact assessments based on economic surplus measurements.

In their various forms, models embracing the benefit–cost and economic surplus approaches have had wide application in research evaluation and technology impact assessment (Antony and Anderson, 1991). These models assume that new technology adoption increases production which, under certain conditions, can be translated into measures of benefits and their shares between producers and consumers. When the programme costs are also considered, the estimated benefits can be projected over time and discounted to present-day values to yield the social net present values, benefit–cost ratios and internal rates of return. The two approaches are therefore closely allied in the *ex ante* sense and this association is strengthened where the distribution of potential benefits is an important consideration.

The economic impact of livestock disease control depends on the disease attributes (virulence, morbidity and mortality effects), the characteristics of the production systems affected and the nature of the market for the disease-affected product. These considerations indicate that the main economic components of the HS control programme assessment are: (a) the market impacts in terms of the level and distribution of benefits from the increased beef supplies post control, and (b) the timing of the benefits and costs over the programme period.

The first component was assessed using a single commodity economic surplus model which assumed that the expected benefits from HS control were equivalent to the value of loss prevented over the beef animal population throughout the region. HS control increases beef productivity by reducing per unit production costs, and control was expected to generate economic benefits in terms of the economic surplus changes resulting from the beef supply increase. Because there have been no quantitative studies of the beef markets in this region, two market situations

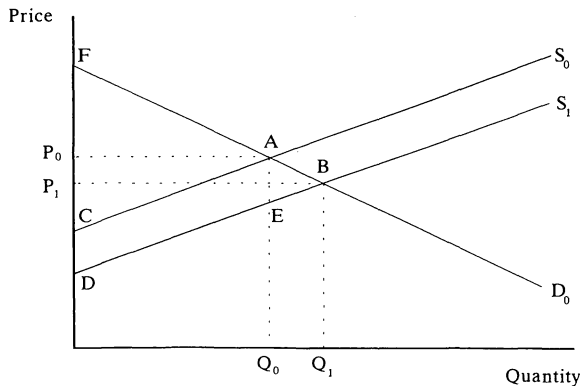


Fig. 1. Market situation 1: Normally sloping supply and demand curves.

were considered based on different elasticity conditions. While the elasticity values have little effect on the overall benefit levels from HS control, they directly influence benefit shares and this is an important consideration in the sponsorship of the control programme.

Market situation 1 is illustrated in Fig. 1 with normally sloping supply and demand curves under which the expanded supply of beef from HS control reduces beef prices and results in economic surplus increases to both producers and consumers. This market scenario assumes a closed economy equilibrium situation because beef animals sold in the region are either exported live or mainly retained for breeding and slaughter, and breeding stock face the same market prices. Beef production from cattle and buffalo is  $Q_0$  for which consumers pay a price of  $P_0$ . Producers have an economic surplus equivalent to  $P_0AC$  while consumer surplus is the area  $P_0AF$ . The adoption of HS control technology reduces per unit production costs and shifts the beef supply curve outwards to  $S_1$ , resulting in greater output at a lower price. Here, the beef demand curve  $D_0$  remains stationary since the additional output is assumed to face the same demand as all other beef. The area of economic surplus is now  $FBD$  comprising increased consumers' and producers' surpluses of  $P_1BF$  and  $P_1BD$ , respectively, which represent the impact of the HS control technology adoption on both consumers and producers.

The change in economic surplus is equivalent to the benefits of production technology adoption. It is given by the area  $CABD$ , the difference between the areas  $FAC$  and  $FBD$ . The incremental benefit area  $CABD$  incorporates the production cost reductions for the initial output  $Q_0$  (the area  $CAED$ ), and the area  $ABE$  which is the economic surplus change from the extra production at  $S_1$ , net of production costs. Where the supply curve shift is parallel so that the vertical distance between the two supply curves is constant, the changes in the economic surplus areas from the adoption of HS control are given (following the approach of Alston, 1991) as:

– change in consumers' surplus

$$\Delta CS = P_0 Q_0 Z (1 + 0.5 Z \eta) \quad (1)$$

– change in producers' surplus

$$\Delta PS = P_0 Q_0 (K - Z) (1 + 0.5 Z \eta) \quad (2)$$

– change in total surplus ( $\Delta CS + \Delta PS$ )

$$\Delta TS = P_0 Q_0 K (1 + 0.5 Z \eta) \quad (3)$$

where  $P_0$  and  $Q_0$  are the initial equilibrium beef market-clearing price and quantity,  $Z$  is the percentage reduction in price from the beef supply shift defined as  $Z = K\epsilon/(\epsilon + \eta)$ ,  $K$  is the vertical supply shift defined as the unit cost difference before and after HS control expressed as a proportion of the beef farm price, and  $\epsilon$  and  $\eta$  are the price elasticities of supply and demand for

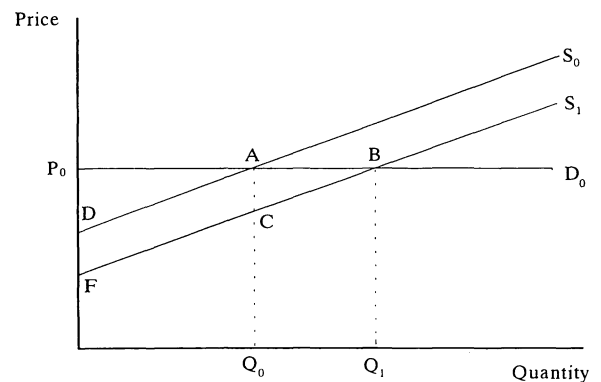


Fig. 2. Market situation 2: Perfectly elastic demand.

beef (the derivation of Eq. 3 is given in the Appendix).

Market situation 2 assumes a highly elastic beef demand (Fig. 2) under which prices are not affected by the post-control production increases. The reasoning here is that Indonesian per capita meat consumption is low (about 5 kg per year) and meat is therefore highly substitutable in consumption. Under this market situation, the beef demand elasticity ( $\eta$ ) has an infinite value ( $-\infty$ ), the beef price reduction ( $Z$ ) approaches zero, and producers derive all the benefits from HS control because the coincidence of the beef price line and demand curve means that there is no consumers' surplus. The change in total (producers') surplus is the area DABF which is given as:

– change in total and producers' surplus

$$\Delta TS (= \Delta PS) = kQ_0 + 0.5P_0[(\epsilon Q_0 k^2)] \quad (4)$$

where the beef supply shift ( $k$ ) in this perfectly elastic demand situation is expressed as the absolute monetary reduction in the variable unit costs of beef production after control. Eqs. (1) to (4) were solved to estimate the benefits in terms of the changes in economic surplus from the HS control programme for various mortality rate reductions. These reductions and the assumed adoption rate for HS control are the critical parameters in the analysis. Because most HS-affected animals quickly die, morbidity effects are minimal and these were not considered further. Mortality rate reductions of 2%, 6% and 10% were assumed because of difficulties in eliciting a single estimate which the experts considered to accurately represent the effects of the disease in all areas. Adoption of HS control was assumed to be total because of the GOI's past successes in implementing HS control programmes in other areas. The current programme was anticipated to have similar success through a high level of adoption and subsequent eradication over three years.

Beef production levels were estimated from gross margin budgets which calculated the annual quantities of beef marketed as being 52 and 77 kg per breeding cow and buffalo, respectively. Regional beef quantities before and after control

were then calculated from the annual changes in output per breeding animal and the cattle and buffalo populations (these were 3.1 and 0.98 million in 1991). Regional prices and livestock census data were obtained from statistics collected by the GOI's Directorate General of Livestock Services (DGLS, 1991), while the beef supply shift parameter ( $K$  proportional and  $k$  absolute) was derived from gross margin budgets of standard beef production systems for average mortality rate reductions (Patrick and Vere, 1992). Animal sales (heifers, steers and culls) was the income component but draught power and manure contributed about one-third of the annual income estimates. Because the budgets only included the variable production costs, the costs of fixed and capital items and labour, management and land rental were not considered. The main effects of this omission has almost certainly been to underestimate the real extent of the cost savings and hence, the benefits of the HS control programme.

The most difficult data to obtain concerned the regional beef supply and demand conditions. There are conflicting estimates of meat demand parameters in Indonesia and other developing Asian countries. Indonesian meat demand elasticities range from  $-1.09$  (Deaton, 1990) to  $-0.53$  (Sabrani, 1982), while those for composite meat, poultry and dairy consumption average about  $-0.91$  (Johnson, Meyers, Jenson, Teklu and Wardhani, 1987). There is less evidence of meat supply response to price changes. One study by Davis, Oram and Ryan (1987) recorded large supply price elasticities for sheep and goat meat which is a close consumption substitute for beef in Asia. A range of elasticities was used for the first market situation. Demand elasticities ( $\eta$ ) from unity to  $-0.53$  followed the Deaton (1990), Johnson et al. (1987) and Sabrani (1982) studies, while the supply elasticity ( $\epsilon$ ) ranged between 1.5 (after Davis et al. for sheep-goat meat) and a relatively inelastic estimate of 0.5 for comparison.

To assess the second component, the estimated benefits and costs of the HS control programme were projected over ten years and discounted to calculate the net present value, internal rate of return and benefit–cost ratio investment criteria. The benefits were assumed to be

Table 1

Estimates of economic surplus change from the control of HS in Eastern Indonesia at varying mortality rate reductions (\$A million)

	2% Mortality reduction			6% Mortality reduction			10% Mortality reduction		
	$\Delta CS$	$\Delta PS$	$\Delta TS$	$\Delta CS$	$\Delta PS$	$\Delta TS$	$\Delta CS$	$\Delta PS$	$\Delta TS$
Market situation 1									
(i) $\eta = 1.5, \varepsilon = 1.5$	0.22	0.22	0.45	0.73	0.73	1.46	1.46	1.25	2.50
(ii) $\eta = 1.5, \varepsilon = 0.5$	0.11	0.34	0.45	0.37	1.09	1.46	0.62	1.87	2.50
(iii) $\eta = 0.53, \varepsilon = 1.5$	0.33	0.12	0.45	1.08	0.38	1.46	1.84	0.66	2.50
(iv) $\eta = 0.53, \varepsilon = 0.5$	0.22	0.23	0.45	0.71	0.75	1.46	1.21	1.29	2.50
Market situation 2									
(i) $\varepsilon = 1.5$	–	0.45	0.45	–	1.44	1.44	–	2.45	2.45
(ii) $\varepsilon = 0.5$	–	0.45	0.45	–	1.43	1.43	–	2.41	2.41

equivalent to the changes in economic surplus from the control programme for the range of mortality rate reductions. Programme costs were assessed on a per cow and buffalo vaccinated basis and included supplying and administering the vaccine, and the support capital provided under the EIVSP (Patrick and Vere, 1992). This gave a cost of \$A0.38 per beef animal vaccinated. The projected benefits and costs were discounted at a rate of 6% real.

### 3. Results

The estimated changes in economic surplus from HS control are in Table 1 and represent the expected annual net benefits from the effective control of HS throughout the eastern islands region. In the first market situation, the economic surplus gains were between \$A0.45 and \$A2.50 million according to the mortality rate reduction

achieved. Both beef producers and consumers gained economic surplus in proportion to the assumed beef market elasticities. Producer gains were about double those received by consumers where the beef price elasticity of supply was low. These benefit shares were reversed in favour of beef consumers under a price elastic supply and inelastic demand. Contrary to expectations, the second market situation resulted in similar total economic surplus gains even though beef consumers did not derive any benefit from the increased beef production under the perfectly elastic demand. This situation was expected to yield larger total benefits because of the apparent geometrical differences in the areas of total surplus change between Figs. 2 and 1 (DABF being larger than ABE), and also because the supply shift measure  $k$  (absolute) is numerically greater than  $K$  (proportional).

The benefit–cost criteria (Table 2) indicate that the mortality rate reduction in beef breeding stock and progeny post HS control needs to be greater than 2% for the vaccination programme to yield positive returns.

Table 2

Benefit–cost criteria for HS control in Eastern Indonesia

	2% Mortality reduction	6% Mortality reduction	10% Mortality reduction
Market situation 1			
NPV (\$A million) <sup>a</sup>	–1.78	5.11	12.17
IRR (%)	–13.0	35.5	93.8
B/C ratio <sup>a</sup>	–1.63:1	2.05:1	3.52:1
Market situation 2			
NPV (\$A million) <sup>a</sup>	–1.78	5.11	11.56
IRR (%)	–13.0	35.5	88.3
B/C ratio <sup>a</sup>	–1.63:1	2.05:1	3.39:1

<sup>a</sup> Discounted at 6% real.

### 4. Discussion

The returns from HS control reflect the economic impact of this and other diseases on Indonesia's livestock sector. The estimated benefits are significant despite the relatively small reductions in unit beef production costs (0.6–3.3%) and hence, beef supply curve shifts (defined in these terms) that can be attributable to HS con-

trol. While the estimated benefits represent only about 2% of the value of livestock production in the region (in 1992 values), it was considered that there were other unquantified benefits resulting from HS control which would be considerably greater than those which could be determined (Muthalib, personal communication, 1992). The importance of livestock to smallholders means that mortality and illness have severe economic effects through factors such as the loss of draught power and in the reduced social and religious values of animals as store capital. These considerations are reinforced by the observation that market price is often a minor factor in the farmers perceived value of cattle and buffalo (Winrock, 1986).

These types of assessments are indicative of the growing requirement of governments and the aid organisations for economic evaluations in assisting funding decisions in animal health improvement in the developing countries. HS is one of many important livestock diseases to which the GOI has undertaken a commitment to control. However, the demonstration of economic returns to the control of a specific disease is only one input in making resource allocation decisions within the overall government budget for controlling disease and other forms of investment in the agricultural sector. Other considerations (political and strategic) are usually also important factors which explains why at times low-benefit programmes may attract funding while those with potentially much higher returns may not. Hence, the level of programme evaluation required in these situations extends beyond the identification and comparison of potential benefits and costs. Also required are indications of the social and demographic implications and the ability of the existing institutional framework to accommodate the project proposal.

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## Appendix

*Derivation of economic surplus formulae for a single-commodity market in a closed economy model.* The following formulae indicate the derivation of the measure of economic surplus change following the adoption of a production increasing technology such as livestock disease control (as is illustrated in Fig. 2). Prior to technology adoption, the supply and demand for a single commodity in a closed economy are given:

$$Q = a + bP \quad (A1)$$

$$Q = c - dP \quad (A2)$$

where  $P$  and  $Q$  are the equilibrium price and output, and  $a$ ,  $c$  and  $b$ ,  $d$  are the intercept and slope coefficients for the supply and demand functions. The equilibrium price  $P_0$  is determined by equating supply and demand while the equilibrium quantity  $Q_0$  is derived by substituting  $P_0$  into either (A1) or (A2):

$$P_0 = (c - a)/(b + d) \quad (A3)$$

$$Q_0 = (ad + bc)/(b + d) \quad (A4)$$

Following technology adoption, the supply function (A1) is modified to incorporate the supply shift parameter  $k$  measured in absolute terms:

$$Q = a + bk + bP \quad (A5)$$

which can be equated with the demand function (A2) to determine the post-adoption equilibrium price  $P_1$  for substitution into either (A1) or (A2) to determine the post-adoption equilibrium quantity  $Q_1$ :

$$P_1 = [(c - a)/(b + d)] - [(bk)/(b + d)] \quad (A6)$$

$$Q_1 = [(ad + bc)/(b + d)] + [(bdk)/(b + d)] \\ = Q_0 + [(bdk)/(b + d)] \quad (A7)$$



The change in total economic surplus from technology adoption based on an absolute measure of  $k$  is given:

$$\Delta ES = kQ_0 + 0.5k(Q_1 - Q_0) \quad (A8)$$

When  $Q_1$  from (A7) is substituted, (A8) becomes:

$$\begin{aligned} \Delta ES &= kQ_0 + 0.5k[(bdk)/(b+d)] \\ &= kQ_0 + [(bdk^2)/2(b+d)] \end{aligned} \quad (A9)$$

The price elasticities of supply ( $\epsilon$ ) and demand ( $\eta$ ) are both defined as:

$$\epsilon \text{ and } \eta = (dQ/dP)(P_0/Q_0) \quad (A10)$$

From the supply (A1) and demand (A2) functions, the slope coefficients are  $b$  and  $d$ , respectively, and hence:

$$\epsilon = b(P_0/Q_0) \quad \text{or} \quad b = \epsilon(Q_0/P_0) \quad (A11)$$

$$\eta = d(P_0/Q_0) \quad \text{or} \quad d = \eta(Q_0/P_0) \quad (A12)$$

When these elasticity terms are substituted into (A9), the expression for the economic surplus change based on the absolute value of the unit production cost reduction from technology adoption ( $k$ ) becomes:

$$\begin{aligned} \Delta ES &= kQ_0 + [(\epsilon\eta(Q_0/P_0)k^2)/2(\epsilon + \eta)] \\ &= kQ_0 + [(\epsilon\eta Q_0 k^2)/2P_0(\epsilon + \eta)] \end{aligned} \quad (A13)$$

However, Fig. 2 (after Alston, 1991) is based on a proportional vertical supply shift where  $k$  is expressed as a proportion of the initial equilibrium price  $P_0$ <sup>2</sup>. The formula for total economic surplus change based on a proportional supply shift measure ( $K$ ) which is defined as  $K = k/P_0$  (or  $k = KP_0$ ) can be derived from (A13) as:

$$ES = KP_0Q_0 + [(\epsilon\eta(Q_0/P_0)(KP_0)^2)/2(\epsilon + \eta)]$$

$$\begin{aligned} &= KP_0Q_0 + [(\epsilon\eta(Q_0P_0K^2))/2(\epsilon + \eta)] \\ &= KP_0Q_0[1 + (\epsilon\eta K)/2(\epsilon + \eta)] \\ &= P_0Q_0K[1 + 0.5(\eta Z)] \end{aligned} \quad (A14)$$

where  $Z = \epsilon K/(\epsilon + \eta)$ .

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<sup>2</sup> There is some debate as to whether the supply shift should be measured absolutely or proportionally in this market situation (Davis and Bantilan, 1991).

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