AN ECONOMIC EVALUATION OF THE IMPACTS OF FUNGI AND AFLATOXINS

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Abstract

This paper first describes five important impacts of fungi and aflatoxins, then it develops an economic model for use in the evaluation of the impacts of fungi and aflatoxins and in the economic assessment of fungi and aflatoxin research projects.

The five impacts that the paper deals with are:

- *fungi and aflatoxins lead to quality deterioration in products;*
- *fungi and aflatoxins cause spoilage of agricultural products;*
- *some countries prohibit the importation of some fungi and aflatoxin contaminated output;*
- *use of aflatoxin contaminated produce as feed increases mortality rates and reduces feed to weight conversion rates in livestock with magnified effects in chickens, ducks, egg layers, and pigs, and*
- *use of aflatoxin contaminated produce as food over a long time period leads to mutagenic and carcinogenic effects on humans.*

Section 2 introduces the five important impacts of fungi and aflatoxins. Section 3 then presents a model dealing with these impacts, suggests ways to calibrate the model and makes some concluding remarks.

A conference paper : The 38th Australian Agricultural Economics Society Conference, Wellington, New Zealand, February 1994

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1 INTRODUCTION

Fungi are a diverse[1] group of organisms ranging from simple single cells through to complex structures. However, food spoilage is usually associated with two groups designated as yeast and moulds (Robinson, 1983).

Extensive research has identified the most important physical and chemical factors which influence grain damage by fungal growth. Of these, environmental conditions, temperature, humidity, oxygen and carbon dioxide tensions seem to play a decisive role in determining fungal growth and toxin production (FAO, 1983). Pitt and Hocking (1991) have indicated that the dominant factor is water activity - a chemical concept which quantifies the relationship between moisture in foods and the ability of micro-organisms to grow on them. Pitt and Hocking conclude that 'Dry a product quickly and keep it dry' remains the most effective method for ensuring fungi do not invade stored products.

When products are not dry while in storage, fungi attack them and fungal growth leads to reduction in the quantity and weight of grains; deterioration in quality of produce for processing and in food value; and the production of aflatoxins.

1.1. Why focus on aflatoxins ?

Appendix I gives examples of commodities that are susceptible to fungal attack, and lists the fungi that are often responsible for damage and quality deterioration of grains. Appendix I lists the following as mycotoxigenic fungi: *Aspergillia, Penicillia, Fusaria* and *Alternaria*. These organisms produce various toxic metabolites. While Appendix I includes field and spoilage fungi as well, the focus of this paper is on a sub-set of mycotoxigenic fungi producing aflatoxins in grains.

Appendix II provides some descriptive details about aflatoxins. While aflatoxins are not the only mycotoxins in foods and feed, they are the more important mycotoxins not only in the countries that are in this study, but in the rest of Asia, Africa and Latin America. For example, Von Egmond(1991, p. 200) notes that:

> "At the time of writing there were about 60 countries that had specific regulations or detailed proposals for regulations on mycotoxins. Most of the existing mycotoxin regulations concern aflatoxins and, in fact, all countries with mycotoxin regulations have tolerances for aflatoxins in foods and/or animal feedstuffs."

1.2 Why focus on maize and peanuts in Indonesia, Philippines and Thailand?

The next stage in this project is to use the economic model to estimate the costs of the impacts of fungi and aflatoxins attributable to the use of aflatoxin contaminated maize and peanuts as food and feed for livestock and poultry in three Southeast Asian countries (Thailand, Philippines and Indonesia). Thus most of the paper has an emphasis on maize and peanuts and on the three Southeast Asian countries.

Amongst commodities which are susceptible to fungal attack and aflatoxin contamination, maize and peanuts are by far the most important in monetary value (Pitt, 1993). Maize and groundnuts have each a wide range of different uses as foods and feedstuffs. Reddy, Nigam and Jambunathan (1992) provided the following summary of the multiple uses of groundnuts.

> The groundnut plant comprises approximately 10 percent roots, 45 percent vines and leaves, and 45 percent pods. The roots and nodules add 125-178 kilograms of nitrogen per hectare to the soil through nitrogen fixation. The vines and leaves are used as green, dry or silage fodder and as fertiliser and fuel. Groundnut husk constitutes about 13 percent of the whole plant and is put to several uses. The whole seed, which constitutes 32 percent of the total mass of the plant, is used for oil and food. The groundnut oil is mainly used for cooking, and in industry for the preparation of several domestic products. The protein rich cake or meal after oil extraction is usually fed to livestock or used as fertiliser. However, in recent years, with proper processing, the meal is being utilised for making products such as hot cakes, biscuits, and baby or invalid foods.

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1 As an indication of the diversity of fungi, in 1991-92, analysis of 1328 samples from field, farm, storage and retail sources in Indonesia and Philippines led to the isolation and identification of approximately 6800 fungi (see ACIAR, 1992). Samples comprised mainly maize, peanuts, rice (both paddy and milled), beans of various types, with smaller numbers of cashews, kemiri nuts and spices.

The economic and social costs of using aflatoxin-contaminated corn and peanuts depends on how consumers of these products use them in the different countries. Appendix IV provides some information on both the production and usage of corn and peanuts in Indonesia, Philippines and Thailand. Table IV.1 to IV.3 summarise information on the supply and demand side of corn and peanuts in Indonesia, Philippines and Thailand. Appendix IV indicates the extent to which people in the three countries use these two products as food. Thus Appendix IV provides data on exposure to aflatoxins in maize and peanuts in Indonesia, Philippines and Thailand. This data is necessary in estimating the human health effects of aflatoxin in terms of primary liver cancer. Pitt and Hocking[2] estimate that about 90 percent of aflatoxins in the Indonesia, Philippines and Thailand come from maize and peanuts.

1.3 Outline of the paper

This paper first describes five important impacts of fungi and aflatoxins, then it develops an economic model for use in the evaluation of the impacts of fungi and aflatoxins and in the economic assessment of fungi and aflatoxin research projects.

The five impacts that the paper deals with are:

- fungi and aflatoxins lead to quality deterioration in products;
- fungi and aflatoxins cause spoilage of agricultural products;
- some countries prohibit the importation of some fungi and aflatoxin contaminated output;
- use of aflatoxin contaminated produce as feed increases mortality rates and reduces feed to weight conversion rates in livestock with magnified effects in chickens, ducks, egg layers, and pigs, and
- use of aflatoxin contaminated produce as food over a long time period leads to mutagenic and carcinogenic effects on humans

Section 2 introduces the five important impacts of fungi and aflatoxins. Section 3 then presents a model dealing with these impacts, suggests ways to calibrate the model and makes some concluding remarks.

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2 Dr. John Pitt and Ailsa Hocking, CSIRO, North Ryde, Sydney, Personal Communication, 14 January 1994. Pitt and Hocking argue that the estimates of aflatoxin loads by Bulatao-Jaymeet. al. (1982) are wrong because they seem to have used analytical techniques which recent advances have shown to be inappropriate for assessing aflatoxin content in some products. Bulatao-Jayme et. al. (1982) interviewed 180 individuals about their dietary histories and estimated that about 20 per cent of the aflatoxin load in Philippines comes from maize and its products. The same study found that about 7 per cent of the aflatoxin load came from peanut and peanut products.

2 Five important impacts of fungi and aflatoxins in agriculture

The purpose of this section is threefold:

- to highlight the importance of each of the five impacts of fungi and aflatoxins; and
- to summarise the empirical evidence of each gleaned from the scientific literature; and
- to provide a basis for selecting the commodities to consider in estimating the cost of fungi and aflatoxins.

2.1 Product quality impacts of fungi and aflatoxins

2.1.1. Grades of produce

Instead of treating maize (corn) as a homogenous product, this paper treats maize as three different products depending on levels of aflatoxin contamination. Similarly, peanuts (groundnuts) are three different products, where each peanut product line corresponds to different levels of aflatoxin contamination.

Total aflatoxins (B_1, B_2, G_1 and G_2) in micrograms per kilogram of product give an indication of the quality of the product. Using data, from ACIAR project PN8806 (see ACIAR, 1989, 1990, 1991, 1992, 1993), on the levels of aflatoxin contamination in peanuts and maize in Southeast Asia it is possible to identify three distinct quality grades of produce:

- high quality produce - this is produce which contains no more than 50 micrograms of total aflatoxins(B_1, B_2, G_1 and G_2) per kilogram of product;
- medium quality produce - this is produce which contains more than 50 micrograms of aflatoxins but the level of aflatoxin contamination is less than or equal to 300 micrograms of total aflatoxins (B_1, B_2, G_1 and G_2) per one kilogram of product;
- low quality produce - this is produce which contains more than 300 micrograms of total aflatoxins (B_1, B_2, G_1 and G_2) per kilogram of product.

The category of high quality produce includes almost aflatoxin-free produce containing no more than 5 micrograms of aflatoxins per kilogram of product. In many countries the limit of 5 micrograms per kilogram of product is applicable to baby food products (see Appendix III). This is also the limit proposed by the European Community for dairy feeds. The reason for such a low limit for dairy feeds is to do with aflatoxin M1 in milk products. The accepted limit for aflatoxin M1 is now 0.05 micrograms per kilogram of product. The conversion ratio aflatoxin B1 in feed to aflatoxin M1 in milk is 100:1. The acceptable limit in dairy feeds to meet this standard is 5 micrograms per kilogram of dairy feeds.

The upper limit of 50 micrograms of total aflatoxins (B_1, B_2, G_1 and G_2) per one kilogram of product for high quality produce is arbitrary but it is consistent with the literature on aflatoxin regulations which specify maximum acceptable levels of aflatoxin contamination in foods and feedstuffs. Appendix III lists these limits for selected countries. Different countries have different limits. In 1991, for peanuts, maize and maize products, the maximum value for the acceptable level of aflatoxin contamination was 50 micrograms per kilogram of product (see Table III.1 and Table III.2 in Appendix III).

The upper limit of 300 micrograms of total aflatoxins (B_1, B_2, G_1 and G_2) per kilogram of product for the medium quality product is also arbitrary. The United States has a limit of 300 micrograms of total aflatoxins (B_1, B_2, G_1 and G_2) per kilogram of product for feedstuffs for adult beef cattle, sheep and goats.

In terms of aflatoxin contamination, products that contain more than 300 micrograms of total aflatoxins (B_1, B_2, G_1 and G_2) per kilogram of product are low quality products. Such products contain more than 10 times the levels of aflatoxins acceptable in some western countries and more than 60 times the levels of aflatoxins acceptable in western countries with the lowest aflatoxin tolerance levels.

Tiongson and Gacilos(1990) give some support for the approach of using postharvest aflatoxin contamination levels to define grades of farm level output when they conclude that:

> "No definite pattern of increase in the incidence of aflatoxin was observed among different stages of operation. This suggests that the grain may reach substantial level of aflatoxin contamination even at the start of off-farm operation depending on the degree by which the grains were earlier predisposed

to *Aspergillus flavus* infection and to on-farm conditions that favour aflatoxin formation during the pre harvest stages of the crop."

Table 1 summarises the relevant data on the quality of maize and peanuts in Indonesia, Philippines and Thailand.

2.1.2 *Price versus quality*

Tiongson and Gacilos (1990) observed an inverse relationship between the price of corn grits and aflatoxin content in the Philippines - that is the lower the level of aflatoxin content, the higher was the price of corn grits.

Cardino-Bermundo, Cabacungan and Bermundo (1991) concluded that moisture content and colour of the commodity determines the price of corn grain in the Philippines. Bottema and Altemeier(1990) and Wattanutchariya et. al (1991) indicate that these two factors (moisture content and colour) are the most important two factors in grain price formation in Indonesia and Thailand respectively. In these countries the grain trader (middleman) measures the two factors through sensory evaluation and visual observation[3]. Generally local grain traders and processors do not use laboratory equipment, like moisture testers, to measure grain attributes. The trader discounts wet or discoloured grain by deducting a certain percentage off the gross weight of grain. Alternatively the trader deducts a percentage off the market price to get the price per unit weight of wet or discoloured grain. The discounts increase with the wetness of grain. Cardino-Bermundo, Cabacungan and Bermundo (1991) observed the following discounts in Philippines:

- for skin dry produce, traders reduced the gross weight or the per unit weight price by a factor ranging from 5 percent to 10 percent depending on the level of dryness,
- for wet grain traders reduced the weight or price of produce by a factor ranging from 15 percent to 20 percent; and
- For damaged grain traders reduced the gross weight or the unit price of the produce by a factor ranging from 30 percent to 50 percent

A pricing regime for grains, taking into account colour and dryness that Cardino-Bermundo, Cabacungan and Bermundo (1991) observed, while not perfect[4], does take into account the factors that are important for aflatoxin contamination of grains.

Assume that the price discounts observed by Cardino-Bermundo et. al. (1991) in Philippines, apply to both maize and peanuts in Indonesia, Philippines and Thailand. If this assumption is valid then it is possible to estimate farmgate price differentials between the three grades of produce, where grades depend on level of aflatoxin contamination. Table 2 reports preliminary estimates of these farmgate price differentials for both maize and peanuts in Indonesia, Philippines and Thailand. In the table the price of medium quality grain is equal to the average farmgate price for grain. For high quality grain, the farm gat price is equal to the average price plus a ten percent premium. The price of low quality grain is about 50 percent of the medium quality grain.

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3 Dr. John Pitt and Dr. Ailsa Hocking CSIRO, North Ryde, Sydney (Personal communication 14 January 1994) noted that (a) visual observation is a very poor and unreliable way to tell whether a product contains aflatoxins or not, (b) current pricing regimes do not capture aflatoxin content of products, (c) traders may have price differentials for other attributes of grains but those price differentials are not likely to reflect aflatoxin content. On the basis of these expert observations, the rest of the paper while differenting grains by aflatoxin content does not introduce aflatoxin related grain price differentials. The paper uses the average price of maize and the average price of peanuts.

4 Cardino-Bermundo, Cabacungan and Bermundo (1991, p. 12) note that this scheme does not provide adequate incentives for dried corn: the price differential between dried and wet corn is not enough to cover the cost of mechanical drying operations. Farmers then tend to produce more wet, poor quality grain than would be the case under a pricing scheme with a larger premium for dry grain.

Table 1 The aflatoxin content of maize and peanuts in Indonesia, Philippines and Thailand.
(Percent of sample tested which had the level of aflatoxin contamination in column 2 of the table)

COMMODITY GRADES	Micrograms of aflatoxin $B_1+B_2+G_1+G_2$ per kilogram of product	INDONESIA	INDONESIA	PHILIPPINES	PHILIPPINES	THAILAND	THAILAND
		MAIZE[a]	PEANUTS[a]	MAIZE[a]	PEANUTS[a]	MAIZE[a]	PEANUTS[a]
Almost aflatoxin free -High quality (1)	µg/kg ≤ 5	68	44	44	67	53	64
High quality (2)	5 < µg/kg ≤ 10	2	1	9	5	0	4
High quality (3)	10 < µg/kg ≤ 50	8	10	27	6	18	7
HIGH QUALITY - TOTAL	0 < µg/kg ≤ 50	78	55	80	78	71	75
MEDIUM QUALITY	50 < µg/kg ≤ 300	18	12	14	6	15	14
Low quality (1)	300 < µg/kg ≤ 1000	3	11	5	9	11	7
Low quality (2)	1000 < µg/kg ≤ 5000	1	17	1	4	4	3
Low quality (3)	5000 < µg/kg ≤ 10000	0	4	0	2	0	0
Low quality (4)	µg/kg exceed 10000	0	1	0	1	0	0
LOW QUALITY - TOTAL	µg/kg exceed 300	4	33	6	16	15	10
TOTAL PERCENTAGE	Not applicable	100	100	100	100	100	100
TOTAL NUMBER OF SAMPLES	Not applicable	96	215	146	81	108	94
TOTAL PRODUCTION	TONS ('000) (1991)	6409[b]	920[b]	4655[b]	34[b]	3990[b]	164[b]

Sources: a ACIAR (1989, 1990, 1991, 1992 and 1993)
b Food and Agriculture Organisation of the United Nations (1992)

Table 2 The farmgate price of maize and peanuts given their aflatoxin content in Indonesia, Philippines and Thailand.

($ Australian per metric ton, 1991)

COMMODITY GRADES	Micrograms of aflatoxin $B_1 + B_2 + G_1 + G_2$ per kilogram of product	INDONESIA MAIZE	INDONESIA PEANUTS	PHILIPPINES MAIZE	PHILIPPINES PEANUTS	THAILAND MAIZE	THAILAND PEANUTS
AVERAGE FARMGATE PRICE							
$Australia/ Metric ton		170[a]	1493[b]	253[c]	765[d]	137[e]	1083[f]
HIGH QUALITY	μg/kg ≤ 50	187[g]	1642[g]	278[g]	842[g]	151[g]	1191[g]
MEDIUM QUALITY	50 < μg/kg ≤ 300	170[h]	1493[h]	253[h]	765[h]	137[h]	1083[h]
LOW QUALITY	μg/kg exceed 300	85[i]	747[i]	127[i]	383[i]	69[i]	542[i]

a CIMMYT(1992) reports prices in US dollars. These prices are converted to Australian dollars assuming an average 1991 exchange rate of $A1 = $US 0.7.

b Piggot, Parton, Treadgold and Hatabarat (1993, p137) estimate the wholesale price to be 1676.38 Indonesian rupiah per kilogram of peanuts. Assuming an inflation rate of 8 percent per annum, the estimate by Piggot et. al. (1993) is equivalent to 2131 Indonesian rupiah per kilogram in 1991. This is converted to Australian dollars at an exchange rate of $A1 = 1414 Indonesian Rupiah.

c CIMMYT(1992) reports prices in US dollars. These prices are converted to Australian dollars assuming an average 1991 exchange rate of $A1 = $US 0.7.

d. This is based on Bureau of Agricultural Statistics (1993) estimate of the 1991 farmgate price of 13.13 pesos per kilogram. This price is converted to Australian dollars at an exchange rate of $A1 = 17.171 Philippine pesos.

e CIMMYT(1992) reports prices in US dollars. These prices are converted to Australian dollars assuming an average 1991 exchange rate of $A1 = $US 0.7

f This estimate is based on a farmgate price of 14903 baht per metric ton in the ACIAR Economic Evaluation Unit's database on Thailand. The figure in the database is for 1988. Assuming a rate of inflation of 8 percent per annum leads to an estimate for 1991 of 18773 baht per metric ton in 1991. This is then converted into Australian dollars at the exchange rate of $A1 = 17.34 Thai baht.

g. High quality produce earns a premium of about 10 percent over the average price. However, note that domestic price signals in Southeast Asian grains markets do not adequately reflect quality differentials between produce of different levels of aflatoxin contamination. See for example, Cardino-Bermundo, Cabacungan and Bermundo (1991) and Tiongson and Gacilos (1990).

h High quality produce 3 and medium quality produce is sold at the average price. However, note that domestic price signals in Southeast Asian grains markets do not adequately reflect quality differentials between produce of different levels of aflatoxin contamination. See for example, Cardino-Bermundo, Cabacungan and Bermundo (1991) and Tiongson and Gacilos (1990)

i Low quality produce is sold at about half the average price. See Cardino-Bermundo, Cabacungan and Bermundo (1991) and Tiongson and Gacilos (1990).

2.2 Product spoilage effects of fungi and aflatoxins

It is possible for fungi to so adversely affect the sensory characteristics (such as taste, odour, texture, colour), the nutritional value and functional properties of grains that the grains become unacceptable as food or feed. In such cases, the farmer or the grain handler has to discard the grain as waste implying that some of the farm level production of food or feed does not reach the retail market. Spoilage of food and feed between the farm sector and the retail sector affects the retail prices of these products. This paper explicitly takes into account these product spoilage effects in estimating the impact of fungi and aflatoxins.

FAO(1983) uses the term damage to indicate the physical and, or mechanical spoilage of a food grain; it may reflect partial deterioration of a food on the basis of a subjective judgement but not necessarily the loss in weight. Fungi and aflatoxins lead to product damage or spoilage in three different ways.

First, fungi lead to discolouration and to deterioration in the physical appearance of grains which not only lower product quality but often make the product unacceptable for consumption as food or feed and thus of no commercial value.

Second, storage fungi change the fat acidity of grains Fatty acids contribute to characteristic off-odours and rancidity (unpleasant stale smell or taste) of stored commodities

Third, invasion of seeds by storage fungi drastically reduce germinability of the seed (FAO, 1983, p48).

Table 3 summarises some estimates of product spoilage attributable to fungi and aflatoxins Table 3 suggests that traders and users of maize and peanut grain in Indonesia, Philippines and Thailand throw away about 5 percent of the grain because of fungi and aflatoxin contamination

Table 3 Spoilage[(a)] rates of maize and peanuts given their aflatoxin content in Indonesia, Philippines and Thailand.

(Percent of farm level output, 1991)

COMMODITY GRADES	Micrograms of aflatoxin $B_1 + B_2 + G_1 + G_2$ per kilogram of product	INDONESIA MAIZE	INDONESIA PEANUTS	PHILIPPINES MAIZE	PHILIPPINES PEANUTS	THAILAND MAIZE	THAILAND PEANUTS
HIGH QUALITY	$\mu g/kg \leq 50$	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]
MEDIUM QUALITY	$50 < \mu g/kg \leq 300$	1.6[c]	1.6[c]	1.6[c]	1.6[c]	1.6[c]	1.6[c]
LOW QUALITY	μg/kg exceed 300	2.0[c]	2.0[c]	2.0[c]	2.0[c]	2.0[c]	2.0[c]
AVERAGE FOR SOUTHEAST ASIA		5[d]	5[d]	5[d]	5[d]	5[d]	5[d]

Sources:

a. Spoilage rates due to fungi and aflatoxins are probability functions where the probability that the spoilage rate takes a particular value is a function of various factors including: the variety of the product (eg yellow corn versus white corn), the time and method of harvest, the period and method of storage, the storage temperature, the moisture content, the drying method prior to storage and so on (see Maize Quality Improvement Research Centre (1992). The numbers in the table are, in a mathematical statistics sense, expected values.

b. High quality products ha[illegible] spoilage rates from fungi and aflatoxins by assumption.

c. There are no studies on [illegible]latoxin spoilage rates in Indonesia, Philippines and Thailand. The numbers in the table come from Ren-Yong, Gen-Zhang and Shan-Yang(1992). The sour[illegible] uses systems analysis to estimate various postharvest losses in the grains sector.

d. Dr John Pitt and Dr Ailsa [illegible]), North Ryde, Sydney (Personal communication, 14 January 1994)

2.3 International trade implications of aflatoxins

Many countries have aflatoxin regulations that restrict international trade in food and feed with unacceptable levels of aflatoxin contamination (see Appendix III). On the oher hand, unrestricted international trade is possible with respect to produce which contain internationally acceptable levels of aflatoxins.

There is extensive literature on the economics of protection in international trade dealing with various aspects of the two traditional approaches to protection:

- pure quotas - quantitative restrictions specifying the maximum amount of a commodity a country can export to another country; and
- tariffs - taxes on imports or exports.

This paper uses the implications from these studies to determine the international trade implications of aflatoxin contamination. For example, using results from Anderson and Neary(1992), it is possible to define shadow prices for aflatoxin regulations and estimate welfare costs of these aflatoxin regulations to the three Southeast Asian countries (Indonesia, Philippines and Thailand).

Table 4: International trade implications of aflatoxins for maize and peanut products in Indonesia, Philippines and Thailand

COMMODITY GRADES	Micrograms of aflatoxin $B_1 + B_2 + G_1 + G_2$ per kilogram of product	INDONESIA MAIZE	INDONESIA PEANUTS	PHILIPPINES MAIZE	PHILIPPINES PEANUTS	THAILAND MAIZE	THAILAND PEANUTS
ALMOST AFLATOXIN-FREE -HIGH QUALITY (1)	µg/kg ≤ 5	Unrestricted	Unrestricted	Unrestricted	Unrestricted	Unrestricted	Unrestricted
HIGH QUALITY (2)	5 < µg/kg ≤ 10	Unrestricted	Unrestricted	Unrestricted	Unrestricted	Unrestricted	Unrestricted
HIGH QUALITY (3)	10 < µg/kg ≤ 50	Restricted	Restricted	Restricted	Restricted	Restricted	Restricted
MEDIUM QUALITY	50 < µg/kg ≤ 300	Quota = 0	Quota = 0	Quota = 0	Quota = 0	Quota = 0	Quota = 0
LOW QUALITY	µg/kg exceed 300	Quota = 0	Quota = 0	Quota = 0	Quota = 0	Quota = 0	Quota = 0

2.4 Livestock health and productivity impacts of aflatoxins

Using feed which contains aflatoxins leads to a number of negative effects on susceptible livestock and poultry. CAST(1989, P11) note that:

> "The impact of fungal toxins upon animals extends beyond their obvious effect in producing death in the wide variety of animals that are likely to consume mycotoxin-contaminated grains or feeds. The economic impact of lowered productivity, reduced weight gain, reduced feed efficiency, less meat and egg production, greater disease incidence because of immune system suppression, subtle damage to vital body organs, and interferences with reproduction is many times greater than that of immediate morbidity and death."

A typical field case of aflatoxicosis is marked not by mortality but by a decline in productivity with no visible disease symptoms (Hamilton, 1987, p57).

Losses that result from using contaminated grain as feed are difficult to measure for various reasons including the following:

- The consequences of aflatoxicosis depend on the dose of aflatoxin, the length of feeding toxic diets and the age at first exposure to the toxin (Rao and Reddy, 1989, p 364).

- Subtle effects due to using aflatoxin contaminated feed do not produce clinical symptoms of toxicity (Nichols, 1987, p345). These effects include reduced growth rate, reduced feed efficiency, the infertility syndrome in swine and cattle, the loss of quality in animal products - examples include milk with aflatoxin M1 because dairy cattle are fed on aflatoxin contaminated feed, chicken carcasses condemned or downgraded because of the broiler bruising syndrome[5] or the pale bird syndrome[6]. Since aflatoxicosis often occurs in these subtle ways, proper diagnosis is dependent on keen observation and good production records. Unfortunately proper diagnosis is often not made.

- The effects of aflatoxins change when there are other aflatoxins in the feed. Feed mixtures may include mycotoxins other than aflatoxins and some of these have additive or synergistic effects with the aflatoxin (Pier, 1987, p 61-62).

- Aflatoxins do not occur uniformly in feed. While the presence of moulds can be an indication that aflatoxins may be present, the degree of visible mould infestation is not necessarily an indication of the level of toxin production in the feed or food. Moreover, mouldiness may not be apparent after milling or processing.

These qualifications put in context the numbers that are in Table 5. The numbers in Table 5 are based on conservative estimates reported in the literature on aflatoxicosis in livestock. The estimates of economic costs in the livestock sector will depend on the parameter values in Table 5.

Table 5 assigns values to those impacts that the paper incorporates in the economic costs of fungi and aflatoxins. The rest of this section discusses the impacts of aflatoxin contaminated feed on each livestock group.

Poultry meat and egg production

Smith, Hill and Hamilton (1971) point out that aflatoxicosis in chicken is characterised by poor growth rates,

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5 Apparently healthy birds exhibit bruises and haemorrhaging at slaughter. Experiments revealed that aflatoxins increase capillary fragility and reduce the ability of supporting tissues to cushion the blood vessels against blows. Hamilton (1987, p. 53)

6 Chickens fed on aflatoxin-contaminated feed fail to realise their colour potential. The yellow colour of chicken skins and egg yolk is attributable to carotenoids. Aflatoxins interfere with the birds capacity to absorb, transport and metabolise carotenoids. (See Hamilton, 1987, p. 53).

inefficient feed conversion and increased mortality rates. Among the results they report are the following which relate to the differences in growth rates, feed conversion and mortality rates for 50 chickens over a period of 21 days:

Aflatoxins affect the following variables	*Without aflatoxins in feed*	*With aflatoxins in feed (10 ppm)*
Mean body weight after 21 days	363 grams	195 grams
Feed consumed/weight gain	1.73	2.23
Mortality rates	0/50	12/50

Aflatoxicosis seems to almost halve the chicken's growth rate, to reduce feed conversion efficiency by about 30 percent and to increase mortality rates.

Hamilton and Garlich (1971) and Huff, Wyatt and Hamilton(1975) demonstrated that aflatoxicosis in laying hens causes an enlarged fatty liver and a decrease in egg production - fewer and smaller eggs are produced. The decrease in egg production does not occur immediately after aflatoxin is introduced in the diet but rather occurs after a 10 to 14 days' lag period.

There are other effects of aflatoxicosis in the poultry and egg production sector not taken into account in this paper because, in the literature, there is inadequate quantification of their magnitude. For example, Boulton, Dick and Hughes (1979) conclude that layers exposed to dietary aflatoxins at the time of Newcastle Disease vaccination may not be adequately vaccinated and that more frequent vaccination may be required. Similarly Wyatt (1979) to the effects covered in table 5 includes the following additional effects of aflatoxicosis in the poultry and egg production sector: increased condemnation or downgrading of carcasses, poor pigmentation of poultry products which reduces their sale value, altered immunity which increases susceptibility to disease and interference with the birds' normal processes of absorption, digestion and utilisation of nutrients.

Hog production

The toxicity of aflatoxins has been reported in suckling piglets, growing and finishing swine and breeder stock (CAST, 1989, 12). Table 5 takes into account three impacts of aflatoxicosis in the hog sector: increased mortality rates, decreased weight gain and decreased feed conversion efficiency. The effects of aflatoxins in pigs are varied, and may be more or less pronounced, depending upon the age of the animal, diet, concentration of aflatoxins, and length of exposure. Swine appear to be resistant to dietary levels of aflatoxins up to 300 ppb fed from time of weaning to marketing (CAST, 1989, 12). Buhatel and Salajan (1977) provide the following results on the possible impacts of aflatoxicosis weight gain and feed conversion efficiency in the hog sector.

Aflatoxins affect the following variables	*Without aflatoxins in feed*	*With aflatoxins in feed (300 ppm)*
Pig's body weight at start (kg)	8.0	8.5
Pig's final body weight (kg)	24.5	15.1
Pig's mean daily weight gain(kg)	0.183	0.073
Percent	100%	40%
Mean daily feed intake (kg)	0.440	0.440
Feed/Weight gain	2.40	6.00
Percent	100%	251%

Wilson, Sangster and Bedell (1984) reported mortality rates of 10 percent in herds of 200 or more swine and 28 percent in herds with 20 to 50 pigs. In Wilson et al. (1984) 30 to 45 percent of the pigs in the sampled herds were visibly ill from consuming grain with aflatoxin levels greater than 350 ppb

Beef cattle

Hsieh (1979) grouped the effects of mycotoxicosis in beef cattle into four major groups

- the lethal effects - that is, consuming aflatoxins in sufficiently high concentration will lead to death of cattle;

- the sublethal mycotoxicoses - aflatoxins interfere with the immune system of cattle which make them more susceptible to disease; aflatoxins also lead to reduced weight gain and reduced feed conversion efficiency;
- carcinogenic effects ; and
- mutagenic and teratogenic effects.

In the animal production industry, because there is rapid turnover of animals, the first two groups of effects are of greater concern than the carcinogenic and mutagenic effects which are longer-term chronic effects. The effects of aflatoxins on the rate of growth and on the feed-conversion efficiency of beef cattle are complex as demonstrated by Keyl and Norred (1979) in the following results they report from a US study:

Aflatoxins affect the following variables	*Without aflatoxins in feed*	*Aflatoxin level 100 ppb*	*Aflatoxin level 300 ppb*	*Aflatoxin level 700 ppb*	*Aflatoxin level 1000 ppb*
Start weight, lb	401	427	417	406	433
Daily weight gain over 133 days, lbs	2.51	2.63	2.40	1.90	1.76
Feed/ weight gain	5.7	6.1	6.3	6.5	6.6

The study focussed on young animals and the negative effects of aflatoxins are clear and one directional as the level of aflatoxins increase. However Keyl and Norred (1979) report results from another study involving older animals with weights of 700 pounds at the start of the experiment. The effects of aflatoxicosis in older animals was non linear. In the experiment 15 animals (the control) consumed aflatoxin-free feedstuffs and another 15 animals consumed feed containing 700 ppb of aflatoxins. In the first 30 days of the experiment aflatoxicosis led to a reduction in weight gain. After another 30 days (by day 60), the trend had reversed. Animals had gained weight and there was no statistically significant difference between the average daily weight gain of animals in the control group and those in the group feeding on aflatoxin-contaminated feed.

Cow milk

Patterson and Roberts(1977) list the following effects of aflatoxicosis in the dairy industry: loss of condition or general malaise of dairy cattle, drop in milk yields, failure of calves to thrive, scouring (a kind of diarrhoea in cattle) with or without haemorrhage, failure of cows to conceive and secondary aflatoxicosis - the transfer of [illegible]ns, particularly aflatoxin M1, from dairy cattle to people. In the context of dairy calves, Neathery et al. (1980) observed non-linear relationships between the average daily weight gain over time in the presence of aflatoxins in diet. In an experiment lasting three weeks the following changes were observed.

Time	*Average daily body weight changes without aflatoxins in feed (kg day)*	*Average daily body weight changes with 0.093 mg kg of aflatoxins in feed (kg day)*
Week1	0.714	0.535
Week 2	0.952	-0.292
Week 3	0.996	0.276
Average over 3 weeks	0.887	0.173

Table 5: Livestock health and productivity impacts of aflatoxins

ANIMAL OR BIRD	TYPE OF IMPACT	IMPACT WITH HIGH QUALITY FEED Aflatoxin B1+B2+G1+G2 in the following range $0 \leq \mu g/kg \leq 50$	IMPACT WITH MEDIUM QUALITY FEED Aflatoxin B1+B2+G1+G2 in the following range $50 < \mu g/kg \leq 300$	IMPACT WITH LOW QUALITY FEED Aflatoxin B1+B2+G1+G2 in the following range $\mu g/kg > 300$
1. Poultry and egg production	1.1 Deaths per year (%)	9[a]	12[b]	14[b]
	1.2 Average weight of a bird	4.4[c]	3.3[d]	2.2[c]
	1.3 Feed consumed/ weight gain	2.9[h]	3.4[g]	3.8[f]
	1.4 Egg weight /bird/year (Index)	100	92[j]	95[i]
2. Hogs	2.1 Deaths per year (%)	1.5[l]	1.5[l]	28[k]
	2.2 Average weight of a pig	75[n]	75[n]	54[m]
	2.3 Feed consumed/ weight gain	2.4[n]	2.4[n]	6.0[n]

Notes

a From Shane (1991,p55). In this table, the values for high quality feed correspond to Shane's standard values for these parameters. This figure includes condemned carcasses

b Shane(1991, p55) claims that the presence of mycotoxins in feed could increase mortality rates of birds by 3% to 5%. In this table the figure of 3% increase in mortality rates is associated with medium quality feed and the figure of 5 % with the low quality feed

c Wu, de Guzman and Bay-Petersen(Editors,1991). This is the average weight for Thailand and Philippines chickens

d This is an estimate of body weight of chicken fed on medium quality feedstuff. It is based on estimates in notes (c) and (e).

e Based on Smith, Hill and Hamilton (1971) where presence of aflatoxins halves the growth rate of chicken. Hamilton (1987) however reports that in a survey of poultry producers good growers (with mean aflatoxin levels in feed of 6.1 ppb) were 10% more productive than poor producers (with aflatoxin levels in feed of 14 ppb).

f Wu, de Guzman and Bay-Petersen(Editors,1991, p 69) feed/gain ratio for Thai native chickens

g Estimated from notes (f) and (h).

h Based on Smith, Hill and Hamilton (1971) where aflatoxicosis depresses feed conversion by about 29 per cent

i CAST(1989, p15) estimates that aflatoxicosis could lead to a reduction of 5 per cent in egg production in laying hens

j By interpolation between the results for the high quality and low quality feed.

k Estimate from Wilson et. al. (1984). This the mortality rate for smaller herds in Georgia, USA and is used here on the assumption that Southeast Asian pig herds tend to be small.

l From CAST(1989, p51) This is the overall mortality rate for hog producers in the Southeastern United States and may be on the conservative side in the case of Southeast Asia.

m Average of pig carcasses in Indonesia, Philippines and Thailand from data in FAO (1992)

n Based on Buhatel and Salajan(1977) and CAST(1989, p 12)

Table 5 (Continued). Livestock health and productivity impacts of aflatoxins

ANIMAL OR BIRD		TYPE OF IMPACT		LEVEL WITH HIGH QUALITY FEED Aflatoxin B1+B2+G1+G2 in the following range µg/kg ≤ 50	LEVEL WITH MEDIUM QUALITY FEED Aflatoxin B1+B2+G1+G2 in the following range 50 < µg/kg ≤ 300	LEVEL WITH LOW QUALITY FEED Aflatoxin B1+B2+G1+G2 in the following range µg/kg >300
3.	Beef cattle	3.1	Deaths per year (%)	No data[o]	No data[o]	No data[o]
		3.2	Live weight gain in an animal (metric ton)	0.223[q]	0.212[q]	0.156[p]
		3.3	Feed consumption/weight gain	5.7[r]	6.3[r]	6.6[r]
4.	Cow milk	4.1	Deaths per year (%)	No data[o]	No data[o]	No data[o]
		4.2	Milk production index	100[s]	86[s]	72[s]
		4.3	Feed consumption/milk produced	5.7[r]	6.3[r]	6.6[r]

o An extensive literature has not uncovered any reference to increased mortality rate as a major problem in the cattle beef sector. Thus there are no estimates of the effect of aflatoxicosis on beef cattle mortality rates. Hamilton (1987, p52) notes that a typical field case of aflatoxicosis is marked not by mortality but by a decline in productivity with no visible disease symptoms

p FAO (1992). The assumption is that the current situation in Southeast Asia is such that beef cattle producers use low quality (highly mycotoxin contaminated) feedstuff

q Based on Keyl and Norren (1979) and FAO (1992) - Keyl and Norred(1979) suggest that animals on aflatoxin free diet and those on diets containing 300 ppb of aflatoxins are about 1.43 times and 1.36 times respectively, the weight of animals on diets containing 1000 ppb of aflatoxins and about

r Based on Keyl and Norren (1979)

s From CAST (1989, 12)

2.5 Human health effects of aflatoxins

When people ingest food containing aflatoxins they may suffer two major types of effects.

- The acute effects of high, short-term exposure to aflatoxins in humans may lead to fatal aflatoxicosis, with jaundice for example, and may play a role in kwashiorkor, and Reye's syndrome (Bhat, 1989, 1991). Such acute outbreaks of disease are preventable if countries introduce and adhere to tolerances to aflatoxins in foods (Kuiper-Goodman, 1991, p71).

- The chronic mutagenic, carcinogenic effects have long latency periods. They include primary liver cancer, Indian childhood cirrhosis - a liver disorder in India correlated with breast milk and baby food contaminated with aflatoxin, and chronic gastritis (Bhat, 1989, 1991).

This paper deals with the most important of these effects - the development of primary liver cancer. Estimates of the numbers of primary liver cancer cases attributable to aflatoxins in maize and peanuts consumed in Indonesia, Philippines and Thailand give an indication of the human health effect of maize and peanut related aflatoxicosis in these three countries.

The weight of evidence with respect to carcinogenicity is against aflatoxins. An FAO/WHO Expert Committee (WHO, 1987) urged reduction of the intake of aflatoxin B1 to the lowest practical level so as to reduce the potential for harm. The International Agency for Research on Cancer (IARC, 1976, 1987) reviewed aflatoxin B1 and concluded that aflatoxin B_1 is a human carcinogen.

A number of studies[7] have established a strong correlation between ingestion of aflatoxins and the incidence of primary liver cancer. Most of these have been population[8]-based correlation studies. Since data in these studies are collected on populations rather than individuals, it is not possible to determine the exposure to aflatoxins of individuals who have the disease Kuiper-Goodman(1991). Furthermore, it appears that primary liver cancer can have a multi factorial origin. Factors like alcohol (Bulatao-Jayme et al., 1982) and hepatitis B virus (Croy and Crouch, 1991) appear to have a synergistic effect on the incidence of primary liver cancer. As well, genetic differences, social economic status, sex and age of the individual may play a role. However, Kuiper-Goodman (1991, p74-75) has argued that hepatitis B virus is not a confounding factor unless its distribution in the various study populations is uneven. He concludes that it cannot be presumed *a priori* that all the older studies in which hepatitis B virus status of individuals was not measured are invalid.

This paper adopts a population-based correlation approach. The aim is to provide indicative estimates of the human health effects of aflatoxins measured in terms of the number of primary liver cancer cases attributable to aflatoxins in maize and peanut. More accurate estimates need to take into account the confounding factors in the discussion above and must be individually based.

Estimating the human health effects of aflatoxins in terms of primary liver cancer, requires data on human exposure to aflatoxins. Information in Table 1 and Appendix IV provides a starting point in exposure assessment. Table 1 gives details on the distribution of aflatoxins in maize and peanuts in Indonesia, Philippines and Thailand. Appendix IV indicates the extent to which people in the three countries use these three products as food.

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7 See Shank et al. (1972a, b,c,d,e) on aflatoxicosis and primary liver cancer in Thailand, CAST(1989, p29 -32) discusses studies of aflatoxin poisoning in Western Ind'a ,Uganda, Taiwan, Thailand and Kenya; Peers et al. (1976, 1987) studied aflatoxicisi in Swaziland, Yeh et al. (1989) deals with hepitilis B virus and primary liver cancer in China; Bulatao-Jayme et al. (1982) correlates exposure to afalatoxins and the incidence of primary liver cancer in the Philippines.

8 Exceptions include Bulatao-Jayme et al. (1982) and Yeh et al. (1989). Yeh et al. (1989) collected data on 7917 men residing in 5 different areas for a period of 3.8 years. However, the study estimated at the population level dietary aflatoxin levels for 4 out of 5 areas on the basis of market sample analyses.

3 AN ECONOMIC MODEL FOR THE EVALUATION OF THE SOCIAL WELFARE IMPACTS OF FUNGI AND AFLATOXINS

3.1 Overview of the model

This subsection provides an overview of the model for the evaluation of the social welfare impacts of fungi and aflatoxins. At the end of the subsection is a complete listing of the model.

Figure 1 presents a schematic representation of the model. Figure 1 lists the different impacts attributable to ingesting maize and peanuts containing aflatoxin. The model starts with farm level outputs of maize and peanuts. At this stage farmers supply at the farmgate produce which they perceive to be homogenous.

During the postharvest stages fungi and aflatoxins in peanuts and maize lead to at least five impacts. Section 2 of the paper described these impacts. Figure 1 indicates the five most important impacts.

We model the quality impacts of fungi and aflatoxins by linking aflatoxin content of maize and peanuts to the quality grades of these products. In the postharvest stages of maize, the model recognises three types of maize, where the level of aflatoxin contamination is the basis for defining grades of produce. Similarly the model recognises three types of peanuts. The three grades are: high quality corresponding to produce containing less than 50 micrograms of aflatoxins per kilogram of produce, medium quality corresponding to produce containing between 50 and 300 micrograms of aflatoxins, and low quality produce containg more than 300 micrograms of produce.

For reasons which section 2 covered we do not introduce price differentials corresponding to the different grades of maize and peanuts. The main reason is that current pricing regimes in Indonesia, Philippines and Thailand do not diffrentiate produce according to aflatoxin content.

It is possible to model the product spoilage impacts of fungi and aflatoxins using a product wastage model (Davis, 1993). The product wastage model distinguishes between farm level output and retail output for maize and peanuts. Some of the farm level output does not reach the retail market due to product spoilage. However, according to current estimates (see Table 3) product spoilage amounts to no more than 5 percent of farm level output. Thus at this stage the model does not incorperate product wastage impacts.

It is also possible to model the international trade implications of aflatoxins by imposing constraints on the export of medium and low quality maize and peanuts. However apart from Thailand, the other countries in this study were net importers of maize and peanuts in the base year for the study.

The paper focusses on the livestock health and productivity impacts of fungi and aflatoxins in the livestock sectors. Table 5 in section 2 indicated that farmers that use feed containing aflatoxins incur two main losses. First, livestock feeding on aflatoxin contaminated feedstuffs have higher mortality rates than livestock feeding on high quality feed. Second, livestock feeding on aflatoxin contaminated feedstuff, have lower feed to weight conversion rates. We assume that current output levels in the livestock sectors incorperate these livestock health and productivity impacts. Thus the current level of output we observe in the livestock sector is lower than it would have been if farmers used feedstuff free from aflatoxin. If the aflatoxin content of maize and peanuts decreases, the livestock sector will experience an increase in output because mortality rates will decrease and feed to weight conversion ratios will rise for poultry meat, hen egg and pigmeat producers.

The main human health effect we model is loss of life due to primary liver cancer attributable to the ingestion of maize and peanut containing aflatoxins. In line with recent literature on the relationship between the ingestion of aflatoxins and the incidence of cancer, we model the number of primary liver cancer deaths as linear functions of the amount of aflatoxins that people in a country ingest.

Research changes the quality of maize and peanuts by reducing the level of aflatoxins in the products. In turn, the relative prices of the different grades of produce also change. This will change the demand patterns for maize and peanuts both in the livestock and household sectors.

The main human health effect is that over time the number of primary liver cancer cases will fall as households consume less of the produce containing aflatoxins in excess of 50 micrograms per kilograms.

Kuiper-Goodman(1991, p 81) suggests the following equation for estimating the number of primary liver cancer cases:

$$C = A + BZ$$

where

C	=	the annual incidence of primary liver cancer per 100, 000 of population;
A	=	background risk of primary liver cancer per 100, 000 of population;
B	=	the the slope of the curve;
Z	=	the quantity of aflatoxin an individual consumes in nanograms of aflatoxins per kilogram body weight per day;
BZ	=	the excess risk of primary liver cancer over the background risk, A, per 100, 000 persons per year from the consumption of foodstuffs containing aflatoxins.

Kuiper-Goodman(1991, p 81) reports that on the basis of ecological studies in Kenya, Swaziland, Thailand, and Mozambique, the values of A and B are 2.2 and 0.106, respectively, for males and females combined. He modifies these figures by multiplying them with 70, the lifespan of humans to get an approximate lifetime risk C* of:

$$C^* = 154 + 7.4\ Z.$$

We use this equation to estimate the number of primary liver cancer cases in the three Southeast Asian countries. We use the distribution of aflatoxins in Table 1 to estimate the amounts of aflatoxins individuals consume currently. Similarly when research changes the quality mix of maize and peanuts available, we estimate the new levels of aflatoxins individuals consume and derive an estimate of the number of primary liver cancers under that scenario.

We use these estimates of primary liver cancer cases and an estimate of the value of life to arrive at the cost of human life corresponding to the use of foods containing aflatoxins in excess of 50 micrograms per kilogram of product.

STAGE AT WHICH IMPACT OCCURS		TYPE OF IMPACT	TYPE OF IMPACT	TYPE OF IMPACT
FARM LEVEL		Farm level output of maize and peanuts	Farm level output of maize and peanuts	Farm level output of maize and peanuts
		⇓	⇓	⇓
POST HARVEST	⇒ Impact 1	Spoilage of product	Spoilage of product	Spoilage of product
POST HARVEST	⇒ Impact 2	Quality changes due to fungi and aflatoxins. A grading of maize and peanuts leads to three qualities of product.		
		⇓	⇓	⇓
		High quality *(Contains less than 50 micrograms per kg of product)*	Medium quality *(Contains less between 50 and 300 micrograms per kg of product)*	High quality *(Contains more than 300 micrograms per kg of product)*
		⇓	X	X
EXPORT SECTOR	⇒ Impact 3	High quality produce is acceptable for export	Medium quality produce is unacceptable for export	Low quality produce is unacceptable for export
		⇓	⇓	⇓
DOMESTIC FEED	⇒ Impact 4	High quality: nil negative impacts on livestock	Medium quality: 1) increased livestock mortality 2) reduced feed to weight conversion	Low quality: 1) increased livestock mortality 2) reduced feed to weight conversion
			⇓	⇓
LIVESTOCK AFFECTED			Chicken, Ducks, Hen egg layers, pigs	Chicken, Ducks, Hen egg layers, pigs
			⇓	⇓
DOMESTIC FOOD	⇒ Impact 5	High quality: nil human health effects	Medium quality: human health effects	Low quality: human health effects

Figure 1 A schematic representation of the model for the valuation of the impacts of fungi and aflatoxins.

3.2 A complete listing of the model

Ideally this analysis would use a general equilibrium model or an explicit model of supply and demand for maize, peanuts, and the livestock sectors whose supply functions depend on the aflatoxin content of maize and peanut feedstuffs. At this stage there is no such structural econometric model for use in the evaluation of the impacts of fungi and aflatoxins. The approach we adopt here involves making first-order approximations to the quantitative effects of changes in exogenous variables using equilibrium displacement modelling. Using this approach, one can make reasonably accurate quantitative estimates of responses to changes in exogenous variables (Piggot et al, 1993, p 169-189):

- provided one is content to confine analyses to small (say, 10 percent or less) changes about an initial equilibrium; and
- provided one is prepared to assume elasticity values.

Equilibrium displacement modelling provides a first order approximation to quantitative effects irrespective of of the underlying functional forms; it allows one to examine how changes in exogenous variables affect each endogenous variable after the system has fully adjusted to the changes. A convenient way of measuring these general equilibrium impacts when only a single exogenous variable changes is through general equilibrium elasticities. These elasticities show the percentage change in an endogenous variable due to a one percent change in an exogenous variable after full market adjustment. This section lists the complete market model and derives the general equilibrium elasticities for use in estimating the social welfare costs of fungi and aflatoxins.

This approach enables us to estimate the percentage change in price and quantity for the enodegenous variables in the model. These together with the base year data are enough to yield estimates of annual welfare gains arising from a reduction in aflatoxin contamination of food and feedstuffs.

Notation

The paper uses the following notation to represent the quantities and prices of commodities a country produces:

Y_{1food} the farm level supply of maize as food with the corresponding farmgate price P_{1f};

Y_{1feed} the farm level supply of maize as feed with the corresponding farmgate price P_{1f};

Y_{11r} the retail supply of high quality maize, which is maize containing no more than 10 micrograms of mycotoxins per kilogram of product with the corresponding price P_{1r};

Y_{12r} the retail supply of medium quality maize , which is maize containing 10 to 300 micrograms of mycotoxins per kilogram of product with the corresponding price P_{1r}; and

Y_{13f} the retail supply of low quality maize, which is maize containing more than 300 micrograms of mycotoxins per kilogram of product with the corresponding price P_{1r}

Y_{2food} the farm level supply of peanuts as food with the farmgate price P_{2f};

Y_{2feed} the farm level supply of peanuts as feed with the farmgate price P_{2f};

Y_{21r} the supply of high quality peanuts, which are peanuts containing no more than 10 micrograms of mycotoxins per kilogram of product with the price P_{2r};

Y_{22r} the supply of medium quality peanuts , which are peanuts containing 10 to 300 micrograms of mycotoxins per kilogram of product with the price P_{2r}; and

Y_{23r} the supply of low quality peanuts - peanuts containing more than 300 micrograms of mycotoxins per kilogram of product with the price P_{2r};

M_1 the total postharvest costs (drying, transport, grading labour costs, etc) for maize;

M_2 the total postharvest costs (drying, transport, grading labour costs, etc) for peanuts;

P_{1r} for the retail price maize;

P_{2r} for the retail price peanuts;

Y_{1r} the retail quantity of maize;

Y_{2r} the retail quantity of peanuts;

δ_1 is percentage of maize spoilt by fungi and aflatoxins between the farm and the retail market;

δ_2 is percentage of peanuts spoilt by fungi and aflatoxins between the farm and the retail market;

ξ_{11}	is the percentage of maize which is of high quality;
ξ_{12}	is the percentage of maize which is of medium quality;
ξ_{13}	is the percentage of maize which is of low quality;
ξ_{21}	is the percentage of peanuts which are of high quality;
ξ_{22}	is the percentage of peanuts which are of medium quality;
ξ_{23}	is the percentage of peanuts which are of low quality;
A_{i1}	is the amount of aflatoxins per kilogram of high quality grain; i=1, 2;
A_{i2}	is the amount of aflatoxins per kilogram of medium quality grain; i=1, 2;
A_{i1}	is the amount of aflatoxins per kilogram of low quality grain; i=1, 2;
PLC_i	is the number of aflatoxin related deaths due to consuming grain i; i=1, 2;
Y_3	is the supply of poultry meat with the price P_3;
Y_4	is the supply of hen eggs with the price P_4;
Y_5	is the sup[illegible]igmeat with the price P_5
Y_0	is the supply of other goods with the price P_0
D_{1fe}	is the demand for maize as a feed in the livestock sector;
D_{1fo}	is the demand for maize as food in the household sector,
D_{2fe}	is the demand for peanuts as a feed in the livestock sector;
D_{2fo}	is the demand for peanuts as food in the household sector;
D_3	is the retail demand for poultry meat with the price P_3;
D_4	is the retail demand for hen eggs with the price P_4;
D_5	is the retail demand for pigmeat with the price P_5
D_0	is the retail demand for other goods with the price P_0

The stars (*) denote equilibrium quantities.

Following is the complete model. The rest of section 3 discusses these equations in detail. A complete listing of the model at the beginning may assist in clarifying the links between the different parts of the model.

Maize market

Y_{1food}	=	$F_{1f}(P_{1f}, P_{2f}, P_3, P_4, P_5,)$;	(Farm level supply of maize food)	(1)
Y_{1feed}	=	$F_{1f}(P_{1f}, P_{2f}, P_3, P_4, P_5,)$;	(Farm level supply of maize feed)	(2)
P_{1r}	=	$f(P_{1f}, M_1, \delta_1)$	(The retail price of maize)	
Y_{1r}	=	$F_{1r}(P_{1r}, P_{2r}, P_3, P_4, P_5, \delta_1)$;	(Retail sector supply of maize)	(3)
Y_{1r}	=	$Y_{11r} + Y_{12r} + Y_{13r}$	(The sum of the suppliesof the 3 grades	(4)
D_{1fo}	=	$D_{1fo}(P_{1r}, P_{2r}, P_3, P_4, P_5$, Income);	(Demand for maize as household food)	(5)
D_{1fe}	=	$D_{1fe}(P_{1r}, P_{2r}, P_3, P_4, P_5$, Income);	(Demand for maize as livestock feed)	(6)

Maize market equilibrium:

Y_{1food*}	=	$F_{1r}(P_{1r}, P_{2r}, P_3, P_4, P_5, \delta_2)$;	(Equilibrium supply of maize as food)	(7)
Y_{1feed*}	=	$F_{1r}(P_{1r}, P_{2r}, P_3, P_4, P_5, \delta_2)$;	(Equilibrium supply of maize feed)	(8)
D_{1food*}	=	$D_{1fo}(P_{1r}, P_{2r}, P_3, P_4, P_5$, Income);	(Equilibrium demand for maize as food)	(9)
D_{1feed*}	=	$D_{2fe}(P_{1r}, P_{2r}, P_3, P_4, P_5$, Income);	(Equilibrium demand for maize as feed)	(10)

with

Y_{1r*}	=	$D_{1fo*} + D_{1fe*}$		(11)
A_1	=	$D_{1fo} x (A_{11} x \xi_{11} + A_{12} x \xi_{12} + A_{13} x \xi_{13})$	(Total aflatoxins from peanuts as food)	(12)
PLC_1	=	$PLC_1(A_1)$	(Aflatoxin in maize liver cancer deaths)	(13)

Peanuts market

Y_{2food} = $F_{2f}(P_{1f}, P_{2f}, P_3, P_4, P_5,)$; (Farm level supply of peanuts as food) (14)
Y_{2feed} = $F_{2f}(P_{1f}, P_{2f}, P_3, P_4, P_5,)$; (Farm level supply of peanuts as feed) (15)
P_{2r} = $f(P_{2f}, M_2, \delta_2)$ (The retail price of peanuts))
Y_{2r} = $F_{2r}(P_{1r}, P_{2r}, P_3, P_4, P_5, \delta_2)$; (Retail sector supply of peanuts) (16)
Y_{2r} = $Y_{21r} + Y_{22r} + Y_{23r}$ (The sum of the supplies of the 3 grades) (17)
D_{2fo} = $D_{2fo}(P_{1r}, P_{2r}, P_3, P_4, P_5, \text{Income})$; (Demand for peanuts as household food) (18)
D_{2fe} = $D_{2fe}(P_{1r}, P_{2r}, P_3, P_4, P_5, \text{Income})$; (demand for peanuts as livestock feed) (19)

Peanuts market equilibrium:

Y_{2food*} = $F_{2r}(P_{1r}, P_{2r}, P_3, P_4, P_5, \delta_2)$; (Equilibrium supply of peanuts as food) (20)
Y_{2feed*} = $F_{2r}(P_{1r}, P_{2r}, P_3, P_4, P_5, \delta_2)$; (Equilibrium supply of peanuts as feed) (21)
D_{2fo*} = $D_{2fo}(P_{1r}, P_{2r}, P_3, P_4, P_5, \text{Income})$; (Equilibrium demand for peanuts as food) (22)
D_{2fe*} = $D_{2fe}(P_{1r}, P_{2r}, P_3, P_4, P_5, \text{Income})$; (Equilibrium demand for peanuts as feed) (23)
with
Y_{2r*} = $D_{2fo*} + D_{2fe*}$ (24)
A_2 = $D_{2fo} x (A_{21} x \xi_{21} + A_{22} x \xi_{22} + A_{23} x \xi_{23})$ (Total aflatoxins from peanuts as food) (25)
PLC_2 = $PLC_2(A_2)$ (Aflatoxin in peanuts liver cancer deaths) (26)

Livestock markets

Y_3 = $F_3(P_{1f}, P_{2f}, P_3, P_4, P_5, Y_{12}, Y_{13}, Y_{12}, Y_{13})$; (Supply of poultry meat) (27)
Y_4 = $F_4(P_{1f}, P_{2f}, P_3, P_4, P_5, Y_{12}, Y_{13}, Y_{12}, Y_{13})$; (Supply of hen eggs) (28)
Y_5 = $F_5(P_{1f}, P_{2f}, P_3, P_4, P_5, Y_{12}, Y_{13}, Y_{12}, Y_{13})$; (Supply of pig meat) (29)
D_3 = $D_3(P_{1f}, P_{2f}, P_3, P_4, P_5, \text{Income})$; (Demand for poultry meat) (30)
D_4 = $D_4(P_{1f}, P_{2f}, P_3, P_4, P_5, , \text{Income})$; (Demand for hen eggs) (31)
D_5 = $D_5(P_{1f}, P_{2f}, P_3, P_4, P_5, , \text{Income})$; (Demand for pig meat) (32)

Livestock market equilibria

Y_{3*} = $F_3(P_{1f}, P_{2f}, P_3, P_4, P_5, Y_{12}, Y_{13}, Y_{12}, Y_{13})$; (Equilibrium supply of poultry) (33)
Y_{4*} = $F_4(P_{1f}, P_{2f}, P_3, P_4, P_5, Y_{12}, Y_{13}, Y_{12}, Y_{13})$; (Equilibrium supply of hen eggs) (34)
Y_{5*} = $F_5(P_{1f}, P_{2f}, P_3, P_4, P_5, Y_{12}, Y_{13}, Y_{12}, Y_{13})$; (Equilibrium supply of pig meat) (35)
D_{3*} = $D_3(P_{1f}, P_{2f}, P_3, P_4, P_5, \text{Income})$; (Equilibrium demand for poultry meat) (36)
D_{4*} = $D_4(P_{1f}, P_{2f}, P_3, P_4, P_5, , \text{Income})$; (Equilibrium demand for hen eggs)(37)
D_{5*} = $D_5(P_{1f}, P_{2f}, P_3, P_4, P_5, , \text{Income})$; (Equilibrium demand for pig meat)(38)
with
Y_{3*} = D_{3*} (39)
Y_{4*} = D_{4*} (40)
Y_{5*} = D_{5*} (41)

In the supply equations for livestock the quantities of medium and low quality maize and peanuts feedstuffs are exogenous variables. These quantities depend on other variables which are outside the scope of this model. However, the information in Table 5 on the effects of aflatoxins on livestock indicates how the livestock sector could respond to changes in the level of aflatoxins in feedstuffs.

3.3 General equilibrium elasticities

The model involves 14 equilibrium equations: equations (7), (8), (9), (10), (20), (21), (22), (23), and (33)-(38). In these equations there are 14 endogenous variables and 5 exogenous.

The endogenous variables are:

the quantity of maize food;
the quantity of maize feed;
the quantity of peanut food;
the quantity of peanut feed;
the quantity of poultry meat;

the quantity of hen eggs;
the quantity of pig meat
the price of maize food;
the price of maize feed;
the price of peanut food;
the price of peanut feed;
the price of poultry meat;
the price of hen eggs;
the price of pig meat

The exogenous variables are:

household income
the quantity of medium quality maize
the quantity of low quality maize;
the quantity of medium quality peanut; and
the quantity of low quality peanut.

A convenient way of measuring general equilibrium impacts is through general equilibrium elasticities. Piggot et al.(1993, pp. 169 - 189) describe the procedure for estimating the general equilibrium elasticities starting from a set of equilibrium determining equations in a framework where the analysis uses a general function model. The procedure involves total differentiation of the set of equilibrium determining equations and uses demand and supply elasticities.

The matrix of general equilibrium elasticities is then equal to the product of the inverse of the matrix of demand and supply elasticities and a matrix of elasticities with respect to a set of exogenous variables.

Appendix 5 gives details of the matrices of demand and supply elasticities, their respective inverses and the general equilibrium elasticities for Indonesia, Philipines and Thailand.

3.4 Estimates of the social costs of fungi and aflatoxins in maize

We estimate the social costs of fungi and aflatoxins by asking the following questio:

> how do prices and quantities that are endogenous to the model change when there is a reduction in the quantity of low quality maize by 10 percent ?

The general equilibrium elasticities matrix provide answers to this type of question. Two of the columns in the matrix give the percentage changes in endogenous variables in response to a one percent change in low quality maize and low quality peanuts.

Since the general equilibrium elasticities matrix leads to estimates of changes in endogenous variables, it is possible to estimate the change in total economic surplus associated with a 10 per cent change in the supply of low quality grain using formulea in Alston (1990, pp 24-33). Adding to this the change in the cost of life lost due to consuming aflatoxin contaminated food yields the total social welfare change due to a 10 percent change in the supply of low quality grain.

Tables 6, 7, and 8 report estimates of the social welfare costs of fungi and aflatoxins saved when there is a reduction in the supply of low quality maize by 10 percent. Using the same model to estimate the welfare gains associated with a ten percent reduction in peanut aflatoxin contamination suggested that the net gains were zero. The estimates in Tables 6, 7, and 8 are preliminary and are conditional on the elasticity matrices in Appendix V. They are associated with a 10 percent reduction in aflatoxins in the low quality grain only, not with total removal of aflatoxins.

These estimates suggest that a 10 per cent reduction in aflatoxin contamination in low grade maize could lead to annual welfare gains of about $ 2.9 million dollars (Australian) in the 3 Southeast Asian countries (Indonesia, Philipines and Thailand). Most of this benefit accrue to the livestock sectors where aflatoxin contamination leads to economic costs in the form of increased mortality rates and reduced feed to weight gain conversion rates.

The change in maize food consumption following a ten percent reduction in the aflatoxin contamination of low quality maize does not lead to perceptible changes in the number of primary liver cancer cases in any of the three countries. This may be due to the fact that the model does not incorporate enough of the dynamic aspects of the relationship between aflatoxin ingestion and the incidence of primary liver cancer.

The initial objective of this project was toestimate the total social costs associated with aflatoxin contamination of grains. With an equilibrium displacement model it is not possible to estimate the total cost of human lives associated with aflatoxin in grains. In order to estimate the the total cost of aflatoxin aflatoxin related primary liver cancer a model similar to one proposed by Martin and Alston (1993) is necessary.

Table 6 Indonesia: Net social welfare gains associated with a 10 percent reduction in low quality maize

SECTOR	CURRENT OUTPUT (MT, 1991) Thousands	CURRENT PRICES $A, 1991	CHANGE IN ECONOMIC SURPLUS ($A '000)
MAIZE FOOD	4834	170	$0
MAIZE FEED	960	170	-$428
PEANUTS FOOD	932	1493	$0
PEANUTS FEED	35	1493	-$124
POULTRY MEAT	498	973	$155
HEN EGGS	400	1141	$407
PIG MEAT	275	1537	$345
SUBTOTAL	na	na	$355
COST OF LIFE LOST	na	na	0
TOTAL			$355

Table 7 Philippines: Net social welfare gains associated with a 10 percent reduction in low quality maize

SECTOR	CURRENT OUTPUT (MT, 1991) Thousands	CURRENT PRICES $A, 1991	CHANGE IN ECONOMIC SURPLUS ($ A '000)
MAIZE FOOD	905	253	$0
MAIZE FEED	3668	253	-$1 839
PEANUTS FOOD	36	765	$0
PEANUTS FEED	7.3	765	-$10
POULTRY MEAT	302	973	$127
HEN EGGS	267	1141	$383
PIG MEAT	690	1537	$1248
SUBTOTAL	na	na	$92
COST OF LIFE LOST	na	na	0
TOTAL			$92

Table 8 Thailand: Net social welfare gains associated with a 10 percent reduction in low quality maize

SECTOR	CURRENT OUTPUT (MT, 1991) Thousands	CURRENT PRICES $A, 1991	CHANGE IN ECONOMIC SURPLUS ($ A '000)
MAIZE FOOD	0	137	$0
MAIZE FEED	2216	137	-$1 509
PEANUTS FOOD	103	1083	$0
PEANUTS FEED	27	1083	-$136
POULTRY MEAT	717	973	$751
HEN EGGS	474	1141	$1 703
PIG MEAT	340	1537	$1 540
SUBTOTAL	na	na	$2 351
COST OF LIFE LOST	na	na	0
TOTAL			$2 351

4. Conclusion

This paper has described five impacts of fungi and aflatoxins which are important in the agricultural sector. It has also used an equilibrium displacement model to arrive at preliminary estimates of the social welfare gains associated with reducing aflatoxins by 10 percent in low quality maize. These estimate include the costs associated with three of these impacts, namely:

- quality derioration of products due to fungi and aflatoxins;
- increased mortality rates and reduced feed to weight gain conversion ratios in the poultry meat, hen eggs and pig meat livestock sectors; and
- the mutagenic and carcinogenic effects of aflatoxins on humans.

Most of these costs are borne by the livestock stock. However there is a need for a model for the estimation of the total social cost (including the human life costs) of aflatoxin contamination of grains. Work is in progress aimed at developing such a model along the lines proposed by Martin and Alston(1993).

APPENDIX I. FUNGI AND COMMODITIES THEY AFFECT

COMMODITY	FIELD FUNGI	SPOILAGE FUNGI	MYCOTOXIGENIC FUNGI
Cashews (Aflatoxin-high-risk)	Cladosporium cladosporioides; Nigrospora oryzae	Chaetomium spp	Aspergillus flavus⊗⊗
Cassava and Sweet potato	Lasiodiplodia theobromae; Nigrospora oryzae, Phoma sp		
Copra (Aflatoxin-high risk)	Nigrospora oryzae	Chaetomium spp; A. tamarii	Aspergillus flavus⊗⊗
Maize (Aflatoxin-high risk)	Nigrospora oryzae; Cuvularia pallescens; C. lunata; C. clavata; Lasiodiplodia theobromae; Bipolaris maydis; Arthrinium phaeospermum; Rhizopas oryzae; Phoma herbarum; Rhizoctonia solani	Aspergillus niger; Chaetomium spp; Penicillium citrinum⊗; P. funiculosum⊗; A. wentii	Aspergillus flavus⊗⊗; Fusarium moniliforme⊗⊗, F. semitectum
Peanuts(Aflatoxin-high risk)	Cladosporium cladosporioides; Lasiodiplodia theobromae, Pestalotiopsis guepinii	Aspergillus niger; Penicillium pinophilum⊗; Chaetomium spp	Aspergillus flavus⊗⊗
Rice (Aflatoxin-high risk)	Bipolaris maydis, Fusarium semitectum; Cladosporium cladosporioides, Nigrospora oryzae; Curvularia lunata; C. geniculatus, C. oryzae; C. eragrostidis, C. pallescens, Phoma sp; Colletotrichum sp.		Altenaria padwickii; A. alternata ; A. longissima
Sorghum	Bipolaris maydis. Fusarium semitectum; Cladosporium cladosporioides; Nigrospora oryzae; Curvularia lunata; C pallescens, Phoma sp, Setosphaeria rostrata	Aspergillus niger; Eurotium chevalieri, E. rubrum, Chaetomium sp	Aspergillus flavus⊗⊗; Fusarium moniliforme; Penicillium citrinum; Alternaria longissima, A. alternata
Soybeans	Arthrinium phaeospermum; Lasiodiplodia theobromae, Fusarium semitectum, Cladosporium cladosporioides; Nigrospora oryzae; Curvularia lunata, C.pallescens; Phoma sp, Epicoccum nigrum, Pestalotiopsis guepinii	Aspergillus niger; A. wentii; A restrictus; A. penicillioides, Eurotium rubrum, Eupen. cinnamopurpureum, Chaetomium sp.	Aspergillus flavus Fusarium moniliforme Penicillium citrinum Alternaria alternata

APPENDIX 1 (cont.). FUNGI AND COMMODITIES THEY AFFECT

COMMODITY	FIELD FUNGI	SPOILAGE FUNGI	MYCOTOXIGENIC FUNGI
High sugar foods (confectionery, dried fruits and jams)		A. restrictus Eurotium species A. candidus Wallemia sebi Xeromyces bisporus Chrysosporium species Eremascus species Zygosaccharomyces rouxii	
Dried meats and meat products		A. restrictus Eurotium species A. candidus Wallemia sebi	
Animal products (milk, cheese)			
Dried seafood products		Polypaecilum pisce Basipetospora halophila Aspergillus species Eurotium species A. wentii	

Note: ⊗ in the table denotes that a fungi is common in South East Asia
⊗⊗ in the table denotes that the fungi is very common in South East Asia
F. moniliforme is the source of the fumonisins, toxins known to be respo[illegible]le for severe diseases in some animals, and suspected (but not proven) to be involved in human oesophageal cancer in parts of China and southern Africa.

Sources: Champ, Highley, Hocking and Pitt (Eds, 1991)

APPENDIX II AFLATOXIN DISCOVERY AND THE STRUCTURAL FORMULAE OF THE VARIOUS AFLATOXINS

Material in this appendix is based on Lillehoj(1987).

The current epoch of fungal research in food and feed safety emerged as a result of an outbreak of disease in turkeys in England in 1960. A search for the causative agent of the disease was the beginning of a new area of agricultural research that has been labelled mycotoxicology. Examination of bird rations showed that a common factor in disease outbreaks was the use of a Brazilian peanut meal.

Tests showed the common occurrence of fungal isolates associated with the *Aspergillus flavus* group. Two closely related species, *Aspergillus flavus* and *Aspergillus parasiticus*, have since been identified as the toxin-producing species.

Tests identified four closely-related fluorescent compounds which were responsible for the toxic activity in bird rations. These four compounds were generically named aflatoxins B_1, B_2, G_1, and G_2 (see Figure II.1). The letters B and G denote blue fluorescence and green fluorescence respectively.

Subsequent studies of aflatoxin production demonstrated the ability of *Aspergillus flavus* to produce exclusively B_1, and B_2 whereas *Aspergillus parasiticus* exhibited the capacity to produce all four toxins.

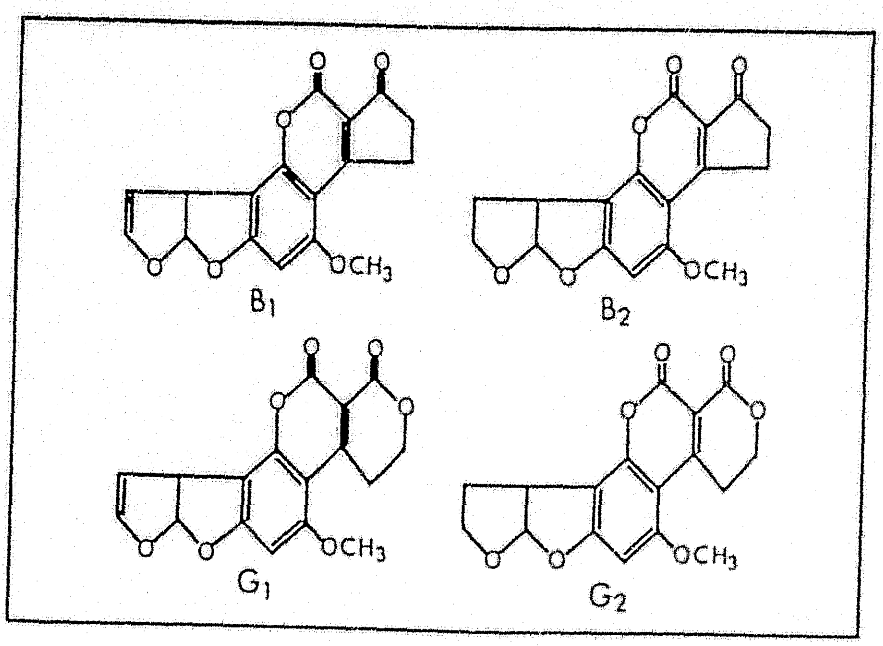

Figure II.1 Structural formulae of aflatoxins B_1, B_2, G_1, and G_2.

APPENDIX III AFLATOXIN REGULATIONS

The Southeast Asian region includes the following countries:

Burma;
Cambodia;
Indonesia;
Laos, PDR;
Malaysia;
Philippines;
Thailand;
Singapore, and
Vietnam.

However, this study focuses on only three of these: Indonesia, Philippines and Thailand.

Table III.1 summarises aflatoxin regulations in selected western (includes Japan) countries which form the major export markets for Southeast Asian, since a major concern is the effect these regulations have on export markets.

Table III.2 summarises aflatoxin regulations in the Southeast Asian region.

The following conclusions can be drawn from the table:

- there is considerable variability in the tolerance levels of different markets to aflatoxin contamination;
- generally, the tolerance limits are lowest in the case of foods for human consumption and feedstuffs for dairy cattle, young cattle, young pigs and birds.
- supplementary feedstuffs have higher tolerance levels presumably because it is assumed that other sources of feedstuffs would somewhat dilute the aflatoxin effect.
- only four countries in the Southeast Asian region are reported to have aflatoxin tolerance limits.

Table III.1 AFLATOXIN LIMITS (µg/KILOGRAM) FOR SELECTED COMMODITIES BY MAJOR (WESTERN) IMPORTING COUNTRY (1991)

COUNTRY	AFLATOXINS	ALL HUMAN FOODS	ALL BABY FOOD	MILK (c)	PEANUTS	NUTS SEEDS CEREALS	MAIZE &MAIZE PRODUCTS	FEEDS FOR DAIRY & YOUNG (CATTLE PIGS, BIRDS)(e)	FEEDSTUFFS FOR PIGS & POULTRY	FEEDSTUFF FOR BEEF CATTLE, SHEEP, GOAT (NOT YOUNG)
USA	Aflatoxin B1+B2+G1+G2	20[a]	20[a]	0.5[a] Aflatoxin M1	20[a]	20[a]	20[a]	20[a]	20[a]	300[a]
Japan	Aflatoxin B1	10[b]	10[b]	Not specified Aflatoxin M1	10[b]	10[b]	10[b]	10[b]	20[b]	20[b]
European Community	Aflatoxin B1+B2+G1+G2	5[a] to 30[a]	5[a]	Not specified Aflatoxin M1	5[a] to 50[a] 200[a, d]	1[a] to 30[a]	5[a] to 50[a] 200[a, d]	10[a,f] 10[a,g] 5[a,h]	20[a,f] 30[a,g] 10[a,h]	50[a,f] 50[a,g] 20[a,h]
Belgium	Aflatoxin B1	5[a]	5[a]	0.1[a] Aflatoxin M1	5[a]	5[a]	5[a]	k	k	k
Denmark	Aflatoxin B1+B2+G1+G2	NS	NS	Not specified Aflatoxin M1	10[a]	10[a]		k	k	k
France	Aflatoxin B1+B2+G1+G2	10[a]	5[a]	0.2[a] Aflatoxin M1	0.1[a] (nut pastes)	5[a]	10[a]	k	k	k
Germany	Aflatoxin B1	NS	NS	0.05[a] Aflatoxin M1	5[a,i] 2[a,j]	5[a,i] 2[a,j]		k	k	k
	Aflatoxin B1+B2+G1+G2	NS	NS		10[a,i] 4[a,j]	10[a,i] 4[a,j]		k	k	k
Greece	Aflatoxin B1	NS	NS		1[a]	1[a]	1[a]	k	k	k
	Aflatoxin B1+B2+G1+G2	NS	NS	Not specified Aflatoxin M1	5[a]	5[a]	5[a]	k	k	k
Ireland	Aflatoxin B1	5[a]						k	k	k
	Aflatoxin B1+B2+G1+G2	30[a]		Not specified Aflatoxin M1				k	k	k
Italy	Aflatoxin B1+B2+G1+G2	NS		Not specified Aflatoxin M1	30[a]	30[a]	30[a]	k	k	k

Table III.1(cont.) **AFLATOXIN LIMITS (µg/KILOGRAM) FOR SELECTED COMMODITIES BY MAJOR (WESTERN) IMPORTING COUNTRY (1991)**

COUNTRY	AFLATOXINS	ALL HUMAN FOODS	ALL BABY FOOD	MILK (c)	PEANUTS	NUTS SEEDS CEREALS	MAIZE &MAIZE PRODUCTS	FEEDS FOR DAIRY & YOUNG (CATTLE PIGS, BIRDS)	FEEDSTUFFS FOR PIGS & POULTRY	FEEDSTUFF FOR BEEF CATTLE, SHEEP, GOAT (NOT YOUNG)
Luxembourg	Aflatoxin B1	NS		Not specified Aflatoxin M1	5[a]			k	k	k
Netherlands	Aflatoxin B1	5[a]		0.05 [a]Milk 0.2 [a]Cheese Aflatoxin M1	50[a]			k	k	k
Portugal	Aflatoxin B1	20[a]	5[a]	Not specified Aflatoxin M1	25[a]			k	k	k
Spain	Aflatoxin B1	5[a]			5[a]	5[a]	5[a]	k	k	k
Britain	Aflatoxin B1+B2+G1+G2	10[a]		Not specified Aflatoxin M1	10[a]	10[a]	10[a]	k	k	k

Notes

NS denotes that the aflatoxin limit is not specified. However, some countries rely instead on general food legislation that prohibits the introduction or receipt for commerce of food containing substances injurous to health.(Van Egmond, 1991).

(a) From Gilbert (1991).

(b) From Van Egmond(1991).

(c) When dairy cattle are fed feedstuff containing aflatoxin B1, some of this toxin is converted by the animal into aflatoxin M1 in milk. In some countries (eg UK) the absence of specific regulations for aflatoxin M1 in milk is because of a belief that if the animal-feed regulations for aflatoxins are obeyed, then aflatoxin M1 should not be detectable in milk at a limit of detection of 0.05 µg/kg. (See Gilbert,1991).

(d) This limit applies if the buyer is an European Community registered manufacturer.

(e) The acceptable level of aflatoxins for dairy has to be set at such a level that it does not lead to detectable levels of aflatoxin M1 in milk products.

(f) This is the pre-1991 limit for complete feedstuffs. The pre-1984 limit for these feedstuffs was 20 micrograms per kilogram of product.

(g) This is the pre-1991 limit for complementary feeds.

(h) This limit applies to both complete and complementry feedstuff since 1991.

(i) Pre-1991 limits.

(j) Limits from May 1991.

(k) European Economic Community limit applies.

Table III.2 AFLATOXIN LIMITS (μg/KILOGRAM) FOR SELECTED COMMODITIES IN SOUTH EAST ASIA (1991)

COUNTRY	AFLATOXINS	ALL HUMAN FOODS	ALL BABY FOOD	MILK	PEANUTS	NUTS SEEDS CEREALS	MAIZE &MAIZE PRODUCTS	COMPLETE FEEDSTUFFS FOR DAIRY CATTLE & YOUNG (CATTLE PIGS, BIRDS)	COMPLETE FEEDSTUFFS FOR PIGS & POULTRY	COMPLEMENTARY FEEDSTUFFS FOR CATTLE, SHEEP, GOAT (NOT YOUNG)
Burma (Myanmar)	Aflatoxin B1+B2+G1+G2	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist
Cambodia	Aflatoxin B1+B2+G1+G2	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist
Indonesia	Aflatoxin B1+B2+G1+G2	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist
Laos, PDR	Aflatoxin B1+B2+G1+G2	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist
Malaysia	Aflatoxin B1+B2+G1+G2	35[b]	35[b]	[a]Limits may not exist	35[b]	35[b]	35[b]	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist
Philippines	Aflatoxin B1	20[b]		[a]Limits may not exist	20[b]	20[b]	20[b]	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist
Singapore	Aflatoxin B1+B2+G1+G2	Zero[b]	Zero[b]	[a]Limits may not exist	Zero[b]	Zero[b]	Zero[b]	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist
Thailand	Aflatoxin B1+B2+G1+G2	20[b]		[a]Limits may not exist	20[b]	20[b]	20[b]	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist
Vietnam	Aflatoxin B1+B2+G1+G2	Zero[b]		[a]Limits may not exist	Zero[b]	Zero[b]	Zero[b]	[a]Limits may not exist	[a]Limits may not exist	[a]Limits may not exist

(a) A literature search to date has not revealed the exisitence of regulations specifying aflatoxin limits in these. However, this liturature search has been limited to literature in English (see Van Egmond, 1991, page 201). Thus it is possible that these regulations exist in the official languages of these countries.

(b) Information from Van Egmond(1991)

APPENDIX IV: DATA ON MAIZE, PEANUTS AND SELECTED LIVESTOCK SECTORS IN INDONESIA, PHILIPPINES AND THAILAND

TABLE IV.1 INDONESIA: SUPPLY OF AND DEMAND FOR MAIZE (CORN) AND PEANUTS (GROUNDNUTS) IN 1991

ROW NUMBER	VARIABLE	MAIZE (CORN)		PEANUTS (GROUNDNUTS)	
	SUPPLY SIDE				
S1	Area harvested (Hectares '000)	3 037[a]		628[g]	
S2	Yield (Metric tons per hectare)	2.1[a]		1.7[g]	
S3	Production (Metric tons '000)	6445[a]		1056[h]	
S4	Imports (Metric tons '000)	0[b]		53[i]	
S5	Total supply = S3+S4 (Metric tons '000)	6445		1109	
	DEMAND SIDE	Metric tons ('000)	(Percent of S5)	Metric tons ('000)	(Percent of S5)
D1	Seeds	129[c]	(2.0 percent)	na[j]	na
D2	Exports	0[b]	(0.0 percent)	2	(0.20 percent)[k]
D3	Use as staple food in Indonesia	4834[d]	(75 percent)[d]	932	(84 percent)[l]
D4	Use as feed in the poultry meat industry	408[e]	(6.33 percent)	15	(1.38 percent)[m]
D5	Use as feed in the hen eggs industry	327[e]	(5.08 percent)	12	(1.11 percent)[m]
D6	Use as feed in the hog industry	225[e]	(3.49 percent)	8	(0.76 percent)[m]
D7	Use as feed in the beef cattle industry	151[e]	(2.35 percent)	6	(0.51 percent)[m]
D8	Use as feed in the production of cow milk	262[e]	(4.06 percent)	10	(0.89 percent)
D9	Use as feed in the goat meat industry	44[e]	(0.69 percent)	2	(0.2 percent)[m]
D10	Other uses - industrial uses(oil, starch, glue, sweeteners)	64	(1.0 percent)[d]	122	(11 percent)[n]
	TOTAL (D1 TO D8)	6445	(100 percent)	1109	(100 percent)
W	Spoilage due to fungi and mycotoxins (Percent)		0[f]		(26 percent)[f]

(a) CIMMYT(1992)
(b) Nataredja and Halid (1993, Table 5) shows that in 1990 and 1991 there were neither imports nor exports of corn in Indonesia.
(c) This estimate is based on Labadan (1993) who estimates that seed are about 2 percent of production.
(d) Piggot, Parton, Treadgold and Hutabarat (1993, p. 100)
(e) Based on the Piggot et al. (1993) who estimate that feedstuffs are about 22 percent of the total farm level production of maize in Indonesia and the relative sizes of livestock industries in Table IV.4.
(f) See Table 3 for some wastage rates by product quality
(g) FAO(1992, Table 38 on groundnuts in shell)
(h) FAO(1992, Table 38 on groundnuts in shell) This is an estimate by FAO based on unofficial information.
(i) On the basis of Fletcher, Zhang and Carley (1992, p31), imports are about 5 3 percent of production in Indonesia. Indonesia has been an importer of peanuts since 1979 (Piggot et al. 1993,p.106).

(j) Not available Fletcher, Zhang and Carley (1992, p31) includes seeds in the other use category.
(k) From Fletcher, Zhang and Carley (1992, p31) exports are about 0.2 percent of total maize production in Indonesia.
(l) Fletcher Zhang and Carley (1992, p31) Bottema and Altemeier (1990, p92) notes that groundnut is primarily used for snacks, and consumption is about 2.5 kilograms per capita per year.
(m) Fletcher, Zhang and Carley (1992, p31) estimated that about 5 percent of Indonesia's peanuts was used as crushed peanut cake meal feed for livestock and table IV 4.
(n) Fletcher, Zhang and Carley (1992, p31)

TABLE IV.2 PHILIPPINES: SUPPLY OF MAIZE (CORN) AND PEANUTS (GROUNDNUTS) IN 1991

ROW NUMBER	VARIABLE	MAIZE (CORN)		PEANUTS (GROUNDNUTS)	
	SUPPLY SIDE				
S1	Area harvested (Hectares '000)	3 699[a]		45[g]	
S2	Yield (Metric tons per hectare)	1.3[a]		1.80[g]	
S3	Production (Metric tons '000)	4677[a]		35[h]	
S4	Imports (Metric tons '000)	348[b]		9[i]	
S5	Total supply = S3+S4 (Metric tons '000)	5025		44	
	DEMAND SIDE	Metric tons ('000)	(Percent of S5)	Metric tons ('000)	(Percent of S5)
D1	Seeds	101[c]	(2 percent)[c]	na[j]	na[j]
D2	Exports	0[b]	(0 percent)[b]	0[k]	
D3	Use as staple food in Philippines	905	(18 percent)[d]	36[k]	(81 percent)[k]
D4	Use as feed in the poultry meat industry	880	(17.5 percent)[e]	3.4	(7.8 percent)[l]
D5	Use as feed in the hen eggs industry	778	(15.5 percent)[e]	2.2	(5.1 percent)[l]
D6	Use as feed in the hog industry	2010	(40.0 percent)[e]	1.7	(3.7 percent)[l]
D7	Use as feed in the beef cattle industry	230	(4.6 percent)[e]	0	
D8	Use as feed in the production of cow milk	47	(0.9 percent)		
D9	Use as feed in the goat meat industry	76	(1.5 percent)[e]	0	
D10	Other uses - industrial uses(oil, starch, glue, sweeteners)	0	0[e]	8	(2.4 percent)[l]
	TOTAL (D1 TO D8)	5025	(100 percent)	44	(100 percent)
W	Spoilage due to fungi and mycotoxins (Percent)		( )[f]		( )[f]

Sources:

(a) CIMMYT(1992). Labadan (1993) indicates that white corn forms 61 percent and yellow corn forms 39 percent of national production of corn in Philippines. White corn takes up 72 percent and yellow corn 28 percent of area harvested. Yield per hectare is higher for yellow corn at 1.75 tons per hectare compared to 1.08 tons per hectare for white corn (Labadan(1993, Tables 3, 4 and 5).

(b) Labadan (1993, Table 8). Labadan(1993, p 42) notes that importation has been allowed in the past to alleviate corn shortage in Philippines. Exports are zero.

(c) This is an estimate based on Labadan(1993) who estimates seeds to be about 2 percent of production.

(d) Labadan (1993, Table 9). This table shows there has been a rapid decline in the percentage of corn used as food in the Philippines from 48 percent in 1980 to 41 percent in 1985 to 18 percent in 1991. White corn variety is the only variety used for food. In the Table 18 percent share of total corn used as food is equivalent to about 45 percent of white corn produced in Philippines.

(e) Labadan (1993, Table 9). One hundred percent of yellow corn and 55 percent of white corn is used as feed. The percentages of corn used as feed in the different livestock sectors are estimated using the relative sizes of livestock industries in Table IV.4 and Labadan's estimate that feeds form about 80 percent of total demand for corn in the Philippines. Labadan(1993, p43) estimates that a complete or mixed feed for hogs or poultry contains 50 percent ground corn. Rebong(1992, p.64) states that as much as 60 percent corn may be used to compound an animal feed. Hogs and chicken need to eat about 3 kilograms of quality feeds to produce 1 kilogram of live weight.

(f) See Table 3 for some wastage rates by product quality.

(g) See Domingo(1992.). The figure is for 1987.

(h) Bureau of Agricultural Statistics (1991, page 57). Production has dropped from 43 000 metric tons (see Domingo, 1992) the average for the period 1980-1987.

(i) Fletcher et al. (1992, p31) estimated that the Philippines imported groundnuts equal to about 25 percent of their average production in the period 1980 to 1989. There were no exports.

(j) Not available. Fletcher, Zhang and Carley (1992, p31) included seeds in the other use category.

(k) Fletcher, Zhang and Carley (1992, p31).

(l) John Pitt and Ailsa Hocking, Personal communication, 14 January 1994 estimated that the pattern of use of peanuts as feed in the poultry and pig meat sector in Philippines is probably the same as in Thailand.

Table IV.3 Thailand: Supply of maize (corn) and peanuts (groundnuts) in 1991

	VARIABLE	MAIZE		PEANUTS (GROUNDNUTS)
	SUPPLY SIDE			
S1	Area harvested (Hectares '000)	1644[a]		119[h]
S2	Yield (Metric tons per hectare)	2.5[a]		1.4[h]
S3	Production (Metric tons '000)	4035[a]		163[h]
S4	Imports (Metric tons '000)	0[b]		0[i]
S5	Total supply = S3+S4 (Metric tons '000)	4035		163
	DEMAND SIDE	Metric tons ('000)	(Percent of S5)	Metric tons('000) Percent of S5
D1	Seeds	17[c]	0.4 percent[c]	na na[i]
D2	Exports	1206[d]	29.9 percent[d]	10 (6 percent)[i]
D3	Use as staple food in Thailand	0[e]	0.0 percent[e]	103 (63 percent)[i]
D4	Use as feed in the poultry meat industry	1038[f]	25.7 percent[f]	13 (7.8 percent)[j]
D5	Use as feed in the hen eggs industry	686[f]	17.0 percent[f]	8 (5.1 percent)[j]
D6	Use as feed in the hog industry	492[f]	12.2 percent[f]	6 (3.7 percent)[j]
D7	Use as feed in the beef cattle industry	259[f]	6.4 percent[f]	3 (1.9 percent)[j]
D8	Use as feed in the production of cow milk	335[f]	8.3 percent[f]	4 (2.5 percent)
D9	Use as feed in the goat meat industry	1[f]	0.04[f]	0 (0 percent)[j]
D10	Other uses - industrial uses(oil, starch, glue, sweeteners)	0	0	16 (10 percent)[i]
	TOTAL (D1 TO D8)	4035	100 percent	163 (100 percent)
W	Spoilage due to fungi and mycotoxins (Percent)		( )[g]	( )[k]

(a) CIMMYT(1992, p45)

(b) Thailand is a net exporter of corn.

(c) Wattanutchariya, Puthikorn, Tugsinavisutti, Isvilanonda and Sanit (1991, p.6).

(d) CIMMYT(1992, p45). Note though in 1960 exports were 95 percent of Thailand's maize production by 1985 this had dropped to 56 percent of total production and by 1991 the export share in total production of maize in Thailand had dropped to less than 30 percent (see Wattanutchariya et. al., 1991, Table 4.20). Wattanutchariya et. al. (1991, p1) argue that aflatoxin contamination resulting from improper postharvest handling has contributed to the reduction in the demand for Thai maize on the world market. There has also been a shift in the countries that buy Thai corn from those with strict mycotoxin regulations to those with less stringent mycotoxin regulations (see Arunthong, 1987).

(e) Human consumption of maize in Thailand is close to zero. Mekvanich (1992, p. 20) *estimates that the feed industry in Thailand* consumes up to 70 percent of the country's maize production.

(f) The percentages of corn used as feed in the different livestock sectors are estimated using the sizes of livestock industries in Table IV.4 and the earlier estimate that feeds form 69.7 percent of total demand for corn in Thailand.

(g) See Table 3 *for some wastage rates by product quality*.

(h) FAO(1992, Table 38 on groundnuts in shell). See also Lampang (1993).

(i) Fletcher, Zhang and Carley (1992, p31). The estimates were for the period 1980 to 1989. They included seeds in the other use category. *In the case of human consumption*, Shank (1971, 247) notes that groundnuts can be a significant source of dietary aflatoxins and that in Thailand most groundnuts are eaten between meals usually away from home.

(j) Based on Fletcher, Zhang and Carley's (1992, p31) estimate that about 21 percent of Thai peanut is used as crushed peanut cake meal feed for livestock plus table IV.4.

(k) See Table 3 for some wastage rates by product quality.

TABLE IV.4 OUTPUTS OF SELECTED LIVESTOCK INDUSTRIES AFFECTED BY FUNGI AND MYCOTOXINS (1991)

1 COUNTRIES	UNITS	1 POULTRY MEAT	2 HEN EGGS	3 PIG MEAT	5 BEEF & VEAL	4 COW MILK	6 GOATS	7 TOTAL
INDONESIA								
Production [a]	Metric tons ('000)	498[F]	400[F]	275[F]	185[F]	320[F]	54	1379
Share in output of livestock sectors vulnerable to mycotoxins	Proportion	0.29	0.23	0.16	0.11	0.18	0.03	1.0
Average weight of animal [a]	Metric tons			0.055	0.156		0.01	
PHILLIPINES								
Production [a]	Metric tons ('000)	302	267	690	79[F]	16	26[F]	1241
Share in output of livestock sectors vulnerable to mycotoxins	Proportion	0.22	0.19	0.50	0.06	0.01	0.02	1.0
Average weight of animal [a]	Metric tons			0.056	0.159		0.013	
THAILAND								
Production [a]	Metric tons ('000)	717	474[F]	340[F]	179[F]	231	1[F]	1365
Share in output of livestock sectors vulnerable to mycotoxins	Proportion	0.37	0.24	0.18	0.09	0.12	0	1
Average weight of animal [a]	Metric tons			0.050	0.200		0.015	

a The data for 1991 is from FAO(1992, Table 92 (Beef and veal), Table 95 (Goat meat), Table 96 (Pigmeat), Table 97 (Poultry meat), Table 99 (Cow milk), Table 103 (hen eggs), Table 89 (stocks of cattle), Table 90 (stocks of pigs and goats), table 91 (stocks of chickens).

F denotes FAO estimate

* denotes unofficial figure

Appendix V: General equilibrium elasticities and related data Indonesia, Philippines and Thailand

TABLE V.1: PIGGOT ET AL.'S ELASTICITY MATRIX INDONESIA

	Price maize food	Price maize feed	Price peanuts food	Price peanuts feed	Price poultry meat	Price hen eggs	Price pig meat	Maize food	Maize feed	Peanut food	Peanut feed	Poultry meat	Hen eggs	Pig meat
Maize supply food	0.495	0	-0.02	0	0	0	0	-1	0	0	0	0	0	0
Maize food demand	-0.2	0	0.02	0	0	0	0	-1	0	0	0	0	0	0
Maize supply feed	0	0.099	0	0	0.11	1	0.8	0	-1	0	0	0	0	0
Maize feed demand	0	-0.5	0	0.02	0.03	0.03	0.03	0	-1	0	0	0	0	0
Peanut supply food	-0.01	0	0.37	0	0	0	0	0	0	-1	0	0	0	0
Peanut food demand	0.05	0	-1	0	0	0	0	0	0	-1	0	0	0	0
Peanut feed supply	0	0.01	0	0.0185	0.003	0.003	0.003	0	0	0	-1	0	0	0
Peanut feed demand	0	0.05	0	-0.05	0	0	0	0	0	0	-1	0	0	0
Poultry meat supply	-0.11	0.03	0.01	-0.003	0.5	0	0	0	0	0	0	-1	0	0
Poultry meat demand	0	0	0	0	-1.3	0.2	0.4	0	0	0	0	-1	0	0
Hen eggs supply	1	0.03	-0.01	-0.003	0	0.35	0	0	0	0	0	0	-1	0
Hen eggs demand	0	0	0	0	0.2	-1.4	0.4	0	0	0	0	0	-1	0
Pig meat supply	-0.8	0.03	0	-0.003	0	0.08	0.45	0	0	0	0	0	0	-1
Pig meat demand	0	0	0	0	0.2	0.2	-1.1	0	0	0	0	0	0	-1

TABLE V.2: INVERSE OF PIGGOT ET AL.'S ELASTICITY MATRIX INDONESIA

	Price maize food	Price maize feed	Price peanuts food	Price peanuts feed	Price poultry meat	Price hen eggs	Price pig meat	Maize food-quantity	feed quantity	Peanut food quantity	Peanut feed quantity	Poultry meat quantity	Hen eggs quantity	meat quantity
Maize supply food	1.4425	1.4425	0	2.78E-17	0.0421	0.04212	0	6.9E-18	0	3E-18	0	3E-17	2E-17	0
Maize food demand	3.2433	3.2433	1.85291	-1.852907	-0.1005	0.10054	0.4171	-0.4171	-0.36	0.358	-1.159	1.159	-1.313	1.313
Maize supply feed	0.0632	-0.0632	-2E-19	-1.52E-18	0.7318	-0.73177	-4E-19	4.3E-19	0	2E-19	0	0	7E-19	0
Maize feed demand	2.953F	2.9536	1.62855	-1.628546	-0.0914	0.09137	14.96	-14.9603	-0.35	0.347	-1.05	1.05	-1.199	1.199
Peanut supply food	0.4759	-0.4759	-0.0422	0.0422004	0.0103	-0.01034	0.0269	-0.02694	0.59	-0.591	0.1047	-0.105	0.201	-0.2
Peanut food demand	1.1471	1.1471	-0.0433	0.0432825	0.0373	-0.03734	0.0276	-0.02763	0.09	-0.094	0.6202	-0.62	0.206	-0.21
Peanut feed supply	0.9518	-0.9518	0.0415	0.0415068	0.0277	-0.02773	0.0265	-0.0265	0.09	-0.09	0.0819	-0.082	0.71	-0.71
Peanut feed demand	0.2872	-0.7128	0	1.735E-18	0.0062	-0.00621	3E-18	-2.6E-18	0	9E-19	0	-7E-18	-2E-18	2E-18
Poultry meat supply	1.6398	-1.6398	-0.8977	-0.102308	0.0507	-0.05071	0.0931	-0.09309	0.2	-0.195	0.5825	-0.583	0.666	-0.67
Poultry meat demand	0.0089	-0.0089	2.2E-19	-9.89E-20	-0.7297	-0.27033	-8E-20	6.1E-20	0	7E-21	2E-19	-2E-19	1E-19	0
Hen eggs supply	-0.0145	0.0145	0.01122	-0.011218	0.0005	0.00046	-0.727	-0.27284	0	5E-04	-0.005	0.005	-0.006	0.006
Hen eggs demand	-0.0085	0.0085	0.0296	-0.029601	0.0051	-0.00511	-0.019	0.0189	-0.71	-0.286	0.0207	-0.021	0.064	-0.06
Pig meat supply	-1.1301	1.1301	0.03555	-0.035553	-0.0391	0.03911	-0.023	0.0227	0.02	-0.023	-0.815	-0.185	0.036	-0.04
Pig meat demand	-0.7224	0.7224	0.02856	-0.028561	-0.021	0.02097	-0.018	0.01823	0.04	-0.038	0.0549	-0.055	-0.7	-0.3

TABLE V.3: PIGGOT ET AL.'S EXOGENOUS VARIABLES ELASTICITY MATRIX (D) MATRIX INDONESIA

	INCOME	MAIZE MEDIUM QUALITY	MAIZE LOW QUALITY	PEANUTS MEDIUM QUALITY	PEANUTS LOW QUALITY
Price maize food	0	0	0	0	0
Price maize feed	0	0	0	0	0
Price peanuts food	0	0	0	0	0
Price peanuts feed	0	0	0	0	0
Price poultry meat	0	0	0	0	0
Price hen eggs	0	0	0	0	0
Price pig meat	0	0	0	0	0
Maize food-quantity	0.55	0	0	0	0
Maize feed quantity	-1.5	0	0	0	0
Peanut food quantity	-0.65	0	0	0	0
Peanut feed quantity	0	0	0	0	0
Poultry meat quantity	-1.03	0.0504	0.022	0.0336	0.1815
Hen eggs quantity	-1.5	0.0036	0.002	0.0024	0.0165
Pig meat quantity	-1.03	0	0.0224	0	0.1848

TABLE V.4: PIGGOT'S GENERAL EQUILIBRIUM ELASTICITIES MATRIX INDONESIA

	INCOME	MAIZE MEDIUM QUALITY	MAIZE LOW QUALITY	PEANUTS MEDIUM QUALITY	PEANUTS LOW QUALITY
Price maize food	-5E-18	1E-18	-3E-19	9.825E-19	2E-18
Price maize feed	0.5019	0.0537	0.05227	0.0357798	0.4312
Price peanuts food	2E-18	2E-21	-4E-20	1.56E-21	-3E-19
Price peanuts feed	-8.4514	0.0486	0.04756	0.0324099	0.3923
Price poultry meat	-0.5039	-0.0046	-0.0064	-0.003036	-0.0527
Price hen eggs	0.4473	-0.0305	-0.0178	0.020344	-0.1472
Price pig meat	-0.3402	-0.0016	-0.0163	-0.001048	-0.1344
Maize food-quantity	2E-18	-4E-19	-1E-19	-2.37E-19	-1E-18
Maize feed quantity	0.07	-0.027	-0.0264	-0.017975	-0.2178
Peanut food quantity	3E-19	-8E-21	-6E-21	-5.2E-21	-5E-20
Peanut feed quantity	-0.1525	0.0003	0.00024	0.0001685	0.0019
Poultry meat quantity	1.2584	-0.0008	-0.0018	-0.000542	-0.0146
Hen eggs quantity	0.1569	-0.0092	-0.0048	-0.006144	-0.0398
Pig meat quantity	1.393	-0.0053	-0.0093	-0.003523	-0.077

TABLE V.5: PIGGOT ET AL.'S ELASTICITIES MATRIX PHILIPPINES

	Price maize food	Price maize feed	Price peanuts food	Price peanuts feed	Price poultry meat	Price hen eggs	Price pig meat	Maize food	Maize feed	Peanut food	Peanut feed	Poultry meat	Hen eggs	Pig meat
Maize supply food	0.122	0	-0.02	0	0	0	0	-1	0	0	0	0	0	0
Maize food demand	-0.2	0	0.02	0	0	0	0	-1	0	0	0	0	0	0
Maize supply feed	0	0.61	0	0	0.11	1	0.8	0	-1	0	0	0	0	0
Maize feed demand	0	-0.5	0	0.02	0.03	0.03	0.03	0	-1	0	0	0	0	0
Peanut supply food	-0.01	0	0.37	0	0	0	0	0	0	-1	0	0	0	0
Peanut food demand	0.05	0	-1	0	0	0	0	0	0	-1	0	0	0	0
Peanut feed supply	0	-0.01	0	0.0185	0.003	0.003	0.003	0	0	0	-1	0	0	0
Peanut feed demand	0	0.05	0	-0.05	0	0	0	0	0	0	-1	0	0	0
Poultry meat supply	-0.11	0.03	0.01	-0.003	0.5	0	0	0	0	0	0	-1	0	0
Poultry meat demand	0	0	0	0	1.3	0.2	0.4	0	0	0	0	-1	0	0
Hen eggs supply	-1	0.03	-0.01	-0.003	0	0.35	0	0	0	0	0	0	-1	0
Hen eggs demand	0	0	0	0	0.2	-1.4	0.4	0	0	0	0	0	-1	0
Pig meat supply	-0.8	0.03	0	-0.003	0	0.08	0.45	0	0	0	0	0	0	-1
Pig meat demand	0	0	0	0	0.2	0.2	-1.1	0	0	0	0	0	0	-1

TABLE V.6: INVERSE OF PIGGOT ET AL.'S ELASTICITIES MATRIX PHILIPPINES

	Price maize food	Price maize feed	Price peanuts food	Price peanuts feed	Price poultry meat	Price hen eggs	Price pig meat	Maize food-quantity	feed quantity	Peanut food quantity	Peanut feed quantity	Poultry meat quantity	Hen eggs quantity	meat quantity
Maize supply food	3.1226	-3.1226	0	-3.47E-18	0.0912	-0.09117	2E-17	-2.4E-17	0	7E-18	1E-16	-8E-17	9E-17	6E-17
Maize food demand	-3.6062	3.6062	0.95175	-0.951753	-0.1083	0.10829	0.2142	-0.21425	-0.18	0.184	-0.595	0.595	-0.674	0.674
Maize supply feed	0.1368	-0.1368	2.2E-19	-3.25E-19	0.7339	-0.73392	4E-19	-8.7E-19	0	4E-19	7E-18	-3E-18	4E-18	3E-18
Maize feed demand	-3.3926	3.3926	0.83651	-0.836509	-0.1017	0.10169	14.782	-14.782	-0.19	0.194	-0.555	0.555	-0.638	0.638
Peanut supply food	0.9524	-0.9524	-0.0217	0.0216764	0.0242	-0.02419	0.0316	-0.03156	0.59	-0.587	0.0918	-0.092	0.186	-0.19
Peanut food demand	2.4034	-2.4034	-0.0222	0.0222322	0.0739	-0.07395	0.0324	-0.03237	0.09	-0.09	0.607	-0.607	0.191	-0.19
Peanut feed supply	1.9838	-1.9838	-0.0213	0.0213201	0.0578	-0.0578	0.031	-0.03104	0.09	-0.086	0.0693	-0.069	0.696	-0.7
Peanut feed demand	-0.6218	-0.3782	1.3E-18	0	-0.0036	0.00356	2E-18	-2.2E-18	0	4E-19	3E-17	-7E-18	1E-17	1E-17
Poultry meat supply	1.8955	-1.8955	-0.4611	-0.538897	0.0568	-0.05679	0.1914	-0.19137	0.11	-0.111	0.3095	-0.31	0.357	-0.36
Poultry meat demand	0.0194	-0.0194	8.5E-20	-2.04E-19	-0.7294	0.27064	-4E-20	4.9E-21	0	3E-20	-1E-18	-6E-19	6E-19	5E-19
Hen eggs supply	-0.0107	0.0107	0.00576	-0.005762	-0.0003	0.00033	-0.728	-0.27161	0	-5E-04	-0.002	0.002	-0.002	0.002
Hen eggs demand	0.0361	-0.0361	0.0152	-0.015205	0.0065	-0.00646	-0.022	0.02214	-0.71	-0.289	0.0297	-0.03	0.075	-0.07
Pig meat supply	-2.3808	2.3808	0.01826	-0.018262	-0.0756	0.07557	-0.027	0.02659	0.03	-0.026	-0.804	-0.196	0.048	-0.05
Pig meat demand	-1.5111	1.5111	0.01467	-0.01467	-0.044	0.04395	-0.021	0.02136	0.04	-0.041	0.0636	-0.064	-0.69	-0.31

TABLE V.7: PIGGOT ET AL.'S EXOGENOUS VARIABLES ELASTICITIES MATRIX (D) PHILIPPINES

	INCOME	MAIZE MEDIUM QUALITY	MAIZE LOW QUALITY	PEANUTS MEDIUM QUALITY	PEANUTS LOW QUALITY
Price maize food	0	0	0	0	0
Price maize feed	0	0	0	0	0
Price peanuts food	0	0	0	0	0
Price peanuts feed	0	0	0	0	0
Price poultry meat	0	0	0	0	0
Price hen eggs	0	0	0	0	0
Price pig meat	0	0	0	0	0
Maize food-quantity	0.55	0	0	0	0
Maize feed quantity	-1.5	0	0	0	0
Peanut food quantity	-0.65	0	0	0	0
Peanut feed quantity	-1.5	0	0	0	0
Poultry meat quantity	-1.2	0.0392	0.0318	0.0168	0.0848
Hen eggs quantity	-1.2	0.0028	0.003	0.0012	0.008
Pig meat quantity	-1.5	0	0.0336	0	0.0896

TABLE V.8: PIGGOT ET AL.'S GENERAL EQUILIBRIUM ELASTICITIES MATRIX PHILIPPINES

	INCOME	MAIZE MEDIUM QUALITY	MAIZE LOW QUALITY	PEANUTS MEDIUM QUALITY	PEANUTS LOW QUALITY
Price maize food	-3E-16	-3E-18	-5E-19	-1.29E-18	1E-18
Price maize feed	0.0146	0.0214	0.03956	0.0091892	0.1055
Price peanuts food	-2E-17	-1E-19	3.4E-21	-5.36E-20	9E-21
Price peanuts feed	-7.9897	0.02	0.03715	0.0085578	0.0991
Price poultry meat	-0.4884	-0.0031	-0.0086	-0.00132	-0.023
Price hen eggs	-0.2188	-0.0233	-0.0251	-0.009969	-0.067
Price pig meat	0.0978	-0.0008	-0.0235	-0.000329	-0.0626
Maize food-quantity	-6E-17	-2E-19	1.3E-19	-1.05E-19	3E-19
Maize feed quantity	-0.1854	0.0111	-0.0208	-0.004772	-0.0553
Peanut food quantity	7E-19	-2E-20	-2E-21	-9.89E-21	-6E-21
Peanut feed quantity	-0.1498	7E-05	0.00012	3.157E-05	0.0003
Poultry meat quantity	1.2802	-0.001	-0.0032	-0.00041	-0.0086
Hen eggs quantity	1.4478	-0.0076	-0.0077	-0.003239	-0.0206
Pig meat quantity	1.2509	-0.0044	-0.0145	-0.001896	-0.0387

TABLE V.9: PIGGOT ET AL.'S ELASTICITIIES MATRIX THAILAND

	Price maize food	Price maize feed	Price peanuts food	Price peanuts feed	Price poultry meat	Price hen eggs	Price pig meat	Maize food	Maize feed	Peanut food	Peanut feed	Poultry meat	Hen eggs	Pig meat
Maize supply food	-0.0001	0	0	0	0	0	0	-1	0	0	0	0	0	0
Maize food demand	0	0	0	0	0	0	0	-1	0	0	0	0	0	0
Maize supply feed	0	0.61	0	0	0.11	1	0.8	0	-1	0	0	0	0	0
Maize feed demand	0	-0.5	0	0.02	0.03	0.03	0.03	0	-1	0	0	0	0	0
Peanut supply food	-0.01	0	0.37	0	0	0	0	0	0	-1	0	0	0	0
Peanut food demand	0.05	0	-1	0	0	0	0	0	0	-1	0	0	0	0
Peanut feed supply	0	-0.01	0	0.0185	0.003	0.003	0.003	0	0	0	-1	0	0	0
Peanut feed demand	0	0.05	0	-0.05	0	0	0	0	0	0	-1	0	0	0
Poultry meat supply	-0.11	0.03	0.01	-0.003	0.5	0	0	0	0	0	0	-1	0	0
Poultry meat demand	0	0	0	0	-1.3	0.2	0.4	0	0	0	0	-1	0	0
Hen eggs supply	-1	0.03	-0.01	-0.003	0	0.35	0	0	0	0	0	0	-1	0
Hen eggs demand	0	0	0	0	0.2	-1.4	0.4	0	0	0	0	0	-1	0
Pig meat supply	-0.8	0.03	0	-0.003	0	0.08	0.45	0	0	0	0	0	0	-1
Pig meat demand	0	0	0	0	0.2	0.2	-1.1	0	0	0	0	0	0	-1

TABLE V.10: INVERSE OF PIGGOT ET AL.'S ELASTICITIIES MATRIX THAILAND

	Price maize food	Price maize feed	Price peanuts food	Price peanuts feed	Price poultry meat	Price hen eggs	Price pig meat	Maize food-quantity	feed quantity	Peanut food quantity	Peanut feed quantity	Poultry meat quantity	Hen eggs quantity	meat quantity
Maize supply food	-10000	10000	-2E-17	1.735E-17	-9E-19	-1.7E-18	3E-18	1E-17	0	7E-18	1E-16	3E-17	-6E-17	0
Maize food demand	11549	-11549	0.95175	-0.951753	-0.003	0.003	0.2142	-0.21425	-0.18	0.184	-0.595	0.595	-0.674	0.674
Maize supply feed	-437.96	437.96	-3E-19	6.502E-19	0.7299	-0.72993	0	6.5E-19	0	4E-19	7E-18	3E-18	-3E-18	0
Maize feed demand	10865	-10865	0.83651	-0.836509	-0.0026	0.00263	14.782	-14.782	-0.19	0.194	-0.555	0.555	-0.638	0.638
Peanut supply food	-3050.1	3050.1	-0.0217	0.0216764	-0.0036	0.00362	0.0316	-0.03156	0.59	-0.587	0.0918	-0.092	0.186	-0.19
Peanut food demand	-7696.9	7696.9	-0.0222	0.0222322	0.0038	-0.00378	0.0324	-0.03237	0.09	-0.09	0.607	-0.607	0.191	-0.19
Peanut feed supply	-6353.2	6353.2	-0.0213	0.0213201	-0.0001	0.00012	0.031	-0.03104	0.09	-0.086	0.0693	-0.069	0.696	-0.7
Peanut feed demand	-1E-16	-1	4.2E-22	-1.27E-21	2E-22	0	8E-22	-1.7E-21	0	0	0	0	8E-21	8E-21
Poultry meat supply	-6070.2	6070.2	-0.4611	-0.538897	0.0015	-0.00145	0.1914	-0.19137	0.11	-0.111	0.3095	-0.31	0.357	-0.36
Poultry meat demand	-62.044	62.044	-4E-20	-6.18E-20	-0.7299	-0.27007	-1E-19	1.7E-19	0	3E-20	-9E-19	3E-20	-5E-19	0
Hen eggs supply	34.208	-34.209	0.00576	-0.005762	-2E-05	1.9E-05	-0.728	-0.27161	0	-5E-04	-0.002	0.002	-0.002	0.002
Hen eggs demand	-115.55	115.55	0.0152	-0.015205	0.0054	-0.00541	-0.022	0.02214	-0.71	-0.289	0.0297	-0.03	0.075	-0.07
Pig meat supply	7624.3	-7624.3	0.01826	-0.018262	-0.0061	0.00606	-0.027	0.02659	0.03	-0.026	-0.804	-0.196	0.048	-0.05
Pig meat demand	4839.2	-4839.2	0.01467	-0.01467	0.0002	-0.00017	-0.021	0.02136	0.04	-0.041	0.0636	-0.064	-0.69	-0.31

TABLE V.11: PIGGOT ET AL.'S EXOGENOUS VARIABLES ELASTICITIES MATRIX (D) MATRIX THAILAND

	INCOME	MAIZE MEDIUM QUALITY	MAIZE LOW QUALITY	PEANUTS MEDIUM QUALITY	PEANUTS LOW QUALITY
Price maize food	0	0	0	0	0
Price maize feed	0	0	0	0	0
Price peanuts food	0	0	0	0	0
Price peanuts feed	0	0	0	0	0
Price poultry meat	0	0	0	0	0
Price hen eggs	0	0	0	0	0
Price pig meat	0	0	0	0	0
Maize food quantity	0.55	0	0	0	0
Maize feed quantity	-1.5	0	0	0	0
Peanut food quantity	-0.65	0	0	0	0
Peanut feed quantity	1.5	0	0	0	0
Poultry meat quantity	1.2	0.042	0.0795	0.0392	0.053
Hen eggs quantity	1.2	0.003	0.0075	0.0028	0.005
Pig meat quantity	-1.5	0	0.084	0	0.056

TABLE V.12: PIGGOT'S GENERAL EQUILIBRIUM ELASTICITIES MATRIX THAILAND

	INCOME	MAIZE MEDIUM QUALITY	MAIZE LOW QUALITY	PEANUTS MEDIUM QUALITY	PEANUTS LOW QUALITY
Price maize food	-2E-18	1E-18	6E-18	9.326E-19	-4E-18
Price maize feed	0.0146	0.023	0.09889	0.0214415	0.0659
Price peanuts food	-5E-18	1E-19	-7E-20	1.274E-19	-5E-20
Price peanuts feed	-7.9897	0.0214	0.09289	0.0199681	0.0619
Price poultry meat	-0.4884	-0.0033	-0.0215	-0.003079	-0.0144
Price hen eggs	0.2188	-0.0249	0.0628	-0.023261	-0.0419
Price pig meat	0.0978	-0.0008	-0.0587	-0.000768	-0.0392
Maize food quantity	-2E-20	3E-23	7E-22	2.372E-23	5E-22
Maize feed quantity	-0.1854	-0.0119	-0.0519	-0.011135	-0.0346
Peanut food quantity	3E-18	3E-23	-4E-20	2.77E-23	-3E-20
Peanut feed quantity	-0.1498	8E-05	0.0003	7.367E-05	0.0002
Poultry meat quantity	1.2802	-0.001	-0.0081	-0.000956	-0.0054
Hen eggs quantity	1.4478	-0.0081	-0.0193	-0.007558	-0.0129
Pig meat quantity	1.2509	-0.0047	-0.0363	-0.004423	-0.0242

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ABBREVIATIONS	
ACIAR:	Australian Centre for International Agricultural Research
CAST	Council for Agricultural Science and Technology, USA
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo (International Maize and Wheat Improvement Center)
FAO	Food and Agriculture Organisation of the United Nations
IARC	International Agency for Research on Cancer
ICRISAT	International Crops Research Institute for Semi-Arid Tropics
ISNAR	International Service for National Agricultural Research
IUPAC	International Union of Pure and Applied Chemistry
PAN	Polska Akademia Nuak
WHO	World Health Organisation

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