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# PROJECTING INTERNATIONAL DEMAND FOR AND SUPPLY OF PROTEIN FEED

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*South Africa is currently a net importer of protein meal with 1998 imports exceeding R1 billion. Information regarding the cost of future imports will assist South African decision makers with regard to stimulating the South African protein industry. A spreadsheet model which readily allows scenario analysis is developed to project future supply of and demand for protein feed. Estimated price elasticities of supply and demand enable the model to project equilibrium consumption and price until 2020. The model incorporates as growth parameters: income growth, population growth and income elasticity of demand. It also allows for income elasticities to decline as incomes rise. Assuming a 3% annual growth in supply, the model forecasts that real price for protein meal will remain relatively constant to 2020. However, if supply increases linearly price is forecast to increase 22% by 2020. Developing Asia, notably China, accounts for most demand growth and projections are sensitive to growth assumptions for China.*

## 1. INTRODUCTION

Protein feed consumption in South Africa has increased significantly in recent years and South Africa is currently a net importer of oilcake with 1998 imports exceeding R1 billion. These meal imports are largely composed of soybean cake for use in the poultry industry. A recent study indicated that South African oilcake consumption in 2020 could be substantially above current levels (Nieuwoudt, 1998b). The Protein Research Trust (PRT), in planning for this possible increase in future demand, is interested in the projected international supply of and demand for oilcake up to 2020. Projections are needed to aid decision making about whether sufficient future supplies of oilcake will be available at low prices on the world market, which will influence the priority given to local production. Currently the PRT is involved in stimulating South African production of protein meal, largely through investing in research and farmer education.

The objective of this study is to project the international price and consumption of protein feed to 2020 under different scenarios. A

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computerized interactive spreadsheet model, which can be readily updated and is useful for scenario (and "what if") analysis, is developed for this purpose. The model incorporates income elasticities that decrease with rising incomes and estimated price elasticities of demand and supply are used to project equilibrium consumption.

## 2. THE INTERNATIONAL MARKET FOR PROTEIN MEAL

### 2.1 Market share of oilcakes

Oilseeds are processed for the joint products oilcake (meal) and vegetable oil. The meal has a high protein content and is therefore a valuable ingredient in feed rations. Oilcake has largely replaced fishmeal as a source of feed protein in South Africa due to limited supply and relatively high prices of fishmeal (Griessel, 1999). Fishmeal production has remained relatively constant over time (0.23% annual growth 1987 to 1997), in contrast to the high growth of soymeal (2.95% 1987 to 1997) and total meal (3.14% 1987 to 1997). Globally, fishmeal usage for feed is unlikely to increase significantly and, consequently, the nine major oilseeds crushed internationally are considered in this paper.

Oilseeds yield oil and meal in varied ratios and contain differing percentages of crude protein. Soybeans yield up to 80 percent meal while containing the highest crude protein percentage (Table 1) and most complete amino acid content (Degussa, 1996).

**Table 1: Oilcake share of world production (2000), trade (1999) and average percentage crude protein of different oilcakes**

| | % Crude protein | % Market share | % Trade share |
|---|---|---|---|
| Cake of Coconuts | 18.55 | 1.05 | 1.07 |
| Cake of Cotton Seed | 41.91 | 7.75 | 1.09 |
| Cake of Groundnuts | 43.20 | 3.52 | 0.44 |
| Cake of Linseed | 30.00 | 0.87 | 0.69 |
| Cake of Palm Kernels | 14.23 | 1.80 | 5.63 |
| Cake of Rapeseed | 35.13 | 11.87 | 7.55 |
| Cake of Sesame Seed | 41.09 | 0.51 | 0.03 |
| Cake of Soya Beans | 45.64 | 61.12 | 75.73 |
| Cake of Sunflower Seed | 33.51 | 6.81 | 6.78 |

*Source: Degussa (1996) and FAO (2000)*

Soymeal dominates the international protein meal market in terms of both market and trade share (Table 1). Figure 1 shows production of different





oilcakes, emphasizing the dominance of soymeal. In 2000, soymeal consumption exceeded 100 million tons (61 percent of total oilmeal produced) and world soymeal trade exceeded 32 million tons (75 percent of total meal trade). Rapeseed meal is also widely used, although only meal from rape varieties low in glucosinolates (sometimes traded as Canola) is suitable as animal feed. Cottonseed meal, consumed largely in Asia, is the third most consumed oilcake although trade is minimal.

### 2.2 International consumption trends of oilcake

Presently, the high-income countries of the industrial world consume the greatest quantity of protein meal in both per-capita[3] and absolute terms. For example, the EU (108kg/capita) and the USA (118kg/capita) consume 44 % of world oilcake production. Per capita consumption of oilcake is significantly lower in the developing countries of Asia (15kg/capita), Africa (8kg/capita) and South America (25kg/capita) than in the industrial world. Total consumption of oilcake in developing Asia however is substantial at 31 % of world supply. China (18 kg/capita) accounts for 44% of Asian consumption at (14% of world consumption) followed by India at 19 % (6% of world consumption).

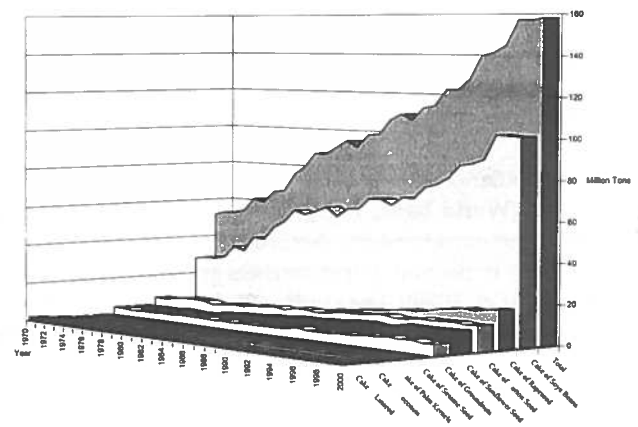

**Figure 1: International consumption of major oilseeds (1990 to 2000), million tonnes**

*Source: FAO (2000)*

[3] *Protein meal is not consumed directly by humans, but per capita consumption measures give an indication of the prevalence of protein meal use in a particular country.*

Meal consumption trends from 1990 to 1999, (Figure 2) indicate a decline in consumption growth for the EU and USA over recent years. In contrast, meal consumption growth in developing Asia and China has been high (consumption declined following the Asian financial crisis). This trend has occurred in tandem with the significant increases in Asian meat consumption noted by Delgado *et al* (1999) and Rutherford (1999). China accounts for most of the growth in Asian consumption with increases in meal use of 15 % compound per annum between 1989 and 1997.

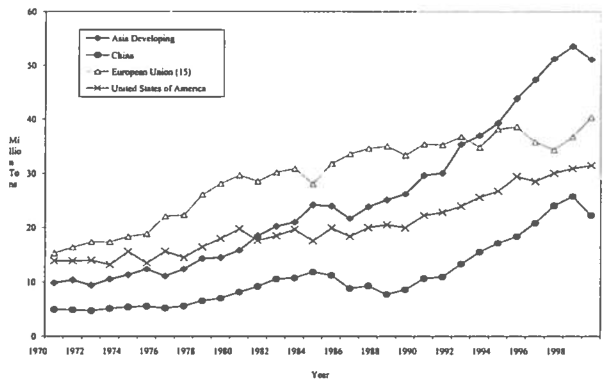


**Figure 2: Oilcake consumption growth trends (1970-1999)**
***Source****: Own calculations from FAO (2000) data.*
***Notes****: Consumption is production plus imports less exports.*

China has an estimated population of about 1.3 billion people or over 20 % of the total world population (World Bank, 1999), and thus accounts for a large share of food production and consumption. Accordingly, changes in Chinese demand have a considerable impact on world markets and international trade (Fan *et al*, 1994; Rosegrant *et al*, 1998). The study of consumption patterns in China is therefore important when projecting future world demand (Habrendt *et al*, 1994).

### 2.3 International production trends

Argentina, Brazil and the United States of America (USA) collectively export 70% of world oilseeds and produce about 40 % of world meal and 70 % of world soymeal. Together with the European Union (EU) (which imports large quantities of oilseed for domestic crushing) these countries account for about 50 % of world oilcake production. Brazil and Argentina are the most





important exporters because of their large local production and relatively small domestic consumption.

Oilcake production in Asia was 30 % of world total in 2000, yet Asia is a net importer of protein meal. Only 34 % of Asian oilcake are derived from soybeans compared to 58 % of EU production and upwards of 76 % in Argentina, Brazil and USA. China, the largest Asian producer, manufactures more oilcake than either Argentina or Brazil. China is however a significant importer of oilseeds and oilcake. India, the second largest Asian producer of oilseed and oilcake, is the only Asian exporter of oilcake.

International annual meal production increased about 38% from 1990 to 2000 or at an annual rate of 3.3%. In the developed world, over the same period, the USA increased production 36% and the EU 23%. Concurrently, amongst the major emerging nations, Brazil increased production by 35%, Argentina by 120%, China by 64% and India by 33% (soymeal production increased 100% in India). Argentina has shown the most notable increase in exports following a rise in export market share from 2% in 1980 to 31% in 1999.

### 2.4 Price trends

While soymeal commands a premium in the oilcake market, annual prices for the most traded meals, soymeal, rapemeal and sunflower meal are highly correlated. To capture the common movement in these prices, a principal component analysis of monthly prices from 1985 to 2000 was conducted. The results are presented in Table 2.

**Table 2: Component matrix**

| | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| SOYMEAL | 0.950 | -0.171 | -0.262 |
| SUNMEAL | 0.943 | -0.232 | 0.239 |
| RAPEMEAL | 0.907 | 0.420 | 0.026 |

Component 1 explained 87% of the variation in soymeal, rapemeal and sunmeal monthly prices while the three coefficients have the same sign. It can be inferred that meal prices move very closely together because these products are substitutes on the demand side and, to a lesser extent, on the supply side. A supply or consumption change affecting one meal type affects the others within the same month. Simple correlation of the first component with each price is 0.962 (soymeal), 0.933 (sunflower meal) and 0.901

(rapemeal). Therefore, soymeal price serves as an almost perfect meal price index and is used as an indicator price (Doll & Chin, 1970) for all meal in this study. The reason for the high correlation with soymeal is that it is the dominant feed in terms of value.

Component 2 explains 8.6% of variation occurring when rapemeal prices move in the opposite direction to sunflower meal and soymeal. Doll and Chin (1970:592) note that 'signs of this type may indicate a lagged effect between the series that is independent of the first component'. However, the period considered here is only one month. So, in the longer term prices are likely to be more closely correlated. Nevertheless, fluctuations orthogonal to main price movement are small. The decision to group all meal types as a single commodity for projection purposes is justified because a projected percentage price increase will be appropriate for the entire meal market.

In the short term there is scope to adjust quantities of different feed types used within the constraints of least cost feed formulations in response to price fluctuations. Substitutions between the different feed types and arbitrage in the market ultimately result in the long-term correlation of prices.

Internationally real meal prices have declined consistently since the 1970's (Figure 3). Nevertheless, prices are sensitive to supply and demand factors as evident in recent fluctuations. Prices in 1996/7 were relatively high (Figure 4) following strong increases in global demand, driven largely by high Asian GDP growth, and sluggish growth in world supply. However, by 1998 the Asian financial crisis, caused a decrease in demand while a record world oilseed crop, a result of increased plantings and excellent weather, combined to lead to a market surplus and low prices (USDA, 1999b).

## 2.5 Future impact of biotechnology on protein feed production

Recent progress in genetic engineering (GE) has enabled researchers to alter and move genetic material in living cells, creating genetically modified organisms (GMO's). Using this technique, desirable genetic traits from other species can be artificially incorporated in crops. This has led to the development of soybeans resistant to glyphosate, the active compound in the weed killing herbicide Roundup. These GMO soybeans, marketed as Roundup-Ready, enable farmers to kill weeds without also harming the crop. Acreage of GMO soybeans in the USA has increased from 17% in 1997 to 57% in 1999 (USDA, 1999c). The USDA (1999c) found that total herbicide use decreased while yield and profitability increased with the use of GMO





soybeans. Such findings indicate that GMO technology could increase future supply growth if widely adopted by producers.

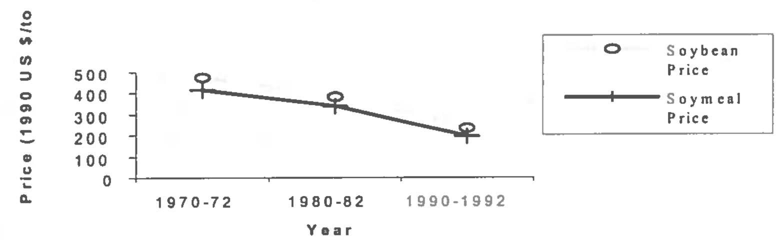


**Figure 3: Real soybean and soymeal prices from 1970/72 to 1990/92**
*Source: Delgado et al (1999)*
*Notes: Soybeans are U.S. c.i.f. Rotterdam, soymeal is any origin, Argentine 45-46% extraction, c.i.f. Rotterdam*

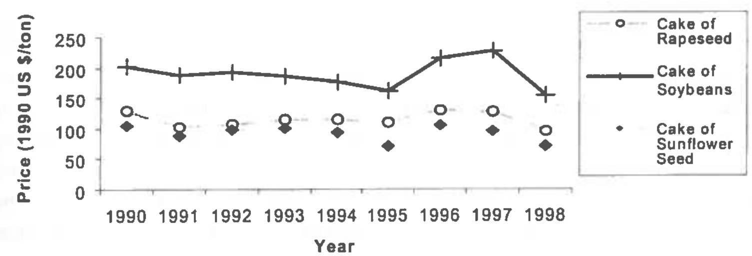


**Figure 4: Real export prices for selected protein meal from 1990-1998**
*Source: Own calculations from FAO (1999) data, price calculated as export value/export quantity*

It is envisaged that future development in GE will involve enhancing the value of crops (output traits) (USDA, 1999c). Soybeans with improved oils or amino acid (particularly lysine and methionine) content are already near commercial production (USDA, 1999c). From this technology based perspective, the rise in relative importance of rapeseed meal (production increased 6.3% annually from 1980 to 2000 versus 2.82% for soymeal) following the development of double low (low erucic acid, low glucosinolates) rape varieties is interesting. Reducing erucic acid content allowed the oil to be used in human consumption while reducing glucosinolates made meal acceptable as feed, thus making the crop more marketable (Weiss, 1983). Most oilseed GE research is undertaken on rape and soybeans. So, meal usage from these crops could continue to grow relative to other oilseed meals. An in depth look at the possible effects of GE on supply, price (especially prices that reflect GE enhanced quality attributes) and marketing are beyond the scope of this paper. However, a shift in future supply is possible and the rate of oilmeal (especially soymeal) supply growth may exceed the rate of supply growth experienced in recent years. Hence, the necessity of developing a model which can allow for different supply growth scenarios

Although GMO crops promise improved yield and profitability, trade disputes have arisen such as that between the EU and the USA regarding the labeling of GMO crops and products (Frank, 1999). Increasing barriers to trade, such as labeling requirements, may retard the adoption and development of GMO's in the short term. This situation presents a contrasting influence on supply to that proposed earlier. If constraints are imposed on GMO technology in the long-term, growth in production will be retarded.

## 3. METHODOLOGY FOR OWN PROJECTIONS

Global meal consumption and real price are projected to 2020 using 1999 as the base. Future consumption is estimated by the equilibrium solution of projected supply and demand curves. Projections are made for a base scenario, involving various assumptions on critical parameters, and scenarios in which parameters are adjusted allowing for "what if" and scenario analysis. Per capita income and population growth rates are used to estimate future demand. Real GDP per capita growth was used as a measure of per capita income growth.

### 3.1 Data

Data on oilcake production and trade were retrieved from the FAO (2000) online statistical databases. The major oilcakes are treated as one commodity because of the high level of substitution possible between different oilcakes and the correlation in price movements observed between different oilcakes. Consumption is calculated as production minus exports plus imports. No data on stock held were obtained and thus consumption figures used assume stocks remain constant. World production is assumed to match consumption (no surplus) in past years, in line with USDA (1997,1999a) world production and consumption levels for 1995 and 1996 that show relatively little change in stocks.





Population growth rate assumptions are taken from World Bank (1999) published forecasts. GDP growth assumptions are USDA (1999a), FAPRI (1999) or FAPRI (2000) forecast GDP growth rates [converted to per capita growth using World Bank (1999) population growth rates] for each country. The USDA (1999a) and FAPRI (1999) forecast GDP growth rates to 2008/9. FAPRI (2000) GDP growth rates are forecast to 2009/10. GDP growth rates given for 2008/9 (or 2009/10) are assumed to remain constant through to 2020. FAPRI (1999,2000) publishes GDP growth rates for each year and include the estimated impacts of the Asian financial crisis. USDA (1999) forecast growth rates are given for the periods 1997 to 2002 and 2003 to 2008/9. The model allows the user to choose which source to use for GDP growth rates. FAPRI (2000) GDP growth rates are used for the base scenario predictions.

### 3.2 Projecting oilcake supply shifts

In the absence of detailed information about factors affecting oilcake supply, and the difficulty of developing an accurate model for supply, future supply shifts are projected based on past production trends.

Production appears to have followed an approximately linear trend over time. For base scenario projections an estimated linear regression of production against time for the period 1990 to 2000 is extrapolated to 2020. The period 1990 to 2000 is chosen to capture recent structural changes in supply. However, as shown in Figure 5, the annual increase in production (slope of linear regression) increased from 1980-1990 to 1990-2000 and an exponential curve can be used to describe the production trend from 1980 to 2000. Alternative scenarios, with supply projected using constant growth models, are therefore also presented in section 0.

A supply index is calculated for each year from the selected base year (Index = 100) to 2020 as follows:

$$SI_N = (SP_N/BP)*100 \qquad (1)$$

where:

$SI_N$ = Supply Index in year N;
$SP_N$ = Projected Supply in Year N (from Linear or Growth Model);
BP = Production of Protein Meal in Base Year [1].

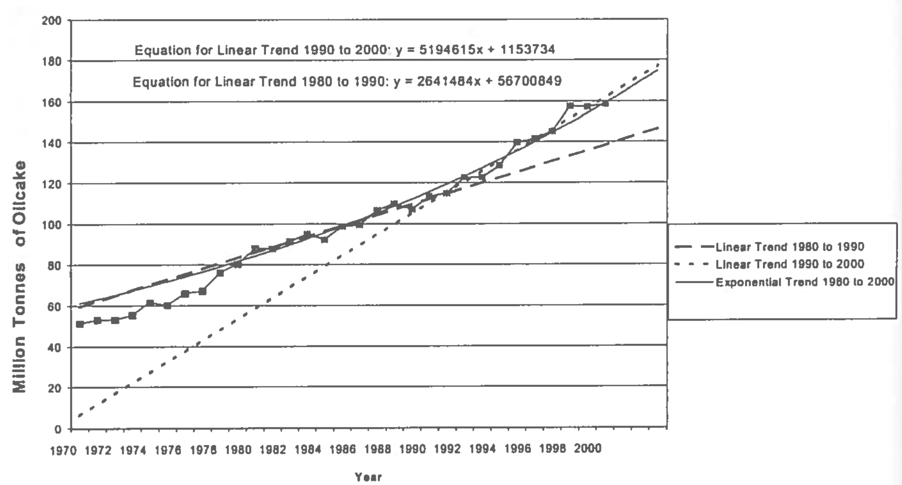


**Figure 5: Annual world oilcake production from 1970 to 2000**
*Source: Own calculations from FAO (2000) data*

The spreadsheet model allows selection of a desired supply projection model using any data period from 1970 to 2000 or the use of an independently chosen growth rate.

### 3.3 Projecting oilcake demand shifts

As protein meal consumption is derived from the demand for livestock products, projections for meal demand are based on expected income and population growth rates. Demand projections are made for 12 countries and the EU. The countries chosen represent the major consumers in the industrial world and those countries identified as having potential for consumption growth in the developing world. All the larger developing Asian and Latin American countries are represented. Projections are made from the chosen base year, to 2010 and 2020. An index for demand in each country after n years is calculated as follows:

$$I_i = 100*[\{(1+g_i)^n - 1\}* E_i + 1]*[1+p_i^n] \quad (2)$$

where:

$I_i$ = demand Index for country i;





g = forecast GDP per capita annual growth rate as a fraction in country i;
n = number of years in period;
E = income elasticity of demand for meal in country i; and
p = forecast annual population growth rate as a fraction) in country i.

A novel feature of this model is that income elasticities are permitted to decline as incomes increase. A demand function estimated by Schroeder *et al* (1995) that allows income elasticities to vary with income level is adapted for this purpose.

The index calculations outlined above are used to calculate future quantity demanded in each country (Index * Base year consumption). A world total demand level (for the selected countries) is obtained by aggregating the projected quantities demanded for each county as detailed below.

$$WI_N = \left[ \sum_{i=1}^{13} \frac{(I_i / 100 \ * BC_i)}{WC} \right] * 100 \quad (3)$$

where:

$WI_N$ = world index in year N
I = country
$I_i$ = index from (2) above
$BC_i$ = actual consumption in country i in the Base Year; and
WC = actual world consumption in the Base Year for the selected countries.

It is assumed that total world quantity demanded increases at the same rate as that of the selected countries. This assumption is not necessarily valid as it is likely that the selected countries will consume an increasing share of world production.

### 3.4 Income elasticities of demand for meal

Estimates of income elasticity are required in order to estimate income induced demand growth. Income elasticity estimates are not readily available for protein meal demand and thus independent estimates need to be made. The income elasticities of demand for protein feed were taken as approximated by the income elasticity of demand for livestock products.

Income elasticities for individual foods tend to decline as incomes rise (Tomek & Robinson, 1990). It is therefore appropriate to adjust income elasticities over time when making long term projections (USDA, 1997). The use of declining elasticities is especially relevant for China and South East Asian countries, who have experienced high GDP growth rates in recent years.

In the wealthier developed nations, income elasticities are expected to remain relatively constant as incomes are expected to increase more modestly and diets are satisfied. Crompton and Phillips (1993) report income elasticities in the EU for pork and poultry of 0.25 and 0.27, respectively. Own projections use an elasticity of 0.26 for the EU and USA for each year, on the basis that both regions have similar per capita incomes and consumer diets are largely satisfied.

Schroeder *et al* (1995) estimated the effects of national per capita income growth on national per capita meat consumption, using annual data for 32 countries for 1975-1990. The authors estimated single-equation demand models for pork, poultry, lamb and beef as follows:

$$\ln Q_{ijt} = \beta_0 + \beta_i \ln P_{ijt} + \sum_h \beta_h \ln P_{hjt} + \beta_{y1} \ln INC_{jt} + \beta_{y2}[\ln INC_{jt}]^2 \quad h \neq I \qquad (4)$$

where i and h refer to meat commodity (pork, poultry, lamb or beef), j refers to country, t refers to year, Q is per capita consumption, P is price, and INC is per capita income (GDP per capita in U.S. $). GDP per capita are deflated to 1985 constant dollars. The squared INC variable allows income elasticity to vary with income level. The income elasticity is calculated as:

$$\frac{\partial \ln Q_{ijt}}{\partial \ln INC_{jt}} = \beta_{y1} + 2\beta_{y2} \ln INC_{jt} \qquad (5)$$

The parameters $\beta y1$ and $\beta y2$ are shown in Table 3 for pork and poultry. Using these parameters and GDP per capita deflated to 1985 constant dollars, income elasticities are estimated for each developing country for poultry and pork to 2020.[2] The income elasticities estimated from (5) for pork are substantiated by other publications and were used as an estimate of protein meal elasticity in the base scenario forecast for all developing countries except China.

China's role in the world market is important because of her large population and the fact that China is expected to account for much of protein meal growth in the future. The elasticity used to project future Chinese





**Table 3: Estimates of parameters $\beta_1$ and $\beta_2$ from equation 1**

| | $\beta_1$ | $\beta_2$ |
|---|---|---|
| Pork | 3.070 | -0.146 |
| Poultry | 6.962 | -0.367 |

*Source: Schroeder et al (1995)*

consumption therefore needs especially careful consideration. Most studies on China's food demand were carried out in the late 80's and early 90's and income elasticity estimates vary widely depending on survey data and model specification (Tian, 1999). Tian and Chudleigh (1999) point out that while earlier studies on income elasticities for livestock products in China obtained high estimates, elasticities might have since declined. The authors argue that parameters estimated in the late 80's and early 90's might be inappropriate for predicting income induced demand growth into the future. Furthermore, income elasticities estimated by Schroeder *et al* (1995) using equation (5) appear high for China (over 2.0 for poultry and 1.09 for pork) when compared to recent estimates (Table 4). For these reasons the income elasticity for China is estimated as described below, while the elasticity decline as estimated by Schroeder *et al* (1995) was further incorporated.

Per capita meat consumption in China consists mostly of pork and to a lesser extent poultry meat. Beef and lamb are only consumed in very small amounts (USDA, 1997 and Crompton & Phillips, 1993). Most oilseed meal is used in pork and poultry production. Table 3 displays income elasticities and population ratios for China.

Consumption data for China USDA (1999a) indicates that the ratio of pork to poultry consumed is roughly 75:25. An income elasticity of meal in China for 1997 is calculated as follows from consumption of both pork and poultry.

**Table 4: Income elasticities and population ratios used to calculate elasticity for oilcake in China**

| | **Urban** | **Rural** |
|---|---|---|
| Pork income elasticity | 0.50 | 0.80 |
| Poultry income elasticity | 0.99 | 1.10 |
| Percentage population (1997) | 30 | 70 |

*Source: USDA (1999a), World Bank (1999)*

Urban income elasticity of meat demand = (0.5*0.75)+(0.99*0.25)= 0.623 (6)
Rural income elasticity of meat demand = (0.8*0.75)+(1.1*0.25) = 0.875 (7)

Chinese income elasticity of meat (Pork and Poultry)

= (0.623 * Urban Population Ratio) +(0.875 * Rural Population Ratio)
= (0.623*0.3)+(0.875*0.7)
= 0.80

The income elasticity of 0.80 for China was incorporated in the model along with the information provided by Schroeder *et al* (1995) on the decline of the income elasticity over time. Because of China's importance in the world market and the fact that urbanisation in China will result in a changing rural to urban population ratio, alternative income elasticities are considered in scenario (what if) analysis.

### 3.5 Projected consumption using linear supply and demand models

In the above projections of supply and demand, relative prices are assumed constant. Future consumption however depends upon shifts of demand and supply and therefore relative prices of oilcake. The effect of relative prices can be simulated using estimated price elasticities of supply and demand (Nieuwoudt, 1998b).

#### 3.5.1 *Estimate of price elasticity of input demand*

Protein feed is an essential factor of production and has no direct substitutes.[3] The price elasticity of input demand for all protein feed is therefore expected to be low. The relationship between the price elasticity of demand for an input (protein feed) and an output (broilers, pork etc) can be described as follows (NCSU, 1975):

$$n_{11} = a_1 n_{yy} - (1-a_1)\tau_{12} \quad (8)$$

where

$n_{11}$ = price elasticity of demand for input (protein feed)
$n_{yy}$ = price elasticity of demand for the product (broilers, pork etc)
$\alpha_1$ = the factor share of the final product = $\frac{X_1 P_{x1}}{Y_1 P_y}$





where:

$X_1$ = quantity of input (protein feed);
$P_{x1}$ = price of input (protein feed);
$Y_1$ = quantity of product (broilers, pork, etc.); and
$P_y$ = price of product (broilers, pork etc)
$\tau_{12}$ = elasticity of substitution between protein and other feeds (It is assumed that for fixed proportions $\tau_{12}$ = 0 i.e. cannot replace protein feed.)

The ratio $\alpha_1$ is estimated to be about ¼ for broilers and ⅓ for pork (Appendix B). Estimates of demand elasticity for meats range between -0.17 to -1.16 for poultry and -0.4 to -0.95 for pork (Delgado *et al*, 1999; Schroeder *et al*, 1995; USDA, 1997).

So if $n_{yy}$ = -0.5 for broilers and -0.4 for pork, and
$\alpha_1$ = ¼ for broilers and ⅓ for pork,

then estimates of $n_{yy}$ = (¼)(-0.5) = -0.125 and $n_{yy}$ = (⅓)(-0.4) = -0.13 are obtained, -0.13 is used for base scenario forecasts. An upper estimate of $n_{yy}$ = (¼)(-1) = -0.25 and lower estimate of $n_{yy}$ = (¼)(-0.2) = -0.05 are derived for use in sensitivity analysis from the ranges of data presented above.

Price elasticities of demand for protein meal as estimated here are lower in magnitude than the estimated income elasticities of demand for most countries. However, the homogeneity assumption (Slutsky-Schultz relation) is not applicable in this case as protein feed is an input. Little can thus be deduced from this assumption about the relative magnitude of income and price elasticities.

#### 3.5.2 *Estimate of input supply elasticity*

Mercier and Myberg (1993) estimate acreage response elasticities for soybeans of 0.176 for the period 1953 to 1989 in the United States. For the shorter periods 1973-1976 and 1986 to 1989 acreage response elasticities of 0.176 and 0.2 respectively were estimated. Elasticity of supply for all protein meal is taken as 0.19 for base projections in this paper. However, it is possible that global supply is more elastic since all countries respond simultaneously to global market conditions.

### 3.5.3 *Estimating future consumption and price*

The demand and supply equations for the Base Year are calculated as follows:

At the base year:

Quantity Index (Q): = 100
Price Index (P): = 100

Demand:

$$P = 869 - 1/Edd^*Q \quad (9)$$
$$P = 869 - 7.7Q$$

where

*Edd* = Price elasticity of demand = -0.13 (base scenario)

Supply:

$$P = -426 + 1/Ess^*Q \quad (10)$$
$$P = -426 + 5Q$$

where

*Ess* = Price Elasticity of input supply = 0.2 (base scenario)

Equilibrium indices are calculated at the simultaneous solution of supply and demand equations, where quantity demanded and supplied are from equations 1 and 3. The curves are pivoted on the price axis (intercept kept constant) to maintain supply and demand elasticity constant at each price i.e. at a price of 100 demand and supply elasticities remain the same as calculated above. The spreadsheet model allows instantaneous adjustment of price elasticities to compare results.

Using this technique implies that the model endogenously determines price. Certain scenarios will therefore not be accounted for. For example, it is possible that an increase in protein supply, resulting from consecutive good seasons, would lead to depressed meal prices and cause production to increase at a rate slower than that built into the model. Nevertheless, the ease with which this type of model can be updated allows the most recent price and production data to be used. Data should ideally be updated regularly to





ensure projections are made from base data that include the latest price and production trends.

## 4. RESULTS AND DISCUSSION OF INTERNATIONAL PROJECTIONS

### 4.1 Base scenario projections

A summary of the base scenario assumptions is presented in Table 5. Results for own base scenario projections of international consumption and price are reported in Table 6. Projections indicate real price remaining constant and consumption increasing 38% from 1999 to 2010. By 2020, the model projects a real price increase of 22% and a consumption increase of 78% at an annual growth rate of 1.84%. World per capita consumption of meal is projected at 31kg in 2010 and 35kg in 2020 up from 26kg in 1999.

**Table 5: Base scenario assumptions**

| Parameter | Assumption |
|---|---|
| Per Capita Income Growth | FAPRI (2000) projections |
| Population Growth | World Bank (1999) projections |
| Income Elasticities | As calculated in using FAPRI GDP growth rates |
| Demand Elasticity | -0.13 |
| Supply Elasticity | 0.19 |
| Supply Projection | Linear Extrapolation of 1990 to 1999 production data. |

The projected price trend to 2010 is relatively flat (Figure 6), with prices slightly below base price for most of that period. Low, or negative, GDP growth rates following the Asian financial crisis limit annual demand growth, such that supply growth is slightly greater in each year up to 2010. From 2010 to 2020 growth in demand exceeds supply growth, raising projected price. Although the forecast price increase of 22% by 2020 is not considerable, it is of significant importance given the background of consistently falling commodity prices (Figure 6).

Figure 6 illuminates how supply and demand assumptions effect the projected price. Supply growth is a function of a linear model and therefore annual compound supply growth rates decrease annually as the projected year approaches 2020. Demand growth however is a non-linear function of GDP growth, population growth and income elasticity. Supply growth rates therefore decline relative to demand growth rates, ultimately forcing the model to project increasing prices in the longer term.

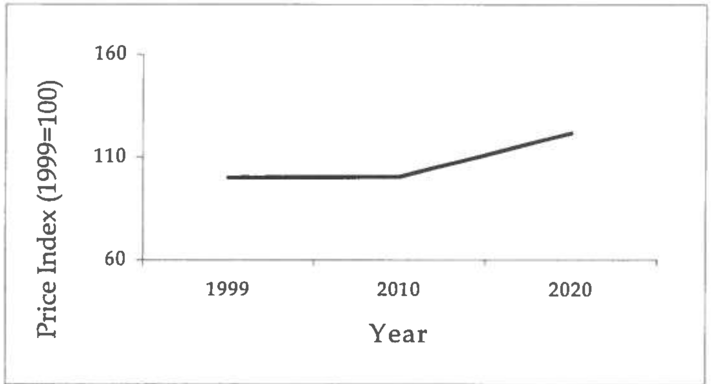


**Figure 6: Projected meal price trend, 1999 to 2020**

Historically the slope of the production trend appears to have increased at intervals (Figure 5), such a shift is possible over the next 20 years. Scenarios using different supply models are considered to provide alternative projections.

## 4.2 Sensitivity analysis

Adjusting the elasticity of demand to the upper (-0.25) and lower (-0.05) estimates has a minimal effect on projections to 2010 (Table 6). Price projections in 2020 are 4.9% lower for an elasticity of -0.25 and 6.1% greater for an elasticity of -0.05. Similarly projections do not show large sensitivity to changes in the price elasticity of supply. Increasing the supply elasticity by 100% results in a 6% lower price projection by 2020, while decreasing supply elasticity 100% results in a 7% higher price projection by 2020 (Table 6).

The model is substantially more sensitive to changes in the assumed income elasticities of demand. The model is run with all income elasticities increased and decreased by 10% (Table 6). Increasing (decreasing) income elasticities leads to price increases of 6.6% (6.7%) and 9.5% (9.7%) by 2010 and 2020 respectively





**Table 6: Projected international price and consumption of protein feed to 2010 and 2020**

| | 2010 | | | | 2020 | | | |
|---|---|---|---|---|---|---|---|---|
| | Quan-tity (Index) | Price (Index) | Quantity (million tons) | Growth Rates (1) | Quantity (Index) | Price (Index) | Quantity (million tons) | Growth Rates (1) |
| **Base Year (1999)** | 100 | 100 | 156 | | | | | |
| **Base Scenario** | 138 | 101 | 216 | 2.97% | 178 | 122 | 279 | 2.78% |
| **Sensitivity Analysis** | | | | | | | | |
| Demand Elasticity = -0.05 | 138 | 100 | 216 | 2.97% | 180 | 128 | 282 | 2.84% |
| Demand Elasticity = -0.25 | 137 | 100 | 216 | 2.90% | 176 | 115 | 276 | 2.73% |
| Supply Elasticity = 0.10 | 138 | 100 | 216 | 2.97% | 176 | 129 | 276 | 2.73% |
| Supply Elasticity = 0.38 | 138 | 100 | 216 | 2.97% | 180 | 113 | 282 | 2.84% |
| Income Elasticity Decreased by 10% in all Countries | 136 | 93 | 213 | 2.83% | 174 | 109 | 273 | 2.67% |
| Income Elasticity Increased by 10% in all countries | 140 | 107 | 218 | 3.11% | 182 | 132 | 285 | 2.89% |
| Increase Income Elasticity for China by 20% to 0.93 in 1999 (2) | 140 | 106 | 218 | 3.11% | 182 | 132 | 284 | 2.89% |
| Decrease Income Elasticity for China by 20% to 0.62 in 1999 (2) | 174 | 109 | 273 | 5.16% | 136 | 94 | 213 | 1.47% |
| **Scenario Analysis** | | | | | | | | |
| Supply Scenario1a.(1990-1999) (3) | 145 | 62 | 227 | 3.44% | 199 | 29 | 313 | 3.33% |
| Supply Scenario1b.(1980-1999) (3) | 138 | 97 | 218 | 3.00% | 187 | 86 | 293 | 3.02% |
| Supply Scenario 2. (3.5%) (4) | 141 | 82 | 221 | 3.17% | 191 | 64 | 300 | 3.13% |
| Supply Scenario 3. (3%) (4) | 138 | 99 | 216 | 2.97% | 184 | 96 | 289 | 2.95% |
| Supply Scenario 4. (2,75%) (4 ) | 137 | 107 | 214 | 2.90% | 181 | 112 | 283 | 2.87% |
| Supply Scenario 5. (10% Greater) (5) | 143 | 71 | 224 | 3.32% | 185 | 92 | 290 | 2.98% |
| Supply Scenario 6. (10% Lower) (5) | 132 | 134 | 209 | 2.55% | 170 | 155 | 243 | 2.57% |

| China Scenarios | Quan-tity (Index) | Price (Index) | Quantity (million tons) | Growth Rates (1) | Quantity (Index) | Price (Index) | Quantity (million tons) | Growth Rates (1) |
|---|---|---|---|---|---|---|---|---|
| | 2010 | | | | 2020 | | | |
| A. Higher Income Growth & Higher Income Elasticity in China (6) | 140 | 109 | 219 | 2.55% | 183 | 137 | 287 | 2.57% |
| B. Lower Income Growth & Lower Income Elasticity in China (6) | 136 | 92 | 213 | 2.55% | 173 | 107 | 271 | 2.57% |

***Notes:*** *(1) Growth in meal consumption compounded annually. (2) In base scenario projections, the income elasticity for China is 0.76. (3) Supply Scenarios 1a and 1b use a log-linear regression of production vs. time for the period shown in parenthesis to project supply (growth rate: 1a= 4%, 1b=3.24%). (4) Supply Scenarios 2 to 4 assume the supply growth indicated in parenthesis. (5) Supply projections in Scenarios 5 and 6 are increased (decreased) by 10% each year. (6) For China Scenario A (B) income elasticity is increased (decreased) by 20% and GDP growth increased (decreased) by 5% annually.*





Increasing the base year income elasticity for China by 20% results in a price increase of 9.2% (compared to base scenario) and a consumption increase of 2% by 2020. Decreasing China's income elasticity in the base year by 20% decreases price by 9.5% and quantity by 2% compared to base projections.

### 4.3 Scenario analysis

Long-term projections are subject to considerable uncertainty and assumptions made about growth parameters have a significant impact on final projections, especially over a 20-year projection horizon. It is therefore prudent to examine the effect of changing the underlying forces driving supply and demand. In this section various scenarios are simulated by altering baseline assumptions of vital parameters, including income growth, supply growth and income elasticity to gain an understanding of how projections might differ from the base scenario.

#### *4.3.1 Alternative supply growth scenarios*

Alternative scenarios are run by employing different supply growth projections. Results for constant supply-growth scenarios and linear projections are given in Table 6. Use of a log-linear regression over the period 1990 to 1999 to project supply (growth model) has a dramatic effect on price projections (Scenario 1a), with 2020 price forecast at only 24% of base scenario projections. Projected consumption levels are 5% higher in 2010 and 12% higher in 2020. This outcome is expected considering the high supply growth (3.97% for 20 years) of this model. If supply is projected using a log-linear model based on 1980 to 1999 data (Scenario 1b), a gentler price trend is projected with prices falling 14% by 2020.

The effect of decreasing supply growth rates is shown in Scenarios 2, 3 and 4 (Table 6). Growth rates of 3.5% (Scenario 2) depress prices, although not as dramatically as in Scenario 1. Scenario 3 yields results similar to base projections up to 2010, however by 2020 supply growth is slightly higher than demand growth and price is thus 4% lower. A supply growth rate of 2.75% (Scenario 4) is insufficient to match demand growth leading to price increases. The annual compound growth in meal production from 1980 to 2000 was 2.99%, if this long-term growth rate is maintained Scenario 3 is most likely.

In the case of the linear model, increasing or decreasing supply by 10% (Scenarios 4 and 5) results in relatively large price variation, of up to 28%, although quantity consumed only changes by 4 to 4.5%.

#### 4.3.2 Changing income growth and income elasticities in China simultaneously

Owing to the importance of China, two more scenarios (Scenarios A and B in Table 6) are presented to demonstrate the simultaneous effects of high (low) income growth in China and higher (lower) income elasticity for China. If different positive and negative effects occur simultaneously, price projections could change significantly. Scenario A shows price increasing 37% by 2020 whereas Scenario B shows a 7% increase in price, in comparison to base scenario projections.

### 4.4 Comparison with other projections

FAPRI (2000) forecast world soymeal production and consumption to 2009/10 while the USDA (1999a) provide international projections to 2008/9 and USDA (2000) project USA soymeal prices to 2009/10. A shorter-term forecast to 2003 for all meal is made by Knopke *et al* (1999), with soymeal price used as the indicator price for protein meal. Comparisons are made with own projections for consumption (Table 7) and price (Table 8).

**Table 7: Comparison of own meal consumption projections with other projections**

| | 2003/4 | 2003/4 | 2009/10 | 2009/10 |
|---|---|---|---|---|
| | Annual Consumption Growth rate (%) | Consumption (million tons) | Annual Consumption Growth rate (%) | Consumption (million tons) |
| Knopke *et al* | 2.9 | 179 | | |
| USDA* | 3.1 | 180 | 2.9 | 214 |
| FAPRI* | 3.1 | 180 | 2.6 | 208 |
| Own Projections | 3.1 | 180 | 2.9 | 213 |

***Source:*** *Knopke et al (1999), USDA (1999), FAPRI (1999) and Own Projections.*
***Notes:*** ** Own estimate of all meal consumed assuming soymeal/all meal ratio of 62%. Consumption growth is annual compound growth from 1999, e.g. assume 4.5yrs to 2003/4. Knopke et al projects growth rates in consumption of 2.9% to 2003, this rate is used to arrive at projections for 2003/4. USDA projects growth rates in consumption of 2.9% to 2008/9, this rate is used to arrive at projections to 2009/10. For Own Projections the average of projections for 2009 and 2010 is used.*

All studies reviewed, project similar consumption to 2003/4 while FAPRI (2000) forecast marginally slower consumption growth to 2009/10. FAPRI (2000) and USDA (1999) project price decreases of 3.4% in real terms by 2009/10, while own projections show meal prices at the same level.





**Table 8: Comparison of real (1999 US dollars) meal price projections**

| | 1999 | 2003/4 | 2009/10 |
|---|---|---|---|
| | US $/ton | | |
| Knopke *et al* | *153 | 184 | |
| USDA | 152 | 154 | 165 |
| USDAb | | | 145 |
| FAPRI | 152 | 151 | 145 |
| World Bank** | #189 | | 244 |
| Own Projections | 152 | 150 | 152 |

***Source:*** *Knopke et al (1999),USDA (1999), USDA (2000), FAPRI (1999), Oilworld (2000), Delgado et al and Own Projections.*
***Notes:*** *1999 base price from Oilworld. *This price was forecast from 1997. ** As presented in Delgado et al (1999), converted to 1999 dollars by inflating with USA GDP deflator. # World Bank projected price for 2000. USDA price projections deflated by USDA projections of inflation (GDP chained price index). FAPRI projections deflated by FAPRI GDP deflator projections, USDAb is USDA(1999) projection to 2008/9, deflated by FAPRI GDP deflator projections, assume price in 2008/9 = 2009/10.*

## 5. CONCLUSION

An interactive spreadsheet model, which is useful for scenario analysis, was designed to make projections on future supply of and demand for protein. The demand-side of the model includes as parameters income growth rates, population growth rates and variable income elasticities that decline as incomes rise. Supply is projected by extrapolating past production data using either a linear or constant growth model. Alternatively, the model allows for independent choice of constant supply growth. Price elasticities of supply and demand are used to derive supply and demand curves and thereby to arrive at equilibrium price and consumption.

Base scenario projections indicate that international prices are likely to remain near 1999 levels to 2010 and increase slightly by 2020 in real terms. The real price of protein meal in 2010 is forecast 1% higher than the 1999 price, by 2020 however a price increase of 22% from 1999 is estimated. Consumption of all meals is projected to increase 38% by 2010 and 78% by 2020. A sensitivity analysis showed that adjusting the price elasticities of demand and supply for meal did not significantly alter projections, although adjusting income elasticities had a pronounced effect on projections.

Employing a linear supply model results in declining rate of supply growth, leading to increasing price form 2010 to 2020. For this reason constant growth supply projections were also considered. If the long-term growth in meal production of 3% is maintained, a 4% price drop is forecast for 2020.

It is noted that meal prices have historically fluctuated more in a single year than the price increase projected to 2020. Furthermore, real prices of commodities, particularly soybeans and soymeal have declined consistently over the long-term. The 22% real protein price increase that is forecast for 2020 is significant given this trend. It appears as if the long-term trend of declining real oilcake prices is arrested by strong demand growth in developing Asia. Nevertheless, as demonstrated by the use of alternative supply models, prices will continue to decline if supply maintains a constant growth rate in excess of about 2.94%.

The most important region for protein consumption growth is likely to remain developing Asia, especially China, where demand for protein is driven by increasing per capita incomes and a high population base. Projections are sensitive to the income elasticity of demand estimated for China and differing forecasts for protein feed demand in China have significant effects on projected global consumption and price.

An advantage of the model is that a large number of alternative scenarios can be considered. Scenario analysis was used for some of the parameters where data are more uncertain. A worst/best case scenario shows that if positive and negative impacts on income growth and income elasticities in China occur simultaneously, prices are either estimated to be significantly higher or modestly lower.

Supply projections in the model follow a fixed trend, and price is endogenously determined. It is however possible that increased supply, resulting from consecutive good seasons, would depress prices causing production to increase at a rate slower than that built into the model. The limited potential to store protein meal for extended periods may reduce the likelihood of this possibility.

The model predicts an increase in real international meal prices over the next 20 years. It is therefore suggested that stimulation of the local protein industry is justified. Such stimulation should not involve over protectionist policy (which in any case will be limited by WTO commitments).





## NOTES

1. *The model includes the option of calculating BP as an average of production in the Base year and years preceding and following the Base year. This option is useful where record high or low Base year production levels lead to unrealistic supply projections.*

2. *The elasticities are restricted from falling below 0.26 (the elasticity used for developed countries).*

3. *Protein feed includes all protein meals. Fishmeal is a substitute but use has declined in recent years To a small extent maize can also be substituted for protein meal but this effect is assumed to be negligible as maize is already included in rations.*

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## APPENDIXES

### A) Estimating ($\alpha_1$) the ratio of protein feed cost to income from product:

For broilers protein required is 20 % of total feed, feed conversion is 2:1, protein content of meal is 0.45 (soymeal). For pork protein required is 18 % of total feed, pork feed conversion is 3:1, protein content of meal is 0.45 (soymeal). Therefore for broilers protein used per 1kg of live mass (0.7 kg dressed mass) = 0.2*2kg/0.45 = 0.89. Using a soymeal price of R1500 per ton and broiler price of R8/kg $\alpha_1$ is calculated as

$$\frac{X_1 P_{x1}}{Y_1 P_y} = 0.24.$$

Similarly for pork (dressed mass 67% of slaughter mass) $\alpha_1 = 0.3$ using pork price of R9/kg.

## B) Income elasticities

**Appendix Table 1: Estimated Income Elasticities of Demand for Protein Meal, using Base Scenario GDP Growth Rates, in 1997, 2010 and 2020**

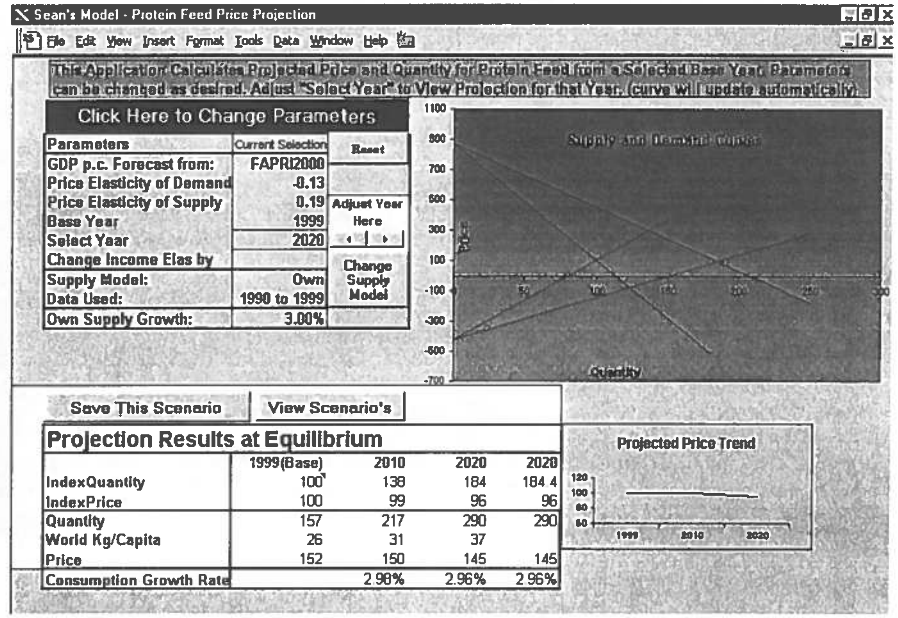
| | 1997 | 2010 | 2020 |
|---|---|---|---|
| United States | 0.26 | 0.26 | 0.26 |
| Japan | 0.26 | 0.26 | 0.26 |
| EU | 0.26 | 0.26 | 0.26 |
| China, Mainland[1] | 0.80 | 0.64 | 0.51 |
| Indonesia | 0.95 | 0.84 | 0.73 |
| Malaysia | 0.64 | 0.59 | 0.52 |
| Philippines | 1.03 | 0.96 | 0.87 |
| Thailand | 0.70 | 0.49 | 0.33 |
| Korea South | 0.33 | 0.27 | 0.27 |
| India | 1.15 | 1.01 | 0.90 |
| Pakistan | 1.22 | 1.16 | 1.10 |
| Argentina | 0.36 | 0.27 | 0.27 |
| Brazil | 0.46 | 0.35 | 0.26 |
| Mexico | 0.60 | 0.50 | 0.39 |

*Source: Own calculations using equation (2)*

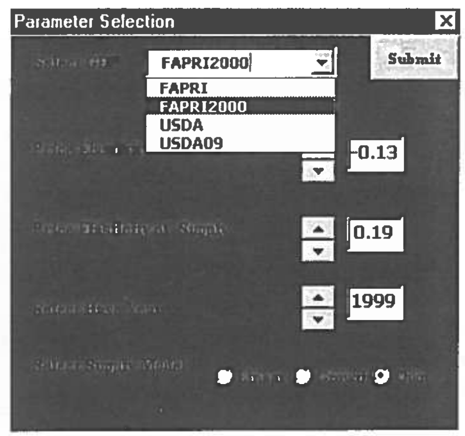




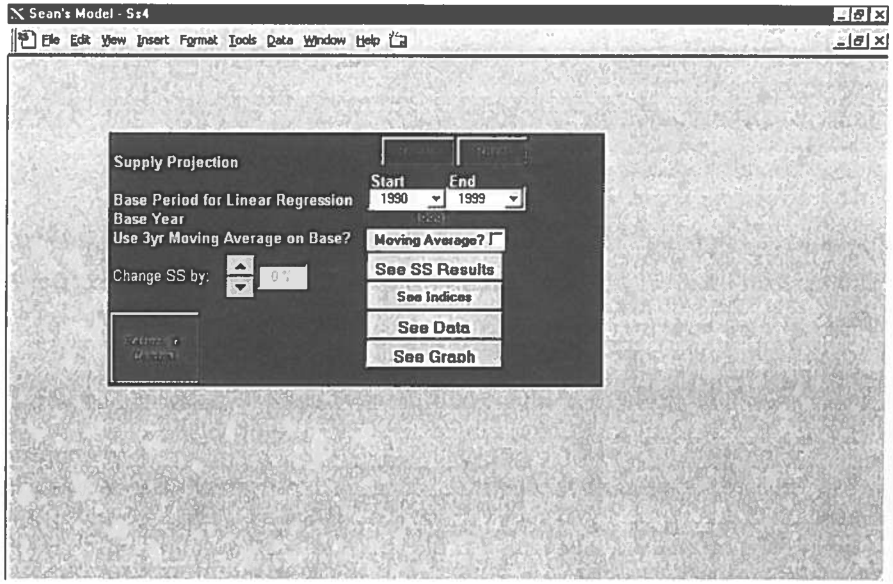
## C) Screen Prints of Spreadsheet Model




Appendix Figure 1: Main control page for projection model




Appendix Figure 2: "Parameter selection" dialogue box




**Appendix Figure 3: Supply model front end**





# MINIMUM ECONOMIC FARM SIZE: A CASE STUDY OF THE SMALLHOLDER TEA SUB-SECTOR IN KENYA

M.M. Kavoi[1], P.O. Owuor[2] and D.K. Siele[2]

*The average area under tea in the smallholder sub-sector is approximately 0.27 ha. The population pressure in the tea growing districts is quite high compared to the neighbouring districts without the enterprise. The robust population growth in tea growing zones translates into continued sub-division of tea farms to school leavers who cannot get alternative employment in other sectors of the economy. This scenario is a potential threat to the future of the smallholder tea production in Kenya. The problem of continued sub-division of tea farms has degenerated into what has been termed as "uneconomic tea farm sizes". The objective of this study was to determine the optimal economic number of bushes a tea farm should have below which it would be referred to as "uneconomic tea farm size." A profit function model was fitted on 259 smallholder farms. It is concluded that all tea farms in these subsets are more successful in responding to the set of prices they face (Price efficiency) and /or because they have higher quantities of fixed factors of production, including entrepreneurship (technical efficiency).*

## 1. INTRODUCTION

The average area under tea in the smallholder tea sub-sector in Kenya is approximately 0.27 ha (Kenya Tea Development Agency, 1964-2000) and it is still declining. The population pressure in the tea growing districts is quite high compared to the neighbouring districts without the enterprise (Kenya, GoK, 1999). For example, the population density in Kirinyaga, Nyambene, Nandi and Nyamira Districts with tea are 309, 153, 200 and 556 persons per sq.km. respectively as compared to 145, 25, 60 and 257 persons per sq.km for the respective neighbouring Nyandarua, Kitui, Transmara and Migori Districts without tea. The high population growth in tea growing zones enhanced by escalating unemployment in the country translates into continued sub-division of tea farms to school leavers who cannot get alternative employment in other sub-sectors of the economy. This scenario is so severe that sub-division of tea to farms of 500 bushes or below is not uncommon. This problem is a great cause of concern to all stakeholders in the tea industry. In the past few years, incessant sub-division of tea farms has degenerated into what has been refereed to as "uneconomic tea farm sizes". Farmers use various spacings to plant tea (Kenya, GoK, 1986). The most common one is the 5 * 2.5 ft which translates to a population of 8 611 plants per hectare. Others range from 4

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