RESEARCH ASSESSMENT IN MULTISTAGE PRODUCTION SYSTEMS WITH QUALITY-DIFFERENTIATED MARKETS[1]

by

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I. INTRODUCTION

The economic assessment of research using the now widely used economic surplus approach has progressed to a wide array of topics both at the conceptual and empirical levels Some developments may be noted The first is a transition from a single market to a multiple market approach as in multistage production systems A basic commodity sequentially reaches a final production stage of higher value-added through intermediate stages Total benefits to research are distributed between the production stages (Just, Hueth and Schmitz, 1982 ; Freebairn, Davis and Edwards, 1982, and Alston and Scobie, 1983)

A second development is a broadening of a coverage of research evaluation to include changes in the quality characteristics of a commodity, as well as changes in production costs for an unchanging product Research-induced change in quality is analysed in several ways Some studies treat the quality resulting from research as a shift of the demand curve for a commodity (Unnevehr, 1986 and Voon and Edwards, 1991) Those studies assume that the resulting commodity with improved characteristics is a perfect substitute in consumption for the old commodity. In some studies the shift in demand curve is associated with a shift of the commodity supply curve, reflecting either a higher or lower cost of producing a commodity with improved quality (e.g Voon and Edwards, 1992). In other studies, the quality effect of research is analysed mainly as a downward shift of the supply curve (Brennan, Godyn and Johnston, 1989)

A third development in the literature of research assessment involves changes in quality characteristics which have some impact in multistage production systems.

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For example, the research-induced improvement in the quality of Morex variety of barley for beer production in the US lowers the costs of beer production due to higher malt extract and shorter germination time (Macagno, 1990).

In the area of assessing quality-improving research, some studies adopt a quality-differentiated market approach (Brennan, Godyn and Johnston,1989; and Voon and Edwards, 1990) A commodity market is divided into two categories - high and low qualities - but these markets are related in an aggregate market. Changes in production and consumption, assuming zero substitution, in one quality category of the market provide corresponding changes in the opposite direction, in the other quality category

The task of filling the gap in the literature on assessing the economic impact of research is a continuing process The present paper provides a modest contribution to narrowing the gap in terms of an analytical framework extending current approaches in tracing the effects of research in multistage production systems, multiple products, and segregated markets for research-induced quality-differentiated markets.

The empirical part of this paper is concerned with two research projects in the Philippine coconut industry that are designed to improve the quality of coconut products Those research projects are expected to result in new knowledge that will allow the development of two new technologies, namely, an improved copra dryer technology and an improved crude coconut oil processing technology. Research on the two improved technologies are expected to lower production costs of producing high qualities of copra and crude coconut oil (CNO)[3], compared to existing technologies.

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[3] Low quality copra - with high moisture content, contaminated with sand and other extraneous mater, has smouky odour, and case hardened (NEDA, 1985; PCA and NRI, 1992) - is a long standing and major issue in the Philippine coconut industry. The quality of copra affects its price as well as the price of its higher value-added products at the processing sector - CNO and copra meal (CM). Mouldy copra due to high moisture level produces CNO of poor quality due to high level of free fatty acid (FFA) and darkness in colour. When copra is crushed into CNO, any aflatoxin present is known to be distributed between the CNO and its by-product copra meal/cake (Samarajeewa and Arseculeratne, 1983). The aflatoxin that is transferred from copra to the CNO is reduced in the expelling process, but the aflatoxin cannot be removed through extra purification in its by-product CM as it can in CNO.

High quality copra has the following attributes: dry with moisture level of ≤ 12%, has 60% CNO recovery rate, free of impurities and mould infection, and white to off-white in colour. A high quality CNO has low free fatty acid, and has favourable odour and light in colour (PCA, 1988). A high quality CM is characterised by low levels of aflatoxin - 20 ppb (parts per billion (EC, 1991).

Figure 1 interprets schematically the general spillover effects of those two research projects in the Philippine coconut industry. Copra is a raw material in the processing of CNO and its by-product copra meal (CM) or cake[4]. The other inputs used are traders' services and processing inputs and other marketing services (POMS).

Research on improved copra drying technology has the following effects: quality differentials in copra and its joint products CNO and CM, and a change in the costs of producing these products. Research impacts are traced from the copra farm stage, through the traders' services stage, POMS stage and CNO processing stage. Research on improved CNO processing technology affects the quality and costs of producing CNO and CM. The effects of research are traced from the CNO processing stage to the lower production stages. The adoption of improved technologies on copra dryer and CNO processing have welfare implications for coconut farmer, copra traders, suppliers of POMS and consumers of CNO and CM.

2. ANALYTICAL METHODOLOGY

There are two possibilities for modelling the effects of the two types of research - copra drying and CNO processing - being addressed in this paper. One possibility is to use a single structural model which encompasses both types of research. The other possibility is to construct individual analytical models in assessing the two research advances. It would be cumbersome to integrate the two models given the varying effects of research along the hierarchy of production in the Philippine coconut industry. Thus, for ease of analysis, the latter approach is adopted in this study. There are two main differences in the assumptions of the two models. The first is the assumption about the costs of traders' services and POMS, and the second is about substitution between inputs used in CNO. In the first model, which assesses research in the copra farm stage, it is assumed that the unit costs of traders' services and POMS are constant - or perfectly elastic supply of these services. This assumption is relaxed in the second model - depicting technological research in the CNO

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[4] About 5% of Philippine copra is utilised in the external market while 95% is processed in the domestic market into CNO. About 75% of CNO is exported, the rest is refined into cooking oil and in the manufacture of coco-chemicals. Edible oil is mainly for domestic use, coco-chemicals are intended for both domestic and export markets. About 90% of CM is exported as animal feed (UCAP, 1991).

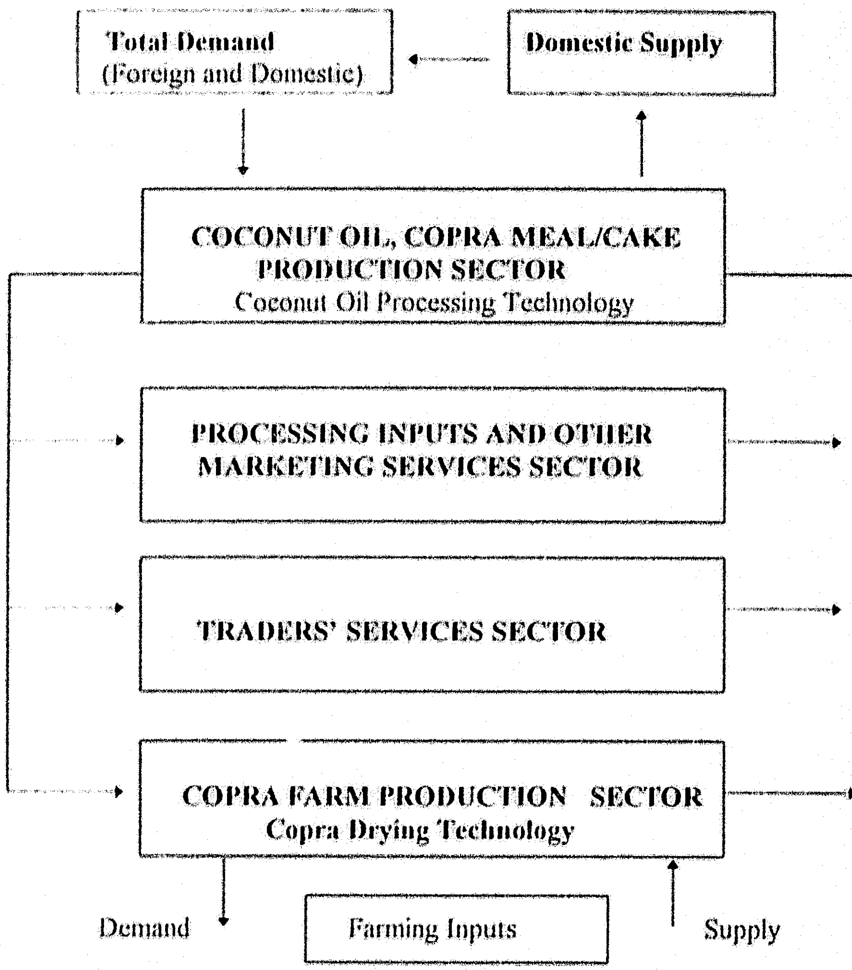

Figure 1 Multi-Market Effects of Research in the Philippine Coconut Industry

processing stage. The first model assumes non-substitution between inputs to CNO, while the second model allows for substitution effects.

The now widely used economic surplus approach with application of disequilibrium model in the second model, is used in the ex-ante assessment of research. The analysis is of the static, partial equilibrium type. For some purposes a model of general equilibrium type is superior, but such a model is deemed unnecessary in the present study. In addition, suitable general equilibrium models are not readily available (Alston, Norton and Pardey, 1995).

The structural models are aggregate open economy models. The majority of Philippine CNO and CM, and a small portion of its copra, is exported. It should be noted here that the research-induced improvements in technologies are assumed to be adopted only in the Philippines. As a net exporter of coconut products, the Philippines would lose from the adoption of its improved technology in the rest of the world (ROW)

The measurement of research benefits is annual static. The estimates of research could be interpreted as benefits accruing in a year from the percentage cost reductions arising from research. The improved copra drying and CNO processing technologies are adopted within the year, and adjustments in supply and demand occur within the year

The estimates of research benefits represent gross benefits. In the absence of data on the costs of the two research projects, it is not possible to compute net benefits from research. The benefits obtained can therefore be used to determine the maximum amount that would be efficient to pay for the research

For simplicity, Philippine coconut products - copra, CNO and CM - are classified into high and low qualities

The above assumptions serve to simplify the theoretical framework and to facilitate empirical analysis.

2.1 Quality-Improving Research at the Farm Level, Fixed Factor Proportions

Improved copra dryer technology in this study refer to semi-direct heat and indirect heat dryers that are improvements to the traditional direct heat or smoke//kiln dryers[5]. Research on improved copra dryers place emphasis on low-cost technologies that are adaptable to the needs of both small and large coconut farmers. In modelling the impact of an improved copra dryer technology, linear supply and demand functions and parallel shifts of the supply curves are assumed. The assumption of constant per unit costs of trading services and POMS in the high and low quality is based on the competitiveness of suppliers of POMS and the numerous copra traders in the Philippines. All inputs used in producing CNO and CM - copra, traders' services, and

[5] Low quality copra in the Philippines has been generally attributed to the use of traditional copra dryers.

POMS - are used in fixed proportions. Also, an existing technology of CNO processing is assumed to be factor-quality specific of the raw material copra. That is, high quality CNO and CM can only be produced by using high quality copra. In the low quality sector, CNO processors use mainly low quality copra. In addition, non-substitution between high and low qualities of CNO and CM is assumed.

For each high and low quality markets, the derived demand for copra ($\mathbf{D_{Ci}} = \mathbf{D_{CNOi}} + \mathbf{D_{CMi}} - \mathbf{M_i}$, i=H,L for high and low qualities) is obtained as the demand for CNO ($\mathbf{D_{CNOi}}$) and CM ($\mathbf{D_{CMi}}$) less the constant margin ($\mathbf{M_i}$). The difference between the prices of CNO and CM ($\mathbf{P_{CNOi}}$ and $\mathbf{P_{Ci}}$) and the price of copra ($\mathbf{P_{Ci}}$) is the margin ($\mathbf{M_i}$)[6] The constant absolute margin is shown by the distances **bh** in the high quality market (Figure 2) and by the distance **b'h'** (Figure 3) in the low quality market. Moreover, the joint products CNO and CM have only one supply function but different demand functions

Theoretically, the supply function of a final product is the vertical summation of all factor supply functions, which implies that the marginal cost of a quantity of the final product is equal to the sum of the marginal costs of all factor inputs. In the case of CNO being analysed here, its marginal cost of production is equal to the marginal cost of raw material (copra), excluding the constant per unit cost of traders' services and POMS, the other inputs In similar manner, the derived demand for POMS is given by subtracting the supply function for copra from the CNO supply function.

2.1.1 High Quality Copra Market The spillover effects of an improved copra dryer technology are presented graphically in Figure 2. The variables used are defined in Table 1. With an assumed constant rate of transformation between copra CNO and CM, the quantities of these products in the graph can be defined in terms of copra (**Qi = H, L**).

The adoption of an improved copra dryer technology reduces the per unit cost, by amount $\mathbf{k_i}$, reflected mainly as a downward shift in parallel fashion of the supply curve for copra from $\mathbf{S_{CH}}$ to $\mathbf{S_{CH1}}$. The price of copra decreases from $\mathbf{P_{CH}}$ to $\mathbf{P_{CH1}}$, and

[6] Under the notion of joint product relationship the price of the common resource material, in this case copra, can be derived as the composite price of CNO and CM less the constant margin, i.e., $P_{ci} = S_{CNOi}P_{CNOi} + S_{CMi} - M_i$, where S_{CNOi} and S_{CMi}, respectively, are the recovery rates of coconut oil and copra meal per unit of copra.

quantity increases from Q_{H} to Q_{H2}. The supply curve for CNO also shifts downwards by the same proportion as the supply curve for copra because of assumption of fixed factor proportions, linear supply and demand curves, and parallel shifts of supply curves as in Freebairn, Davis and Edwards (1982). The supply shift in the CNO processing stage comes from two sources (see for example Macagno, 1990). First, the lower price of high quality copra relative to its initial price, causes a reduction in the costs of producing high quality CNO by v_1 per unit output, denoted by an intermediate shift (represented by dashed lines) of the supply curve from S_{CNOH} to S_{CNOH1}. Second, there is a cost reduction of v_1' per unit output, due to the higher recovery rate of CNO[7]. This induces the supply curve of the final products to shift downwards further from S_{CNOH1} to S_{CNOH2}. Wholesale prices of CNO and CM are reduced, respectively, from P_{CNO} to P_{CNOH1}, to P_{CNO2} and from P_{CM} to P_{CMI}, to P_{CM2}.

Table 1 Definitions of Parameters Used in Assessing Quality-Improving Research at the Copra Farm Level, Fixed Factor Proportions

Parameter	Definition
Q_i	Quantity of farm output, copra, i=H,L, H for high quality and L for low quality
P_{Ci}	Farm price of copra
P_{CNOi}	Wholesale price of coconut oil (CNO)
P_{CMi}	Wholesale price of copra meal (CM)
S_{Ci}, D_{Ci}	Supply and demand curves for copra
S_{CNOi}	Supply and demnd curves for coconut oil
D_{CMi}	Demand for copra
k_j	Vertical shift of the supply curve of farm output, i=1,2; where 1 for high quality and 2 for low quality. For example, k1 = (PC-PC1)/PC where PC is the initial farmcost of copra and PC1 the 'with' research farm level cost.
v_j, v'_j	The first nd second vertical shifts of the supply curve for CNO, j=1,2 for high and low qulities, respectively. The first (intermediate) shift is the cost reduction effect from a change in price of copra. The second shift is a cost effect due to the change in recovery rate in CNO.

Quantities of CNO and CM increase, creating a chain effect in the non-farm input sectors - more of traders' services and POMS are required. With perfectly elastic

[7] A one percent increase in CNO and CM per unit is interpreted as a 1% decrease in the per unit output cost of producing the final products.

supply curves for the non-farm inputs, suppliers of these inputs earn normal profits on larger quantities, but they experience no welfare effect.

Due to assumptions of linear functions and parallel shifts, the benefits to adoption of improved copra dryer technology can be measured at either level of the multistage production system. Consumer surplus is decomposed into two components gains to end-users of coconut oil (ΔCS_{CNOH}) represented by area $\mathbf{P_{CNOH}abP_{CNOH2}}$, and end-users of copra meal (ΔCS_{CMH}) which is given by area $\mathbf{P_{CMH}efP_{CMH2}}$. With constant costs of non-farm inputs, producer surplus is measured only for copra producers (ΔPS_H) and is given by area $\mathbf{P_{CH}hij}$). The aggregate gain is denoted by the area **Abgh**. The specifications of the demand and supply equations 'with' and 'without' quality-improving research at the farm sector , are provided in Appendix 1

Referring to Figure 2, the aggregate surplus and its allocation to producers and consumers can be written in the following algebraic terms:

1 $\Delta CS_{CNOH} = 1/2(P_{CNOH} - P_{CNOH2})(Q^S_{CNOH} + Q^S_{CNOH2})$

2 $\Delta CS_{CMH} = 1/2(P_{CMH} - P_{CMH2})(Q^S_{CMH} + Q^S_{CMH2})$

3 $\Delta PS_H = 1/2\,[k1 - (P_{CH} - P_{CH1})](Q^S_{CH} + Q^S_{CH2})$

4 $ATS_H = \Delta CS_{CNOH} + \Delta CS_{CMH} + \Delta PS_H$

2.1.2 Low Quality Copra Market The changes in the high quality market have corresponding changes, in opposite directions, in the low quality market. Increasing the supply of high quality copra resutls in a corresponding decrease in the supply of low quality copra. The rationale is the expected movement or more coconut farmers and hence production resources to the high quality sector. Because of the higher opportunity costs of these resources, it becomes more expensive to produce low quality copra whose quantity has decreased. This is turn induces a proportional increase in the costs of producing low quality CNO. The supply curve of low quality copra is interpreted as shifting upwards by $\mathbf{k_2}$ per unit output, from $\mathbf{S_{CL}}$ to $\mathbf{S_{CL1}}$ (see Figure 3). The supply curve of CNO is viewed as shifting upw..rds twice. The initial shift is an intermediate shift from $\mathbf{S_{CNOL}}$ to $\mathbf{S_{CNOL1}}$ due to the rise in cost of low quality copra. The second shift from $\mathbf{S_{CNOL1}}$ to $\mathbf{S_{CNOL2}}$ is due to a lower recovery rate of CNO of low quality copra. The vertical shifts are denoted by v_2 and v_2', respectively, corresponding to the two downward shifts of the supply curve for high quality CNO. Low quality coconut products are becoming more expensive to produce. As a result, prices increase - from P_{CL} to P_{CL1} for copra; from P_{CNOL} to P_{CNOL1}, to P_{CNOL2}; and from P_{CML} to P_{CML1}, to P_{CML2}, respectively, for CNO and C. Lower quantities are produced for copra, CNO and CM given by the distance Q_L to Q_{L2}. Also, quantities required of traders' services and POMS decrease resulting in lesser profits earned by suppliers of these two inputs because of reduced quantities. There is no producer surplus due to the assumption of perfectly elastic supply for these inputs.

Using similar procedures in the high quality market but incorporating the above changes, the benefits to research in the low quality market are expressed in algebraic terms as follows:

5. $\Delta CS_{CNOL} = 1/2(P_{CNOL2} - P_{CNOL})(Q^S_{CNOL} + Q^S_{CNOL2})$

6. $\Delta CS_{CML} = 1/2(P_{CML2} - P_{CML})(Q^S_{CML} + Q^S_{CML2})$

7. $\Delta PS_L = 1/2\,[k_2 - (P_{CL1} - P_{CL})](Q^S_{CL} + Q^S_{CL2})$

8. $\Delta TS_L = \Delta CS_{CNOL} + \Delta CS_{CML} + \Delta PS_L$

The net changes and distribution of aggregate surplus to the Philippine coconut industry to consumers of CNO and CM, and copra farm producers are expressed as

9. $\Delta CS_{CNO} = \Delta CS_{CNOH} + \Delta CS_{CMNOL}$

10. $\Delta CS_{CM} = \Delta CS_{CMH} + \Delta CS_{CML}$

11. $\Delta TS = \Delta TS_H + \Delta TS_L$

2.2 Quality-Improving Research in the Processing Stage, With Variable Proportions

The second model simulates the following scenario. Ongoing research on high temperature expellers in producing CNO while it reduces aflatoxin, results in a reduced recovery rate of CNO and in darker colour of CNO. In modelling the effects of research on improved CNO processing technology, it is assumed here that high quality

CNO and hence CM are produced without trade-off in CNO recovery rate, and the CNO is of lighter colour. Likewise, the copra meal produced is also of high quality.

An improved CNO processing technology is a biased technical change that uses the input POMS relatively intensively, and saves raw material (copra) and traders' services, the other inputs. The methodology of the present study draws from Mullen, Wohlgenant and Farris (1988), and Mullen, Alston and Wohlgenant (1989). A major concept adopted from Mullen, Wohlgenant and Farris (1988) is the use of a supply shift in POMS in estimating a biased technical change. The effect of a biased technical change is seen a shifting also the supply curve for CNO. A shift in the supply of POMS is used to estimate a shift in input demand arising from technical change[8]. A major difference in the approach of the present study is in excluding exogenous shifts for the final products - CNO and CM.

As with the first structural model, the CNO processing stage is divided into two markets - high and low quality markets. In the high quality market, CNO processors adopt the improved technology. In the low quality market, CNO processors use the old existing technology.

There are other assumptions of the model relating to input substitution. An improved CNO processing technology can produce high quality CNO and CM using low quality copra, implying substitution of low quality copra for high quality copra[9] in the high quality market. Also, the input POMS can be substituted for traders' services. This asssumption accommodates the practice of some oil millers of buying directly from copra farmers (Tiglao, 1983).

2.2.1 An Equilibrium Displacement Model. The equilibrium displacement model consists of a system of output and factor supply and demand equations defining

[8] This concept was earlier introduced by Muth (1964). Accordingly, in a two-input case, an increase in the supply of the first input reduces its price resulting its substitution for the second input. The demand for the second input may either increase or decrease depending upon whether the elasticity of demand for the product is greater than the elasticity of substitution between the two inputs. If the elasticity of demand for the product is greater than the elasticity of substitution between inputs, the demand for the second input will increase.

Furthermore, in order to maintain the equality between the ratio of marginal products with the ratio of input prices, more of the input where technical change occurs is used in order to reduce the marginal product of that input. This also maintains equality between the ratio of output prices and input prices (Mullen, Wohlgenant and Farris, 1988).

[9] At the processing level, oil millers mix different grades of copra. This practice is adopted especially in a situation where the amount of high quality copra that is traded from the farm sector is not sufficient to fill the crushing capacity of oil milling companies (Canapi, pers. comm.).

the initial equilibrium conditions in the output and factor markets. Exogenous shocks to the system due to adopting a new technology are reflected in a shift in supply or demand shift (or a combination), and result in changes in prices and quantities. These exogenous shocks displace the initial equilibirium to a new equilibrium. An inherent feature of an equilibrium displacement model is its first approximations to the quantitative effects of changes in exogenous variables. Because of this feature, the model does not require the specification of functional forms (Hill, Piggot and Griffith, 1995). Changes in prices and quantities can be approximated linearly by totally differentiating the system of equations and converting them to elasticity forms (see Muth, 1964 and Alston, Norton and Pardey, 1995). The change operator can be expressed as

$$dx/x = d(\ln x)$$

$$E(x) = dx$$

The sectors of the Philippine coconut industry being analysed here are specified in terms of general supply and demand conditions for the inputs and outputs of these sectors. An equilibrium displacement model is used to estimate changes in prices and quantities of wholesale products CNO and CM, and their production inputs - high and low quality copra, traders' services and POMS - in the high and low quality markets. Table 2 provides the definitions of the parameters used in the equilibrium displacement model. A constant returns to scale production function is assumed. In the strictest sense, the production function for CNO and CM is joint and non-separable between inputs. For analytical purposes, a production function similar to that of CNO is also specified for CM. This approach allows the measurement of consumer surplus for CM users separately from the consumer surplus for CNO users. Cost functions are used as duals to the constant returns to scale production functions of the high and low quality markets (as in Wohlgenant, 1982, Mullen, Wohlgenant and Farris, 1988; Mullen, Alston and Wohlgenant, 1989). The rationale and assumption of a cost function approach in lieu of a constant returns to scale production approach is given by Diewert (1981).

i. High Quality Market for CNO

The specifications of the production function and its dual cost function, the initial and 'with' research supply and demand conditions are provided in Appendix 2. The system of equations in the high quality market of CNO covers two wholesale products - CNO and CM - and four inputs. The four inputs are high and low quality copra, traders' services, and POMS. As stated earlier, an improved CNO processing technology allows the substitution of low quality copra for high quality copra in producing high quality CNO and hence CM. The matrix form solution to the disequilibrium model appears in Appendix 3. The changes in consumer and producer surpluses are estimated using the following formulas

$$12 \quad \Delta CS_{cNOH} = -EP_{cNOH} \; P_{cNOL} \; Q_{cNOH} \; (1 + 0.5EQ_{cNOH})$$

$$13 \quad \Delta CS_{cMH} = -EP_{cMH} \; P_{cMH} \; Q_{cMH} \; (1 + 0.5EQ_{cMH})$$

$$14 \quad \Delta PS_1 = EW_1 \; W_1 \; X_1 \; (1 + 0.5 EX_1)$$

$$15 \quad \Delta PS_2 = EW_2 \; W_2 \; X_2 \; (1 + 0.5 EX_2)$$

$$16 \quad \Delta PS_{3H} = EW_{3H} \; W_{3H} \; X_{3H} \; (1 + 0.5 EX_{3H})$$

$$17 \quad \Delta PS_{4H} = EW_{4H} \; X_{4H} \; X_{4H} \; (1 + 0.5 EX_{4H})$$

where Δ denotes the change in consumer and produer surpluses; CS_{cNOH} and CS_{cMH} denote surplus to end-users of high quality CNO and CM; PS_1, PS_2, PS_{3H} and PS_{4H}, respectively, refer to the surpluses to coconut farmers producing high and low qualities of copra; copra traders; and suppliers of POMS.

ii. Low Quality Market for CNO

The system of equations in the low quality market for CNO cover low qualities of CNO and CM. Unlike in the high quality market, there are only three inputs in the low quality market - low quality copra, traders' services and POMS. For analytical purposes it is assumed that processors of low quality CNO utilise only low quality copra. Following similar reasoning in the first model, the research on improved CNO

Table 2 Definitions of Parameters Used in Equilibrium Displacement Model of the Philippine Coconut Industry

Parameter	Definition
Q_{cCNOH}, Q_{cCNOL}	Wholesale quantities of CNO (H=high quality, L=low quality
Q_{cCMH}, Q_{cCML}	Wholesale quantities of high and low qualities of CM
P_{rCNOH}, P_{rCNOL}	Prices of high and low qualities of CNO
P_{rCMH}, P_{rCML}	Prices of high and low qualities of CM
X_1, X_2	Quantities of high and low qualities of copra
X_{3i}	Quantity of traders' services, i=H,L
X_{4i}	Quantity of processing inputs and other marketing services (POMS), i=H,L
W_i	Input prices, i=1,2,3,4
ψ_i	Input demand shifter for X_i due to biased technical change
k_{4i}	Supply shifter for input X_{4i} (i=H,L)
E	Relative change operator, i.e., $E(Q_{CNOH}) = dQ_{CNOH}/Q_{CNOH}$
η_{ii}	Own price elasticity of demand for final products
s	Price elasticity of supply of input i
ρ^{ij}	Fraction of total cost accounted for by input ij (i=H,L)
μ_i	Fraction of revenue accounted for by final product i (i=CNOH, CNOL, CMH, CML)
σ_{ij}	Elasticity of substitution between inputs

processing technology that is cost-reducing entails a movement of CNO processors and production resources from the low quality market to the high quality market. This movement of resources results in higher opportunity costs of resources in producing low quality CNO and hence, induces an upward shift of the supply curve for low quality CNO The effect of an improved CNO processing technology in the high quality market is to shift upwards the supply curve of POMS in the low quality market. In the second model, the categories of substitution are as follows: substitution of POMS for low quality copra and substitution of POMS for traders' services. As in the high quality market, it is assumed that traders' services cannot be substituted for low quality copra.

The theoretical considerations of the production function and its dual cost function for the low quality market, the supply and demand conditions in the 'without' and 'with' research' conditions are contained in Appendix 4. The explicit form of the solution matrix of the equilibrium displacement model in the low quality market is provided in Appendix 5 The changes in consumer and producer surpluses are estimated using the following formulas:

18 $\Delta CS_{CNOL} = EP_{CNOL} \cdot P_{CNOL} \cdot Q_{CNOHL} \cdot (1 + 0.5EQ_{CNOL})$

19 $\Delta CS_{CML} = EP_{CML} \cdot Q_{CML} \cdot P_{CML} \ (1 + 0.5EQ_{CML})$

20 $\Delta PS_2 = EW_2 \ W_2 \ X_2 \ (1 + 0.5 \ EX_2)$

21 $\Delta PS_{3l} = EW_{3l} \ W_{3l} \ X_{3l} \ (1 + 0.5 \ EX_{3L})$

22 $\Delta PS_{4l} = EW_{4l} \ X_{4l} \ X_{4l} \ (1 + 0.5 \ EX_{4l})$

3. MEASUREMENT OF THE PARAMETERS OF THE MODELS AND ANALYSIS OF EMPIRICAL RESULTS

In the empirical application of the models, a sensitivity analysis is carried out to help investigate different economic situations for the Philippine coconut industry. These situations are portrayed by the different assumptions about the industry In the first model, which assumes that substitution among inputs to CNO does not occur, different assumptions are imposed on price elasticities of supply and demand for coconut products, size of the vertical shifts of the supply curves for copra and CNO; and levels of price differentials between high and low qualities of copra, CNO and CM. In the second model, sensitivity analysis is conducted not only for most of the parameters indicated above, but also for the three classes of substitution. The three classes of substitution are substitution of low quality copra for high quality copra as an input to CNO; substitution of POMS for high quality copra; and substitution of POMS for traders' services. In both models the sensitivity analysis involves varying the parameters individually and jointly.

Also, in the first model the analysis is extended to allow the research benefits found for quality-improving research using the segregated market approach adopted in this study to be compared with benefits obtained using the homogeneous market approach adopted in other research assessment studies.

3.1 Measurement of the Conceptual Parameters

Historical data are used in the ex-ante simulation analysis conducted in this study. The choice and measurement of parameters of the two structural models are confined within the limits of the available data. Econometric estimates are available for the price elasticities of demand for copra, CNO and CM, but not for most of the parameters of the models. Because of the uncertainty surrounding most of the parameters required by the model, a reasonable range of values is imputed in the sensitivity analysis. The values of the parameters of the two structural models are presented separately in Tables 3 and 4. Some variables common to both models are represented by different symbols in each model.

Table 3. Definitions and Measurements of Parameters in Assessing Quality-Improving Research at the Farm Stage, Model I, with Fixed Factor Proportions

Parameter	Value	Definition
Q^S_{CH}	1,187 thousand tons	Production of high quality copra
Q^S_{CL}	791 thousand tons	Production of low quality copra
Q^D_{CNOH}	686 thousand tons	Consumption of high quality CNO
Q^D_{CNOL}	498 thousand tons	Consumption of low quality CNO
Q^D_{CMH}	366 thousand tons	Consumption of high quality CM
Q^D_{CML}	242 thousand tons	Consumption of low quality CM
P_{CH}	US$212, $222/ton[10]	Domestic average price of high quality copra
P_{CL}	US$180/ton	Domestic average price of low quality copra
P_{CNOH}	US$477, $487/ton[8]	Domestic average price of high quality CNO
P_{CNOL}	US$407/ton	Domestic average price of low quality CNO
P_{CMH}	US$118, $128/ton[8]	Domestic average price of high quality CM
P_{CML}	USUS100/ton	Domestic average price of low quality CM
$\varepsilon_{CH}, \varepsilon_{CL}$	0.81, 2, 10	Price elasticity of farm supply of high and low quality of copra
η_{CH}, η_{CL}	-0.593, -5, -15	Price elasticity of demand of high and low quality copra
η_{CNOH}, η_{CNOL}	-0.62, -2.128, -15	Price elasticity of demand of high and low quality CNO

[10] The latter value is the assumed price of high quality coconut product if its price is increased by $10 per metric ton.

η_{CMH}, η_{CML}	-0.43, -3, -17	Price elasticity of demand of high and low quality CNO
k_1	US$6.36[11],$10.60[12], $21.20/ton[13]	Vertical downward shift of supply curve of high quality copra, if price of high quality copra is $212/ton
	US$6.66[9],$11.10[10], $22.2[11]/ton	If price of high quality copra is $222/ton
k_2	US$2.7[14], $4.5[15], $9[16]/ton	Vertical upward shift of supply curve of low quality copra
v_1	US$14.31,$23.85, $48.70/ton	Vertical downward shift of supply curve of high quality CNO if price is $477[17]/ton
	US$14.61[9],$24.35[10], $47.70[11]/ton	If price of high quality CNO is $487[18]/ton
v_2	US$6.10[12],$10.18[13], $20.35[14]/ton	Vertical upward shift of supply curve of low quality CNO[19]

Table 4 Definitions and Measurements Of Parameters in Assessing Quality-Improving Research at the Processing Stage, Model II, with Variable Proportions

Parameter	Value	Definition
Q_{CNOH}	686 thousand tons	Quantity of high quality CNO
Q_{CMH}	366 thousand tons	Quantity of high quality CM
Q_{CNOL}	498 thousand tons	Quantity of low quality CNO
Q_{CML}	242 thousand tons	Quantity of low quality CM
P_{CNOH}	US$477/ton	Domestic average price of high quality CNO
P_{CMH}	US$118/ton	Domestic average price of high quality CM
P_{CNOL}	US$407/ton	Domestic average price of low quality CNO
P_{CML}	US$100/ton	Domestic average price of low quality CM
X_1	1,187 thousand tons	Quantity of high quality copra

[11] A ssuming 3% vertical shift of supply curve of high quality copra.

[12] Assuming 5% vertical shift of supply curve of high quality copra.

[13] Assuming 10% vertical shift of supplycurve of high quality copra.

[14] Assuming 1.5% vertical shift of supply curve of low quality copra.

[15] Assuming 2.5% vertical shift of supply curve of low quality copra.

[16] Assuming 5% vertical shift of supply curve of low quality copra.

[17] Price effects on high quality CM are $1.77[9], $2.95[10], $5.90/[11]ton., if price of high qulaity CM is $118/ton.

[18] Price effects of high quality CM are $1.92[9], $3.20[10], $6.40[11]/ton, if price of high quality CM is $128/ton.

[19] Price effects on low quality CM are $1.5[12], $2.5[13], $5[14]/ton.

X_2	791 thousand tons	Quantity of low quality copra
X_{3H}	686	Index of quantity of traders' services, high qulity market
X_{3l}	498	Index of quantity of traders' services, low quality market
X_{4H}	686	Index of quantity of POMS in high quality market
X_{4l}	498	Index of quantity of POMS in low quality market
W_1	US$212/ton	Domestic average price of high quality copra
W_2	US$180/ton	Domestic average price of low quality copra
W_{3H}	US$51/ton	Cost of traders' services in high quality market
W_{3l}	US$43/ton	Cost of traders' services in low quality market
W41	US$214/ton	Cost of POMS in high quality market
W42	US$184/ton	Cost of POMS in low quality market
k_{4H}	3%, 5%, 10%	Vertical downward shift of the supply curve of POMS in the high quality market
k_{4l}	1.5%, 2.5 %, 5%	Vertical upward shift of the supply curve of POMS in the low quality market
ψ_i	1/	Input demand shifter in high and low quality market, I = 1,2,3,4
$\varepsilon_{X1}, \varepsilon_{X2}$	0.81, 2	Price elasticity of supply of copra
$\varepsilon_{3H}, \varepsilon_{3l}$	1, 5	Price elasticity of supply of traders' services
$\varepsilon_{4H}, \varepsilon_{4l}$	1, 5	Price elasticity of supply of POMS
η_{CNOH}, η_{CNOl}	-0.62, -2.128	Price elasticities of demand for CNO in the high and low quality market
η_{CMH}, η_{CMl}	-0.43, -3	Price elasticities of demand for CM in the high and low quality market
ρ_1, ρ_2	44%	Fraction of total cost accounted for by high and low qualities of copra
ρ_{3H}, ρ_{3l}	11%	Fraction of total cost accounted for by traders' services used in high and low quality markets
ρ_{4H}, ρ_{4l}	45%	Fraction of total cost accounted for by POMS used in high and low quality markets
μ_{1H}, μ_{1l}	80%	Fraction of total revenue of high and low quality CNO
μ_{2H}, μ_{2l}	20%	Fraction of total revenue of high and low quality CM
σ_{21}	0, 0.1, 0.5	Elasticity of substitution of low quality copra for high quality copra
$\sigma_{4H1}, \sigma_{4L2}$	0, 0.1, 0.5	Elasticity of substitution of POMS for high and low quality copra
$\sigma_{4H3}, \sigma_{4L3}$	0, 0.05, 0.1	Elasticity of substitution of POMS for traders' services

1/ The approach used in deriving the size of input demand shifters and the resulting values are provided in the Appendix 6.

3.2 Empirical Analysis, Model 1: Quality-Improving Research in the Farm Stage, With Fixed Factor Proportions

3.2.1 A Baseline Analysis. The starting point of analysis is the empirical results from the following baseline values of the key parameters: inelastic supply of farm output, elastic demand of final products, and vertical shifts of the supply curves of high and low quality copra, respectively, equal to 3% and 1.5% of their farm prices. The size and distribution of baseline benefits arising from research on an improved copra dryer in the Philippines are given in Table 5. The changes in prices and quantities of copra, CNO and CM are given in Table 6.

Most of Philippine CNO and CM production is exported. It is assumed that the improvements in copra drying technology in the Philippines are not adopted in the ROW. Hence, the consumer benefits and losses in CNO and CM in both the high and low quality markets exclude those accruing to the rest of the world (ROW). Based on the proportions of Philippine CNO and CM exports to total production, it can be established that benefits accruing to ROW - consumers' gains net of producer losses - amount to more than 50% of benefits received in the Philippines in the baseline case.

Table 5. Estimated Yearly Benefits (Losses) from Research Benefits Losses on Improved Copra Dyer Technology in the Philippines
(In million US dollars)

Baseline values: inelastic supply of farm output, ε_{CH}, ε_{3L} = 0.81; elastic demand for wholesale processed products, η_{CNOH}, η_{CNOL} = -2.128; η_{CMH}, η_{CML} = -3; $\mathbf{k_{4H}}$ = 3%, $\mathbf{k_{4L}}$ = 1.5%.

Recipient	High Quality Market		Low Quality Market		Net Benefits (Losses)	
	$M	%	$M	%	$M	%
1. Copra producers	6.56	86	(1.83)	70	4.73	95
2. CNO producers	1.04	14	(0.78)	30	0.26	5
3. CM consumers	0.03	1/	(0.01)	1/	0.02	1/
Aggregate	7.63	100	(2.62)	100	5.01	100

1/ Less than 1%.

Table 6 Change in Prices and Quantities from Research on Improved Copra Dryer Technology in the Philippines
(In million US dollars)

Baseline values: Prices ($ton) - Copra: $212(H), $180(L); CNO: $477(H), $407(L), CM: $118(H), $100(L), Quantities (thousand tons) in the high and low quality markets, - Copra: 1187(H), 791(L); CNO: 86(H); CM: 366(H), 242(L).

Coconut Product	High Quality Market %	Low Quality Market %
1 Copra		
a Change in farm price	(0 42)	0.21
b Change in quantity	2 11	(0 01)
2 CNO		
a Change in wholesale price	(1 50)	1.72
b Change in quantity	3 21	(1 61)
2 CM		
a Change in wholesale price	(0 74)	0.35
b Change in quantity	2.19	(1.24)

Note All other parameters are at baseline values Values in parentheses indicate percentage decrease

As Table 5 shows, a very large percentage of the benefits to research in the domestic market accrue to coconut farmers producing high quality copra Only 5% of the market benefits are received by consumers of high quality CNO Welfare losses of coconut farmers in the low quality market are 28% of the benefits of farmers in the high quality market Domestic consumers of low quality CNO experience welfare losses, offsetting three fourths of the gains to domestic consumers of high quality CNO. Reflecting the smaller quantity of CM relative to copra and CNO, copra meal has the smallest share in aggregate benefits in the high quality market and in aggregate losses in the low quality market.

The cost-reducing effect of research on an improved copra dryer technology causes more coconut farmers to adopt the improved technology. As a result, more high quality copra is produced (Table 6). Larger producer surpluses accrue to the high quality market. Given the elastic demand for CNO and CM, consumers of high quality CNO and CM in the domestic market and ROW increase their consumption significantly in response to the price decrease for high quality coconut products. The difference for what consumers are willing to pay and their actual expenditures increase with the fall in prices; their surplus therefore rises.

Following the arguments in section 2, the movement of coconut farmers from the low quality market to the high quality market causes a reduction in quantities and increase in prices due to the higher costs of production (Table 6). Consumers of low quality CNO and CM can buy smaller quantities because of the price increase. As a result, coconut farmers producing low quality copra suffer welfare losses. Producer losses are interpreted as the rents to the production resources and entrepreneurial profits forgone resulting from the movement of coconut farmers to the high quality market and the corresponding decline of quantities of low quality coconut products.

3.2.2 A Sensitivity Analysis For illustrative purposes, the baseline values of the parameters were varied individually and, for some parameters, jointly. The research benefits derived are always compared with reference to the baseline results

a. Vertical shift of the supply curve for copra The size of the vertical shifts in the high and low quality sectors, measured as cost reductions (increases), affect the magnitude of aggregate benefits and losses but not their distribution (Table 7). For every additional percentage point in the size of the vertical shift over that in the baseline case, the estimated increment to yearly aggregate benefits to the high quality market is $2.6 million while the increment in the aggregate loss to the low quality market is about $1.7 million (Table 7, bottom row).

Table 7. Effects of Increasing the Size of Vertical Shift of the Supply Curve for Copra on Estimated Yearly Benefits (Losses) from Research on Improved Copra Dryer Technology in the Philippines

Recipient	High Quality Market			Low Quality Market		
k_{4i}	3%	5%	10%	1.5%	2.5%	5%
		in percentages			in percentages	
1. Copra producers	86	91	91	70	86	86
2. CNO consumers	14	9	9	30	14	14
3. CM consumers	2/	2/	2/	2/	2/	2/
Aggregate	100	100	100	100	100	100
	$7.83	$12.80	$25.88	($2.62)	($4.30)	($8.50)

2/ Less than 1%.

Note: Except for the shift of the supply curve for copra (k_{4i}), all parameters are at baseline values

b. Elasticities The price elasticity of demand affects the distribution of research benefits while the pri·e elasticity of supply affects both the size and distribution of research benefits from an improved copra dryer technology (Table 8). These findings confirm the results of Duncan and Tisdell (1971), Akino and Hayami (1975), to name a few From their baseline values - inelastic supply for copra and elastic demand for CNO and CM - the elasticities of supply and demand are varied, first, individually and then jointly

i. Demand elasticities Under conditions of more elastic demand for CNO and CM, yearly aggregate research benefits in the high quality ı. .rket did not vary much In the low quality market however, welfare losses increase by 26%, reducing the benefits by 16% (top of Table 8) The pattern of distribution of research benefits is unaltered - high quality coocnut producers receive an even larger share of the aggregate benefits and lower share of losses The rationale behind this is that copra farmers in the high quality market can choose to supply larger quantities of their produce at higher prices In other words, the decrease in the price of high quality copra is less than the production cost-reducing effect of research on improved copra dryer technology The benefits to consumers of CNO and CM are smaller and their losses are greater

ii. Supply elasticity As the price elasticity of supply of copra becomes elastic the size and distribution of research benefits and losses in both markets change. Benefits to research fall by 9% compared with the baseline (middle of Table 8).

iii. Supply and demand elasticities When supply of copra becomes elastic and the demand for CNO and CM become more elastic, aggregate benefits did not vary much, aggregate losses increase by 45% (bottom of Table 8). Net benefits are reduced by 28% Producers of high quality copra receive larger share of aggregate benefits and the share of low quality producers of copra decreases. Conceptually, given more elastic demand for CNO and CM, producers of high quality copra can increase the price of their produce. The benefits accruing to consumers of high quality CNO and CM decrease while losses to consumers of low quality CNO and CM increase.

c. Quality price differential. An increase in the price differential between high quality and low quality coconut products affects the size of aggregate benefits in the high quality market, without a significant effect on the allocation of benefits. For every $10 per ton increase in the prices of high quality copra, CNO and CM, with constant prices of the same products in the low quality market, yearly aggregate benefits in the high quality market increase by one-third of a million dollars or 4.5% from the baseline results (Table 9) Benefits in the low quality market are unaffected. Net benefits increase by 7% for each $10 per ton increase in the prices of high quality copra.

Table 8 Effects of Varying Price Elasticities of Supply of Copra and Demand for CNO and CM on Estimated Benefits (Losses) from Research on Improved Copra Dryer Technology in the Philippines
(In million US dollars)

Industry Situation	High Quality Market		Low Quality Market		Net Benefits (Losses)	
	$M	%	$M	%	$M	%
k_1 = 3%, k_2 = 1.5%						
1. $\varepsilon_{CH}, \varepsilon_{CL}$ = 0.81						
η_{CNOH}, η_{CNOL} = -15						
η_{CMH}, η_{CML} = -17						
a. Copra producers	7.25	96	(2.01)	61	5.24	83
b. CNO consumers	0.26	4	(1.30)	39	(1.04)	(17)
c. CM consumers	0.01	1/	(0.002)	1/	0.01	1/
Aggregate	7.52	100	(3.31)	100	4.21	100
2. $\varepsilon_{CH}, \varepsilon_{CL}$ = 2						
η_{CNOH}, η_{CNOL} = -2.128;						
η_{CMH}, η_{CML} = -3						
a. Copra producers	5.51	78	(1.51)	60	4.00	88
b. CNO consumers	1.50	21	(0.97)	39	0.53	11
c. CM consumers	0.06	1	(0.02)	1	0.04	1
Aggregate	7.07	100	(2.50)	100	4.57	100
3. $\varepsilon_{CH}; \varepsilon_{CL}$ = 2						
$\eta_{CNOH}; \eta_{CNOL}$ = -15						
η_{CMH}, η_{CML} = -17						
a. Copra producers	6.84	92	(1.86)	49	4.00	88
b. CNO consumers	0.56	8	(1.94)	44	(1.38)	(22)
c. CM consumers	0.02	1/	(0.01)	1/	0.01	1/
Aggregate	7.42	100	(3.81)	100	3.61	100

Note: Except for the price elasticities of supply and demand, all parameters are at baseline values.
1/ Less than 1%.

Table 9 Effects of Quality-Price Differential on Estimated Yearly Benefits (Losses) from Research on Improved Copra Dyer Technology in the Philippines (In million US dollars)

Recipient	High Quality Market		Low Quality Market		Net Benefits (Losses)	
	$M	%	%M	%	$M	%
1 Copra producers	6 87	86	(1 83)	70	5.04	94
2 CNO producers	1 07	14	(0 78)	30	0 29	5
3 CM consumers	0 04	1/	(0 01)	1/	0 03	1/
Aggregate	7 98	100	(2 62)	100	5 36	100

Note Except for prices of high quality copra, CNO and CM, all parameters are at baseline values The prices of high quality copra, CNO and CM are increased

1/ Less than 1%

3.2.3 Assessing Research Using a Homogeneous Commodity Approach and a Quality-differentiated Commodity Approach. For comparative purposes, the benefits to research on improved copra dryer technology are also measured using a homogeneous market approach This approach -has been used by Unnevehr, 1986 and Voon and Edwards, 1991 - treats copra, CNO and CM in a single market without quality distinction It also assumes complete replacement in production of high quality coconut products for those produced using the current technology in the absence of research The comparative analysis in this case indicates that the single homogeneous market approach tends to overestimate measured benefits to research by two-thirds (Table 10)

Table 10 Estimates of Yearly Research Benefits from Improved Copra Dryer Technology in the Philippines Using a Homogeneous Market Approach Compared to a Quality-Segmented Market Approach (In million US dollars)

Recipient	Homogeneous Market Approach	Quality-Segmented Market Approach	
		Aggregate Benefits, High Quality Market	Net Benefits1/
	$M	$M	$M
1 Copra producer	10 94	6 56	4.73
2 CNO consumer	2.13	1.04	0 26
3 CM consumer	0 0002	0.03	0.02
Aggregate	13.07	7 63	5.01

Note All parameters are at baseline values

1/ Aggregate benefits in high quality maket less the aggregate benefits in the low quality market

3.3 Empirical Analysis, Model II: Quality-Improving Research in the CNO Processing Stage, With Variable Proportions

3.3.1 A Baseline Analysis The baseline values of the parameters of the second model, which evaluates the impacts of research that results in an improved CNO processing technology in the Philippines are elastic demand for CNO and CM; inelastic supply of copra, perfectly elastic supply of traders' services and POMS; lower bound estimates of the vertical shifts of the supply curves for POMS; limited substitution of low quality copra for high quality copra, and limited substitution of POMS for high and low quality copra, and for traders' services. The baseline resultes are reported in Table 11.

Approximately two-fifths of the agregate benefits in the domestic high quality market is counteracted by welfare losses in the low quality market (Table 11). Those losses, as conceptualised in an earlier section, are the benefits the producers and consumers in the low quality market have to relinguish as production resources shift to the high quality market due to technological research in that market.

Producers of high quality copra receive approximately one-half of aggregate research benefits accruing in the high quality market. Due to substitution of low quality copra for high quality copra, research benefits also accrue to producers of low quality copra. Because of the limited degree of substitution, their benefits however, represent merely 13% of benefits received by high quality copra producer; their share of aggregate research benefits is 6%. In the low quality market, where substitution is assumed not to occur between high and low quality copra, the producer sector comprises mainly coconut farmers producing low quality copra. Their losses represent two fifths of aggegate losses in the low quality market.

In both markets, the producer sector receives more than half of aggregate benefits and two-fifths of aggregate losses. The domestic consumer sector (users of CNO and CM) receives the smallest share of aggregate losses. The results imply that since Philippine CNO and CM are largely exported, most of the consumer benefits and losses resulting from research in an improved CNO processing technology are channeled to users of these products in ROW.

Table 11 Estimated Yearly Benefits (Losses) from Research on Improved CNO Processing Technology in the Philippines
(In million US dollars)

Baseline values $\eta_{CNOH}, \eta_{CNOL} = -2.128$, $\eta_{CMH}, \eta_{CML} = -3$, $\varepsilon_{X1}, \varepsilon_{X2} = 0.81$, $\varepsilon_{X1}, \varepsilon_{X} = 1$
$k_{4H} = 3\%$, $k_{4L} = 1.5\%$, $\sigma_{12}, \sigma_{41}, \sigma_{42} = 0.10$, $\sigma_{143} = .05$

Recipient	High Quality Market		Low Quality Market		Net Benefits (Losses)	
	$M	%	$M	%	$M	%
1 High quality copra producers	3.90	48	(1.36)	41	3.03[2]	68
2 Low quality copra producers	0.51[1]	6				
3 Copra traders	1.22	15	(0.36)	11	0.86	19
4 Suppliers of POMS	1.72	21	(1.18)	35	0.54	12
5 CNO consumers	0.69	8	(0.68)	10	0.01	1/
6 CM consumers	0.14	2	(0.08)	3	0.06	1
Aggregate	8.18	100	(3.68)	100	4.50	100

1/ Refers to research benefits received by producers of low quality copra and in producing high quality CNO

2/ Derived by subtracting the losses in the low quality market from the total research benefits to coconut farmers producing high quality copra and to those producing low quality copra used in the high quality CNO market. For this reason, there are no entries of losses and net benefits for low quality copra producers

The assumed non-constant costs of traders' services and of POMS in the second model permits the measurement of welfare effects of research to the marketing sector of the Philippine coconut industry. With a limited degree of substitution, the marketing sector (copra traders and suppliers of POMS) receives about one-third of aggregate benefits and the largest share in welfare losses, 46%. Suppliers of POMS alone receive about one-fifth of aggregate domestic benefits and one-third of aggregate losses.

3.3.2 A Sensitivity Analysis. Baseline values of the following parameters in both high and low quality markets are varied individually - size of vertical shift of supply curve for POMS, price elasticity of demand for CNO and CM, and price elasticity of supply for inputs to CNO. The parameters demand and supply elasticities are varied jointly on the one hand, and jointly with the degree of substitution among inputs on the other.

a. Substitution effects. The effect of the elasticity of substitution among the inputs into CNO on research benefits is illustrated by two-non-baseline situations of input substitution. In the high quality market, the elasticity of substitution of low quality copra for high quality copra is increased from its baseline value of 0.10 to 0.50, and the elasticity of substitution of POMS for traders' services is increased from 0.05 to 0.10. In the low quality market, the sensitivity analysis is confined to increasing the elasticity of substitution of POMS for low quality copra from 0.10 to 0.50, and the elasticity of substutution of POMS for traders' services from 0.05 to 0.10. In the second non-baseline situation, non-substitution of inputs to CNO in both markets is assumed (Table 12)

i. Higher degree of substitution. Increasing the degree of substitution among inputs to CNO in both quality markets changes the size and allocation of benefits and losses from research. Net benefits increase, with about half accruing to the producer sector. Under conditions of higher elasticity of substitution among key parameters of the model, half of aggregate benefits in the high quality market accrue to the marketing sector. The share of POMS increases by about 70% from its baseline value, while the share of copra traders remains the same. The share of aggregate gains accruing to coconut farmers producing high quality copra decrease by more than half their share in the limited substitution baseline case. The domestic consumer receives only 11% of aggregate gains to research. (Table 12).

In the low quality sector, CNO consumers' share of aggregate losses trebled compared to their share in the baseline analysis. With greater substitution of POMS for low quality copra, the share of coconut farmers producing low quality copra decrease by more than one-half.

ii. Non-substitution of inputs to CNO. In the empirical situation of non-substitution of inputs to CNO, the size of aggregate benefits decrease by 85% from the baseline of limited substitution. Aggregate losses to research however, increase by 32%, decreasing net benefits by about one-half. As with baseline results, in the high quality market coconut farmers producing high quality copra receive the largest share of aggregate research gains. Coconut farmers producing low quality copra bear the biggest portion of welfare losses.

b. Vertical shift of the supply curve for POMS. In the high quality market, increasing the vertical downward shift of the supply curve of POMS from 3% to 5% results in greater aggregate benefits (Table 13). For every one percentage point increase in the supply shift of POMS, aggregate yearly benefits to research increase by $3 million If the downward shift of the supply curve of POMS increases further to 10%, the estimated yearly benefits to research rise by $2.5 million per percentage point Some changes in the distribution of benefits are observed. At the higher bound estimate of the downward shift of the supply curve of POMS, the share of the marketing sector increases by 39% with a corresponding decrease in the share of the producer sector A plausible reason for those changes in the allocation of aggregate research benefits is the slower response of the prices and quantities of CNO and CM to the price decrease of POM In the low quality market, welfare losses to suppliers of POMs are reduced As with the baseline figures, the largest share of aggregate losses is borne by the producer sector

Table 12 Effects of Different Substitution of Inputs to CNO on Estimated Yearly Benefits (Losses) to Research on Improved CNO Processing Technology in the Philippines
(In million US dollars)

Baseline values σ_{21}, σ_{41}, σ_{42} = 0 50, σ_{43} = 0.10; k_{4H} = 3%, L = 1.5%; η_{CNOH}, η_{CNOL} = -2 128, η_{CMH}, η_{CML} = -3, ε_{CH}, ε_{XCL} = 0 81; ε_T, ε_P = 1 Except for elasticities of substitution, all parameters are at baseline values.

Industry Situation/ Recipient	High Quality Market		Low Quality Market		Net Benefits (Losses)	
	$M	%	$M	%	$M	%
σ_{21}, σ_{41},σ_{42} = 0.50, σ_{43} = 0.10						
1. High quality copra producers	2.8	22				
2. Low quality copra producer	1.85	19	(0.37)	17	3.66	49
3. Copra traders	1.47	15	(0.53)	24	0.94	12
4. Suppliers of POMS	3.24	33	(0.44)	20	2.80	37
5. CNO consumers	0.95	10	(0.72)	32	0.23	3
6. CM consumers	0.05	1	(0.16)	7	(0.11)	(0.11)
Aggregate	9.74	100	(2.22)	100	7.52	100
σ_{21}, σ_{41},σ_{42} σ_{43} = 0						
1. High quality copra producers	4.10	59	(2.39)	54	1.71	69

2. Low quality copra producers						
3. Copra traders	0.75	11	(0.52)	12	0.23	9
4. Suppliers of POMS	0.87	13	(0.57)	13	0.30	12
5. CNO consumers	0.96	14	(0.76)	17	0.20	8
6. CM consumers	0.24	3	(0.18)	4	0.06	2
Aggregate	6.92	100	(4.42)	100	2.50	100

Table 13 Effects of Increasing the Size of Vertical Shift of the Supply Curve for POMS on Estimated Yearly Benefits(Losses) from Research on Imporved CNO Processing Technology in the Philippines

Baseline values σ_{21}, σ_{41}, σ_{42} = 0.50; σ_{43} = 0.10, k_{4H} = 3%, L = 1.5%, η_{CNOH}, η_{CNOL} = -2.128; η_{CMH}, η_{CML} = -3; ε_{CH}, ε_{XCL} = 0.81, ε_{T}, ε_{P} = 1. Except for k_{4H} and k_{4L} all parameters are at baseline values

Recipient	High Quality Market		Low Quality Market		Net Benefits (Losses)	
k_i	5%	10%	5%	10%	5%	10%
	- - - - - - -		In US$ million		- - - - - -	
1. High quality copra producers	7.68	10.60	(2.86)	(5.23)	5.56	7.11
2. Low quality copra producers	0.74	1.74				
3. Copra traders	1.97	4.15	(0.70)	(0.94)	1.27	3.21
4. Suppliers of POMS	2.21	8.62	(0.14)	(0.27)	2.07	8.35
5. CNO consumers	1.02	0.71	(0.72)	(1.38)	0.30	(0.67)
6. CM consumers	0.29	0.18	(0.16)	(0.31)	0.13	(0.13)
Aggregate	13.91	26.00	(4.58)	(8.13)	9.33	17.87
	- - - - - - -		in percentages		- - - - - -	
1. High quality copra producers	55	41	62	64	60	40
2. Low quality copra producers	5	7				
3. Copra traders	14	16	15	12	14	18
4. Suppliers of POMS	16	33	3	3	22	47
5. CNO consumers	8	2	16	13	3	(4)
6. CM consumers	2	1/	4	4	1	(1)
Aggregate	100	100	100	100	100	100

1/ Less than 1%.

c. Price elasticities of supply and demand. If the demand for CNO and CM becomes more elastic (from an elastic assumption in the baseline situation), more than half the aggregate gains and losses to research accrue to suppliers of POMS (Table 14). The share of the producer sector in aggregate gains and losses decrease. The domestic consumer sector receives a higher share of gains in the high quality market as

Table 14 Effects of Elasticities of Supply and Demand on Estimated Benefits(Losses) to Research on Improved CNO Processing Technology in the Philippines (In million US dollars)

Baseline values σ_{21}, σ_{41}, σ_{42} = 0.50; σ_{43} = 0.10; $\mathbf{k_1}$ = 3%, $\mathbf{k_1}$ = 1.5%, η_{CNOH}, η_{CNOL} = -2.128, η_{CMH}, η_{CML} = -3, ε_{CH}, ε_{XCT} = 0.81, ε_T, ε_P = 1. Except for elasticities of supply and demand, all parameters are at baseline values.

Industry/Situation Recipient	High Quality Market		Low Quality Market		Net Benefits (Losses)	
	$M	%	$M	%	$M	%
η_{CNOH}, η_{CNOL} = 15, η_{CMH}, η_{CML} = 17 ε_{CH}, ε_{CL} = .81, ε_T, ε_P = 1						
1. High quality copra producers	0.63	13				
2. Low quality copra producers	0.01	1/	(0.38)	12	0.26	16
3. Copra traders	0.01	1/	(0.21)	6	(0.20)	(12)
4. Suppliers of POMS	3.10	64	(1.92)	59	1.18	75
5. CNO consumers	0.88	5	(0.63)	19	0.25	16
6. CM consumers	2.21	22	(0.14)	4	0.08	5
Aggregate	$4.85	100	($3.28)	100	$1.57	100
η_{CNOH}, η_{CNOL} = -.62, η_{CMH}, η_{CML} = -.43 ε_{CH}, ε_{CL} = 2; ε_T, ε_P = 5						
1. High quality copra producers	2.14	36				
2. Low quality copra producers	0.17	3	(0.70)	48	1.61	35
3. Copra traders	1.22	20	(0.09)	6	1.13	24
4. Suppliers of POMS	2.46	41	(0.58)	40	1.88	41
5. CNO consumers	2/		(0.05)	4	(0.04)	2/
6. CM consumers	2/		(0.01)	2	(0.01)	2/
Aggregate	$5.99	100	($1.38)	100	$4.61	100

1/ Less than 1%; 2/ Nil.

well as a higher share of losses in the low quality market. In a situation where the supply curve of copra is assumed to be elastic and the demand for CNO and CM are inelastic, the marketing sector receives the biggest increase in net benefits compared to baseline results. Producer sector's share in aggregate benefits in the high quality market decreases, while its share in aggregate losses in the low quality market increases. With smaller quantities of high quality CNO and CM used by domestic consumers, their share in aggregate benefits falls below its already low baseline level.

4. POLICY IMPLICATIONS

Some implications of the results form the empirical analysis are drawn for research policy in the Philippine coconut industry. These implications relate to the pursuit of both efficiency and distributional objectives of research policy.

One implication follows directly from the fact that the size of the cost reduction achieved in producing copra or coconut products of a given quality is a key determinant of the size or research benefits. This implication is that to maximize benefits from research, resources need to be directed to those areas offering the prospect of the largest cost reductions. This is a simple point but an important one.

A second implication follows from the reality that research benefits arise from research at the CNO processing stage as well as at the copra farm stage. The implication is that if the government, through PCA, is concerned with getting the highest returns to limited research resources, it needs to consider research at both stages. While the PCA undertakes some research at the CNO processing stage, its research efforts are directed predominantly to the farm stage. Even accepting the part played by equity objectives in coconut industry research, it seems likely that this focus on farm stage research reduces economic benefits from research.

Just as farmers may gain as much from research at the processing level as from farm research, processors may gain as much from research that reduces costs at the farm level as from research at the processing level. Most processing research in the Philippine coconut industry is undertaken by the private processing sector. Processing firms cooperate in carrying out research. It would appear that the processing sector has a profit incentive to consider research opportunities at the farm level. There is therefore not the clear need for the government to be concerned about the balance between farm stage and processing stage research undertaken by processors as there is in the case of this balance for research carried out by the PCA.

Another implication is suggested by the finding that net research benefits increase with the elasticities of substitution. This implication is that activities directed to increasing these elasticities of substitution would yield a benefit through enhanced payoff from research, as well as the direct benefit. The scope for increasing research benefits in this way merits further consideration.

According to mainstream economics, research is not an efficient way of achieving objectives other than increasing the economic productivity of resources (Alston, Norton and Pardey, 1995). Nevertheless, many governments attempt to achieve objectives other than increasing economic efficiency through research policy. The Philippine government is one of these. Research policy objectives of the Philippine Department of Agriculture include: equity, employment generation, efficiency, and agricultural sustainability (Lantican and Buetre, 1991). A popular argument for emphasising equity considerations in the context of the Philippine coconut industry is the prevalence of low-income landless workers and small coconut farmers. While the government - being concious of its social importance - attempts to redress this problem through research, it also recognises the important objective of attaining efficiency in agricultural production in the country's long-term bid for industrialisation. The latter objective requires that research and development be geared towards the large farmers.

A general feature of the present study is relevant to the use of research policy to achieve equity objectives. This feature is that research benefits in a multistage production process are shared among stages. That is, it is not possible for research to be used to direct benefits to just one stage, as might be desired on equity grounds. Under the conditions of model 2, for example, the research benefits from a reduction in costs at the farm stage are shared between farmers, copra traders, processors and consumers. The distribution of research benefits that occurs with a given structure of relationships between the various stages may differ greatly from the distribution that accords best with the equity objectives of research policy.

Another equity implication follows from the relationship between quality-improving research and the size of the low quality segment of the coconut industry. Although the present study finds that the low quality coconut sector experiences a reduction in economic surplus due to quality-improving research, that needs to be viewed in the context of the reduction in the size of that sector due to the research. This is consistent with the Philippine government's objective of developing the low quality component - closely associated with the small farm, low income segment - of the coconut industry. That is, quality-improving research facilitates the movement of coconut farmers out of the backward, low quality section of the industry. In this way research contributes to the objective of enhancing the development of the worst-off part of the coconut industry. This is not necessarily to accept that research is the most cost-effective way of addressing the small farm/low income problem.

There are two reasons why benefits to coconut research in the Philippines are less than their potential. First, for broader social and equity reasons, the objectives of research are not confined to increasing economic efficiency. The pursuit of these social objectives through research involves cost in terms of forgone efficiency gains. Second, procedures for allocating research resources in accordance with objectives are not well developed. Even accepting the part played by non-efficiency objectives in coconut industry research, there is substantial scope for increasing research benefits by better economic assessment of research. Indeed, the importance of systematic economic evaluation of research is increased given that limited research resources are used partly for objectives other than enhancing economic efficiency.

REFERENCES

Akino, M. and Y. Hayami (1975). "Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development", *American Journal of Agricultural Economics*, 57(1): 1-10.

Alston, J. and J. D. Mullen (1992). "Economic Effects of Research into Traded Goods: The Case of Australian Wool", *Journal of Agricultural Economics*, 43(2): 258-78.

Alston, J., G. W. Norton and P. Pardey (1995). *Science and Scarcity, Principles and Practice for Agricultural Research Evaluation and Priority Setting.*

International Service for National Agricultural Research, Cornell University Press, Ithaca and London.

Alston, J. and G. M. Scobie (1983). "Distribution of *Research* Gains in Multistage Production Systems: Comment", *American Journal of Agricultural Economics*, 65: 353-56.

Brennan, J. P., D. L. Godyn and B. G. Johnston (1989). "An Economic Analysis of the Economic Potential of Some Innovations in a Wheat Breeding Programme", *Australian Journal of Agricultural Economics*, 33(1): 48-55.

Canapi, E. (1992). United Coconut Association of the Philippines, personal communication.

Diewert, W. E. (1981). "The Comparative Statistics of Industry Long-Run Equilibrium", *Canadian Journal of Economics*, 14(1): 78-92.

Duncan, R. and C. Tisdell (1971). "Research and Technical Progress: The Returns to Producers", *The Economic Record*, 125-29.

European Economic Community (1991). *EC Commission Directive on Aflatoxin Levels for Straight Feedingstuff*, Brussels, Belgium.

Freebairn, J. W., J. S. Davis and G. W. Edwards (1982). "Distribution of Research Gains in Multisatge Production Systems", *American Journal of Agricultural Economics*, 64: 39-46.

Hill, D. J., R. R. Piggott and G. R. Griffith (1995). "Assessing the Impacts of Wool Promotion: An Equilibrium Displacement Modelling Approach". Paper presented to the 39th Australian Agricultural Economic Society Conference, niversity of Western Australia, Nedlands, 14 - 16 February.

Just, R. E., D. E. Hueth and A. Schmitz (1982). *Applied Welfare Economics and Public Policy*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Lantican, J. and B. Buetre (1991). *Interpretation of the Research Policy Objectives of the Department of Agriculture*, ACIAR and ISNAR Research Project Papers, No. 40, August, Canberra, Australia.

Macagno, L. F. (1990). *Measuring the returns to Quality Improving Research in a Multimarket Framework: The Case of Barley Research*, Unpublished PH.D. thesis, University of Minnesota.

Mullen, J. D., J. M. Alston and M. K. Wohlgenant (1989). "The Impact of Farm and Processing Research on the Australian Wool Industry", *Australian Journal of Agricultural Economics*, 33(1): 32-47.

Mullen, J. D., M. K. Wohlgenant and D. E. Farris (1988). "Input Substitution and the Distribution of Surplus Gains from Lower Beef Processing Costs", *American Journal of Agricultural Economics*, 70(2): 245-54.

Muth, R. F. (964). "The Derived Demand for a Productive Factor and the Industry Supply Curve", *Oxford Economic Papers*, 221-34.

National Economic Development Authority (1985). *Coconut Industry Study*, Pasig, Metro-Manila, Philippines.

Philippine Coconut Authority (PCA, 1988). *Coconut Industry Yearbook*, Quezon City.

PCA and NRI (1992). *RP-UK Reduction of Aflatoxin Project*, vol. 3, Philippines-United Kingdom.

Samarajeewa, U. and S. N. Arseculeratne (1983). "Survey of Aflatoxin Contamination of Coconut Products in Sri Lanka, Incidence, Origins and Recommendations", *J. Natn. Conn. Sri Lanka, 11(2): 225-35.*

Tiglao, R. (1983). "The Political Economy of the Philippine Coconut Industry", in R. S. David, T. G. Maceda and S. Coronel, eds., *Political Economy of Philippine Commodities*, Third World Studies Program, University of the Philippines, Diliman, Quezon City.

UCAP (1991). *Coconut Statistics*, Annual 1990, December, IV, No. 23.

Unnevehr, L. J. (1986). "Consumer Demand for Rice Grain Quality and Returns to Research for Quality Improvement in Southeast Asia", *American Journal of Agricultural Economics*, 68(3): 634-41.

Voon, J. P. and G. W. Edwards (1990). "Economic Pay-Off from Research that Reduces the Incidence of Dark-Cutting Beef in Australia". Paper presented at the 34th Annual Conference of the Australian Agricultural Economic Society, University of Queensland, Brisbane, Queensland, Australia, 12-15 February.

____________________________(1991). "Research Pay-offs from Quality Improvement: The Case of Backfat Depth in Pigs", *American Journal of Agricultural Economics*, 42(1): 66-76.

____________________________(1992). "Research Pay-off from Quality Improvement: The Case of Protein in Australian Wheat", *American Journal of Agricultural Economics*, 74(3): 565-72.

Wohlgenant, M. K. (1982). *The Retail-Farm Price Ratio in a Competitive Food Industry with Several Marketing Inputs.* Department of Economics and Business Working Paper No. 12, Raleigh, North Carolina State University.

Appendix 1. Demand and Supply Equation in the "With" and "Without" Reserach on Improved Copra Dryer Technology

Without Research		With Research	
(1)	$Q^D_{CNOi} = a - \alpha_i P_{CNOi}$	(1')	As for (1)
(2)	$Q^D_{CMi} = b - \beta_i P_{CMi}$	(2')	As for (2)
(3)	$Q^D_{Ci} = Q^D_{CNOi} + Q^D_{CMi}$	(3')	As for (3)
	$Q^D_{Ci} = c - \theta_i P_{Ci}$		
(4)	$Q^S_{CNOi} = d + \gamma_i P_{CNOi}$	(4')	$Q^S_{CNOi2} = d + v_i \gamma_i + \gamma_i P_{CNOi2}$
(5)	$Q^S_{Ci} = g + \phi_i P_{Ci}$	(5')	$Q^S_{Ci2} = g + k_i \phi_i + \phi_i P_{Ci1}$

where $c = a + b$, $\theta_i = \alpha_i + \beta_i$ ($i = 1, 2$. 1 for high quality market, 2 for low quality market), v_i is the total vertical shift of supply curve for CNO, i.e., $v_i = v_i + v_i'$; **a, b, c, d, g** are the intercept terms, α, β, θ, γ, ϕ are the demand and supply price slopes, α_i η_{CNOi} (Q^S_{CNOi} / P_{CNOi}), $i = H, L$, H for high quality, L for low quality,
$\beta_i = \eta_{CMi} (Q^S_{CMi} / P_{CMi})$, $\theta_i = \eta_{Ci} (Q^S_{Ci} / P_{Ci})$, $\gamma_i = \varepsilon_{CNOi} (Q^S_{CNOi} / P_{CNOi})$, $\phi_i = \varepsilon_{Ci} (Q^S_{Ci} / P_{Ci})$, η is price elasticity of demand, and ε is price elasticity of supply.

Appendix 2. Research on Improved CNO Processing Technology: Initial and "With" Research Supply and Demand Conditions for the Equilibrium Displacement Model, High Quality Market

A constant returns to scale production function is assumed. In the strictest sense, the production function for CNO and CM is joint and non-separable between inputs. For analytical purposes, a production function similar to that of CNO is also specified for CM. This approach allows the measurement of consumer surplus for CM users separately from the consumer surplus for CNO users.

The production function can be written as

(1) $Y_H = (Q_{CNOH}, Q_{CMH}) = F_H (X_1, X_2, X_{3H}, X_{4H})$

Equation (1) cam be rewritten as

(2) $Q_{CNOH} = G_{H1} (X_1, X_2, X_{3H}, X_{4H})$
(3) $Q_{CMH} = G_{H2} (X_1, X_2, X_{3H}, X_{4H})$

A cost function is used as a dual to the constant returns to scale production described above (see for example Diewert, 1981)

Following the procedure of Mullen, Wohlgenant and Farris (1988), cost is minimised subject to a given level of output, Y_H. Y_H is linearly homogeneous in the input X_i = (i = 1, 2, 3, 4). The cost function can be expressed as

(4) $C_H = c_H(W_1, W_2, W_{3H}, W_{4H}) \cdot Y_H$

Shepard's Lemma is applied to the total cost function to obtain output constrained input demand functions

$$X_1 = g_1(W_1, W_2, W_{3H}, W_{4H}) \cdot Y_H$$
$$X_2 = g_2(W_1, W_2, W_{3H}, W_{4H}) \cdot Y_H$$
$$X_3 = g_3(W_1, W_2, W_{3H}, W_{4H}) \cdot Y_H$$
$$X_4 = g_4(W_1, W_2, W_{3H}, W_{4H}) \cdot Y_H$$

Maximisation of revenue is subject to a constrained level of inputs, G. Because of homogeneity conditions, the revenue function is also separable.

(5) $R_H = G \cdot r(P_{CNOH}, P_{CMH})$

or

$$R_{CNOH} = G_1 \cdot r(P_{CNOH}, P_{CMH})$$
$$R_{CMH} = G_2 \cdot r(P_{CNOH}, P_{CMH})$$

Input-constrained product supply functions are obtained by applying Hotelling's lemma

$$Q_{CNOH} = r_1(P_{CNOH}, P_{CMH})$$
$$Q_{2CMH} = r_2(P_{CNOH}, P_{CMH})$$

The initial equilibria in product and input markets are as follows:

Final product demand:		
High quality coconut oil	(6)	$Q_{CNOH} = f_1(P_{CNOH})$
High quality copra meal	(7)	$Q_{CMH} = f_1(P_{CNOH})$
Equilibrium conditions	(8)	$P_{CNOH} = g_1(W_1, W_2, W_{3H}, W_{4H})$
	(9)	$P_{CMH} = g_2(W_1, W_2, W_{3H}, W_{4H})$
Input demand:		
High quality copra	(10)	$X_1 = m_1(W_1, W_2, W_{3H}, W_{4H}, \psi_1) \cdot Y_H$
Low quality copra	(11)	$X_2 = m_2(W_1, W_2, W_{3H}, W_{4H}, \psi_2) \cdot Y_H$
Traders' services	(12)	$X_{3H} = m_3(W_1, W_2, W_{3H}, W_{4H}, \psi_{3H}) \cdot Y_H$
Processing and Other Marketing Inputs	(13)	$X_{4H} = m_4(W_1, W_2, W_{3H}, W_{4H}, \psi_{4H}) \cdot Y_H$

Input supply (14) $W_1 = n_1(X_1)$

(15) $W_2 = n_2(X_2)$

(16) $W_{3H} = n_3(X_{3H})$

(17) $W_{4H} = n_4(X_{4H}, k_{4H})$

As in the model of Mullen, Wohlgenant and Farris (1988), the share-weighted sum of the relative changes in the demand for inputs (equations 10 to 12) is equal to the relative change in outputs The shift in the supply curve for POMS due to biased technical change is proportional to the shift in demand for copra, traders' services and POMS arising from biased technical change The estimation of the demand shifts for copra and traders' services are provided in Appendix 6.

Small disturbances from initial equilibrium conditions due to adoption of new technology alters prices and quantities The changes in prices and quantities can be approximated linearly by total differentiation of equations (6) to (17) and converting them to elasticity forms The log-linear differential equations are:

(6') $E(Q_{cNOH}) = (1/\eta_{cNOH})\, E(P_{cNOH})$

(7') $E(Q_{cMH}) = (1/\eta_{cMH})\, E(P_{cMH})$

(8') $\mu_{cNOH} E(P_{cNOH}) = \rho_1 E(W_1) + \rho 2\, E(W_2) + \rho_3 E(W_{3H}) + \rho_4 E(W_{4H})$

(9') $\mu_{cMH} E(P_{cMH}) = \rho_1 E(W_1) + \rho 2\, E(W_2) + \rho_3 E(W_{3H}) + \rho_4 E(W_{4H})$

(10') $E(X_1) = -(\rho_2 \sigma_{21} + \rho_3 \sigma_{31} + \rho_4 \sigma_{41})\, E(W_1) + \rho_2 \sigma_{21} E(W_2) + \rho_3 \sigma_{31} E(W_{3H}) + \rho_4 \sigma_{41} E(W_{4H}) + E(Y_H) + E(\psi_1)$

(11') $E(X_2) = \rho_1 \sigma_{21} E(W_1) - (\rho_1 \sigma_{21} + \rho_3 \sigma_{32} + \rho_4 \sigma_{42})\, E(W_2) + \rho_3 \sigma_{32} E(W_{3H}) + \rho_4 \sigma_{42} E(W_{4H}) + E(Y_H) + E(\psi_2)$

(12') $E(X_{3H}) = \rho_1 \sigma_{31} E(W_1) + (\rho_2 \sigma_{32} E(W_2) - \rho_1 \sigma_{31} + \rho_2 \sigma_{32} + \rho_4 \sigma_{43} E(W_{3H}) + \rho_4 \sigma_{43} E(W_{4H}) + E(Y_H) + E(\psi_{3H})$

(13') $E(X_{4H}) = \rho_1 \sigma_{41} E(W_1) + (\rho_2 \sigma_{42} E(W_2) + \rho_3 \sigma_{43} E(W_{3H}) - (\rho_1 \sigma_{41} + \rho_2 \sigma_{42} + \rho_3 \sigma_{42})\, E(W_{4H}) + E(Y_H) + E(\psi_{4H})$

(14') $E(W_1) = s_1 E(X_1)$

(15') $E(W_2) = s_2 E(X_2)$

(16') $E(W_{3H}) = s_3 E(X_{3H})$

(17') $E(W_{4H}) = s_4 E(X_{4H}) + E(k_{4H})$

The above system of equations can be solved numerically to give solutions for the relative changes in input and output prices and quantities as functions of the demand and supply shifters. First, the model is tranformed so that the exogenous shifters are on the left-hand side. The model may be represented as

$E(Q_{cNOH}) - \eta_{cNOH} E(P_{cNOH}) = 0$

$E(Q_{cMH}) - \eta_{cMH} E(P_{cMH}) = 0$

$$\mu_{cNOH}\, E(P_{cNOH}) - \rho_1 E(W_1) - \rho 2\, E(W_2) - \rho_3 E(W_{3H}) - \rho_4 E(W_{4H}) = 0$$

$$\mu_{cMH}\, E(P_{cMH}) - \rho_1 E(W_1) - \rho 2\, E(W_2) - \rho_3 E(W_{3H}) - \rho_4 E(W_{4H}) = 0$$

$$E(X_1) + (\rho_2\sigma_{21} + \rho_3\sigma_{31} + \rho_4\sigma_{41})\, E(W_1) - \rho_2\sigma_{21}\, E(W_2) -$$
$$\rho_3\sigma_{31}\, E(W_{3H}) - \rho_4\sigma_{41}\, E(W_{4H}) - E(Y_H) - E(\psi_1) = 0$$

$$E(X_2) - \rho_1\sigma_{21}\, E(W_1) + (\rho_1\sigma_{21} + \rho_3\sigma_{32} + \rho_4\sigma_{42})\, E(W_2) -$$
$$\rho_3\sigma_{32}\, E(W_{3H}) + \rho_4\sigma_{42}\, E(W_{4H}) - E(Y_H) - E(\psi_2) = 0$$

$$E(X_{3H}) - \rho_1\sigma_{31}\, E(W_1) - (\rho_2\sigma_{32}\, E(W_2) + (\rho_1\sigma_{31} + \rho_2\sigma_{32} +$$
$$\rho_4\sigma_{43})E(W_{3H}) - \rho_4\sigma_{43}\, E(W_{4H}) - E(Y_H) - E(\psi_{3H}) = 0$$

$$E(X_{4H}) - \rho_1\sigma_{41}\, E(W_1) - \rho_2\sigma_{42}\, E(W_2) - \rho_3\sigma_{43}E(W_{3H}) +$$
$$(\rho_1\sigma_{41} + \rho_2\sigma_{42} + \rho_3\sigma_{42})\, E(W_{4H}) - E(Y_H) - E(\psi_{4H}) = 0$$

$$E(W_1) - s_1 E(X_1) = 0$$
$$E(W_2) - s_2 E(X_2) = 0$$
$$E(W_{3H}) - s_3 E(X_{3H}) = 0$$
$$E(W_{4H}) - s_4 E(X_{4H}) = E(k_{4H})$$

In matrix form, the model is written as

$$M_H\, Y_H = X_H$$

where H represents the high quality market, M_H is a matrix of market parameters; Y_H is a vector of changes in the endogenous variables, i e , prices and quantities, and X_H is a matrix of percentage shifts in the exogenous variables The matrix form for the disequilibrium model can be written in its explicit form in Appendix 3

Appendix 6. Input Demand Shifters of a Biased Technical Change, Improved CNO Processing Technology

Following Mullen, Wohlgenant and Farris (1988, pp.246-247), a biased technical change in CNO processing technology is attributed to a vertical downward shift of the supply curve of the intensive input-processing inputs and other marketing inputs (POMS). In a multiproduction stages, the demand shift for the other inputs - high quality copra (X_1), low quality market (X_2), and traders' services (X_3) - are proportional to a shift of the supply curve for POMS.

Given a linearly homogeneous system, the share-weighted sum of the relative changes in quantities demanded of the inputs (equations 10' to 13' of Appendix 2) are equal to the relative change in output Y (CNO and CM). This relationship is based on the following condition,

$E\Psi'_i = -E\Psi'_4\rho_4/\rho_i \quad i = 1, 2, 3$ for inputs X_1, X_2, X_3

The input demand functions (equations 10' to 13') can be written as

(10') $$E(X_1) = -(\rho_2\sigma_{21} + \rho_3\sigma_{31} + \rho_4\sigma_{41})\, E(W_1) + \rho_2\sigma_{21}\, E(W_2) + \rho_3\sigma_{31}\, E(W_{3H}) + \rho_4\sigma_{41}\, E(W_{4H}) + EY_H - \rho_4/\rho_1 E\psi_{4H}$$

(11') $$E(X_2) = \rho_1\sigma_{21}\, E(W_1) - (\rho_1\sigma_{21} + \rho_3\sigma_{32} + \rho_4\sigma_{42})\, E(W_2) + \rho_3\sigma_{32}\, E(W_{3H}) + \rho_4\sigma_{42}\, E(W_{4H}) + EY_H + \rho_4/\rho_2 E\psi_{4H}$$

(12') $$E(X_{3H}) = \rho_1\sigma_{31}\, E(W_1) + (\rho_2\sigma_{32}\, E(W_2) - \rho_1\sigma_{31} + \rho_2\sigma_{32} + \rho_4\sigma_{43}\, E(W_{3H}) + \rho_4\sigma_{43}\, E(W_{4H}) + EY_H + \rho_4/\rho_3 E\psi_{4H}$$

(13') $$E(X_{4H}) = \rho_1\sigma_{41}\, E(W_1) + \rho_2\sigma_{42}\, E(W_2) + \rho_3\sigma_{43} E(W_{3H}) - (\rho_1\sigma_{41} + \rho_2\sigma_{42} + \rho_3\sigma_{43})\, E(W_{3H}) + \rho_4\sigma_{43} E(W_{4H}) + EY_H + E\psi_{4H}$$

where

$$E\psi_{4H} = Ek_4\, \rho_i\sigma_{4i} + 1) / (\rho_2 (\eta_{CNOH} S_4 + 1) + \rho_i (\eta_{CNOH} S_4 + 1))$$

$i = 1, 2, 3$, for X_1, X_2, X_3

Appendix 4. Research on Improved CNO Processing Technology: Initial and "With" Research Supply and Demand Conditions for the Equilibrium Displacement Model, Low Quality Market

Unlike in the high quality market, there are only three inputs in the low quality market - low quality copra, traders' services and POMS. For analytical purposes, it is assumed that processors of low quality CNO utilize only low quality copra.

The production function can be written as

(18) $Y_l\ (Q_{CNOL} .\ Q_{CML}) = F_l\ (X_2, X_{3L}, X_{4L})$

Equation (18) cam be written as

(19) $Q_{CNOL} = G_{l\,1}\ (X_2, X_{3L}, X_{4L})$

(20) $Q_{CML} = G_{l\,2}\ (X_2, X_{3L}, X_{4L})$

Similarly with the high quality sector, a cost function is used as a dual to the constant returns to scale production described above. Cost is also minimised subject to a given level of output, Y_L. Y_l is linearly homogeneous in the input X_i ($i = 1, 2, 3, 4$) for low quality copra, traders' services and POMS. The cost function can be expressed as

(21) $C_L = c_l\ (X_2, X_{3L}, X_{4L})\ .\ Y_L$

Shepard's Lemma is applied to the total cost function to obtain output constrained input demand functions.

$X_2 = g_2\ (X_2, X_{3L}, X_{4L})\ .\ Y_L$
$X_{3L} = g_3\ (X_2, X_{3L}, X_{4L})\ .\ Y_L$
$X_{4L} = g_4\ (X_2, X_{3L}, X_{4L})\ .\ Y_L$

(22) $R_L = G.\ r\ (P_{CNOL}, P_{CML})$

or

$R_{CNOL} = G_1..r\ (P_{CNOL}, P_{CML})$
$R_{CML} = G_2.r\ (P_{CNOL}, P_{CML})$

Input-constrained product supply functions are obtained by applying Hotelling's lemma.

$$Q_{CNOL} = r_1 (P_{CNOL}, P_{CML})$$
$$Q_{2CML} = r_2 (P_{CNOL}, P_{CML})$$

The initial equilibria in product and input markets are as follows.

Final product demand		
Low quality coconut oil	(23)	$Q_{CNOL} = f_1 (P_{CNOL})$
Low quality copra meal	(24)	$Q_{CML} = f_1 (P_{CNOL})$
Equilibrium conditions	(25)	$P_{CNOL} = g_1 (X_2, X_{3L}, X_{4L})$
	(26)	$P_{CML} = g_2 (X_2, X_{3L}, X_{4L})$
Input demand		
Low quality copra	(27)	$X_2 = m_2 (X_2, X_{3L}, X_{4L}, \psi_2) \cdot Y_L$
Traders' services	(28)	$X_{3l} = m_3 (X_2, X_{3L}, X_{4L}, \psi_{3L}) \cdot Y_L$
Processing and Other Marketing Inputs	(29)	$X_{4l} = m_4 (X_2, X_{3L}, X_{4L}, \psi_{4L}) \cdot Y_L$
Input supply	(30)	$W_2 = n_2(X_2)$
	(31)	$W_{3l} = n_3(X_{3L})$
	(32)	$W_{4L} = n_4(X_{4L}, k_{4L})$

The log-linear approximations to equations (23) to (32) and converting them to elasticity forms are

(23') $E(Q_{CNOL}) = (1/\eta_{CNOL}) E(P_{CNOL})$

(24') $E(Q_{CML}) = (1/\eta_{CML}) E(P_{CML})$

(25') $\mu_{CNOL} E(P_{CNOL}) = -\rho_2 E(W_2) - \rho_3 E(W_{3L}) - \rho_4 E(W_{4l})$

(26') $\mu_{CML} E(P_{CML}) = -\rho_2 E(W_2) - \rho_3 E(W_{3L}) - \rho_4 E(W_{4L})$

(27') $E(X_2) = +(\rho_3 \sigma_{32} + \rho_4 \sigma_{42}) E(W_2) - \rho_3 \sigma_{32} E(W_{3L}) - \rho_4 \sigma_{42} E(W_{4L}) - E(Y_L) - E(\psi_2)$

(28') $E(X_{3L}) = -\rho_3 \sigma_{32} E(W_2) + (\rho_3 \sigma_{32} + \rho_4 \sigma_{43}) E(W_{3L}) - \rho_4 \sigma_{42} E(W_{4L}) - E(Y_L) - E(\psi_{3L})$

(29') $E(X_{4L}) = -\rho_2 \sigma_{42} E(W_2) - \rho_3 \sigma_{43} E(W_{3L}) + (\rho_2 \sigma_{42} + \rho_3 \sigma_{42}) E(W_{4L}) - E(Y_L) - E(\psi_{4L})$

(30') $E(W_2) = s_2 E(X_2)$

(31') $E(W_{3L}) = s_3 E(X_{3L})$

(32') $E(W_{4L}) = s_4 E(X_{4L}) + E(k_{4L})$

The transformation of the model is represented as follows:

$$E(Q_{cNOL}) - \eta_{cNOL}\, E(P_{cNOL}) = 0$$
$$E(Q_{cML}) - \eta_{cML}\, E(P_{cML}) = 0$$
$$\mu_{cNOL}\, E(P_{cNOL}) + \rho_2 E(W_2) + \rho_3 E(W_{3L}) + \rho_4 E(W_{4L}) = 0$$
$$\mu_{cML}\, E(P_{cML}) + \rho_2 E(W_2) + \rho_3 E(W_{3L}) + \rho_4 E(W_{4L}) = 0$$
$$E(X_2) - (\rho_3\sigma_{32} + \rho_4\sigma_{42})\, E(W_2) + \rho_3\sigma_{32}\, E(W_{3L}) + \rho_4\sigma_{42}\, E(W_{4L}) + E(Y_L) + E(\psi_2) = 0$$
$$E(X_{3L}) + \rho_2\sigma_{32}\, E(W_2) - (\rho_{c3}\sigma_{32} + \rho_4\sigma_{43})E(W_{3L}) + \rho_4\sigma_{42}\, E(W_{4L}) + E(Y_L) + E(\psi_{3L}) = 0$$
$$E(X_{4L}) - \rho_2\sigma_{42}\, E(W_2) + \rho_3\sigma_{43} E(W_{3L}) - (\rho_2\sigma_{42} + \rho_3\sigma_{42})\, E(W_{4L}) + E(Y_L) + E(\psi_{4L}) = 0$$
$$E(W_2) - s_2 E(X_2) = 0$$
$$E(W_{3L}) - s_3 E(X_{3L}) = 0$$
$$E(W_{4L}) - s_4 E(X_{4L}) = E(k_{4L})$$

In matrix form, the model is written as

$$M_L Y_L = X_L$$

where L represents the high quality market, M_L is a matrix of market parameters, Y_L is a vector of changes in the endogenous variables, i e , prices and quantities, and X_L is a matrix of percentage shifts in the exogenous variables The matrix form for the disequilibrium model for the low quality sector is provided in Appendix 5

Appendix 6. Input Demand Shifters of a Biased Technical Change, Improved CNO Processing Technology

Following Mullen, Wohlgenant and Farris (1988, pp.246-247), a biased technical change in CNO processing technology is attributed to a vertical downward shift of the supply curve of the intensive input-processing inputs and other marketing inputs (POMS). In a multiproduction stages, the demand shift for the other inputs - high quality copra (X_1), low quality market (X_2), and traders' services (X_3) - are proportional to a shift of the supply curve for POMS.

Given a linearly homogeneous system, the share-weighted sum of the relative changes in quantities demanded of the inputs (equations 10' to 13' of Appendix 2) are equal to the relative change in output Y (CNO and CM). This relationship is based on the following condition,

$E\Psi_i = - E\Psi_4 \rho_4/\rho_i \quad i = 1, 2, 3$ for inputs X_1, X_2, X_3

The input demand functions (equations 10' to 13') can be written as

(10') $$E(X_1) = -(\rho_2\sigma_{21} + \rho_3\sigma_{31} + \rho_4\sigma_{41})\ E(W_1) + \rho_2\sigma_{21}\ E(W_2) + \rho_3\sigma_{31}\ E(W_{3H}) + \rho_4\sigma_{41}\ E(W_{4H}) + EY_H - \rho_4/\rho_1\ E\psi_{4H}$$

(11') $$E(X_2) = \rho_1\sigma_{21}\ E(W_1) - (\rho_1\sigma_{21} + \rho_3\sigma_{32} + \rho_4\sigma_{42})\ E(W_2) + \rho_3\sigma_{32}\ E(W_{3H}) + \rho_4\sigma_{42}\ E(W_{4H}) + EY_H + \rho_4/\rho_2\ E\psi_{4H}$$

(12') $$E(X_{3H}) = \rho_1\sigma_{31}\ E(W_1) + (\rho_2\sigma_{32}\ E(W_2) - \rho_1\sigma_{31} + \rho_2\sigma_{32} + \rho_4\sigma_{43}\ E(W_{3H}) + \rho_4\sigma_{43}\ E(W_{4H}) + EY_H + \rho_4/\rho_3\ E\psi_{4H}$$

(13') $$E(X_{4H}) = \rho_1\sigma_{41}\ E(W_1) + \rho_2\sigma_{42}\ E(W_2) + \rho_3\sigma_{43}E(W_{3H}) - (\rho_1\sigma_{41} + \rho_2\sigma_{42} + \rho_3\sigma_{43})\ E(W_{3H}) + \rho_4\sigma_{43}E(W_{4H}) + EY_H + E\psi_{4H}$$

where

$$E\psi_{4H} = Ek_4\ \rho_i\sigma_{4i} + 1) / (\rho_2\ (\eta_{CNOH}\ S_4 + 1) + \rho_i\ (\eta_{CNOH}\ S_4 + 1))$$

$i = 1, 2, 3$, for X_1, X_2, X_3