Investment and Change in the Coconut Industry of North Sulawesi: An Equilibrium Displacement Analysis

by

Benjamin B. Henderson, Lynn Henry and Gordon MacAulay
Agricultural and Resource Economics
Faculty of Agriculture, Food and Natural Resources
The University of Sydney, NSW, 2006.

Contributed paper presented to the 50th Annual Conference of the
Australian Agricultural and Resource Economics Society,
8-10 February 2006, Sydney, NSW

Investment and Change in the Coconut Industry of North Sulawesi: An Equilibrium Displacement Analysis

Benjamin B. Henderson, Lynn Henry and Gordon MacAulay*

The coconut industry of North Sulawesi is dominated by a small number of products which are primarily exported from the province. Accordingly, demand for these products is generally very elastic. Conversely, the supply of coconuts is highly inelastic, especially in the short to medium-term. Hence, small shifts in supply and demand lead to large fluctuations in farmer incomes. From this context an equilibrium displacement model is used to examine the intra-industry consequences of investments into farm and marketing sector efficiency. These investments are assessed in terms of the distribution of producer surplus benefits that they generate, and their ability to improve the position of coconut farmers.

Keywords: coconut industry, equilibrium displacement model, investment.

1. Introduction

North Sulawesi is the second largest coconut producing province in Indonesia and in 2003 accounted for 7.4 per cent of coconut land area, nationally. With more suitable growing conditions, North Sulawesi enjoys higher levels of productivity than the other provinces and in 2003 contributed 9.6 per cent to total production, behind only Riau with 17.3 per cent (table 1). The relative superiority of coconut production in North Sulawesi is partly attributed to the presence of well drained, fertile volcanic soils, and ideal climatic conditions which make it one of the most suitable regions for coconut production in the world (Sondakh 1984). More than 90 per cent of the coconuts produced are exported after some degree of processing. Consequently, even though North Sulawesi contributed less than 10 per cent to total production between 1998 and 2001, it accounted for more than one third of the nation's export income from coconut products, over the same period.

In 2000, the coconut industry contributed 35 per cent to agricultural gross regional domestic product, and accounted for nearly 80 per cent of agricultural land devoted to perennial crops in North Sulawesi (Tillekeratne *et al.* 2001). The industry's contribution to export income is even more important, with 45 per cent of North Sulawesi's total export income coming from coconut products in 1999 (Sondakh and Jones 2003). Approximately 96 per cent of all coconut land is farmed by smallholders with an average of 1.5 hectares of land (Sondakh and Jones 2003). Hence, the coconut industry supports a considerable proportion of the Province's, largely, rural population. Usman *et al.* (2001) reported that, in 1999, nearly 70 per cent of the Province's population relied on coconuts as their primary source of income.

As part of the movement for increased autonomy among Indonesia's regions, there is a growing need for provincial and local governments to take greater responsibility for the development of their key industries. Decentralisation policies over the past decade

* ACIAR Senior Research Assistant, The University of Sydney; Associate Lecturer, The University of Sydney; Professor, The University of Sydney. The financial support of the Australian Centre for International Agricultural Research is gratefully acknowledged. Email contact may be made through hendersonb@agric.usyd.edu.au.

and a half have led to a shift of authority from Jakarta to the regions. Accompanying this transfer of power, the provincial and local governments (*kabupaten* and *kota* levels of administration) have sought the introduction of a number of taxes and levies, under the auspices of Law 22/1999, in an effort to generate *pendapatan asli daerah* (PAD) or 'own source' revenues. These revenues are required to fund both their routine operations and regional development plans (SMERU 2001). Despite this, the central government still funds most of the R&D into the coconut industry either directly through its own agency in the region, the Indonesian Coconut and Palmae Research Institute (ICOPRI), but also by providing *dana alokasi umum* (DAU), or general purpose funds, to the local Plantations Office (Dinas Perkebunan). Despite the best intentions of these institutions, financial and organisational constraints have limited their effectiveness. Thus, R&D investments in the coconut industry have been both scant and sporadic over the past few decades and have, understandably, had very little impact in promoting growth and development at either the farm level or within the various market sectors of the industry.

While there have been concerns about the efficiency of local administrations, it is likely that 'own source' revenues will become increasingly important for R&D activities. In 2001 the Minahasa district allocated approximately 20 per cent of its 'own source' revenues to development activities (SMERU 2001). In the coconut industry, at present, local government levies are only charged for the transport of copra and coconuts, and for large manufacturers of coconut products. In addition, manufacturing firms also pay value-added tax and income tax to the central government. Coconut producers have not yet been required to pay any government levies under Law 22/1999, however, there are levies charged to traders and manufacturers, which put downward pressure on farm prices.

Because the coconut industry is so integral to the vitality of the Province's economy, R&D to redress stagnation in farm productivity and agro-industrial development should be a government priority. When formulating a development strategy for any industry, questions regarding where to obtain funding for R&D programs, and where in the industry they should be directed, must be asked. Modelling the potential impacts of R&D programs on various industry participants, can provide some useful answers. The major objective of this research is to determine where, within the complex value chain of the coconut industry, R&D investments should be directed, in terms of its ability to improve both industry and farm-level incomes, and to determine who should pay these investments.

2. Structure of the industry

Coconut palms provide the raw material for a wide range of products, including coconut oil, desiccated coconut, coconut meal, activated carbon and timber, most of which are derived from the coconut fruit. Despite this versatility, copra and commercial coconut oil production continue to dominate the industry's processing sector in North Sulawesi, and Indonesia in general. This legacy of copra and coconut oil production is a consequence of the industry structure that was promoted and developed early last century in response to industrial demand by Western Europe and North America (Foale 2003). A percentage breakdown of the shares of the major coconut products and their contribution to export income in both Indonesia and North Sulawesi is provided in table 2.

Commercial coconut oil is the most valuable export product for the industry at both the national and provincial level. The supply chain for commercial coconut oil in North Sulawesi can be disaggregated into a number of different stages. First of all farmers, through a simple smoking process, create copra by placing split coconut in a crudely constructed kiln for 5-6 hours until the white kernel of the nut is sufficiently dry. This provides the raw material for crude coconut oil production. Copra produced by farmers usually contains moisture levels that range between 10-15 per cent (Tillekeratne *et al.* 2001). The distribution of copra from the farm gate to oil mills and exporters can involve several levels of traders. Large scale collecting traders purchase copra, delivered by either smaller village level traders or directly by farmers, and refine the product further by sun drying the copra until a moisture level of around 5 per cent is obtained.[1] After this it is delivered directly to either oil mills or exporters or, in some cases, to another level of middlemen and traders. In North Sulawesi there are only two companies which export copra from the province, and four which purchase copra and process it further into crude and refined (edible) oil.[2] The biggest of these, PT Bimoli, accounts for just over half of the copra processing capacity in the Province (Dumais *et al*. 2005).

Crude coconut oil is made from copra by breaking copra into small pieces before crushing the copra in screw expellers. The residue is crushed and steamed using specialised equipment before the oil is expelled (Tillekeratne *et al.* 2001). The residue forms a solid, fibrous 'cake' known as copra meal, which is high in protein and is packaged and sold as a high quality livestock feed, making a substantial contribution to export income (table 2). The oil is filtered and then either exported in its crude form or sold to the PT Bimoli oil refinery, where it is refined, bleached and deodorised to make it suitable for edible purposes. In North Sulawesi approximately 15 per cent of manufactured crude oil is processed further into refined (edible) oil. Farm productivity has failed to keep up with the productive capacity of oil mills in the Province, and now more than 30 per cent of the copra, used to manufacture commercial coconut oil, is imported from other provinces including Gorontalo, Central Sulawesi and the Moluccas.

Desiccated coconut ranked second at both the national and provincial levels, in terms of its contribution to the coconut industry's total export value. The marketing channel for desiccated coconut can be described in three to four stages. Farmers supply fresh dehusked nuts either to collecting traders who then deliver the nuts to processing firms, or they supply them directly to the processing firms. Commercial processing occurs in large-scale factories that use modern processing equipment and professional management of key areas such procurement of raw material, processing, quality control and marketing (Tillekeratne *et al.* 2001). Manufacturing desiccated coconut involves de-shelling the coconuts, cleaning the flesh before chopping it, while still wet, into small pieces before blanching them with steam. The product is then transferred to a dryer until its moisture content is reduced to 3 per cent, after which it is sifted and graded. There are only six desiccated coconut processing firms in this province (Dumais *et al*. 2005).

---

[1] In some cases kilns are also used.

[2] This process involves refining, bleaching and deodorising crude coconut oil to a commercially acceptable level.

While farmers provide the raw materials for the main industry products (coconut oil and desiccated coconut) they also manufacture traditional coconut oil and milk for local consumption. The production of both of these farm products typically involves grating the fresh flesh of a mature coconut, adding water and then pressing the mixture, either by hand or mechanically, to extract a mixture of water and coconut milk. The coconut milk fraction is either removed or used directly, or the mixture is cooked at high temperatures until all that remains is coconut oil and a waste by-product.[3]

In addition to copra meal, a number of other by-products are utilised within the coconut industry of north Sulawesi. Shell-derived products, such as activated carbon and charcoal, account for a small proportion of export income. The majority of charcoal is manufactured by smallholder farmers and desiccated coconut manufacturers. Charcoal is normally sold to collecting traders that either deliver the product to exporters or to activated carbon processors, of which there are three within the Province. Activated carbon is a more advanced product, requiring more capital inputs and is only viable for commercial scale production. Coir fibre, which is derived from the husk of the coconut, is a potentially valuable by-product that is not utilised commercially, at present.

Coconut water is the other major by-product from the coconut fruit, most of which is currently discarded as waste during copra and desiccated coconut production. The water can be consumed fresh, but is increasingly used to manufacture *nata de coco*, which is a jelly-like dessert made by fermentation. Recent attempts to introduce this technology to coconut farmers, by The North Sulawesi Industry and Trade Affairs, are yet to have a widespread impact.

3. Development priorities

Because the coconut industry supports a very large proportion of the Province's impoverished rural population, growth in farm sector income will help improve rural welfare directly, but is also likely to be an important driver of economic development within the Province. From this perspective R&D investments that improve profitability of the coconut industry's farm sector are highly desirable. This can be achieved through improvements in both farm-level productivity and marketing efficiency. According to Allorerung (2000), the combination of technical changes and improved management efficiency could increase productivity from 1.1 to between 2.6 to 3.3 tonnes of copra per hectare per year. Replanting provides a means of improving productivity and profits in the long-run, while rehabilitation of neglected plantations will also help in the short-run.

The over reliance of the coconut industry on copra and crude coconut oil, exposes its participants to significant financial risks, as their returns are determined, almost entirely, by the price movements of a single commodity. According to research by UNCTAD (2003) into the price movements of globally traded commodities, the price

[3] There are some variants to this procedure, for example, in some cases the flesh is fried first before the oil is extracted in a mechanical press. Another approach involves stirring the extracted milk and water mixture and allowing it to stand over night until it separates into a semi-solid coconut cream layer and water layer. This semi solid fraction is then removed and boiled to remove any remaining water (Tillekeratne *et al*, 2001).

of coconut oil was the second most unstable, behind only pepper, between 2000-2002. Thus, investment strategies that increase market resilience by encouraging greater product diversity are also preferred. One useful strategy for coconut producers to raise their income levels and reduce their dependence on copra production is through encouraging greater farmer participation in value-adding activities. Very recently, a number of techniques have been developed that allow the production of high quality 'virgin coconut oil' on a small scale. These capital requirements for its production are reasonably modest and for some of the procedures being trialled, they are very similar to those currently used to produce traditional coconut oil. Local and domestic demand for this new product appear to be growing, hence, adoption of virgin coconut oil could achieve multiple objectives of raising farmer income, increasing local ownership of processing resources and reducing reliance on unstable export markets.

The farm sector and the industry in general will also benefit from efficiency improvements in the marketing and manufacturing sectors. If these improvements lower the costs of these activities, they can provide increased profits for manufacturers and traders, as well for farmers, by raising demand for farm products. There has been a great deal of concern among farmers as to the efficiency of the copra marketing channel, since there is often a multitude of middlemen, each receiving a share of the price margin between the farm gate and oil refineries. Improved marketing efficiency in this sector is another development priority. While it is acknowledged that R&D into commercial coconut oil and desiccated coconut industries could benefit the industry, it is doubtful whether the provincial and local governments can make an impact in these areas.

4. Methodology

Comparative static analysis is used, through the development of an equilibrium displacement model (EDM), to examine the intra-industry consequences of several hypothetical R&D. The EDM used in this study is based on the work of previous authors including Muth (1964), Mullen *et al*. (1988) and Zhao *et al*. (2003). The EDM measures the impacts of movements from an initial industry equilibrium to a new equilibrium, following exogenous shifts in the industry's factor supply curves and product demand curves. This type of analysis is particularly useful in situations where quantitative results are needed, but data are too limited or unreliable for econometric analyses (Piggot 1992).

4.1 Conceptual model of the industry

A conceptual model, created for the purpose of modelling the coconut industry of North Sulawesi, is presented in figure 1. The industry is horizontally disaggregated into four major product-market channels. The largest of these is the commercial coconut oil channel with export copra, crude coconut oil, refined coconut oil, copra meal and shell charcoal as its final products. The other major commercial export-oriented market channel has desiccated coconut and charcoal as its outputs. The domestic market is supplied primarily by the traditional coconut oil and coconut milk market channel, which also produces shell charcoal. Shell charcoal from these three sources is either packaged and exported or used locally to make activated carbon. Each of these market channels are separated vertically into between 2 and 5 different market sectors, with the farm sector providing raw and intermediate products for each

channel. The rectangles in the diagram represent production functions, whilst the ovals represent supply and demand functions.

Coconut fibre and coconut water by-products were not included in the conceptual model. Because they are primarily discarded as waste, their omission from the model was considered to be a minor abstraction and permitted the construction of a more manageable set of simultaneous equations. The products included are estimated to contribute more than 95 per cent to total industry value added.

4.2 The structural model[4]

First of all, a structural model is developed, to describe the industry through a system of decision functions, and supply and demand functions, using general functional forms.[5] It is assumed that each sector is profit maximising, that the technologies are characterised by constant returns to scale, and that all multi-output technologies are separable in inputs and outputs (Zhao *et al*. 2003).

Supply of domestically produced coconuts

$$X_c = X_c(w_c, T_{Xc}) \quad (1)$$

Equation (1) is the supply function for coconuts, relating total quantity supplied (X_c) to own price (w_c). T_{Xc} is the supply shifter for coconut production and can be used to represent cost reducing increases in productivity, which could occur through a combination of improved management and/or technical change.

Input-constrained output supply for on-farm uses of coconuts

$$X_{cc} = r'_{Xc,cc}(w_{cc}, w_{ct}, w_{cd})X_c^* \quad (2)$$

$$X_{ct} = r'_{Xc,ct}(w_{cc}, w_{ct}, w_{cd})X_c^* \quad (3)$$

$$X_{cd} = r'_{Xc,cd}(w_{cc}, w_{ct}, w_{cd})X_c^* \quad (4)$$

Equations (2), (3) and (4) are the input-constrained output supply functions for coconuts used to make copra and charcoal (X_{cc}), traditional coconut oil/milk and charcoal (X_{ct}), and dehusked nuts (X_{cd}), respectively. $r'_{Xc,cc}(w_{cc}, w_{ct}, w_{cd})$, $r'_{Xc,ct}(w_{cc}, w_{ct}, w_{cd})$ and $r'_{Xc,cd}(w_{cc}, w_{ct}, w_{cd})$ are partial derivatives of the unit revenue functions $r_{Xc,cc}(w_{cc}, w_{ct}, w_{cd})$, $r_{Xc,ct}(w_{cc}, w_{ct}, w_{cd})$ and $r_{Xc,cd}(w_{cc}, w_{ct}, w_{cd})$, respectively, derived using the Samuelson-McFadden Lemma (Chambers 1988, p. 264). The movement of coconuts from one market channel into another is not perfectly unrestricted in the short-run, since farmers normally have contractual obligations to product manufacturers. These revenue functions are used to control the movements between each channel.

[4] A description of the variables used in the model is provided in table 3.
[5] Quantities are represented by capital letters and prices by lower-case letters.

Marketing clearing condition for coconuts

$$r_{Xc}(w_{cc},w_{ct},w_{cd}) = w_c \quad (5)$$

Equation (5) is the value equilibrium condition, and ensures consistency between the overall unit price of coconuts, and the unit prices for the coconuts in each market channel.

Supply of farm marketing inputs

$$X_m = X_m(w_m,T_{Xm}) \quad (6)$$

Equation (6) is the supply function for the aggregate farm marketing input, relating total quantity supplied (X_m) to its own price (w_m). This input is used to produce the range of intermediate and final farm products, and is comprised mostly of labour with some minor capital components (tools, temporary shelter, basic kiln, steel drums) as well as bulk packing materials and on-farm transport costs.

On-farm uses of marketing inputs

$$X_m = X_{mc} + X_{mt} + X_{md} \quad (7)$$

Equation (7) describes the allocation of mobile farm marketing inputs between the production of farm copra and charcoal (X_{mc}), traditional coconut oil/milk and charcoal (X_{mt}), and dehusked coconuts (X_{md}).

Output-constrained input demand for farm copra and charcoal production

$$X_{cc} = c'_{Yfcsc,cc}(w_{cc},w_m)Y_{fcsc}^* \quad (8)$$

$$X_{mc} = c'_{Yfcsc,mc}(w_{cc},w_m)Y_{fcsc}^* \quad (9)$$

Equations (8) and (9) are the output-constrained input demand functions for coconuts (X_{cc}) and farm marketing inputs (X_{mc}) used in the production of farm copra and charcoal. $c'_{Yfcsc,cc}(w_{cc},w_m)$ and $c'_{Yfcsc,mc}(w_{cc},w_m)$ are partial derivatives of the unit cost functions $c_{Yfcsc,cc}(w_{cc},w_m)$ and $c_{Yfcsc,mc}(w_{cc},w_m)$, respectively, derived using Shepard's Lemma (Chambers 1988, p. 262).

Input-constrained output supply for farm copra and charcoal production

$$Y_{fc} = r'_{Xccmc,fc}(v_{fc},v_s)X_{ccmc}^* \quad (10)$$

$$Y_{sc} = r'_{Xccmc,sc}(v_{fc},v_s)X_{ccmc}^* \quad (11)$$

Equations (10) and (11) are the input-constrained output supply functions for farm copra (Y_{fc}) and its by-product, shell charcoal (Y_{sc}). $r'_{Xccmc,fc}(v_{fc},v_s)$ and $r'_{Xccmc,sc}(v_{fc},v_s)$ are the partial derivatives of the unit revenue functions $r'_{Xccmc,fc}(v_{fc},v_s)$ and $r'_{Xccmc,sc}(v_{fc},v_s)$, respectively, and are derived using the Samuelson-McFadden Lemma.

Market clearing conditions for farm copra and charcoal production

$$Y_{fcsc}(Y_{fc},Y_{sc}) = X_{ccmc}(X_{cc},X_{mc}) \quad (12)$$

Equation (12) is the product transformation function for farm copra and charcoal production. It ensures that marginal changes in the aggregated output index (Y_{fcsc}) are equal to the marginal changes in aggregate input index (X_{ccmc}).

$$r_{Xccmc}(v_{fc},v_s) = c_{Yfcsc}(w_{cc},w_m) \quad (13)$$

The value equilibrium condition described by equation (13) ensures that the unit cost (c_{Yfcsc}) of producing a unit of the aggregated output (Y_{fcsc}), is equal to the unit revenue (r_{Xccmc}) earned for each unit of aggregated input (X_{ccmc}).

Additional input supply for traditional coconut oil/milk and charcoal production

$$X_{kt} = X_{kt}(w_{kt}, T_{Xkt}) \quad (14)$$

Equation (14) is the supply function for capital inputs used in the production of traditional coconut oil/milk and charcoal, and it relates the quantity supplied (X_{kt}) to its own price (w_{kt}). These inputs represent the simple capital requirements for producing traditional coconut oil and milk. T_{Xkt} is the supply shift variable and can be used to simulate cost-reducing change in the supply of X_{kt}.

Output-constrained input demand for traditional coconut oil/milk and charcoal production

$$X_{ct} = c'_{Ytost,ct}(w_{ct},w_{m,}w_{kt})Y_{tost}^* \quad (15)$$

$$X_{mt} = c'_{Ytost,mt}(w_{ct},w_{m,}w_{kt})Y_{tost}^* \quad (16)$$

$$X_{kt} = c'_{Ytost,kt}(w_{ct},w_{m,}w_{kt})Y_{tost}^* \quad (17)$$

Equations (15), (16) and (17) are the output-constrained input demand functions for coconuts (X_{ct}), general farm marketing inputs (X_{mt}) and specific capital inputs (X_{kt}), respectively, used to produce traditional coconut oil/milk and charcoal. $c'_{Ytost,ct}(w_{ct},w_m,w_{kt})$, $c'_{Ytost,mt}(w_{ct},w_m,w_{kt})$ and $c'_{Ytost,kt}(w_{ct},w_{m,}w_{kt})$ are the partial derivatives of the unit cost functions $c_{Ytost,ct}(w_{ct},w_m,w_{kt})$, $c_{Ytost,mt}(w_{ct},w_m,w_{kt})$ and $c_{Ytost,kt}(w_{ct},w_{m,}w_{kt})$, respectively, and are derived using Shepard's Lemma.

Input-constrained output supply for traditional coconut oil/milk and charcoal production

$$Y_{to} = r'_{Xctmtkt,to}(v_{to},v_s)X_{ctmtkt}^* \quad (18)$$

$$Y_{st} = r'_{Xctmtkt,st}(v_{to},v_s)X_{ctmtkt}^* \quad (19)$$

Equations (18) and (19) are the input-constrained output supply curves for traditional coconut oil/milk (Y_{to}) and its by-product, charcoal (Y_{st}), respectively. $r'_{Xctmtkt,to}(v_{to},v_s)$ and $r'_{Xctmtkt,st}(v_{to},v_s)$ are the partial derivatives of the unit revenue functions

$r_{Xctmtkt,to}(v_{to},v_s)$ and $r_{Xctmtkt,st}(v_{to},v_s)$, respectively, and are derived using the Samuelson-McFadden Lemma.

Market clearing conditions for traditional coconut oil/milk and charcoal production

$$Y_{tost}(Y_{to},Y_{st}) = X_{ctmtkt}(X_{ct},X_{mt},X_{kt}) \quad (20)$$

Equation (20) is the product transformation function for traditional coconut oil/milk and charcoal production. It ensures that marginal changes in the aggregated output index (Y_{tost}) are equal to the marginal changes in aggregate input index (X_{ctmtkt}).

$$r_{Xctmtkt}(v_{to},v_s) = c_{Ytost}(w_{ct},w_{mt},w_{kt}) \quad (21)$$

The value equilibrium condition described by equation (21) ensures that the unit cost (c_{Ytos}) of producing a unit of the aggregated output (Y_{tost}), is equal to the unit revenue (r_{Xccmc}) earned for each unit of aggregated input (X_{ctmtkt}).

Output-constrained input demand for dehusked coconut production

$$X_{cd} = c'_{Yfd,cd}(w_{cd},w_m)Y_{fd}^* \quad (22)$$

$$X_{md} = c'_{Yfd,md}(w_{cd},w_m)Y_{fd}^* \quad (23)$$

Equations (22) and (23) are the output-constrained input demand functions for coconuts (X_{cd}) and farm marketing inputs (X_{md}), respectively, used in the production of dehusked nuts. $c'_{Yfd,cd}(w_{cd},w_m)$ and $c'_{Yfd,md}(w_{cd},w_m)$ are partial derivatives of the unit cost functions $c_{Yfd,cd}(w_{cd},w_m)$ and $c_{Yfd,md}(w_{cd},w_m)$, respectively, and are derived using Shepard's Lemma.

Market clearing condition for dehusked coconut production

$$v_{fd} = c_{Yfd}(w_{cd},w_m) \quad (24)$$

The market clearing condition described by equation (24) ensures that the inputs are paid their marginal value of production.

Additional input supply for desiccated coconut and charcoal production

$$Y_{md} = Y_{md}(v_{md}, T_{Ymd}) \quad (25)$$

Equation (25) is the supply function for the additional marketing input for the desiccated coconut sector, and relates the quantity supplied (Y_{md}) to its own price (v_{md}). This input is an aggregate of transport, handling, processing and distribution activities. T_{Ymd} is its corresponding intercept shift variable, which can be used to simulate cost-reducing technical change.

Output-constrained input demand for desiccated coconut and charcoal production

$$Y_{fd} = c'_{Zdcsd,fd}(v_{fd},v_{md})Z_{dcsd}^{*} \quad (26)$$

$$Y_{md} = c'_{Zdcsd,md}(v_{fd},v_{md})Z_{dcsd}^{*} \quad (27)$$

Equations (26) and (27) are the output-constrained input demand functions for dehusked coconuts (Y_{fd}) and additional marketing inputs (Y_{md}), respectively, used to produce dessicated coconut and charcoal. $c'_{Zdcsd,fd}(v_{fd},v_{md})$ and $c'_{Zdcsd,md}(v_{fd},v_{md})$ are partial derivatives of the unit cost functions $c_{Zdcsd,fd}(v_{fd},v_{md})$ and $c_{Zdcsd,\ md}(v_{fd},v_{md})$, respectively, and are derived using Shepard's Lemma.

Input-constrained output supply for desiccated coconut and charcoal production

$$Z_{dc} = r'_{Yfdmd,dc}(p_{dc},v_s)Y_{fdmd}^{*} \quad (28)$$

$$Z_{sd} = r'_{Yfdmd,sd}(p_{dc},v_s)Y_{fdmd}^{*} \quad (29)$$

Equations (28) and (29) are the input-constained output supply functions for desiccated coconut (Z_{dc}) and its by-product, shell charcoal (Z_{sd}), respectively. $r'_{Yfdmd,dc}(p_{dc},v_s)$ and $r'_{Yfdmd,sd}(p_{dc},v_s)$ are the partial derivatives of the unit revenue functions $r_{Yfdmd,dc}(p_{dc},v_s)$ and $r_{Yfdmd,sd}(p_{dc},v_s)$, respectively, and are derived using the Samuelson-McFadden Lemma.

Market clearing conditions for desiccated coconut and charcoal production

$$Z_{dcsd}(Z_{dc},Z_{sd}) = Y_{fdmd}(Y_{fd},Y_{md}) \quad (30)$$

Equation (30) is the product transformation function for desiccated coconut and charcoal production. It ensures that marginal changes in the aggregated output index (Z_{dcsd}) are equal to the marginal changes in aggregate input index (Y_{fdmd}).

$$r_{Ycdmd}(p_{dc},v_s) = c_{Zdcsd}(v_{fd},v_{md}) \quad (31)$$

Equation (31) is the value equilibrium condition, stating that the unit revenue (r_{Ycdmd}) earned per unit of the aggregated input (Y_{cdmd}) equals the unit cost (c_{Zdcsd}) of producing a unit of the aggregated output (Z_{dcsd}).

Additional input supply for refined copra production

$$Y_{mc} = Y_{mc}(v_{mc}, T_{Ymc}) \quad (32)$$

Equation (32) is the supply function for the aggregate marketing input[6] used in the production of refined copra, and it relates the quantity supplied (Y_{mc}) to its own price (v_{mc}). T_{Ymc} is the corresponding intercept shift variable.

[6] This variable is an aggregate of specific (e.g. fixed capital) and non-specific (e.g. labour) inputs.

Output-constrained input demand for refined copra production

The output-constrained input demand functions can be derived by applying:

$$Y_{fc} = c'_{Zcp^d,fc}(v_{fc},v_{mc})Z_{cp}^{d*} \quad (33)$$

$$Y_{mc} = c'_{Zcp^d,mc}(v_{fc},v_{mc})Z_{cp}^{d*} \quad (34)$$

Equations (33) and (34) are the output-constrained input demand functions for farm copra (Y_{fc}) and the additional marketing input (Y_{mc}), respectively, used to produce refined copra (Z_{cp}^d). $c'_{Zcp^d,fc}(v_{fc},v_{mc})$ and $c'_{Zcp^d,mc}(v_{fc},v_{mc})$ are the partial derivatives of the unit cost functions $c_{Zcp^d,fc}(v_{fc},v_{mc})$ and $c_{Zcp^d,mc}(v_{fc},v_{mc})$, repectively, and are derived using Shepard's Lemma.

Market clearing condition for refined copra production

$$p_{cp}^d = c_{Zcp}^d(v_{fc},v_{mc}) \quad (35)$$

Equation (35) is the value equilibrium condition for the refined copra sector, specifying that the unit price for refined copra (p_{cp}^d) equals its unit cost (c_{Zcp}^d) of production.

Destinations for domestically produced copra

$$Z_{cp}^d = Z_{cp}^o + Z_{cp}^e \quad (36)$$

According to equation (36), domestically produced copra can either be used to produce coconut oil and copra meal (Z_{cp}^o) or exported without any further processing (Z_{cp}^e).

Supply of refined copra from outside of the Province

$$Z_{cp}^i = Z_{cp}^i(p_{cp}^i, T_{Zcp}^i) \quad (37)$$

Equation (37) is the supply function for copra imported from outside of North Sulawesi, and it relates the quantity supplied (Z_{cp}^i) to its own price (p_{cp}^i). Copra is imported from neighbouring provinces to meet the demands of coconut oil manufacturers in the Province. T_{Zcp}^i is the supply shifter, which can be used to represent cost reducing technical changes that occur in neighbouring provinces.

Additional input supply for coconut oil and copra meal production

$$Z_{mo} = Z_{mo}(p_{mo}, T_{Zmo}) \quad (38)$$

Equation (38) is the supply function for marketing inputs used to manufacture coconut oil and copra meal, and it relates the quantity supplied (Z_{mo}) to its own price (p_{mo}). Again, a single aggregate variable is used to describe a range of marketing inputs. T_{Zmo} is the intercept shift variable.

Output-constrained input demand for crude coconut oil and copra meal production

$$Z_{cp}^{o} = c'_{Qcocm,cp}{}^{o}(p_{cp}{}^{d},p_{cp}{}^{i},p_{mo})Q_{cocm}* \quad (39)$$

$$Z_{cp}^{i} = c'_{Qcocm,cp}{}^{i}(p_{cp}{}^{d},p_{cp}{}^{i},p_{mo})Q_{cocm}* \quad (40)$$

$$Z_{mo} = c'_{Qcocm,mo}(p_{cp}{}^{d},p_{cp}{}^{i},p_{mo})Q_{cocm}* \quad (41)$$

Equations (39), (40) and (41) are the input demand functions for domestic copra (Z_{cp}^{o}), imported copra (Z_{cp}^{i}) and the additional marketing input (Z_{mo}), respectively, for coconut oil and copra meal production. $c'_{Qcocm,cp}{}^{o}(p_{cp}{}^{d},p_{cp}{}^{i},p_{mo})$, $c'_{Qcocm,cp}{}^{i}(p_{cp}{}^{d},p_{cp}{}^{i},p_{mo})$ and $c'_{Qcocm,mo}(p_{cp}{}^{d},p_{cp}{}^{i},p_{mo})$ are the partial derivatives of the unit cost functions $c_{Qcocm,cp}{}^{o}(p_{cp}{}^{d},p_{cp}{}^{i},p_{mo})$, $c_{Qcocm,cp}{}^{i}(p_{cp}{}^{d},p_{cp}{}^{i},p_{mo})$ and $c_{Qcocm,mo}(p_{cp}{}^{d},p_{cp}{}^{i},p_{mo})$, respectively, and are derived using Shepard's Lemma.

Input-constrained output supply for crude coconut oil and copra meal production

$$Q_{co} = r'_{Zcpmo,co}(u_{co},u_{cm})Z_{cpmo}* \quad (42)$$

$$Q_{cm} = r'_{Zcpmo,cm}(u_{co},u_{cm})Z_{cpmo}* \quad (43)$$

Equations (42) and (43) are the input-constrained output supply curves for crude coconut oil (Q_{co}) and its by-product, copra meal (Q_{cm}), respectively. $r'_{Zcpmo,Qco}(u_{co},u_{cm})$ and $r'_{Zcpmo,Qcm}(u_{co},u_{cm})$ are the partial derivatives of the unit revenue functions $r_{Zcpmo,Qco}(u_{co},u_{cm})$ and $r_{Zcpmo,Qcm}(u_{co},u_{cm})$, respectively, and are derived using the Samuelson-McFadden Lemma.

Market clearing conditions for crude coconut oil and copra meal production

$$Q_{cocm}(Q_{co},Q_{cm}) = Z_{cpmo}(Z_{cp}{}^{o},Z_{cp}{}^{i}, Z_{mo}) \quad (44)$$

Equation (44) is the product transformation function for coconut oil and copra meal production. It ensures that marginal changes in the aggregated output index (Q_{cocm}) are equal to the marginal changes in aggregate input index (Z_{cpmo}).

$$r_{Zcpmo}(u_{co},u_{cm}) = c_{Qcocm}(p_{cp}{}^{d},p_{cp}{}^{i},p_{mo}) \quad (45)$$

Equation (45) is the value equilibrium condition, ensuring that the unit revenue (r_{Zcpmo}) earned per unit of the aggregated input (Z_{cpmo}) equals the unit cost (c_{Qcocm}) of producing a unit of the aggregated output (Q_{cocm}).

Destinations for crude coconut oil

$$Q_{co} = Q_{co}{}^{r} + Q_{co}{}^{e} \quad (46)$$

Equation (46) determines the proportion of crude coconut oil which is used to manufacture refined (edible) coconut oil (superscript 'r') within North Sulawesi and the quantities that are exported outside of the province (superscript 'e', respectively).

Additional input supply for refined (edible) coconut oil production

$$Q_{mr} = Q_{mr}(u_{mr}, T_{Qmr}) \quad (47)$$

Equation (47) is the supply function for the aggregate marketing input used to process refined coconut oil, and it relates the quantity supplied (Q_{mr}) to its own price (u_{mr}). These inputs include the capital and material inputs require to bleach, refine and deodorise crude coconut oil, along with packing and distribution activities. T_{Qmr} is the intercept shift variable, which can be used to simulate cost reducing technical changes.

Output-constrained input demand for refined (edible) coconut oil production

$$Q_{co}^{r} = c'_{Oro,co}(u_{co},u_{mr})O_{ro}^{*} \quad (48)$$

$$Q_{mr} = c'_{Oro,mr}(u_{co},u_{mr})O_{ro}^{*} \quad (49)$$

Equations (48) and (49) are the output-constrained input demand functions for crude coconut oil (Q_{co}^{r}) and the additional marketing input (Q_{mr}), respectively, used to produce refined coconut oil (O_{ro}). $c'_{Oro,co}(u_{co},u_{mr})$ and $c'_{Oro,mr}(u_{co},u_{mr})$ are partial derivatives of the unit cost functions $c_{Oro,co}(u_{co},u_{mr})$ and $c_{Oro,mr}(u_{co},u_{mr})$, respectively, and are derived using Shepard's Lemma.

Market clearing condition for refined (edible) coconut oil production

$$b_{ro} = c_{Oro}(u_{co},u_{mr}) \quad (50)$$

Equation (50) is the value equilibrium condition for the refined coconut oil sector, specifying that the unit price for refined coconut oil (b_{ro}) equals its unit cost of production (c_{Oro}).

Additional input supply for activated carbon production

$$Z_{ma} = Z_{ma}(p_{ma},T_{Zma}) \quad (51)$$

Equation (51) is the supply function for the aggregate marketing inputs used to produce activated carbon, and describes the quantity supplied (Z_{ma}) as a function of its own price (p_{ma}). T_{Zma} is the intercept shift variable.

Sources of charcoal supply

$$Z_s = Z_{sd} + Y_{sc} + Y_{st} \quad (52)$$

According to equation (52) the supply of shell charcoal (Z_s) can be sourced from the desiccated coconut and farm sectors as by products from desiccated coconut production (Z_{sd}), farm copra production (Y_{sc}) and from traditional coconut oil/milk production (Y_{st}).

Destinations for charcoal

$$Z_s = Z_s^e + Z_s^a \tag{53}$$

Equation (53) specifies that shell charcoal can either be sold directly onto the export market (Z_s^e) or it can be sold to activated carbon manufacturers within the province (Z_s^a).

Output-constrained input demand for activated carbon production

$$Z_s = c'_{Qac,s}(v_s,p_{ma})Q_{ac}^* \tag{54}$$

$$Z_{ma} = c'_{Qac,ma}(v_s,p_{ma})Q_{ac}^* \tag{55}$$

Equations (54) and (55) are the output-constrained input demand functions for shell charcoal (Z_s) and the additonal marketing input (Z_{ma}), respectively, used to produce activated carbon (Q_{ac}). $c'_{Qac,s}(v_s,p_{ma})$ and $c'_{Qac,ma}(v_s,p_{ma})$ are the partial derivatives of the unit cost functions $c_{Qac,s}(v_s,p_{ma})$ and $c_{Qac,ma}(v_s,p_{ma})$, respectively, and are derived using Shepard's Lemma.

Market clearing condition for activated carbon production

$$p_{ac} = c_{Qac}(v_s,p_{ma}) \tag{56}$$

Equation (56) is the value equilibrium condition for the activated carbon sector, and specifies that the unit price for refined coconut oil (p_{ac}) is equal to its unit cost of production (c_{Qac}).

Destinations for copra meal and desiccated coconut products

$$Q_{cm} = Q_{cm}^e + Q_{cm}^d \tag{57}$$

Equation (57) specifies the distribution of copra meal into export (e) and local (d) markets.

$$Z_{dc} = Z_{dc}^e + Z_{dc}^d \tag{58}$$

Equation (58) specifies the proportion of desiccated coconut destined for export (e) and domestic (d) markets.

It was assumed that all of the commercial coconut oil and activated carbon products are exported.

Final demand for industry products

$$O_{ro} = O_{ro}\ (b_{ro}, N_{Oro}) \tag{59}$$

$$Q_{co} = Q_{co}\ (u_{co}, N_{Qco}) \tag{60}$$

$$Y_{to} = Y_{to}(v_{to}, N_{Yto}) \tag{61}$$

$$Q_{cm}^{e} = Q_{cm}^{e} (u_{cm}, N_{Qcm}^{e}) \quad (62)$$

$$Q_{cm}^{d} = Q_{cm}^{d} (u_{cm}, N_{Qcm}^{d}) \quad (63)$$

$$Z_{cp}^{e} = Z_{cp}^{e}(p_{cp}^{d}, N_{Zcp}^{e}) \quad (64)$$

$$Z_{dc}^{e} = Z_{dc}^{e} (p_{dc}, N_{Zdc}^{e}) \quad (65)$$

$$Z_{dc}^{d} = Z_{dc}^{d} (p_{dc}, N_{Zdc}^{d}) \quad (66)$$

$$Z_{s} = Z_{s} (v_{s}, N_{Zs}) \quad (67)$$

$$Q_{ac} = Q_{ac} (u_{ac}, N_{Zac}) \quad (68)$$

Equations (59) to (68) are the demand functions for all of the industry products. Each one relates the quantities demanded to their own prices and the *N* variables, in the above 10 equations, are intercept shifters and can be used to represent increases and/or reductions in demands for each market.

The structural model shown above defines an equilibrium for all 10 markets. By totally differentiating the above system of equations at the initial equilibrium points, and converting the differentials to partial elasticities and proportional change parameters, the impact of changes in the exogenous shift variables on the model's endogenous price and quantity variables, can be approximated linearly. The displacement model is represented by equations (1') to (68') in the Appendix. Integrability conditions (e.g. symmetry and homogeneity) are implicitly imposed at the initial equilibrium points (Zhao *et al*. 2000).

5. Data

There are three types of data that are required to solve equations (1') to (68') listed in the Appendix: 1) base equilibrium prices and quantities for all three sectors and all six markets; 2) market parameters including domestic retail and export demand elasticities, input supply elasticities, as well as input substitution and product transformation elasticities; 3) values of exogenous variables quantifying the effects of R&D activities and changes in demand.

5.1 Base equilibrium data

The data describing the base equilibrium values and quantities, which define the base equilibrium status of the system, were derived from data provided by the Faculty of Agriculture at Sam Ratulangi University (Manado, North Sulawesi), the North Sulawesi Estate Management Affairs Department and the North Sulawesi Trade and Industry Affairs Department. Annual data, from 1998 to 2003, were used to derive average annual prices and quantities for all sectors and products outlined in the model. An average was used in order to minimise the impacts of unusual weather events, market fluctuations and other inconsistencies. These data are summarised in table 5.

Initially, the values and quantities of the final coconut products were obtained from financial and physical records. By using physical conversion parameters supplied by specialists from Sam Ratulangi University, it was possible to derive the quantities of various intermediate products and, eventually, an equivalent number of coconuts, based on the quantities of these final products. Relevant prices were used to calculate values for coconuts and intermediate products. By using these values in conjunction with those of the final products it was possible to residually derive cost shares for the aggregate marketing inputs. Aggregate marketing inputs represent all of the costs that are additional to coconuts and coconut-based intermediate products in producing the industry's final products. These costs include capital, labour, transport and warehousing costs, as well as financial services. The supply of aggregate marketing inputs is assumed to be very elastic compared with supply of coconuts. These parameters are discussed in more detail below.

5.2 Market parameters

A list of the market elasticity parameters is provided in table 6. Some of these parameters are from previous empirical studies, while others are assumed in accordance with theoretical and subjective considerations. Given that this analysis focuses on an adjustment period of approximately two years short-run elasticity values for both supply and demand were sought. Because coconut palms are perennial and do not yield any coconuts until around six to eight years after they are planted, the supply of coconuts is very inelastic in the short-run. There is scope to increase the supply of coconuts over a two-year period by harvesting more trees and through rehabilitation of neglected plantations. Sugiyanto (2002) estimated the short-run price elasticity of supply of coconuts, using a single equation, in Indonesia as 0.004.

There are very few estimates for the price elasticity of supply for marketing and processing inputs in the literature, and most equilibrium displacement studies assume values for these parameters. For example, Zhao *et al.* (2000) in an analysis of the Australian beef industry assumed a value of 5 for aggregate marketing inputs; and Zhao *et al.* (2003) in their analysis of the Australian wine industry assumed values ranging from 0.4 to 1 for specific marketing inputs, such as processing equipment, and assumed a value of 5 for non-specific marketing inputs, such as labour. In line with these studies, along with considerations of the contribution of non-specific factors (mobile inputs) compared with specific factors (less mobile inputs) to the overall marketing costs, supply elasticity values, for each aggregate marketing input, were assumed.

There is a small number of price elasticity of demand estimates available for coconut oil, and desiccated coconut, but for the other products there is very little information. Thus, once again subjective judgements, made with consideration of relevant theory, were used to fill the gaps in the data. Demand elasticities for coconut oil have been estimated in a number of empirical studies (e.g. Suryana 1986; Larson 1990; Sugiyanto 2002; Owen *et al.* 1995; and Niemi 2004). Short-run estimates of the elasticity of demand range from -0.6 (Suryana 1986) to -6.97 depending on whether they are consumed domestically or exported. A conservative export demand elasticity of -5 was used in this study for both crude and refined oil. While the inelastic measure

of -0.5 was assumed for traditional coconut oil, based on an estimate by Sugiyanto (2002) for domestic cooking oil demand in Indonesia.

Langford (1994) used dominant firm theory to provide demand elasticities for a number of exporting countries. Own-price elasticity values for non-dominant suppliers ranged from -0.09 to -5.85. In the absence of any empirical estimates for North Sulawesi and given the Province's small size a highly elastic value of -5 was assumed for exports, based on the upper range of estimates provided by Langford (1994). Because, empirical estimates of the demand elasticity for copra meal were not found, identical values as those for coconut oil and desiccated coconut domestic and export markets, were chosen. Demand elasticity values of -5 were also assumed for charcoal and activated carbon exports.

As shown in equations (1') to (68'), Allen-Uzawa elasticities of substitution are required for all combinations of inputs for each sector. In accordance with other equilibrium displacement studies, including those by Zhao *et al*. (2003), Mounter *et al*. (2004), Mullen *et al*. (1989) and Ambarawati *et al*. (2004), substitution elasticity values of 0.1 are used to allow a small amount of substitution between marketing and raw/intermediate farm products. An Armington elasticity of substitution value of 5 is used to model the substitution relationship between imported and locally produced copra, for oil production. Warr (2005) assumed a value of 6 for this parameter, when modelling the consumption relationship between imported and locally produced rice, in Indonesia. Mullen *et al.* (1989), used a value of 5 when modelling substitution possibilities between locally produced and imported wool, based on a preliminary estimate of 6.5.

Fixed output proportions between the major products and their by-products, such as charcoal and copra meal were assumed in the multi-output production functions. Thus, the product transformation elasticities, in these cases, were set to 0. For the farm sector, transformation elasticities of -1 were used to limit the extent to which farm products are sold to different market sectors. This allows some flexibility in choosing product markets at the farm level, but also acknowledges the rigidity that forward contracts, which are common in the coconut industry, impose on transactions in the short-run.

5.3 Exogenous shifts

Only ten of the nineteen exogenous variables that could be used to shift the demand and supply schedules were tested in this study. Productivity and efficiency-enhancing R&D investments were assumed to reduce the costs of producing coconuts and the various coconut products. Accordingly, these improvements were modelled by shifting the supply curves in the relevant sectors, downwards, by 1 per cent. Quality-enhancing R&D investments, on the other hand, were assumed to increase consumers' 'willingness to pay' and were modelled by shifting the demand curves in the relevant sectors, upwards, by 1 per cent.

The following investment scenarios were simulated:

1. Cost reducing R&D into coconut production (T_{Xc} = -0.01)
2. Cost reduction in the supply of imported copra (T_{Zcp}^{i} = -0.01)
3. Cost reduction in copra trade (T_{Ymc} = -0.01)
4. Cost reducing R&D into desiccated coconut processing (T_{Ymd} = -0.01)
5. Cost reducing R&D into crude coconut oil processing (T_{Zmo} = -0.01)
6. Cost reducing R&D into refined coconut oil processing (T_{Qmr} = -0.01)
7. Quality-enhancing R&D into traditional coconut oil processing (N_{Yfl} = 0.01)
8. Quality-enhancing R&D into crude and refined coconut oil processing (N_{Qco} = 0.01 & N_{Oro} = 0.01)
9. Quality-enhancing R&D into desiccated coconut export (N_{Zdc}^{e} = 0.01)

Because the displacement equations (equations (1') to (68') in the Appendix only provide local linear approximations to the disturbances caused by changes in the exogenous variables, small shifts are preferred in order to minimise the approximation errors (Zhao *et al.* 2000). These measurement errors are also minimised under the assumption of parallel shifts in the demand and supply curves. The relative price and quantity changes for each scenario were used to calculate producer surplus values. Since these curves are only related to own-prices, they have only one source of equilibrium feedback and the producer surplus measures can, therefore, be measured off ordinary Marshallian supply curves. While changes in total benefits will be proportional to the size of the shifts, the distribution of benefits among the various industry participants will only vary according to the source of the shift.

6. Results

The distribution of the changes in producer surplus benefits, as a consequence of each exogenous change, is examined in this section. The producer surplus changes are measures of the annual profit flows to the suppliers of quasi-fixed factors of production. All measures are in US dollars, because this was the original unit of measurement used to value exported coconut products. Consumer surplus changes are not presented, because the focus of this study is on producer groups within the Province of North Sulawesi, and because almost all of the consumers of the products are located outside of this province. Also, to save space, the price and quantity adjustments following each displacement are not presented in this paper, but will be made available, upon request, from the authors.

The results of the supply and demand side shifts are summarised in tables 7 and 8, respectively.

6.1 Shifts in supply

The simulated 1 per cent cost reduction in coconut supply led to an overall producer surplus gain of US$ 425,399 per year, 99.93 per cent of which went to the farm sector (table 7)[7]. This is roughly 1 per cent of the total value of coconuts produced each year

[7] Please note that farm sector benefits are calculated by summing together the benefits that accrue to suppliers of coconuts X_c, suppliers of aggregate farm marketing inputs X_m, and suppliers of marketing

(42,615,168 US$). The reason the farm sector received such a large share was partly because this is the sector where the efficiency change occurred, but mostly because the coconut supply curve is so inelastic compared that for the other inputs. If the coconut supply curve was shifted upwards instead of downwards, by 1 per cent, there would have been a loss equal in magnitude to the simulated gain. This could be viewed as a cost to the industry of a short term decline in farm productivity, which may occur as a result of plantation neglect.

Because producers in North Sulawesi are in competition with copra suppliers in neighbouring provinces, it is important for them to stay competitive and keep their costs of production as low as possible. A 1 per cent downward shift in the imported copra supply curve was used to simulate the costs of failing to 'keep up' with producers in nearby provinces. Although this lead to an overall gain in producer surplus benefits of US$ 174,491, 95.91 per cent of these benefits went to the suppliers of imported copra. The farm sector, on the other hand, would suffer a loss equal to 13.82 per cent of the producer surplus benefits (US$ 24,030). On the whole, producers within the Province would only gain US$ 7,140 or 4.09 per cent of the total benefits, however, the benefits would be heavily skewed in favour of the commercial coconut oil sector.

Increased efficiency in the system of trade that delivers copra from farms to processors and exporters, which was examined using a 1 per cent downward shift in the supply curve for refined copra marketing inputs, would lead to a US$ 76,874 gain for the industry as a whole. The farm sector would receive an overwhelmingly large share, equal to 99.20 per cent of these benefits.

R&D investments into cost reducing technology for the commercial manufacturing sectors of the industry would also result in a large surplus gain for the industry. The simulated cost reduction in crude coconut oil manufacturing resulted in a large producer surplus gain of US$ 176,369, for the industry as a whole. This time the farm sector would obtain a 68.36 per cent share of the benefits, while commercial oil processors and suppliers of imported copra would receive shares equal to 11.93 per cent and 20.90 per cent, respectively. Desiccated coconut manufacturers, on the other hand, would suffer losses equal to -1.38 per cent, as an increase in the price of coconuts would raise their production costs. The farm sector would receive a smaller share of total producer surplus benefits, in this instance, because more of the gains would be shared with the suppliers of quasi-fixed oil manufacturing inputs and imported copra. If the cost reducing technical change occurs in the refined coconut oil sector, instead of the crude coconut oil sector, the impacts are more modest, with a total gain of only US$ 8,937. This is largely because of the small size of this sector relative to the crude coconut oil sector. The farm sector's share of the benefits is smaller compared to the previous simulation, as a result of two factors. Firstly, the benefits must be shared with a larger proportion of quasi-fixed capital inputs. Secondly, because refined oil manufacturers can draw on a large pool of crude oil that is normally exported, derived demand for coconuts would not increase by as much.

---

inputs specific to traditional coconut oil and milk production X_{kt}, because the farm sector supplies all three inputs.

The simulated reduction in the costs of processing desiccated coconut would result in a surplus gain of US$ 84,870. In this instance, the farm sector would only obtain 40.26 per cent of these benefits, while 62.47 per cent would accrue to the suppliers of the desiccated coconut processing inputs. Commercial oil processors would suffer combined surplus losses equal to -2.99 per cent, while suppliers of imported copra would receive a 0.72 per cent of the benefits. Desiccated coconut manufacturers would receive a relatively large slice of the surplus benefits, relative to what coconut oil manufactures received in the previous simulation, because they supply a much larger share of quasi-fixed production inputs.

6.2 Shifts in demand

If R&D is directed towards improving the quality of traditional coconut oil, the subsequent increase in consumers 'willingness to pay' for the product would result in a total producer surplus gain of US$ 14,724, of which the farm sector would receive 109.37 per cent. The only other suppliers to benefit are copra importers, who would contribute 1.90 per cent to total gains. Desiccated coconut manufacturers and local copra traders would suffer losses equal to 2.14 per cent and 1.20 per cent, respectively. Commercial coconut oil manufacturers suffer the largest loss, which equivalent to 7.94 per cent of the surplus benefits. These distributions represent a reallocation of industry profits from commercial manufacturers to the farm sector. This simulation is of particular interest, because of the recent introduction of a number of new technologies for small-scale virgin coconut oil production. As discussed in section 3, virgin coconut oil can be produced using very similar technology, but it is far superior in quality to the oil that farmers currently produce. While the gains appear modest, it must be remembered that only a small share of coconuts is used to make traditional coconut oil and milk. Moreover, according to current market conditions, virgin coconut oil is fetching prices that are more than 5 times higher than those for traditional coconut oil.

Increased 'willingness to pay' for crude and refined coconut oil as a result quality-enhancing R&D is simulated using 1 per cent shifts in the demand curves for both of these products. Because these sectors account for 83 per cent of all locally produced coconuts, the simulation leads to very large gains in total producer surplus benefits of US$ 838,122, with the farm sector receiving a 71.02 per cent share of. Suppliers of imported copra would be the next largest winners, with 21.91 per cent of the gains, while crude and refined coconut oil processors would receive a 7.61 per cent and 0.47 per cent share, respectively. The desiccated coconut sector, on the other hand, would receive a loss equal to -1.43 per cent.

Finally, an increase in overseas consumer's willingness to pay for desiccated coconut, as a result of quality-enhancing R&D, would lead to a producer surplus gain of US$ 102,674. However, the benefits would be skewed in favour of the suppliers of desiccated coconut processing inputs, who would obtain a 60.54 per cent share. The farm sector would receive a significant 42.32 per cent share of the benefits, while the commercial oil sectors would suffer combined losses equal to -3.15 per cent.

6.3 Summary of the results

Of all the investment scenarios examined, only R&D into improving farm sector efficiency would provide producer surplus benefits for each sector. Compared with the other simulations, this one provides coconut producers with the largest share of the benefits. This finding corresponds with those from other EDM studies, including those by Alston and Scobie (1983) and Zhao *et al.* (2003), which also found that R&D investments into farm sector productivity provide farmers with a larger share of benefits than those directed downstream of the farm gate, within the various marketing sectors. Under the assumption of fixed input and output proportions, industry participants would be indifferent as to where in the marketing chain, R&D and promotional investments are directed, in terms of the distribution of benefits. However, once these restrictive assumptions are relaxed, the position of the investment in the marketing chain becomes a critical determinant of this distribution.

The share of benefits that the farm sector would receive, from R&D into cost reducing technical changes for product manufacturers, is determined primarily by the proportion of total costs that coconuts comprise relative to other marketing inputs for each product. This explains why the farm sector receives a smaller share of the producer surplus benefits, following reductions in the manufacturing costs of desiccated coconut compared with similar reductions in crude coconut oil and copra marketing costs.

The distributional impacts of the demand-side shifts followed a similar pattern to the supply-side shifts, for each market sector. However, the R&D-induced increases in 'willingness to pay' provided the farm sector with both larger shares and total amounts of the producer surplus benefits. This is because there is less substitution between coconuts for more elastic marketing inputs following increases in product demand. Farmers obtained the largest share of the benefits following increased demand for traditional coconut oil, because local coconuts comprise a larger share of total costs, compared with the other products, and because the (aggregate) marketing inputs were assumed to be even more elastic in traditional coconut oil production. Furthermore, the farm sector is also a supplier of these inputs.

Total surplus benefits, following R&D into manufacturing sectors, are related to the size of the sector. This is why the supply shift for the crude coconut oil sector resulted in much larger absolute benefits than the supply shift for the desiccated coconut sector. This also helps to explain why increased demand for commercial coconut oil produced much larger benefits for the farm sector and the industry as a whole than either the increase in export demand for desiccated coconut or the increase in demand for traditional coconut oil.

7. Conclusions

7.1 Policy implications

When interpreting EDM results it is important to remember that when the cost efficiencies of the alternative investment scenarios are unknown, the magnitudes of the surplus benefits provide limited useful information. On the other hand, it is always

meaningful to compare the distribution of benefits among industry participants, because it is independent of the size of the initial shift (Zhao *et al.* 2000).

If the investment scenarios are judged solely on the basis of their ability to provide farmers with the largest share of surplus benefits, then R&D into virgin coconut oil production would be ranked first, followed by R&D into increasing farm productivity. With regard to the commercial manufacturing sectors, R&D investments into the commercial coconut oil sector would be preferred to those aimed at improving efficiency and quality in desiccated coconut production.

As discussed in the introduction, there is a growing need, as part of the movement towards increased regional autonomy, for the Provincial and local governments to take greater responsibility for their R&D activities. Part of this process involves making decisions about where these activities should be directed, but also about how they should be funded. The above distributions provide some indication of who should pay for the proposed R&D activities. Currently, Provincial and local government levies only affect copra trade and commercial manufacturing activities, but it is likely that coconut producers will be subject to these charges in the near future. If this occurs, then based on the distribution of benefits, farmers would clearly prefer their payments to fund R&D aimed at enhancing farm productivity and encouraging the adoption and transfer of virgin coconut oil technology.

It is also important when making decisions on where to direct R&D funds, to make judgements about the feasibility or cost efficiency of these potential investments. In addition, the desirability of the investment scenarios will depend on their ability to satisfy other policy objectives, including the promotion of product diversity. With regard to these considerations, the R&D investments into promoting farm productivity and virgin coconut oil adoption also rank highly. As discussed in section 3, existing research suggests that there is potential for farms to increase their productivity by up to 30 per cent, through a combination of replanting and rehabilitation of plantations.

Likewise, the recent development of small-scale virgin coconut oil technologies, combined with evidence of high levels of consumer demand in local and domestic markets, mean that this could be the most cost efficient of all the scenarios tested. Because these technologies can be owned and operated by smallholders, the farm sector would also gain the surplus benefits (value-added income) associated with supplying the processing inputs. This would also have benefits for the economy of North Sulawesi, as the income generated by smallholders will be retained and spent within the province, to a greater extent than income generated by large commercial operators. Furthermore, the development of this product offers a promising means of increasing domestic consumption of locally produced products, which should help stabilise farmer incomes.

Policy recommendations that are based the distribution of benefits alone, can be misleading and can conflict with other policy objectives, particularly for the major commercial market sectors. According to the modelling results, R&D directed at the commercial coconut oil sectors would provide a larger share of benefits for the farm sector than if similar investments were made in the desiccated coconut sector. While that may indeed be the case, R&D that leads to the expansion of the commercial

coconut oil at the expense of other product sectors, is likely to further exacerbate the problem of income instability for coconut producers.

Also, additional analyses, not presented here, show that if both sectors utilised the same amount of locally produced coconuts, the absolute returns to both the farm sector and the industry as a whole, would be much larger following R&D into desiccated coconut manufacturing. This is precisely because the production of desiccated coconut requires a higher proportion of relatively elastic marketing inputs than commercial coconut oil. Because of this, there would be a larger expansion of manufacturing activity and, thus, derived demand for coconuts, in response to R&D-induced shifts in supply (for its marketing inputs) and demand (for its output).

Furthermore, because the companies that comprise the commercial oil and desiccated coconut processing sectors are highly capitalised firms, which are generally owned by investors from outside the Province, it is doubtful whether the regional and local government R&D programmes would have much leverage among these sectors. From this point of view R&D funds that are either raised by or under the control of the Provincial and local governments, will be used most effectively if they are focussed on coconut production, copra trade and virgin coconut oil production.

7.2 Caveats and further research

Because of the competitive market assumption, the partial equilibrium setting and uncertainty surrounding some of the parameters in the model, the results of this study should be treated with some degree of caution. Nasution and Suhaeti (1990) and Sondakh and Jones (2003) suggest that there is evidence of market power in the purchase of copra from farmers. While this is yet to be tested empirically, there is concern that, with PT Bimoli oil refinery controlling the purchase of around half of the copra produced in the Province, the assumption of perfect competition may be untenable. Studies, including those by Alston *et al.* (1997), Kim *et al.* (1987), Huang and Sexton (1996) and Sexton and Sexton (1996), have demonstrated, in a variety of ways, that farmer's surplus benefits, as a consequence of reductions in the cost of supplying both farm products and marketing inputs, are reduced under conditions of imperfect competition.

Due to a paucity of empirical econometric studies on the coconut industry, it was necessary to assume values for many of the market parameters used in this research. Because there is uncertainty regarding their values, it will be important to test the sensitivity of the results to variations in these parameters. A systematic and stochastic approach, such as that suggested by Davis and Espinoza (1998), which takes into account possible distributions for market elasticity parameters, is recommended.

A final issue, requiring attention, relates to the partial equilibrium setting of the analysis. Inclusion of the impact of the price of substitutes in demand for various coconut products, such as the impact of the price of palm oil on demand for coconut oil, may generate more realistic responses to the exogenous changes.

REFERENCES

Allorerung, D. 2000, 'Regional income inequality in Indonesia and the initial impact of the economic crisis', *Bulletin of Indonesian Economic Studies*, vol. 38, pp. 201–222.

Alston, J.M., Sexton, R.J. and Zhang, M. 1997, 'The effects of imperfect competition on the size and distribution of research benefits', *American Journal of Agricultural Economics*, vol. 79, pp. 1252–1265.

Alston, J.M. and Scobie G.M. 1983, 'Distribution of research gains in multistage production systems: Comment', *American Journal of Agricultural Economics*, vol. 65, pp. 353–356.

Chambers, R. G. 1988, *Applied Production Analysis: A Dual Approach,* Cambridge University Press, Cambridge.

Davis, G. C. and Espinoza, M.C. 1998, 'A unified approach to sensitivity analysis in equilibrium displacement models', *American Journal of Agricultural Economics*, vol. 80, pp. 868–879.

Dumais, J., Anapu, H., Henry, L.A. and Henderson, B.B. 2005, 'Marketing of coconuts in North Sulawesi, Unpublished ACIAR Report, Faculty of Agriculture, Sam Ratulangi University, Manado, North Sulawesi.

Foale, M. 2003, *The Coconut Odyssey: The Bounteous Possibilities of the Tree of Life*, Australian Centre for International Agricultural Research, Canberra.

Huang, S.Y. and Sexton R.J. 1996, 'Measuring returns to innovation in an imperfectly competitive market: application to mechanical harvesting of processing tomatoes in Taiwan', *American Journal of Agricultural Economics*, vol. 78, pp. 558–71.

Idroes, A. 2004, *Coconut Statistical Yearbook 2003,* Asian and Pacific Coconut Community, Jakarta, Indonesia.

Kim, C.S., Schaible, G., Hamilton, J. and Barney, K. 1987, 'Economic effects on consumers, growers, and processors resulting from mechanical tomato harvesting in California – revisited', *Journal of Agricultural Economics Research*, vol. 39, pp. 39–45.

Langford, M. 1994, 'The world market for desiccated coconut: a Philippines perspective', *Research Report*, no. 4, Australian Centre for International Agricultural Research, Canberra.

Larson, D.F. 1990, 'The Indonesian vegetable oils sector: modeling the impact of policy changes', *World Bank Working Paper Series*, No. 382, Washington DC, World Bank.

Mullen, J.D., Alston J.M. and Wohlgenant M.K. 1989, 'Input substitution and the distribution of surplus gains from lower U.S. beef processing costs', *American Journal of Agricultural Economics*, vol. 70, pp. 245–54.

Muth, R.F. 1964, 'The derived demand curve for a productive factor and the industry supply curve', *Oxford Economic Papers*, col. 16, pp. 221–34.

Nasution, A. and Suhaeti, R.N. 1990, 'Marketing constraints on smallholder coconut in north Sulawesi, Indonesia', *Indonesian Agricultural Research & Development Journal*, vol. 12, pp. 6–9.

Niemi, J. 2004, 'The European market for ASEAN agricultural exports: estimates of income and price elasticities', *ASEAN Economic Bulletin*, vol. 21, pp. 261–277.

Owen, A.D., Chowdhury K. and Garrido, J.R.R. 1995, 'Modelling trade flows in coconut oil', *Research Report,* no. 11, Australian Centre for International Agricultural Research, Canberra.

Sexton R.J. and Sexton T.A. 1996, 'Comment: measuring research benefits in an imperfect market', *Agricultural Economics*, vol. 13, pp. 201–204.

SMERU 2001, 'Regional Autonomy and the Business Climate: North Sulawesi and Gorontalo', Report by the SMERU Research Institute in association with The Partnership for Economic Growth (PEG) and The United States Agency for International Development (USAID).

Sondakh, W.L. 1984, 'Growth and equity aspects of credit programs for small-farm coconut development in Sulawesi Utara, Indonesia', unpublished PhD thesis, University of New England, Armidale, NSW.

Sondakh, L. and Jones G. 2003, 'An economic survey of North Sulawesi: turning weaknesses into strengths under regional autonomy', *Bulletin of Indonesian Economic Studies,* vol. 39, pp. 273–302.

Sugiyanto, C. 2002, 'The impact of trade liberalisation on the Indonesian palm oil and coconut oil markets', unpublished PhD thesis, Graduate College of the University of Illinois, Urbana-Champaign.

Suryana, A. 1986, 'Trade prospects of Indonesian palm oil in the international markets for fats and oils', unpublished PhD thesis, Department of Economics and Business, North Carolina State University, Raleigh.

Tillekeratne, H.A., Elsje T.T. and Lay A. 2001, 'Report of the study on the coconut industry and new market initiatives in North Sulawesi Province, Republic of Indonesia', report for the Poverty Alleviation Through Rural-Urban Linkages (PARUL) programme, involving collaboration between the National Development Planning Agency of the Government of Indonesia, The United Nations Development Programme and The United Nations Commission for Human Settlement.

UNCTAD (2003), *UNCTAD Commodity Yearbook.* United Nations Conference on Trade and Development, Geneva, Switzerland.

Zhao, X., Mullen, J.D., Griffith, G.R., Griffiths, W.E. and Piggott, R.R. 2000, 'An equilibrium displacement model of the Australian beef industry', *Economic Research Report*, No. 4, NSW Agriculture, Orange.

Zhao, X., Anderson, K. and Wittwer, G. 2003, 'Who gains from Australian generic wine promotion and R&D?', *The Australian Journal of Agricultural and Resource Economics*, vol. 47, pp. 181–209.

Acknowledgements

The authors gratefully acknowledge ACIAR funding for this research. The research work reported here was supported by Indonesian members of the ACIAR team from the Socio-Economic Department, Faculty of Agriculture, Sam Ratulangi University, Manado: Dr Hanny Anapu, Mr Joachim Dumais, Dr Jen Tatuh, and Mr Nordy Waney; the Department of Economics, Faculty of Economics and Management, Bogor Agricultural University, Bogor: Dr Rina Oktaviani and Miss Sahara; Indonesian Coconut and Palmae Research Institute, Manado: Dr Hengky Novarianto, Abner Lay and Mr.Ronald Hutapea.

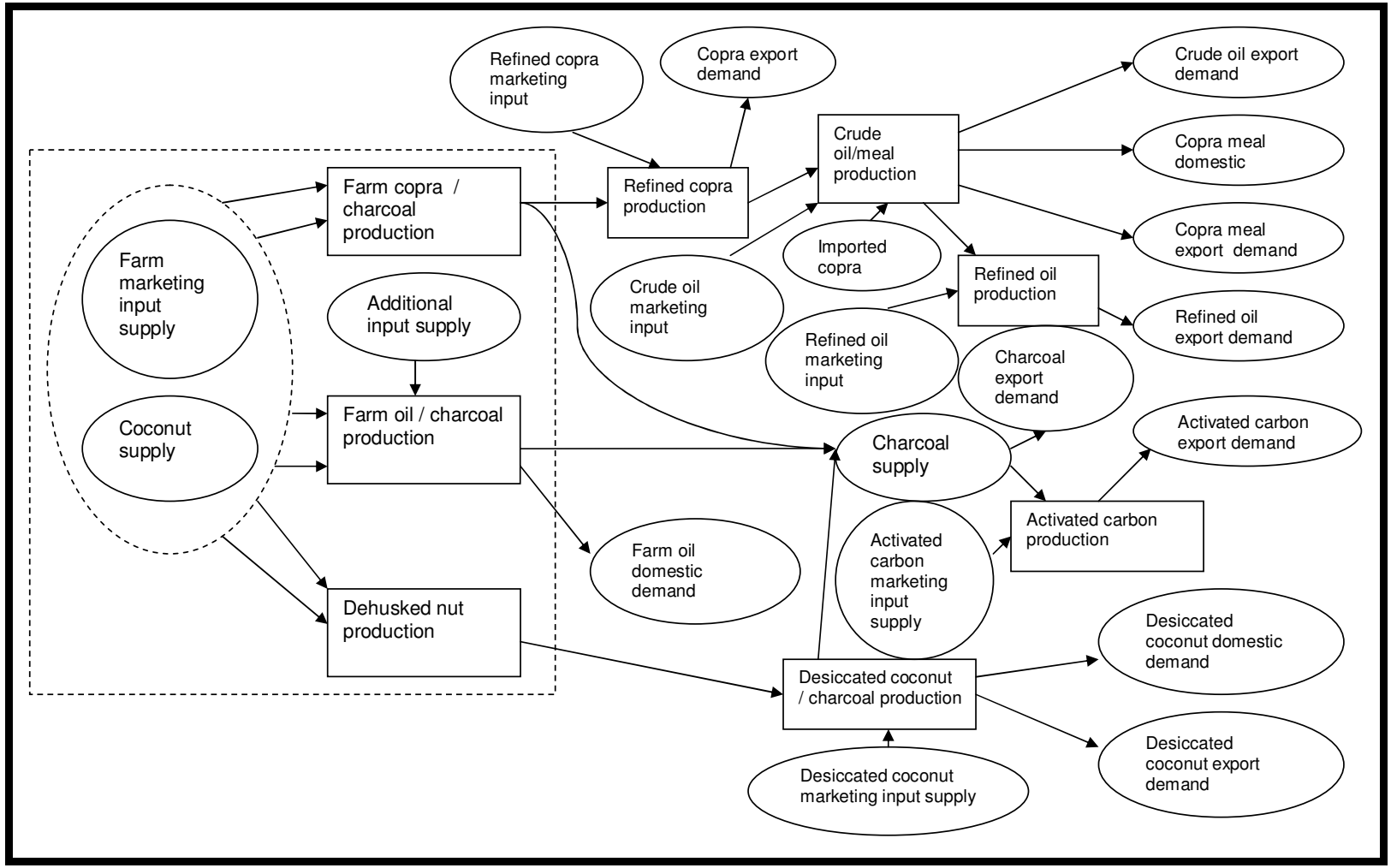

Figure 1 Conceptual model of the coconut industry of North Sulawesi

Table 1 Coconut production among provinces in Indonesia, 2003

Province	Area		Production	
	Hectares	Percentage share	Mega tonnes	Percentage share
Riau	598,415	16.3	527,601	17.3
Central Java	288,266	7.9	228,708	7.5
East Java	286,180	7.8	270,978	8.9
North Sulawesi	271,277	7.4	292,580	9.6
Central Sulawesi	178,381	4.9	194,504	6.4
Others	2,048,926	55.8	1,539,670	50.4
Total	3,671,445	100.0	3,054,041	100.0

Source: Idroes (2004)

Table 2 Percentage shares of coconut-based exports from Indonesia (2000) and Sulawesi (2000)

Export product	% share of export value	
	Indonesia	North Sulawesi
Commercial coconut oil	78.97	87.48
Copra meal	8.49	4.85
Copra	2.52	1.49
Desiccated coconut	5.93	5.37
Charcoal	1.65	0.56
Activated carbon	2.42	0.25
Coir and related products	0.02	n/a*
Total	100	100

Source: Idroes (2004) (Indonesia); Department of Trade and affairs (2005) (North Sulawesi)

Table 3 Definitions of the endogenous variables in the structural model

Endogenous variables	
X_c	quantity of domestically produced coconuts
X_{cc}	quantity of coconuts used to make copra
X_{ct}	quantity of coconuts used for traditional coconut oil/milk and charcoal production
X_{cd}	quantity of coconuts dehusked for desiccated coconut production
X_m	quantity of aggregate farm marketing input
X_{mc}	quantity of farm marketing input used for copra and charcoal production
X_{mt}	quantity of farm marketing input used for traditional coconut oil/milk and charcoal production
X_{md}	quantity of farm marketing input used for dehusked coconut production
X_{ccmc}	aggregated input index for farm copra and charcoal production
Y_{fcsc}	aggregated output index for farm copra and charcoal production
Y_{fc}	quantity of farm copra
Y_{sc}	quantity of charcoal as a by-product from farm copra production
X_{ctmtkt}	aggregated input index for traditional coconut oil/milk and charcoal production
X_{kt}	quantity of specific capital input for traditional coconut oil/milk and charcoal production
Y_{tost}	aggregated output index for traditional coconut oil/milk and charcoal production
Y_{to}	quantity of traditional coconut oil and milk
Y_{st}	quantity of charcoal as a by-product from traditional coconut oil/milk and charcoal production
Y_{fdmd}	aggregated input index for desiccated coconut and charcoal production
Y_{md}	quantity of additional marketing input for desiccated coconut and charcoal production
Y_{fd}	quantity of dehusked nuts
Z_{dcsd}	aggregated output index for desiccated coconut and charcoal production
Z_{dc}	quantity of desiccated coconut
Z_{dc}^{e}	quantity of desiccated coconut exported from the province
Z_{dc}^{d}	quantity of desiccated coconut consumed within the province
Z_{sd}	quantity of charcoal as a by-product from desiccated coconut and charcoal production
Y_{mc}	quantity of additional marketing input for refined copra production
Z_{cpmo}	aggregated input index for crude coconut oil and copra meal production
Z_{cp}^{d}	quantity of refined copra produced in North Sulawesi
Z_{cp}^{o}	quantity of refined copra produced in North Sulawesi that is used by oil mills in the Province
Z_{cp}^{e}	quantity of refined copra produced in North Sulawesi that is exported from the Province
Z_{cp}^{i}	quantity of refined copra imported into the Province
Z_{mo}	quantity of additional marketing input for crude coconut oil and copra meal production
Q_{cocm}	aggregated output index for crude coconut oil and copra meal production
Q_{cm}	quantity of copra meal
Q_{cm}^{e}	quantity of copra meal exported from the Province
Q_{cm}^{d}	quantity of copra meal consumed within the province
Q_{co}	quantity of crude coconut oil
Q_{co}^{e}	quantity of crude coconut oil exported from the province
Q_{co}^{r}	quantity of crude coconut oil used as an input for refined coconut oil production
Q_{mr}	quantity of additional marketing input for refined coconut oil production
O_{ro}	quantity of refined coconut oil
Z_s	quantity of shell charcoal (composite from the three different sources)
Z_s^{e}	quantity of shell charcoal exported from the Province
Z_s^{a}	quantity of shell charcoal used as an input in activated carbon production
Z_{ma}	quantity of additional marketing input for activated carbon production
Q_{ac}	quantity of activated carbon
w_c	price of domestically produced coconuts
v_{fc}	price of farm copra
v_s	price of shell charcoal
w_{cc}	price of coconuts used to make copra
w_{ct}	price of coconuts used for traditional coconut oil/milk and charcoal production
w_{cd}	price of coconuts dehusked for desiccated coconut production
w_m	price of aggregate farm marketing input
w_{kt}	price of specific capital input for traditional coconut oil/milk and charcoal production
v_{to}	price of traditional coconut oil and milk
v_{md}	price of additional marketing input for desiccated coconut and charcoal production
v_{fd}	price of dehusked nuts
p_{dc}	price of desiccated coconut
v_{mc}	price of additional marketing input for refined copra production
p_{cp}^{i}	price of refined copra imported into the Province
p_{mo}	price of additional marketing input for crude coconut oil and copra meal production
p_{cp}^{d}	price of refined copra produced in North Sulawesi
u_{co}	price of crude coconut oil
u_{cm}	price of copra meal
u_{mr}	price of additional marketing input for refined coconut oil production
b_{ro}	price of refined coconut oil
p_{ma}	price of additional marketing input for activated carbon production
u_{ac}	price of activated carbon

Table 4 Definitions of the exogenous variables in the structural model

Exogenous variables		Exogenous variables	
Supply shifters		Demand shifters	
T_{Xc}	Supply shifter for X_c supply	N_{Oro}	Demand shifter for O_{ro} demand
T_{Xm}	Supply shifter for X_m supply	N_{Qco}	Demand shifter for Q_{co} demand
T_{Xkt}	Supply shifter for X_{kt} supply	N_{Yto}	Demand shifter for Y_{to} demand
T_{Ymd}	Supply shifter for X_{kt} supply	N_{Qcm}^{e}	Demand shifter for Q_{cm}^{e} demand
T_{Ymc}	Supply shifter for Y_{mc} supply	N_{Qcm}^{d}	Demand shifter for Q_{cm}^{d} demand
T_{Zcp}^{i}	Supply shifter for Z_{cp}^{i} supply	N_{Zcp}^{e}	Demand shifter for Z_{cp}^{e} demand
T_{Zmo}	Supply shifter for Z_{mo} supply	N_{Zdc}^{e}	Demand shifter for Z_{dc}^{e} demand
T_{Qmr}	Supply shifter for Q_{mr} supply	N_{Zdc}^{d}	Demand shifter for Z_{dc}^{d} demand
T_{Zma}	Supply shifter for Z_{ma} supply	N_{Zs}	Demand shifter for Z_s demand
		N_{Zac}	Demand shifter for Z_{ac} demand

Table 5 Base equilibrium values for 2003 (in US$)

Item	Parameters
On farm production	
Total value	TV = 58,202,191
Coconut[a] production	
Total value	TV_c = 42,615,168
Revenue shares	m_{Xcc} = 0.89, m_{Xct} = 0.063, m_{Xcd} = 0.047
Farm marketing input	
Total value	TV_m = 15,044,597
Destinations	δ_{Xmc} = 0.901, δ_{Xmt} = 0.084, δ_{Xmd} = 0.015
Farm copra / charcoal production	
Total value	TV_{Yfcsc} = 51,487,388
Cost shares	s_{Xcc} = 0.74, s_{Xmc} = 0.26
Revenue shares	m_{Yfc} = 0.988, m_{Ysc} = 0.012
Traditional coconut oil and milk / charcoal production	
Total value	TV_{Ytost} = 4,485,964
Cost shares	s_{Xct} = 0.597, s_{Xmt} = 0.282, s_{Xkt} = 0.121
Revenue shares	m_{Yto} = 0.99, m_{Yst} = 0.01
Dehusked coconut production	
Total value	TV_{Yfd} = 2,228,839
Cost shares	s_{Xcd} = 0.9, s_{Xmd} = 0.1
Refined copra production	
Total value	TV_{Zcp} = 58,463,810
Cost shares	κ_{Yfc} = 0.87, κ_{Ymc} = 0.13
Refined copra destinations	λ_{Zcp}^{e} = 0.06, λ_{Zcp}^{o} = 0.94
Crude oil/meal production	
Total value	TV_{Qcocm} = 100,505,584
Cost shares	μ_{Zcp}^{o} = 0.54, μ_{Zcp}^{i} = 0.26, μ_{Zmo} = 0.20
Revenue shares	ω_{Qco} = 0.91, ω_{Qcm} = 0.09
Crude oil destinations	θ_{Qco}^{r} = 0.15, θ_{Qco}^{e} = 0.85
Copra meal destinations	θ_{Qcm}^{e} = 0.63, θ_{Qcm}^{d} = 0.47
Refined (edible) oil production	
Total value	TV_{Oro} = 15,134,098
Cost shares	α_{Qco} = 0.93, α_{Qmr} = 0.07
Desiccated coconut production	
Total value	TV_{Zdcsd} = 13,025,548
Cost shares	κ_{Yfd} = 0.17, κ_{Ymd} = 0.83
Revenue shares	μ_{Zdc} = 0.997, μ_{Zsd} = 0.003
Charcoal production	
Total value	TV_{Zs} = 700,910
Charcoal source	β_{Ysc} = 0.890, β_{Yst} = 0.063, β_{Zsd} = 0.047
Charcoal destinations	φ_{Zs}^{a} = 0.58, φ_{Zs}^{e} = 0.42
Activated carbon production	
Total value	TV_{Qac} = 762,903
Cost shares	μ_{Zs} = 0.53, μ_{Zma} = 0.47

[a]This category refers to locally produced coconuts, and does not include imported dehusked nuts or imported copra.

Source: Sam Ratulangi University; North Sulawesi Estate Management Affairs Department; and the North Sulawesi Trade and Industry Affairs Department.

Table 6 Market elasticities

Item	Parameters
Supply of domestically produced coconuts	$\varepsilon_{(Xc,wc)}$ = 0.004
Supply of aggregate farm marketing input	$\varepsilon_{(Xm,wm)}$ = 10
Supply of additional input for for traditional coconut oil/milk nd charcoal production	$\varepsilon_{(Xkt,wkt)}$ = 5
Supply of additional marketing input for refined copra production	$\varepsilon_{(Ymc,vmc)}$ = 10
Supply of refined copra imported into the Province	$\varepsilon_{(Zcp^{i},pcp^{i})}$ = 1
Supply of additional marketing input for crude coconut oil and copra meal production	$\varepsilon_{(Zmo,pmo)}$ = 2.5
Supply of additional marketing input for refined coconut oil production	$\varepsilon_{(Qmr,umr)}$ = 2.5
Supply of additional marketing input for activated carbon production	$\varepsilon_{(Zma,pma)}$ = 2.5
Supply of marketing inputs for desiccated coconut sector	$\varepsilon_{(Ymd,vmd)}$ = 2.5
Export demand for refined copra	$\eta_{(Zcp^{e},Pcp^{d})}$ = -5
Export demand for refined coconut oil	$\eta_{(Oro,bro)}$ = -5
Export demand for crude coconut oil	$\eta_{(Qco,uco)}$ = -5
Demand for copra meal	
Domestic	$\eta_{(Qcm^{d},ucm)}$ = -0.5
Export	$\eta_{(Qcm^{e},ucm)}$ = -5
Demand for desiccated coconut	
Domestic	$\eta_{(Zdc^{d},pdc)}$ = -0.5
Export	$\eta_{(Zdc^{e},pdc)}$ = -5
Demand for traditional coconut oil/milk (domestic only)	$\eta_{(Yto,vto)}$ = - 0.5
Export demand for shell charcoal	$\eta_{(Zs,vs)}$ = -5
Export demand for activated carbon	$\eta_{(Qac,uac)}$ = -5
Input substitution elasticities	
Farm copra and charcoal production	
Farm marketing input – coconuts	$\sigma_{(Xmc,Xcc)}$ = 0.1
Refined copra production	
Refined copra marketing input – Farm copra	$\sigma_{(Ymc,Yfc)}$ = 0.1
Dehusked nut production	
Farm marketing input – coconuts	$\sigma_{(Xmd,Xcd)}$ = 0.1
Traditional coconut oil/milk and charcoal production	
Farm marketing input – specific marketing input	$\sigma_{(Xmt,Xkt)}$ = 0.1
Farm marketing input – coconuts	$\sigma_{(Xmt,Xct)}$ = 0.1
Specific marketing input – coconuts	$\sigma_{(Xkt,Xct)}$ = 0.1
Crude oil and copra meal production	
Domestic refined copra – imported refined copra	$\sigma_{(Zcp^{o},Zcp^{i})}$ = 5
Domestic refined copra – crude oil marketing input	$\sigma_{(Zcp^{o},Zmo)}$ = 0.1
Imported refined copra – crude oil marketing input	$\sigma_{(Zcp^{i},Zmo)}$ = 0.1
Refined coconut oil sector	
Crude oil – refined oil marketing input	$\sigma_{(Qco,Qmr)}$ = 0.1
Desiccated coconut sector	
Domestic dehusked nuts – desiccated marketing input	$\sigma_{(Yfd,Ymd)}$ = 0.1
Activated carbon sector	
Shell charcoal – activated carbon marketing input	$\sigma_{(Zs,Zma)}$ = 0.1
Product transformation elasticities	
Coconut uses	
Farm copra – dehusked nuts	$\tau_{(Xcc,Xcd)}$ = -1
Farm copra – Traditional coconut oil/milk	$\tau_{(Xcc,Xct)}$ = -1
Traditional coconut oil/milk – dehusked	$\tau_{(Xcd,Xct)}$ = -1
Farm copra and charcoal production	
Farm copra – charcoal	$\tau_{(Yfc,Ysc)}$ = 0
Traditional coconut oil and milk and charcoal production	
Traditional coconut oil and milk - charcoal	$\tau_{(Yto,Yst)}$ = 0
Desiccated coconut and charcoal production	
Desiccated coconut – charcoal	$\tau_{(Zdc,Zsd)}$ = 0
Crude coconut oil and copra meal production	
Crude coconut oil – copra meal	$\tau_{(Qcm,Qco)}$ = 0

Table 7 Changes in producer surplus for various industry participants from alternative investment scenarios

	T_{Xc}	T_{Zcp}^{i}	T_{Ymc}	T_{Ymd}	T_{Zmo}	T_{Qmr}	N_{Yto}	N_{Zdce}	N_{Qcoe} & N_{Ore}
ΔPS_{Xc}	425,101	-24,030	76,261	34,631	120,165	5,363	15,495	44,046	512,744
ΔPS_{Xm}	56	-91	289	-449	455	20	183	-570	1,945
ΔPS_{Xkt}	1	11	-34	-15	-54	-2	426	-19	-229
ΔPS_{Ymd}	55	487	-1,544	53,016	-2,432	-109	-315	62,163	-10,368
ΔPS_{Ymc}	31	-60	944	-386	300	13	-177	-491	1,282
ΔPS_{Zcp}^{i}	-48	167,351	-300	608	36,869	1,643	280	773	158,046
ΔPS_{Zmo}	192	29,508	1,200	-2,432	20,485	573	-1,119	-3,093	54,941
ΔPS_{Qmr}	9	1,317	54	-109	573	1,435	-50	-138	-11,750
ΔPS_{Zma}	2	-1	4	5	6	0	1	3	25
Total	425,399	174,491	76,874	84,870	176,369	8,937	14,724	102,674	706,635

Table 8 Percentage changes in producer surplus for various industry participants from alternative investment scenarios

	T_{Xc}	T_{Zcp}^{i}	T_{Ymc}	T_{Ymd}	T_{Zmo}	T_{Qmr}	N_{Yto}	N_{Zdce}	N_{Qcoe} & N_{Ore}
ΔPS_{Xc}	99.9298	-13.7715	99.2032	40.8053	68.1330	60.0096	105.2340	42.8983	71.0197
ΔPS_{Xm}	0.0132	-0.0522	0.3760	-0.5286	0.2583	0.2274	1.2429	-0.5555	0.2694
ΔPS_{Xkt}	0.0003	0.0062	-0.0443	-0.0178	-0.0304	-0.0268	2.8959	-0.0187	-0.0317
ΔPS_{Ymd}	0.0130	0.2788	-2.0081	62.4675	-1.3790	-1.2149	-2.1365	60.5441	-1.4358
ΔPS_{Ymc}	0.0072	-0.0344	1.2274	-0.4547	0.1702	0.1499	-1.2053	-0.4779	0.1775
ΔPS_{Zcp}^{i}	-0.0113	95.9080	-0.3903	0.7166	20.9047	18.3875	1.8993	0.7531	21.9118
ΔPS_{Zmo}	0.0452	16.9111	1.5616	-2.8661	11.6150	6.4083	-7.5974	-3.0122	7.6140
ΔPS_{Qmr}	0.0020	0.7546	0.0697	-0.1279	0.3249	16.0560	-0.3391	-0.1344	0.4715
ΔPS_{Zma}	0.0006	-0.0007	0.0049	0.0058	0.0034	0.0030	0.0063	0.0031	0.0035
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Appendix

The model in displacement form

In the following set of equations E(.) = Δ(.)/(.), represents a small finite relative change in variable (.).

Supply of domestically produced coconuts

$$EX_c = \varepsilon_{(Xc,wc)}(Ew_c - T_{Xc}) \tag{1'}$$

Input-constrained output supply for on-farm uses of coconuts

$$EX_{cc} = -(m_{Xct}\tau_{(Xcc,Xct)} + m_{Xcd}\tau_{(Xcc,Xcd)})Ew_{cc} + m_{Xct}\tau_{(Xcc,Xct)}Ew_{ct} + m_{Xcd}\tau_{(Xcc,Xcd)}Ew_{cd} + EX_c \tag{2'}$$

$$EX_{ct} = m_{Xcc}\tau_{(Xcc,Xct)}Ew_{cc} - (m_{Xcc}\tau_{(Xcc,Xct)} + m_{Xcd}\tau_{(Xct,Xcd)})Ew_{ct} + m_{Xcd}\tau_{(Xct,Xcd)}Ew_{cd} + EX_c \tag{3'}$$

$$EX_{cd} = m_{Xcc}\tau_{(Xcc,Xcd)}Ew_{cc} + m_{Xct}\tau_{(Xct,Xcd)}Ew_{ct} - (m_{Xcc}\tau_{(Xcc,Xcd)} + m_{Xct}\tau_{(Xct,Xcd)})Ew_{cd} + EX_c \tag{4'}$$

Market clearing condition for coconuts

$$m_{Xcc}Ew_{cc} + m_{Xct}Ew_{ct} + m_{Xcd}Ew_{cd} = Ew_c \tag{5'}$$

Supply of farm marketing inputs

$$EX_m = \varepsilon_{(Xm,wm)}(Ew_m - T_{Xm}) \tag{6'}$$

On-farm use of marketing inputs

$$EX_m = \delta_{Xmc}EX_{mc} + \delta_{Xmt}EX_{mt} + \delta_{Xmd}EX_{md} \tag{7'}$$

Output-constrained input demand for farm copra and charcoal production

$$EX_{cc} = -s_{Xmc}\sigma_{(Xmc,Xcc)}Ew_{cc} + s_{Xmc}\sigma_{(Xmc,Xcc)}Ew_m + EY_{fcsc} \tag{8'}$$

$$EX_{mc} = s_{Xcc}\sigma_{(Xmc,Xcc)}Ew_{cc} - s_{Xcc}\sigma_{(Xmc,Xcc)}Ew_m + EY_{fcsc} \tag{9'}$$

Input-constrained output supply for farm copra and charcoal production

$$EY_{fc} = -m_{Ysc}\tau_{(Yfc,Ysc)}Ev_{fc} + m_{Ysc}\tau_{(Yfc,Ysc)}Ev_s + EX_{ccmc} \tag{10'}$$

$$EY_{sc} = m_{Yfc}\tau_{(Yfc,Ysc)}Ev_{fc} - m_{Yfc}\tau_{(Yfc,Ysc)}Ev_s + EX_{ccmc} \tag{11'}$$

Market clearing conditions for farm copra and charcoal production

$$m_{Yfc}EY_{fc} + m_{Ysc}EY_{sc} = s_{Xcc}EX_{cc} + s_{Xmc}EX_{mc} \quad (12')$$

$$m_{Yfc}Ev_{fc} + m_{Ysc}Ev_{s} = s_{Xcc}Ew_{cc} + s_{Xmc}Ew_{m} \quad (13')$$

Additional input supply for traditional oil/ milk and charcoal production

$$EX_{kt} = \varepsilon_{(Xkt,wkt)}(Ew_{kt} - T_{Xkt}) \quad (14')$$

Output-constrained input demand for traditional coconut oil/milk and charcoal production

$$EX_{ct} = -(s_{Xmt}\sigma_{(Xmt,Xct)} + s_{Xkt}\sigma_{(Xkt,Xct)})Ew_{ct} + s_{Xmt}\sigma_{(Xmt,Xct)}Ew_{m} + s_{Xkt}\sigma_{(Xkt,Xct)}Ew_{kt} + EY_{tost} \quad (15')$$

$$EX_{mt} = s_{Xct}\sigma_{(Xmt,Xct)}Ew_{ct} - (s_{Xct}\sigma_{(Xmt,Xct)} + s_{Xkt}\sigma_{(Xmt,Xkt)})Ew_{m} + s_{Xkt}\sigma_{(Xmt,Xkt)}Ew_{kt} + EY_{tost} \quad (16')$$

$$EX_{kt} = s_{Xct}\sigma_{(Xkt,Xct)}Ew_{ct} + s_{Xmt}\sigma_{(Xmt,Xkt)}Ew_{m} - (s_{Xct}\sigma_{(Xkt,Xct)} + s_{Xmt}\sigma_{(Xmt,Xkt)})Ew_{kt} + EY_{tost} \quad (17')$$

Input-constrained output supply for traditional coconut oil/milk and charcoal production

$$EY_{to} = -m_{Yst}\tau_{(Yto,Yst)}Ev_{to} + m_{Yst}\tau_{(Yto,Yst)}Ev_{s} + EX_{ctmtkt} \quad (18')$$

$$EY_{st} = m_{Yto}\tau_{(Yto,Yst)}Ev_{to} - m_{Yto}\tau_{(Yto,Yst)}Ev_{s} + EX_{ctmtkt} \quad (19')$$

Market clearing conditions for traditional oil/coconut milk and charcoal production

$$m_{Yto}EY_{to} + m_{Yst}EY_{st} = s_{Xct}EX_{ct} + s_{Xmt}EX_{mt} + s_{Xkt}EX_{kt} \quad (20')$$

$$m_{Yto}Ev_{to} + m_{Yst}Ev_{s} = s_{Xct}Ew_{ct} + s_{Xmt}Ew_{m} + s_{Xkt}Ew_{kt} \quad (21')$$

Output-constrained input demand for dehusked coconut production

$$EX_{cd} = -s_{Xmd}\sigma_{(Xmd,Xcd)}Ew_{cd} + s_{Xmd}\sigma_{(Xmd,Xcd)}Ew_{m} + EY_{fd} \quad (22')$$

$$EX_{md} = s_{Xcd}\sigma_{(Xmd,Xcd)}Ew_{cd} - s_{Xcd}\sigma_{(Xmd,Xcd)}Ew_{m} + EY_{fd} \quad (23')$$

Market clearing condition for dehusked coconut production

$$Ev_{fd} = s_{Xcd}Ew_{cd} + s_{Xmd}Ew_{m} \quad (24')$$

Additional input supply for desiccated coconut and charcoal production

$$EY_{md} = \varepsilon_{(Ymd,vmd)}(Ev_{md} - T_{Ymd}) \tag{25'}$$

Output-constrained input demand for desiccated coconut and charcoal production production

$$EY_{fd} = -\kappa_{Ymd}\sigma_{(Yfd,Ymd)}Ev_{fd} + \kappa_{Ymd}\sigma_{(Yfd,Ymd)}Ev_{md} + EZ_{dcsd} \tag{26'}$$

$$EY_{md} = \kappa_{Yfd}\sigma_{(Yfd,Ymd)}Ev_{fd} - \kappa_{Yfd}\sigma_{(Yfd,Ymd)}Ev_{md} + EZ_{dcsd} \tag{27'}$$

Input-constrained output supply of desiccated coconut and charcoal production

$$EZ_{dc} = \mu_{Zsd}\tau_{(Zsd,Zdc)}Ep_{dc} - \mu_{Zsd}\tau_{(Zsd,Zdc)}Ev_{s} + EY_{fdmd} \tag{28'}$$

$$EZ_{sd} = -\mu_{Zdc}\tau_{(Zsd,Zdc)}Ep_{dc} + \mu_{Zdc}\tau_{(Zsd,Zdc)}Ev_{s} + EY_{fdmd} \tag{29'}$$

Market clearing conditions desiccated coconut and charcoal production

$$\mu_{Zdc}EZ_{dc} + \mu_{Zsd}EZ_{sd} = \kappa_{Yfd}EY_{fd} + \kappa_{Ymd}EY_{md} \tag{30'}$$

$$\mu_{Zdc}Ep_{dc} + \mu_{Zsd}Ev_{s} = \kappa_{Yfd}Ev_{fd} + \kappa_{Ymd}Ev_{md} \tag{31'}$$

Additional input supply for refined copra production

$$EY_{mc} = \varepsilon_{(Ymc,vmc)}(Ev_{mc} - T_{Ymc}) \tag{32'}$$

Output-constrained input demand for refined copra production

$$EY_{fc} = -\kappa_{Ymc}\sigma_{(Ymc,Yfc)}Ev_{fc} + \kappa_{Ymc}\sigma_{(Ymc,Yfc)}Ev_{mc} + EZ^{d}_{cp} \tag{33'}$$

$$EY_{mc} = \kappa_{Yfc}\sigma_{(Ymc,Yfc)}Ev_{fc} - \kappa_{Yfc}\sigma_{(Ymc,Yfc)}Ev_{mc} + EZ^{d}_{cp} \tag{34'}$$

Market clearing condition for refined copra production

$$Ep^{d}_{cp} = \kappa_{Yfc}Ev_{fc} + \kappa_{Ymc}Ev_{mc} \tag{35'}$$

Destinations for domestic refined copra

$$EZ^{d}_{cp} = \lambda_{Z^{o}_{cp}}EZ^{o}_{cp} + \lambda_{Z^{e}_{cp}}EZ^{e}_{cp} \tag{36'}$$

Supply of refined copra from foreign sources

$$EZ^{i}_{cp} = \varepsilon_{(Z^{i}_{cp},p^{i}_{cp})}(Ep^{i}_{cp} - T_{Z^{i}_{cp}}) \tag{37'}$$

Additional input supply for coconut oil and copra meal production

$$EZ_{mo} = \varepsilon_{(Zmo,pmo)}(Ep_{mo} - T_{Zmo}) \tag{38'}$$

Output-constrained input demand for coconut oil and copra meal production

$$EZ_{cp}^{o} = -(\mu_{Zcp}^{i}\sigma_{(Zcp^{o},Zcp^{i})} + \mu_{Zmo}\sigma_{(Zcp^{o},Zmo)})Ep_{cp}^{d} + \mu_{Zcp}^{i}\sigma_{(Zcp^{o},Zcp^{i})}Ep_{cp}^{i} + \mu_{Zmo}\sigma_{(Zcd^{o},Zmo)}Ep_{mo} + EQ_{cocm} \quad (39')$$

$$EZ_{cp}^{i} = \mu_{Zcp}^{o}\sigma_{(Zcp^{o},Zcp^{i})}Ep_{cp}^{o} - (\mu_{Zcp}^{o}\sigma_{(Zcp^{o},Zcp^{i})} + \mu_{Zmo}\sigma_{(Zcp^{i},Zmo)})Ep_{cp}^{i} + \mu_{Zmo}\sigma_{(Zcp^{i},Zmo)}Ep_{mo} + EQ_{cocm} \quad (40')$$

$$EZ_{mo} = \mu_{Zcp}^{o}\sigma_{(Zcp^{o},Zmo)}Ep_{cp}^{d} + \mu_{Zcp}^{i}\sigma_{(Zcp^{i},Zmo)}Ep_{cp}^{i} - (\mu_{Zcp}^{o}\sigma_{(Zcp^{o},Zmo)} + \mu_{Zcp}^{i}\sigma_{(Zcp^{i},Zmo)})Ep_{mo} + EQ_{cocm} \quad (41')$$

Input-constrained output supply for coconut oil and copra meal production

$$EQ_{co} = \omega_{Qcm}\tau_{(Qcm,Qco)}Eu_{co} - \omega_{Qcm}\tau_{(Qcm,Qco)}Eu_{cm} + EZ_{cpmo} \quad (42')$$

$$EQ_{cm} = -\omega_{Qco}\tau_{(Qcm,Qco)}Eu_{co} + \omega_{Qco}\tau_{(Qcm,Qco)}Eu_{cm} + EZ_{cpmo} \quad (43')$$

Market clearing conditions for coconut oil and copra meal production

$$\omega_{Qco}EQ_{co} + \omega_{Qcm}EQ_{cm} = \mu_{Zcp}^{o}EZ_{cp}^{o} + \mu_{Zcp}^{i}EZ_{cp}^{i} + \mu_{Zmo}EZ_{mo} \quad (44')$$

$$\omega_{Qco}Eu_{co} + \omega_{Qcm}Eu_{cm} = \mu_{Zcp}^{o}Ep_{cp}^{d} + \mu_{Zcp}^{i}Ep_{cp}^{i} + \mu_{Zmo}Ep_{mo} \quad (45')$$

Destinations for crude coconut oil

$$EQ_{co} = \theta_{Q_{co}^{r}}EQ_{co}^{r} + \theta_{Q_{co}^{e}}EQ_{co}^{e} \quad (46')$$

Additional input supply for refined (edible) coconut oil production

$$EQ_{mr} = \varepsilon_{(Qmr,umr)}(Eu_{mr} - T_{Qmr}) \quad (47')$$

Output-constrained input demand for refined (edible) coconut oil production

$$EQ_{co}^{r} = -\alpha_{Qmr}\sigma_{(Qco,Qmr)}Eu_{co} + \alpha_{Qmr}\sigma_{(Qco,Qmr)}Eu_{mr} + EO_{ro} \quad (48')$$

$$EQ_{mr} = \alpha_{Qco}\sigma_{(Qco,Qmr)}Eu_{co} - \alpha_{Qco}\sigma_{(Qco,Qmr)}Eu_{mr} + EO_{ro} \quad (49')$$

Market clearing condition for refined (edible) coconut oil production

$$Eb_{ro} = \alpha_{Qco}Eu_{co} + \alpha_{Qmr}Eu_{mr} \quad (50')$$

Additional input supply for activated carbon production

$$EZ_{ma} = \varepsilon_{(Zma,pma)}(Ep_{ma} - T_{Zma}) \quad (51')$$

Sources of charcoal supply

$$\beta_{Zsd}EZ_{sd} + \beta_{Ysc}EY_{sc} + \beta_{Yst}EY_{st} = EZ_{s} \quad (52')$$

Destinations for charcoal

$$EZ_s = \varphi EZ_s^e + \varphi EZ_s^a \tag{53'}$$

Output-constrained input demand for activated carbon production

$$EZ_s^a = -\mu_{Zma}\sigma_{(Zs,Zma)}Ev_s + \mu_{Zma}\sigma_{(Zs,Zma)}Ep_{ma} + EQ_{ac} \tag{54'}$$

$$EZ_{ma} = \mu_{Zs}\sigma_{(Zs,Zma)}Ev_s - \mu_{Zs}\sigma_{(Zs,Zma)}Ep_{ma} + EQ_{ac} \tag{55'}$$

Market clearing condition for activated carbon production

$$Eu_{ac} = \mu_{Zs}Ev_s + \mu_{Zma}Ep_{ma} \tag{56'}$$

Destinations for copra meal and desiccated coconut products

$$EQ_{cm} = \theta_{Q_{cm}^e}EQ_{cm}^e + \theta_{Q_{cm}^d}EQ_{cm}^d \tag{57'}$$

$$EZ_{dc} = \lambda_{Z_{dc}^e}EZ_{dc}^e + \lambda_{Z_{dc}^d}EZ_{dc}^d \tag{58'}$$

Final demand for industry products

$$EO_{ro} = \eta_{(Oro,bro)}(Eb_{ro} - N_{Oro}) \tag{59'}$$

$$EQ_{co} = \eta_{(Qco,uco)}(Eu_{co} - N_{Qco}) \tag{60'}$$

$$EY_{to} = \eta_{(Yto,vto)}(Ev_{to} - N_{Yto}) \tag{61'}$$

$$EQ_{cm}^e = \eta_{(Q_{cm}^e,u_{cm})}(Eu_{cm} - N_{Q_{cm}^e}) \tag{62'}$$

$$EQ_{cm}^d = \eta_{(Q_{cm}^d,u_{cm})}(Eu_{cm} - N_{Q_{cm}^d}) \tag{63'}$$

$$EZ_{cp}^e = \eta_{(Z_{cp}^e,p_{cp}^d)}(Ep_{cp}^d - N_{Z_{cp}^e}) \tag{64'}$$

$$EZ_{dc}^e = \eta_{(Z_{dc}^e,p_{dc})}(Ep_{dc} - N_{Z_{dc}^e}) \tag{65'}$$

$$EZ_{dc}^d = \eta_{(Z_{dc}^d,p_{dc})}(Ep_{dc} - N_{Z_{dc}^d}) \tag{66'}$$

$$EZ_s^e = \eta_{(Z_s^e,v_s)}(Ev_s - N_{Z_s^e}) \tag{67'}$$

$$EQ_{ac} = \eta_{(Qac,uac)}(Eu_{ac} - N_{Qac}) \tag{68'}$$