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Specifying and Testing an Equilibrium Displacement Model of the Coconut Market in Sri Lanka[1]

Erandathie Pathiraja[a] , Garry Griffith[b] , Robert Farquharson[c] and Robert Faggian[d]

[a] Former PhD candidate, Faculty of Veterinary and Agricultural Sciences, University of Melbourne, Parkville, Vic. 3010, Australia; and Senior Research Officer, Coconut Research Institute, Lunuwila, Sri Lanka, 61150. Email: erandathiep@yahoo.com
[b] Principal Fellow, Faculty of Veterinary and Agricultural Sciences, University of Melbourne, Parkville, Vic. 3010, Australia; and Professorial Research Fellow, UNE Business School, University of New England, Armidale, NSW 2351, Australia.
[c] Senior Lecturer, Faculty of Veterinary and Agricultural Sciences, University of Melbourne, Parkville, Vic. 3010, Australia.
[d] Associate Professor - Climate Change Adaptation, Centre for Regional and Rural Futures, Deakin University, Burwood, Vic. 3125, Australia.

Abstract

The focus of this study is to develop an economic modelling framework for the coconut industry in Sri Lanka using the equilibrium displacement modelling approach. This is necessary for two main reasons. With the industry shifting from an export oriented industry to a domestic industry and coconut yield becoming highly variable due to climatic factors, a number of government interventions have been implemented according to market conditions. There are a few previous studies which have assessed the impact of these measures on individual industry sectors. However, there is no economic framework to undertake the assessment of various policies being used for the whole industry. In addition, the Sri Lankan coconut sector is likely to be significantly adversely effected by climate change and there are a number of possible adaptation options being considered, but again there is no framework to undertake an economic assessment of these options. In this study we develop and test an equilibrium displacement model of the Sri Lankan coconut industry that will then be available to analyse the economic impact of different climate and policy scenarios and the distribution of these impacts among the various stakeholders in the industry.

Key words: Equilibrium displacement model, value chain, coconut, Sri Lanka,

Introduction

This study aims to develop an economic modelling framework for the Sri Lankan coconut industry. The coconut industry in Sri Lanka is frequently influenced by external shocks especially due to ad hoc

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[1] This paper is taken from Erandathie Pathiraja's PhD dissertation at the University of Melbourne. The authors thank the examiners of the dissertation and the referee for their assistance in improving the paper.

policy changes and yield fluctuations. However, there is no economic framework for the industry to assess the economic impact of those changes and the distribution of that impact among different industry stakeholders. A model that disaggregates demand and supply relationships in the market both vertically and horizontally will enable such an assessment of government policies and yield shocks expected due to climate change.

To provide a motivation for this aim, the current status of the Sri Lankan coconut industry was reviewed recently by Pathiraja et al. (2015). Two main sets of issues were highlighted in this review.

Firstly, the structure of the sector has been changing from an export oriented industry in the 1970s to a domestic industry in recent years with an increasing domestic demand for fresh coconuts. The industry currently occupies some 20 per cent of arable lands and the majority are operated at smallholder scale since the land reforms of 1976. However, annual national production has stagnated and has become more variable from year to year. The coconut processing sector is facing stiff competition for raw materials.

As a result, since around 1992, importation of substitute edible oils was facilitated and the government began to use import tariffs as a tool for compensating the other processing sectors (especially desiccated coconut) and domestic coconut consumers at the expense of the coconut oil sector during comparatively low yielding years. Other measures taken to address this issue are export bans on fresh nuts and copra. Export levies are charged on a quantity basis to reinvest in developing the processing sectors. The government also has been financing research and development of the sector to address numerous issues related to productivity decline, pest and diseases, marketing, technologies and land fragmentation. This includes a number of subsidy schemes for growers and processors. The effectiveness of these strategies is sometimes questioned by the stakeholders, especially the exporters, but there is no consistent analytical framework available to undertake an assessment of these claims.

The second issue is that farming systems in the dry and intermediate climatic zones of Sri Lanka are predicted to be the most vulnerable to climate change in the future. Approximately 88,000 ac and 108,000 ac respectively are in areas deemed “highly vulnerable” and “moderately vulnerable” to drought conditions (Ministry of Environment, 2011). These areas are located in the major coconut growing areas. Floods and landslides are the other conditions that damage coconut farming systems. Over 14,000 ac of coconut areas are in highly vulnerable areas with another 49,000 ac in moderately vulnerable areas. While coconut palms can withstand flood conditions for about a week, prolonged flooding may damage the palms. Increased soil erosion due to high intensity rainfall may increase soil degradation. Another climate-related concern is sea level rise which may reduce the arable lands in coastal areas and increase soil salinity.

Fluctuations in yield, and consequently in prices, increase grower uncertainty with respect to farm income. These price and quantity shocks are expected to transfer over the whole value chain. Some chain actors may be eliminated from the industry. Further, the coconut fibre sector and shell sector value chains are expected to be influenced by the raw material flow deficits. This may cause a contraction in production volumes, exports and employment in the sector, with consequent significant costs to the Sri Lankan economy.

However, there is potential for adaptation to a changing climate (Pathiraja et al., 2015). Adaptation at the plantation level is possible by mulching to reduce weed growth and soil water loss, incorporating organic matter, use of cover crops, rainwater harvesting, use of irrigation in water deficit periods and, in the longer term, development of drought tolerant cultivars or varieties. It is important to identify the effectiveness of these adaptation strategies to withstand the changing climatic conditions. The degree to which these adaptation measures would support the industry depends on future climatic conditions. A comprehensive climate change prediction considering the historic climate and future scenarios will provide the grounds for a detailed analysis of the economic merit of these adaptations. Pathiraja et al. (2015) stated that the impact of potential climate change and adaptation strategies on the coconut industry value chain of Sri Lanka is an important issue for further research.

From both the policy point of view and the climate change point of view it is important to identify the overall impact of each measure and its distributional impact among different stakeholders before making an investment or changing an existing intervention (Zhao et al., 2003).

Selection of Modelling Method

There are two key points to be considered in selecting a modelling framework. In a climate change impact assessment study, these are the change in crop yields as predicted by crop and climatic models and the relative importance of a crop in an economy (Winters et al., 1998). Moreover, due to the fact that it is a global phenomenon, the world market for a particular commodity will change and the impact will be transmitted as a price shock to an economy (Winters et al., 1998).

For this study an equilibrium displacement model (EDM) of the coconut industry was selected. This is a type of model from the partial equilibrium family of models. The relatively small contribution of the coconut industry to GDP suggested that it was more appropriate to choose a partial equilibrium model rather than a general equilibrium model which measures economy wide influences. Further, the research objectives were to develop an economic framework for the industry which can be used to measure the distribution of impacts among industry stakeholders due to climate change and adaptation practices. These cannot be addressed by other methods. In EDM, the impacts of government policies, climate change and adaptation are considered to be exogenous shifts to the supply curves.

Piggott (1992) also terms this methodology 'Muth Modelling' considering the initial work based on this methodology (Muth, 1964). The application of EDM is found in many studies for analysing the returns from research and promotion investments and the impact of policy changes (Ahn et al., 2010; Ambarawati et al., 2003; Griffith, 2009; Griffith et al., 2010; Henderson et al., 2006; Mounter et al., 2008; Perrin et al., 1981; Zhao et al., 2003; Zhao et al., 2000b). EDMs are expressed in elasticity form which facilitates the use of partial elasticities to identify the importance of different exogenous demand and supply shifters in a market equilibrium (Lusk et al., 2011). This method has the advantage of using previously estimated elasticities and it requires fewer data compared to econometric estimates.

Generally, the true demand and supply curves are not known. However, the arguments from previous literature regarding which functional form to use and the nature of the shift (parallel or proportional), and under which circumstances the EDM yields exact results, were comprehensively addressed by Zhao's study (Zhao, 1999; Zhao et al., 1997).

Exact results for estimated price, quantity and economic surplus changes are found in EDM analyses when the true demand and supply functions are linear, the shift is parallel and the percentage change of a variable is defined in terms of a finite change (Alston, 1990; Zhao et al., 1997). For constant elasticity form functions, the results are exact in the event of a proportional shift when the percentage change is defined in terms of a log change; but if the functions are linear, the magnitude of the error is small when the size of the parallel shift is small (Alston, 1990; Zhao et al., 1997).

Another assumption made under this analysis is that of a competitive market structure of the industry. Further, it is assumed that each sector is profit maximising, has constant returns to scale, and that multi-output technologies are separable in inputs and outputs. These assumptions allow the use of duality theory (Alston, 1990; Chambers, 1988).

Uncertainty of the parameters is a major drawback. This can be minimised by applying a stochastic sensitivity analysis approach using Monte Carlo simulation (Griffiths et al., 2000; Zhao, 1999; Zhao et al., 2000a).

To restate, the main objective of this study is to develop an EDM framework which identifies the relationships among different industry sectors in the Sri Lankan coconut industry and uses these relationships to predict the economic impacts of exogenous changes. In this paper, to test the validity of the framework we use some hypothesised exogenous changes which are described under 14 hypothetical scenarios. In subsequent analyses the impact of climate change and the effectiveness of adaptation strategies is the main focus (see Pathiraja et al. (2017) for some preliminary results). More generally, developing a consistent and disaggregated economic framework will make it possible to assess other possible changes to the industry such as changes in policy settings.

Model Structure

A carefully designed market structure to represent an industry is vital in accurately estimating the impacts of exogenous shocks to the market and its segments (Mounter et al., 2008; Zhao et al., 2000b). Further, disaggregation of the industry in both vertical and horizontal directions allows a sound analysis of the impacts across different sectors and, where relevant, regions (Mounter et al., 2008; Zhao et al., 2000b).

Previous literature on the coconut industry was also examined but none of the previous studies focused on both vertical and horizontal disaggregation and all are quite dated. De Silva (1985) hypothesised the impacts of different domestic and export policies but these were illustrated graphically due to a lack of coefficients in estimating the actual impact. A coconut market model was estimated (Samarajeewa, 2002a; Samarajeewa et al., 2002) which considered three major products - culinary coconut, coconut oil and desiccated coconut. The supply and demand functions were linked using the equilibrium price and those functions were econometrically estimated. Producer surplus for growers was analysed in terms of trade liberalisation, cultivation subsidies and an export levy on desiccated coconut. However, the economic surpluses were not estimated for all the horizontal markets and vertical disaggregation was not considered.

The structure of the coconut industry in Sri Lanka is shown in Figure 1. This is based on the detailed mapping of the various sector value chains previously reported (Pathiraja et al., 2015). Following previous EDM studies (Mounter et al., 2007; Mounter et al., 2008; Zhao, 1999; Zhao et al., 2003), each rectangle represents a production function. The arrows represent demand and supply relationships where an arrowhead represents a product demand while the arrow shaft indicates the supply of a product. The ovals represent factor supplies and product demands where an exogenous shift would occur.

The industry is vertically disaggregated into coconut production, processing, marketing and consumption. Horizontally, it is segmented into four major product groups. Thus, there are eight industry sectors in the model - fresh nut retailing, desiccated coconut processing, export marketing of desiccated coconut, copra processing, coconut oil processing, export marketing of coconut oil, domestic marketing of coconut oil and "other products" processing.

Total production indicates the annual national production of the country in the equilibrium year. In this structure it is not represented as a production function considering the complexity of modelling production of a perennial crop. Generally, farmers provide their harvest directly or through collectors to the wholesaler. This accumulation function involves a marketing cost, but prices are not generally recorded for these transactions[2]. The distribution link from farmers to wholesalers is contracted to wholesalers in this model. For simplicity, it is assumed that wholesalers then distribute the raw coconuts to different production sectors.

Nearly 65 percent of the produce is retailed and freshly consumed (this figure includes the farm consumption of fresh nuts due to the unavailability of disaggregated data). The remaining 35 percent is used in other processing industries.

The desiccated coconut industry uses nearly 11 percent of the raw nuts and nearly 99 percent of this output is exported. Copra is an intermediary product used in coconut oil production which utilises about 20 percent of raw coconuts. Nearly 97 percent of copra production is used for coconut oil production while the rest is exported. Approximately 96 percent of coconut oil is domestically consumed while the rest is exported.

"Other products" includes a variety of export products (instant coconut milk powder, coconut milk, coconut cream, seed nuts). All of these products are aggregated into the one category that altogether utilises approximately five percent of the raw coconuts.

Wholesalers distribute coconuts to the processors and retailers. This involves transportation, handling, initial processing (removing husk), storage and marketing costs. Therefore, in this model, the wholesale price is considered as the supply price and it is common for all the horizontal markets. For this reason, total fresh nut production is assumed to be at the wholesale level.

Coconut retailers purchase from wholesalers and it involves transportation, storage and marketing inputs in reaching the ultimate consumers. It is assumed that wholesalers sell the husked nuts to the processors.

Desiccated coconut is processed and packed at the factory and sold by auction to the exporters. The major part of this output is exported. Copra is processed and sold through dealers to a coconut oil miller. The millers process and sell coconut oil to wholesalers or retailers and exporters.

The above structure can be described in terms of demand and supply equations. The industry is assumed to be in equilibrium and, together with assumptions of normal profit and constant returns to scale technologies, this ensures that all the markets clear. The relationship among the industries is represented by general functional forms. Exogenous shift variables are incorporated in product demand and factor supply equations. These exogenous and endogenous variables are defined in Appendix 1. For interested readers, the details of the theoretical development of the equations in the model, and the transformation of these equations into the displacement form used in the simulations, are provided in Appendix 2 and 3 respectively.

[2] Although there is some evidence of an average price mark up of nearly 32 percent between farm gate and wholesale price which could be an approximation for the benefit share of this segment.

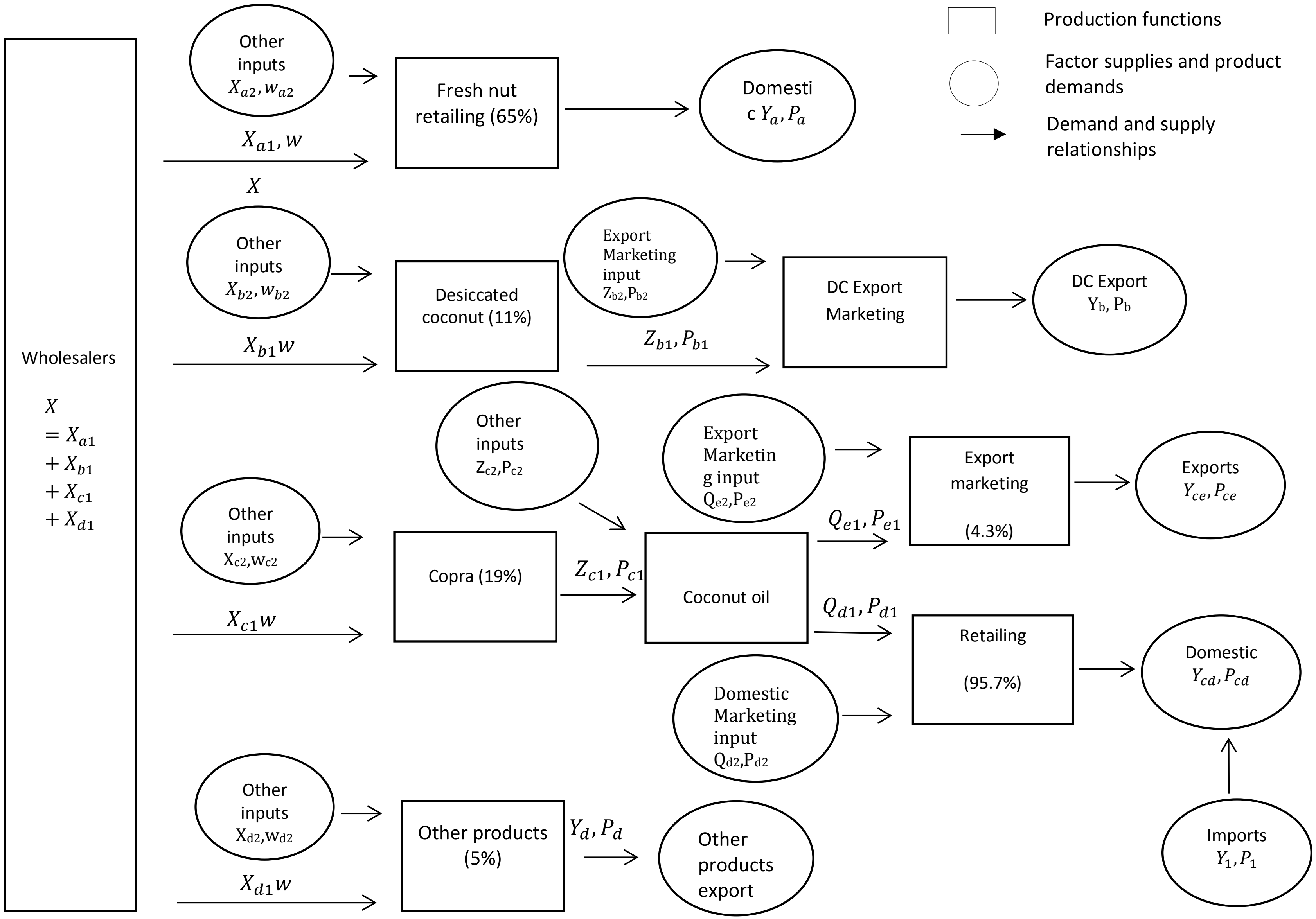

Figure 1: Structure of the model

Data Requirements

An EDM requires equilibrium price and quantity data and parameter values to solve the equations in the specified model for a given displacement of a curve. A medium-term perspective, a 3-5 year adjustment period, is taken.

Parameter values

Empirically estimated parameters, theoretical considerations and judgements made by the authors are some of the approaches used in acquiring the parameter values (Mounter et al., 2007; Mounter et al., 2005; Zhao, 1999). Some parameters were obtained from previous empirical estimates (Jayalath et al., 2014; Samarajeewa, 2002a, 2002b; Samarajeewa et al., 2002). Product transformation and input substitution elasticities are not available in any previous studies. Therefore, the value of 0.1 is used as is common practice in other work (Henderson et al., 2006; Mounter et al., 2008; Mounter et al., 2005; Zhao, 1999). The selected parameter values are given in Table 1. These are based on the information reviewed in Appendix 4.

Table 1: Selected market parameter values

Supply elasticity of fresh nuts	$\varepsilon_{x,w} = 0.195$
Other factor supply elasticities	$\varepsilon_{x_{a2},w_{a2}}=2$, $\varepsilon_{x_{b2},w_{b2}}=2$, $\varepsilon_{x_{c2},w_{c2}}=2$, $\varepsilon_{x_{d2},w_{d2}} = 2$ $\varepsilon_{Z_{b2},P_{b2}} = 2$, $\varepsilon_{Z_{c2},P_{c2}} = 2$, $\varepsilon_{Q_{e2},P_{e2}} = 2$, $\varepsilon_{Q_{d2},P_{d2}} = 2$,
Input substitution elasticities (Allen-Uzawa)	$\sigma_{(X_{a1},X_{a2})} = 0.1, \sigma_{(Z_{b1},Z_{b2})} = 0.1$, $\sigma_{(X_{d1},X_{d2})} = 0.1, \sigma_{(X_{c1},X_{c2})} = 0.1$, $\sigma_{(X_{b1},X_{b2})} = 0.1$, $\sigma_{(Z_{c1},Z_{c2})} = 0.1$, $\sigma_{(Q_{d1},Q_{d2})} = 0.1$, $\sigma_{(Q_{e1},Q_{e2})} = 0.1$,
Product transformation elasticities	$\tau_{Q_{e1},Q_{d1}} = 0.1$
Domestic fresh coconut retail demand elasticity	$\eta_{(Y_a,P_a)} = -0.11$
Desiccated coconut export demand elasticity	$\eta_{(Y_b,P_b)} = -2.00$
Coconut oil export demand elasticity	$\eta_{(Y_{ce},P_{ce})} = -2.00$
Coconut oil retail demand elasticity	$\eta_{(Y_{cd},P_{cd})} = -0.479$
Other products export demand elasticity	$\eta_{(Y_d,P_d)} = -5.00$

The supply elasticity of fresh nuts was 0.195 based on a study by Samarajeewa, (2002b). This is a long-term supply elasticity based on 1970-2000 data. Coconut being a perennial crop and having a lag period of 7 to 9 years for bearing, it responds slowly to the supply price. Considering the above factors and the time required to respond to better crop management practices, including harvesting more palms and rehabilitating neglected coconut lands, a short-term elasticity of 0.004, which is for two years, was estimated for Indonesia by Sugiyanto (2002) (Henderson et al., 2006). In this study, medium term elasticities for a 5 year period are required and previously estimated elasticities are not available. Therefore, 0.19 was used as the selected value.

Estimates for other factor supply elasticities for marketing and processing inputs are not available for the coconut sector. Previous studies on EDM analyses used assumptions on these (Henderson et al., 2006; Zhao et al., 2003; Zhao et al., 2000b).

A value of 2.5 was assumed for the coconut industry in Indonesia by Henderson et al. (2006) and a mean value of 5 was used for the Australian beef sector (Zhao, 1999). For this study, a value of 2 was used.

Substitutability of inputs is assumed to be around 0.1 to 0.2 in previous studies (Henderson et al., 2006; Zhao, 1999). A value of 0.1 is assumed here. Product transformation elasticity between export and domestic coconut oil markets was assumed to be -0.1 considering the smaller share of the export market compared to the domestic sector. This pattern was observed since 1990 and the export share remained stable and non-significant compared with market conditions before 1990. For the farm sector in the Indonesian coconut sector the product transformation elasticity was estimated to be -1 (Henderson et al., 2006), and -0.05 to -0.1 were used for transformation between export and domestic markets of Australian beef (Zhao,1999).

The domestic fresh coconut retail demand elasticity was -0.11 according to an estimate by Samarajeewa (2000). Export demand elasticity for desiccated coconut was -0.041 for Sri Lanka which was a long-term value (Samarajeewa, 2002b) and -5 for Indonesia which was a short-term value (Henderson et al., 2006). A value of -4 was selected. The estimate for coconut oil retail demand elasticity was -0.479 (Samarajeewa, 2002b) for Sri Lanka and -0.5 for Indonesia based on an estimate by Sugyanto (2002) as in (Henderson et al., 2006). A value of -0.479 was used.

An export demand elasticity for coconut oil was available for Indonesia, -5, but not for Sri Lanka. Therefore, a value of -2 was assumed for coconut oil which is assumed less elastic than Indonesia and other exports demand elasticities considering the more or less stable and low market share.

The export demand elasticity for other exports was chosen as -5 due to the high volatility of the export quantities. The parameters are based on the values obtained from Samarajeewa, (1999) and Samarajeewa et al., (2002b).

The own price elasticity of demand for coconut was estimated as -0.11 for the period 1970 to 2000 (Samarajeewa, 2002a). This shows that the consumer response is low for the retail price since there are no close substitutes for culinary coconuts. Further, this study showed an income elasticity of 0.38 indicating the income effect is higher than that of own price.

According to the world demand for desiccated coconut, it is expected that the influence of export quantity of Sri Lanka in the world market has minor influence on export prices. During the period 2008-2012, the average world market share was nearly 11 percent (it was 16 percent among Asia Pacific Coconut Community countries). Generally, desiccated coconut production quantity is associated with annual coconut production in a given year. However, a decline in demand for culinary nuts was observed over the period which can be related to a change in food preparation and consumption patterns.

Export demand elasticity for desiccated coconut is estimated to be -0.041 (Samarajeewa et al., 2002). This was an estimation for the period 1970 to 2000. Previously estimated export demand elasticities for coconut oil and other export products are not available. It is assumed to be -2.00 for coconut oil and -5.00 for other export products. The export quantities of these products show considerable volatility.

However, model results are typically sensitive to these parameters (Zhao et al., 2000b), especially given their uncertain values. In this paper, the single values specified in Table 1 are used in estimating the model and a sensitivity analysis will be conducted in a later stage in another paper with the results of the supply shift due to climate change.

Equilibrium prices and quantities

The base equilibrium prices and quantities were estimated considering the five year average of annual data (2009-2013). The data were obtained from the annual publications of the Coconut Development Authority and the Central Bank of Sri Lanka (Central Bank of Sri Lanka, 2013; Coconut Development Authority, 1970-2013). These data are shown in Table 2. Based on the discussion in Pathiraja et al. (2015), the average over these five years is considered to be representative of recent conditions.

Exogenous shifts

All the possible exogenous shift variables are shown in Table 3, together with the hypothetical values assumed in this set of analyses. In all cases, the various demand or supply shift scenarios are analysed on the basis that all other shift variables remain set to zero. That is, the shifters are examined one by one, in isolation. Typically, in these sorts of analyses we hypothesise 1 per cent improvements in productivity for supply side shifts or 1 per cent improvements in consumer willingness to pay for demand side shifts.

Economic surplus calculations

Finally, the various formulae used to calculate the economic surplus measures for each of the sectors are given in Table 4 (Alston et al., 1995, p. 207).

Results

The model specified in Appendix 1, calibrated for the elasticity parameters given in Table 1 and the equilibrium prices and quantities given in Table 2, was simulated for each of the 14 hypothetical scenarios given in Table 3. The estimated quantity and price changes from the solution of the model for each of these 14 scenarios are summarised in Appendix 5. These estimated price and quantity changes are then translated into estimated economic surplus changes based on the formulae given in Table 4. The total economic surplus changes and their distribution among the different industry sectors for each of the 14 hypothetical scenarios are shown in Tables 5a to 5d. The net economic surplus change for each scenario is also calculated.

Total benefits

According to the "absolute value" of total surplus, the shift in domestic demand for retail coconut (scenario 10, Rs 752 million) shows the largest total impact, and this is followed by the shift in coconut wholesale supply (scenario 1, Rs 723 million). Both of these values for gross benefits ("absolute value") are about three quarters of one percent of the total value of the industry at equilibrium, approximately Rs. 102,393 million. Only four other scenarios produce gross benefits greater than Rs 200 million, or greater than two tenths of one percent: scenario 2, Rs 218 million; scenario 11, Rs 514 million; scenario 13, Rs 339 million; and scenario 14, Rs 365 million.

However, as is evident in the results reported in Tables 5a to 5d, in all but one of the scenarios there is a mix of positive and negative values for the surplus measures. Scenario 1, the shift in coconut

Table 2: Base equilibrium prices, quantities and cost and revenue shares (average of 2009-2013)

Market	Quantity (Million coconuts) and Price (Rs. Million)		Cost ,revenue and quantity shares
Wholesalers	X=2668	w=27.10	
	TV=72301		
Coconut Retailing	X_{a1}= 1744.36	w=27.10	$k_{X_{a1}} = 0.69$
	$TV_{X_{a1}}$= 47271		$k_{X_{a2}} = 0.31$
	Y_a=1744	P_a=39.53	$\rho_{X_{a1}} = 0.65$
	TV_{Y_a}= 68947		
Desiccated coconut processing and export marketing	X_{b1}=286.49	w=27.10	$k_{X_{b1}} = 0.95$
	$TV_{X_{b1}}$=7764		$k_{X_{b2}} = 0.05$
	Z_{b1}= 286.49	$P_{b1} = 28.54$	$k_{Z_{b1}} = 0.89$
	$TV_{Z_{b1}}$ =8176		$k_{Z_{b2}} = 0.11$
	Y_b =286.49	$P_b = 32.23$	
	$TV_{Y_b} = 9232$		$\rho_{X_{b1}} = 0.11$
Copra processing	X_{c1}=502.35	w=27.10	$k_{X_{c1}} = 0.99$
Oil processing and marketing	$TV_{X_{c1}} = 13613$		$k_{X_{c2}}$ =0.01
	Z_{c1}= 502.35	$P_{c1} = 27.50$	$k_{Z_{c1}} = 0.94$
	$TV_{Z_{c1}} = 13815$		$k_{Z_{c2}} = 0.06$
	Q_{e1}= 21.54	$P_{e1} = 29.15$	$\gamma_{Q_{e1}} = 0.04$
	Q_{d1}= 480.81	P_{d1} =29.15	$\gamma_{Q_{d1}}$ =0.96
	$Y_{ce} = 21.54$	$P_{ce} = 55.90$	$k_{Q_{e1}} = 0.52$
	$TV_{Y_{ce}} = 1204$		$k_{Q_{e2}} = 0.48$
	Y_{cd} =480.81	P_{cd} =34.53	$k_{Q_{d1}} = 0.84$
	$TV_{Y_{cd}}$ =16604		$k_{Q_{d2}} = 0.16$
			$\rho_{X_{c1}} = 0.19$
Other products	X_{d1}=134.39	w=27.10	$k_{X_{d1}}$ =0.57
	$TV_{X_{d1}}$ =3653		$k_{X_{d2}}$ =0.43
	Y_d= 134.79	P_d= 47.52	
	$TV_{Y_d} = 6405$		$\rho_{X_{d1}} = 0.05$

Table 3: Exogenous shift variables for various investment scenarios

Scenario 1
t_x= -0.01 : the cost of production is assumed to decrease by 1 per cent due to productivity improvements in coconut cultivation.
Scenario 2
t_{xa2}= -0.01 : the cost of production of other inputs into fresh nut retailing is assumed to decrease by 1 per cent due to a productivity increase as a result of more efficient input use.
Scenario 3
t_{xb2}= -0.01: the cost of production of other inputs into desiccated coconut processing is assumed to decrease by 1 per cent due to a productivity improvement in processing technologies.
Scenario 4
t_{xc2}= -0.01: the cost of production of other inputs into copra processing is assumed to decrease by 1 per cent due to a productivity improvement in processing technologies.
Scenario 5
t_{xd2}= -0.01: the cost of production of other inputs into other coconut processing is assumed to decrease by 1 per cent due to a productivity improvement in processing technologies.
Scenario 6
t_{Zb2}= -0.01: the cost of production of other inputs into export marketing is assumed to decrease by 1 per cent due to a productivity improvement in these processes.
Scenario 7
t_{Zc2}= -0.01: the cost of production of other inputs into coconut oil processing is assumed to decrease by 1 per cent due to a productivity improvement in processing technologies.
Scenario 8
t_{Qe2}= -0.01 : the cost of production of other inputs into coconut oil export marketing is assumed to decrease by 1 per cent due to a productivity improvement in these processes.
Scenario 9
t_{Qd2}= -0.01 : the cost of production of other inputs into coconut oil domestic marketing is assumed to decrease by 1 per cent due to a productivity improvement in these processes.
Scenario 10
n_1= 0.01 : a 1 per cent upward shift in demand for fresh coconut consumption is assumed with population increase.
Scenario 11
n_2= 0.01 : a 1 per cent upward shift in export demand for desiccated coconut is assumed due to a world demand increase.
Scenario 12
n_3= 0.01 : a 1 per cent upward shift in export demand for coconut oil is assumed due to quality improvements or changing the concern about coconut oil (health concerns).
Scenario 13
n_4= 0.01 : a 1 per cent upward shift in domestic demand for coconut oil is assumed due to population increase and shifting from other oils to coconut oil.
Scenario 14
n_5= 0.01 : a 1 per cent upward shift in the demand for other product exports is assumed due to world demand increase for these products.

Table 4: Formulae to calculate economic surplus

Coconut suppliers (Wholesale)	$\Delta PS_X = wX(Ew - t_1)(1 + 0.5EX)$
Retailing other input suppliers	$\Delta PS_{X_{a2}} = w_{a2}X_{a2}(Ew_{a2} - t_2)(1 + 0.5EX_{a2})$
Desiccated coconut other input suppliers	$\Delta PS_{X_{b2}} = w_{b2}X_{b2}(Ew_{b2} - t_3)(1 + 0.5EX_{b2})$
Desiccated coconut export marketing input suppliers	$\Delta PS_{Z_{b2}} = P_{b2}Z_{b2}(EP_{b2} - t_6)(1 + 0.5EZ_{b2})$
Copra other input suppliers	$\Delta PS_{X_{c2}} = w_{c2}X_{c2}(Ew_{c2} - t_4)(1 + 0.5EX_{c2})$
Coconut oil other processing input suppliers	$\Delta PS_{Z_{c2}} = P_{c2}Z_{c2}(EP_{c2} - t_8)(1 + 0.5EZ_{c2})$
Coconut oil export marketing input suppliers	$\Delta PS_{Q_{e2}} = P_{e2}Q_{e2}(EP_{e2} - t_9)(1 + 0.5EQ_{e2})$
Coconut oil retailing other input suppliers	$\Delta PS_{Q_{d2}} = P_{d2}Q_{d2}(EP_{d2} - t_{10})(1 + 0.5EQ_{d2})$
Other export products processing input suppliers	$\Delta PS_{X_{d2}} = w_{d2}X_{d2}(Ew_{d2} - t_5)(1 + 0.5EX_{d2})$
Domestic coconut consumers	$\Delta CS_{Y_a} = P_aY_a(n_1 - EP_a)(1 + 0.5EY_a)$
Export desiccated coconut consumers	$\Delta CS_{Y_b} = P_bY_b(n_2 - EP_b)(1 + 0.5EY_b)$
Domestic coconut oil consumers	$\Delta CS_{Y_{cd}} = P_{cd}Y_{cd}(n_4 - EP_{cd})(1 + 0.5EY_{cd})$
Export coconut oil consumers	$\Delta CS_{Y_{ce}} = P_{ce}Y_{ce}(n_3 - EP_{ce})(1 + 0.5EY_{ce})$
Export other products consumers	$\Delta CS_{Y_d} = P_dY_d(n_5 - EP_d)(1 + 0.5EY_d)$
Sum	$\Delta ES = \sum\Delta PS_i + \sum\Delta CS_i$

wholesale supply, has uniformly positive values, so the value for total surplus for all changes is the same as for net change, Rs 723 million. In all other cases, positive and negative values offset each other to a greater or lesser extent so that the net total surplus values are smaller than the all changes total values. Scenario 10, the shift in domestic demand for retail coconut, still has a relatively large positive net impact of Rs 690 million, but only one other scenario produces gross benefits greater than Rs 200 million and that is scenario 2, with Rs 217 million.

Distribution of benefits

We cannot compare the investment scenarios directly since, in these hypothetical analyses, the cost for each investment required to generate the relevant supply or demand shift is not available. Data on the export levy collected, the expenditure on grower subsidies, and the research and extension expenditure to induce the hypothetical 1 percent shift are required to properly compare the returns from each. However, the distribution of benefits from each investment does not change and it can be used to identify the groups in the value chain which receive the best relative returns (Zhao et al., 2003; Zhao et al., 2001).

The highest net impact occurs when the supply of coconuts is shifted downwards by 1 percent (scenario 1). Given the assumed retail demand elasticity (Table 1) this is about a 0.2 per cent outward shift in the coconut supply curve, modelling a positive shift in productivity due for example to new varieties or better management practices. The total surplus change is nearly three quarters of 1 percent (Rs 723 million) of the total industry value at the initial equilibrium. This is a gain in economic value, distributed as a benefit among all the industry stakeholders. Some 66 percent of the economic benefit accrues to the fresh nut wholesalers (this is shared by wholesalers, coconut growers and other intermediary collectors) and another 22 percent accrues to domestic fresh coconut consumers. Another 10 percent is distributed among coconut product consumers and only 2 percent ends up with other input suppliers.

The second highest impact on the Sri Lankan coconut industry is when the domestic retail demand for coconut is shifted upwards by 1 percent (scenario 10). Given the assumed retail demand elasticity (Table 1) this is about a 0.1 per cent outward shift in the demand curve. The net change in surplus is Rs 690 million or about three quarters of 1 percent of the total value of the industry at equilibrium. However, in this scenario, the distribution of the net benefit is quite different. A very high proportion of the net benefits are retained by domestic fresh coconut consumers, and fresh nut wholesalers and retailers are also net beneficiaries, but consumers of processed coconut products and input suppliers into coconut processing are all losers from this scenario.

The pattern of impacts from scenario 2 is very similar to that of scenario 10, with domestic fresh nut consumers being the big beneficiaries, fresh nut wholesalers and retailers receiving some benefit but all other sectors losing.

The impact of other exogenous shifters in the industry is comparatively low. Efficiency improvements in coconut oil retailing inputs produce large gains for domestic coconut oil consumers, with about one quarter of the gains being transmitted back to nut wholesalers and then to producers. Efficiency gains in processing input supply are shared between suppliers and consumers depending mainly on export proportions. A considerable share is generally passed back to nut wholesalers.

Fresh nut wholesalers (including wholesalers, coconut growers and other intermediary collectors) benefit from all scenarios, with benefit shares generally between a quarter and a half of the aggregate, all changes, value. The exceptions are scenario 2 and 10.

Discussion

This study has developed an EDM for the coconut industry in Sri Lanka to allow subsequent analyses of the impact of different external shocks to the industry.

One future objective will be to assess the impact of yield shocks due to climate change. Scenario 1 describes the distribution of impacts among different industry stakeholders of a 1 percent productivity improvement in coconut supply. If we looked at the reverse situation, of a 1 percent *increase* in the cost of supplying raw coconuts, equivalent to about a 0.2 percent drop in the supply of coconut, we could predict a loss of around Rs 723 million per year in the value of the Sri Lankan coconut industry. This loss would be mainly (66 percent) shared by coconut wholesalers (including producers and other fresh nut collectors) and domestic consumers (22 percent). There would also be small losses to every other sector in the coconut value chain. If climate models and yield models used together resulted in predictions of future yield declines of even just a couple of percent from the average, this would imply grave consequences for the Sri Lankan coconut industry. Total losses could be in the order of Rs 7.2 billion per year.

Another future objective will be to assess the impact of current policy settings for the industry. Taking the results from scenario 1 as they stand, they give an insight into the effectiveness of other producer subsidy schemes and investments on research and extension. A productivity improvement investment would benefit both growers and consumers with producers benefitting the most. It shows that current farmer assistance schemes including fertilizer subsidies, replanting and new planting subsidies, and research and extension services mainly benefit the farmers while consumers get some benefit.

Table 5a: Economic surplus changes (in Rs.Million) and percentage shares of total surplus changes to various industry groups under different scenarios

	Scenario 1 (tx=-1%)		Scenario 2 (txa2=-1%)		Scenario 3 (txb2=-1%)		Scenario 4 (txc2=-1%)	
	Rs.Million	%	Rs.Million	%	Rs.Million	%	Rs.Million	%
ΔPSX (Fresh nut wholesalers)	477.54	66.09	2.458	1.125	9.545	45.094	1.632	35.011
ΔPSXa2 (Fresh nut retailers)	0.24	0.03	10.628	4.864	-0.009	0.044	-0.002	0.034
ΔPSXb2 (Desiccated coconut processors)	0.93	0.13	-0.0093	0.0043	0.299	1.414	-0.006	0.133
ΔPSXc2 (Copra other input suppliers)	0.10	0.01	-0.001	0.000	-0.004	0.018	0.099	2.128
ΔPSXd2 (other export products processors)	6.19	0.86	-0.062	0.028	-0.241	1.141	-0.041	0.886
ΔPSZb2 (Desiccated coconut export marketing)	2.38	0.33	-0.024	0.011	0.263	1.242	-0.016	0.340
ΔPSZc2 (Coconut oil other processing)	0.39	0.05	-0.004	0.002	-0.015	0.072	0.014	0.293
ΔPSQe2 (Coconut oil export marketing)	0.27	0.04	-0.003	0.001	-0.011	0.050	0.010	0.204
ΔPSQd2 (Coconut oil retailing)	1.23	0.17	-0.012	0.006	-0.048	0.226	0.043	0.917
Subtotal producer surplus, all changes	**489.26**	**67.71**	**13.20**	**6.04**	**10.44**	**49.30**	**1.86**	**39.94**
ΔCSYa (Domestic coconut consumers)	160.03	22.15	204.556	93.622	-6.231	29.438	-1.066	22.856
ΔCSYb (Export desiccated coconut consumers)	22.96	3.18	-0.231	0.106	2.540	12.000	-0.153	3.287
ΔCSYcd (Domestic coconut oil consumers)	43.52	6.02	-0.436	0.200	-1.695	8.009	1.518	32.558
ΔCSYce (Export coconut oil consumers)	0.63	0.09	-0.006	0.003	-0.025	0.116	0.022	0.471
ΔCSYd (Export other products consumers)	6.17	0.85	-0.062	0.028	-0.241	1.137	-0.041	0.883
Subtotal consumer surplus, all changes	**233.31**	**32.29**	**205.291**	**93.958**	**10.732**	**50.701**	**2.800**	**60.055**
Total surplus, all changes	**722.56**	100	**218.49**	100	**21.167**	100	**4.662**	100
Total surplus, net change	**722.56**		**216.80**		**4.13**		**2.01**	

Table 5b: Economic surplus changes (in Rs.Million) and percentage shares of total surplus changes to various industry groups under different scenarios

	Scenario 5 (txd2=-1%)		Scenario 6 (tZb2=-1%)		Scenario 7 (tZc2=-1%)		Scenario 8 (tQe2=-1%)	
	Rs.Million	%	Rs.Million	%	Rs.Million	%	Rs.Million	%
ΔPSX (Fresh nut wholesalers)	63.611	42.859	24.425	45.092	4.009	27.127	2.794	27.13
ΔPSXa2 (Fresh nut retailers)	-0.062	0.042	-0.024	0.044	-0.004	0.027	-0.003	0.027
ΔPSXb2 (Desiccated coconut processors)	-0.241	0.163	0.263	0.485	-0.015	0.103	-0.011	0.103
ΔPSXc2 (Copra other input suppliers)	-0.025	0.017	-0.009	0.018	0.015	0.099	0.010	0.10
ΔPSXd2 (other export products processors)	12.887	8.683	-0.618	1.140	-0.101	0.686	-0.071	0.69
ΔPSZb2 (Desiccated coconut export marketing)	-0.617	0.416	1.176	2.172	-0.039	0.263	-0.027	0.26
ΔPSZc2 (Coconut oil other processing)	-0.102	0.068	-0.039	0.072	0.454	3.075	0.042	0.41
ΔPSQe2 (Coconut oil export marketing)	-0.071	0.048	-0.027	0.050	0.042	0.285	-0.30	2.95
ΔPSQd2 (Coconut oil retailing)	-0.318	0.214	-0.122	0.225	0.189	1.280	0.132	1.28
Subtotal producer surplus, all changes	**77.93**	**52.51**	**26.70**	**49.30**	**4.87**	**32.94**	**3.39**	**32.94**
ΔCSYa (Domestic coconut consumers)	-41.522	27.976	-15.945	29.436	-2.617	17.709	-1.824	17.71
ΔCSYb (Export desiccated coconut consumers)	-5.967	4.020	6.503	12.004	-0.376	2.546	-0.262	2.55
ΔCSYcd (Domestic coconut oil consumers)	-11.296	7.611	-4.338	8.008	6.718	45.458	4.681	45.46
ΔCSYce (Export coconut oil consumers)	-0.163	0.110	-0.063	0.116	0.097	0.658	0.068	0.66
ΔCSYd (Export other products consumers)	11.537	7.773	-0.616	1.137	-0.101	0.684	-0.070	0.68
Subtotal consumer surplus, all changes	**70.485**	**47.491**	**27.464**	**50.702**	**9.910**	**67.055**	**6.906**	**67.06**
Total surplus, all changes	**148.419**	100	**54.169**	100	**14.779**	100	**10.298**	100
Total surplus, net change	**27.66**		**10.57**		**8.26**		**5.16**	

Table 5c: Economic surplus changes (in Rs.Million) and percentage shares of total surplus changes to various industry groups under different scenarios

	Scenario 9 (tQd2=-1%)		Scenario 10 (n1=+1%)		Scenario 11 (n2=+1%)		Scenario 12 (n3=+1%)	
	Rs.Million	%	Rs.Million	%	Rs.Million	%	Rs.Million	%
ΔPSX (Fresh nut wholesalers)	12.558	27.124	90.297	12.00	236.120	45.925	6.452	27.488
ΔPSXa2 (Fresh nut retailers)	-0.012	0.027	11.239	1.49	-0.232	0.045	-0.006	0.027
ΔPSXb2 (Desiccated coconut processors)	-0.048	0.103	-0.342	0.046	2.555	0.497	-0.024	0.104
ΔPSXc2 (Copra other input suppliers)	0.046	0.099	-0.035	0.00	-0.092	0.018	0.024	0.101
ΔPSXd2 (other export products processors)	-0.318	0.686	-2.282	0.30	-5.958	1.159	-0.163	0.695
ΔPSZb2 (Desiccated coconut export marketing)	-0.122	0.263	-0.876	0.12	6.538	1.272	-0.063	0.267
ΔPSZc2 (Coconut oil other processing)	0.189	0.409	-0.144	0.019	-0.377	0.073	0.097	0.414
ΔPSQe2 (Coconut oil export marketing)	0.132	0.285	-0.100	0.01	-0.262	0.051	0.068	0.289
ΔPSQd2 (Coconut oil retailing)	1.827	3.947	-0.451	0.06	-1.180	0.229	0.304	1.297
Subtotal producer surplus, all changes	**15.25**	**32.94**	**105.77**	**14.06**	**253.31**	**49.27**	**7.20**	**30.68**
ΔCSYa (Domestic coconut consumers)	-8.198	17.707	619.498	82.35	-154.078	29.968	-4.212	17.945
ΔCSYb (Export desiccated coconut consumers)	-1.179	2.546	-8.468	1.13	58.303	11.340	-0.606	2.580
ΔCSYcd (Domestic coconut oil consumers)	21.049	45.463	-16.033	2.13	-41.901	8.150	10.813	46.067
ΔCSYce (Export coconut oil consumers)	0.304	0.658	-0.232	0.03	-0.606	0.118	-0.477	2.033
ΔCSYd (Export other products consumers)	-0.317	0.684	-2.276	0.30	-5.941	1.155	-0.163	0.693
Subtotal consumer surplus, all changes	**31.046**	**67.058**	**646.505**	**85.94**	**260.829**	**50.731**	**16.270**	**69.318**
Total surplus, all changes	**46.298**	100	**752.273**	100	**514.142**	100	**23.472**	100
Total surplus, net change	**25.57**		**689.79**		**92.89**		**12.05**	

Table 5d: Economic surplus changes (in Rs.Million) and percentage shares of total surplus changes to various industry groups under different scenarios

	Scenario 13 (n4=+1%)		Scenario 14 (n5=+1%)	
	Rs.Million	%	Rs.Million	%
ΔPSX (Fresh nut wholesalers)	106.834	31.542	158.617	43.365
ΔPSXa2 (Fresh nut retailers)	-0.104	0.031	-0.155	0.042
ΔPSXb2 (Desiccated coconut processors)	-0.405	0.120	-0.601	0.164
ΔPSXc2 (Copra other input suppliers)	0.392	0.116	-0.062	0.017
ΔPSXd2 (other export products processors)	-2.700	0.797	29.013	7.932
ΔPSZb2 (Desiccated coconut export marketing)	-1.040	0.307	-1.538	0.421
ΔPSZc2 (Coconut oil other processing)	1.610	0.475	-0.253	0.069
ΔPSQe2 (Coconut oil export marketing)	1.120	0.331	-0.176	0.048
ΔPSQd2 (Coconut oil retailing)	5.050	1.491	-0.793	0.217
Subtotal producer surplus, all changes	**118.24**	34.91	**191.21**	**52.27**
ΔCSYa (Domestic coconut consumers)	-69.730	20.587	-103.519	28.302
ΔCSYb (Export desiccated coconut consumers)	-10.020	2.958	-14.863	4.063
ΔCSYcd (Domestic coconut oil consumers)	135.440	39.987	-28.156	7.698
ΔCSYce (Export coconut oil consumers)	2.590	0.765	-0.407	0.111
ΔCSYd (Export other products consumers)	-2.690	0.794	27.620	7.551
Subtotal consumer surplus, all changes	**220.470**	65.092	**174.565**	**47.725**
Total surplus, all changes	**339**	100	**365.773**	100
Total surplus, net change	**167.08**		**64.73**	

Scenario 2 shows that more efficient marketing strategies would benefit the consumers and may be helpful in price hikes. Direct sales during lean periods that cater to the urban consumers (conducted with the support of the Coconut Development Authority) are an example of actions which shrink the marketing chain. Coconut oil retailing benefits the coconut oil consumers, coconut consumers and wholesalers. Current strategies of improving storage facilities, improving quality, and packaging and branding would improve marketing efficiency. However, the total benefit is comparatively low and the cost required to achieve a 1 percent shift is an important factor.

The benefits of export marketing improvements are mainly transferred to the coconut wholesalers, domestic coconut consumers and export or domestic consumers of the relevant product depending on the market share. It shows that the coconut processors are not benefitting when the export levy is invested in improving export marketing.

Efficiency improvements in coconut product processing technologies show that the gains accrue mainly to coconut wholesalers and consumers. The benefit accrued by a 1 percent cost reduction is comparatively low as a result of more elastic supply curves and the small value of each industry. Government assistance schemes for mill development, new technology adoption and processing research activities are some of the investments that rarely benefit the processors. Generally, export levies collected from the processors are used to reinvest in technology improvements and to subsidise new technology.

Shifting the domestic demand for fresh coconuts produces double the benefit of shifting the domestic demand for coconut oil. In both cases, domestic consumers get the most out of the total benefits. Nearly 82 percent of the benefits from a fresh coconut demand shift are shared by domestic coconut consumers followed by wholesalers (12 percent) and coconut retailers. In the case of a coconut oil demand shift, nearly 40 percent goes to coconut oil consumers and 31 percent to wholesalers. However, in this case fresh coconut consumers lose, as do other consumers and input suppliers. During lean crops, substitute oil imports are facilitated by the government to overcome the negative benefit for coconut, and coconut oil, consumers. Generally, other edible oils are cheaper and the import tariff is reduced or removed. This downward shift is a loss for coconut wholesalers. Since there is no quantitative restriction, the coconut oil demand further drops and production reduces. Adulteration of coconut oil with substitute oil is another concern since the majority of the oil is retailed without branding or labelling. This is common in lean crop years where growers and coconut oil millers request tariff protection.

Export demand shifts provide positive benefits for wholesalers and the relevant product consumers but negatively affect the fresh coconut consumers and other consumers. An increase in processing demand for fresh coconuts increases the wholesale price benefitting the wholesalers and it is negative for the coconut consumers and other product processors. During lean crops, fresh nut exports are banned to reduce the demand for other export products. Domestically, this is negative on coconut wholesalers and positive on consumers.

Application of this model in climate change scenarios will show who should be mainly assisted with the yield change. It provides an insight into impact distribution. If the yield declines, growers and consumers are the most affected. Facilitating adaptation measures in coconut lands and improving the efficiency of retail marketing of coconuts would be effective. In the presence of lean crops, export bans and substitute oil imports under low tariff rates would yield negative benefits on growers and processors while supporting the consumers.

However, as in all these types of models, these results are sensitive to selected parameter values and assumptions. In reality, these parameter values may not represent the actual figures. Selection of input substitution elasticities, or allowing input substitution, changes the distribution of benefits. In this study, input substitution and product transformation elasticities were set at 0.1 and other factor supply elasticities were set at 2. Perfect competition is assumed for all the sectors. There are some deviations in market structures when different sales arrangements exist. There are some dominant or preferred wholesalers and contract arrangements in the coconut supply sector. Regional auctions assist in giving a reasonable price for the growers. The desiccated coconut industry has restricted entry for new mills considering the raw material limitation. The new export products market has technology barriers to entry. Generally, processors export through brokers and there are some direct sales arrangements showing a diversity of the market arrangements.

Conclusions

This study has focused on developing an economic modelling framework for the coconut industry in Sri Lanka. An EDM was developed which facilitates incorporating both vertical and horizontal disaggregation of the industry segments. A number of hypothetical simulations have shown the ability of the model to be used in future policy assessment studies and climate change impact distribution analyses. This is the first form of economic framework developed for Sri Lankan coconut industry which captures the essential economic characteristics of the coconut value chain in Sri Lanka. However, the model has embedded limitations that come from the assumptions of the EDM approach.

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Appendix 1: Definition of Variables and Parameters in the Model

Endogenous variables	
X	Quantity of total coconut supply
X_{a1}	Quantity of coconut supply for retailing
X_{b1}	Quantity of coconut supply for desiccated coconut
X_{c1}	Quantity of coconut supply for copra
X_{d1}	Quantity of coconut supply for other processed products
Z_{b1}	Quantity of desiccated coconut supply for export marketing
Z_{c1}	Quantity of copra supply for coconut oil production
Q_{e1}	Quantity of coconut oil supply for export marketing
Q_{d1}	Quantity of coconut oil supply for domestic retail marketing
Y_a	Quantity of coconut demanded by domestic consumers
Y_b	Quantity of export desiccated coconut demand
Y_{ce}	Quantity of export coconut oil demand
Y_{cd}	Quantity of domestic consumer coconut oil demand
Y_d	Quantity of other product export demand
X_{a2}	Quantity of other coconut retailing input supply
X_{b2}	Quantity of other desiccated coconut processing input supply
X_{c2}	Quantity of other copra processing input supply
X_{d2}	Quantity of other inputs supply for other export products processing
Z_{b2}	Quantity of desiccated coconut export marketing inputs supply
Z_{c2}	Quantity of other coconut oil processing inputs supply
Q_{e2}	Quantity of coconut oil export marketing inputs supply
Q_{d2}	Quantity of coconut oil domestic marketing input supply
w	Supply price of coconuts
P_{b1}	Price of desiccated coconut supplied for export marketing
P_{c1}	Price of copra supplied for coconut oil processing
P_{e1}	Price of coconut oil supplied for export marketing
P_{d1}	Price of coconut oil supplied for domestic marketing
P_a	Price of domestic retail coconuts
P_b	Price of export desiccated coconut
P_{ce}	Price of export coconut oil
P_{cd}	Price of domestic retail coconut oil
P_d	Price of other export products
w_{a2}	Price of other coconut retailing input supply
Endogenous variables	
w_{b2}	Price of other desiccated coconut processing input supply

w_{c2}	Price of other copra processing input supply
w_{d2}	Price of other inputs supply for other export products processing
P_{b2}	Price of desiccated coconut export marketing inputs supply
P_{c2}	Price of other coconut oil processing inputs supply
P_{e2}	Price of coconut oil export marketing inputs supply
P_{d2}	Price of coconut oil domestic marketing input supply
Z_c	Aggregated input index of coconut oil processing
Q	Aggregated output index of coconut oil processing
Exogenous variables	
T_x	Supply shifters
t_x	Amount of shift T_x as a percentage of supply price
N_x	Demand shifters
n_x	Amount of N_x as a percentage of demand price
Parameters	
$\varepsilon_{x,w}$	Supply elasticity of variable 'x' with respect to change in price 'w'
$\rho_{X_{a1}}, \rho_{X_{b1,}} \rho_{X_{c1,}}$	Quantity shares of $X_{a1}, X_{b1}, X_{c1}, X_{d1}$
k_x	Cost share of input 'x'
γ_{Y_i}	Revenue shares of output
$\sigma_{(X_i,X_j)}$	Allen's elasticity of input substitution between input 'X_i' and input 'X_j'
τ_{Y_i,Y_j}	Allen's elasticity of product transformation between outputs Y_i and Y_j
$\eta_{(Y,P)}$	Demand elasticity of variable 'Y' with respect to change in price 'P'
$\bar{\varepsilon}_{x,w}$	Constant-input output supply elasticity of output 'X', with respect to change in input price 'w.
$\bar{\eta}_{(Y,P)}$	Constant-output input demand elasticity of input 'X' with respect to change in input price 'p.

(Different letters are used as subscripts to differentiate the products and markets those go to)

Appendix 2. Details of the Model Specification

Supply of coconuts

Coconut supply

1. $X = X(w, T_1)$

Coconut supply equality

2. $X = X_{a1} + X_{b1} + X_{c1} + X_{d1}$

Equation 1 is the supply function of coconut related to its own price. This represents the wholesale supply where all farm supply is assumed to be collected. T is an exogenous supply shifter. Equation 2 is the coconut supply equality where each industry sector is facing the same wholesale coconut price.

Fresh nut retailing

Supply of other inputs

3. $X_{a2} = f(w_{a2}, T_2)$

Output constrained input demand functions

4. $X_{a1} = Y_a * c'_{Ya,w}(w, w_{a2})$
5. $X_{a2} = Y_a * c'_{Y_a,w_{a2}}(w, w_{a2})$

Fresh nut retailing value equilibrium condition

6. $c_{Ya}(w, w_{a2}) = r_{x_a}(P_a)$

Domestic retail demand for fresh nuts

7. $Y_a = f(P_a, N_1)$

Equation 3 is the other retail marketing input supply function. This includes transportation, handling and transaction costs which are non-specific to this sector. T_2 is a supply shifter representing the impacts of efficiency improvements. Equation 4 and 5 are the output constrained input demand functions of X_{a1} and X_{a2} derived using Shephard's Lemma (Chambers, 1988, p. 261). $c'_{Ya,w}(w, w_{a2})$ and $c'_{Y_a,w_{a2}}(w, w_{a2})$ are the partial derivatives of the unit cost function. Equation 6 is the market clearing condition, specifying that the unit price of fresh nuts at retail equals the unit costs of production. Equation 7 is the retail demand function for fresh coconuts. N_1 is a demand shifter in the retail market.

Desiccated Coconut (DC) processing

Supply of other DC processing inputs

8. $X_{b2} = f(w_{b2}, T_3)$

Output constrained input demand functions

9. $X_{b1} = Z_{b1} * c'_{Z_{b1},w}(w, w_{b2})$
10. $X_{b2} = Z_{b1} * c'_{Z_{b1},w_{b2}}(w, w_{b2})$

Desiccated coconut processing equilibrium

11. $c_{Zb1}(w_{b2}, w) = r_{X_b}(P_{b1})$ value equilibrium

Equation 8 is the supply function of other processing inputs to desiccated coconut processing. Own price of inputs is represented by w_{b2}. T_3 is a supply shifter of other inputs. Equation 9 and 10 are output constrained input demand functions of inputs X_{b1} and X_{b2} derived using Shephard's Lemma. $c'_{Z_{b1},w}(w, w_{b2})$ and $c'_{Z_{b1},w_{b2}}(w, w_{b2})$ are the partial derivatives of unit cost function with respect to input prices. Equation 11 shows the value equilibrium where output price equals the unit cost of producing output.

Desiccated coconut export marketing

12. $Z_{b2} = f(P_{b2}, T_6)$ Marketing input supply

Output constrained input demand of export marketing inputs

13. $Z_{b1} = Y_b * c'_{Yb,Pb1}(P_{b1}, P_{b2})$
14. $Z_{b2} = Y_b * c'_{Yb,Pb2}(P_{b1}, P_{b2})$

DC export marketing value equilibrium condition

15. $c_{Yb}(P_{b1}, P_{b2}) = r_{Zb}(P_b)$

Export demand for desiccated coconut

16. $Y_b = f(P_{b,} N_2)$

Equation 12 is the export marketing input supply function of desiccated coconut. P_{b2} is the own price of inputs. T_6 is a supply shifter. Reduced brokerage fees or transaction costs, low cost packaging and transport are some of the possible reasons for more efficient processing. Equation 13 and 14 are the output constrained input demand functions of Z_{b1} and Z_{b2}. These were derived from unit cost functions applying Shephard's Lemma.

Equation 15 shows the market clearing condition for export marketing where the output price equals unit cost of producing the output. Equation 16 is the export demand function for desiccated coconut. $P_{b,}$ is the free on board (FOB) price and N_2 is the outward demand shifter.

Copra processing

Supply of other copra processing inputs

17. $X_{c2=}f(w_{c2}, T_4)$

Output constrained input demand functions

18. $X_{c1=}Z_{c1} * c'_{Z_{c1},w}(w, w_{c2})$

19. $X_{c2=}Z_{c1} * c'_{Z_{c1},w_{c2}}(w, w_{c2})$

Copra processing value equilibrium

20. $c_{\ Zc1}(w, w_{c2}) = r_{\ Xc}(P_{c1})$

Equation 17 is the supply function of copra processing inputs. w_{c2} is the own price and T_4 is a supply shifter. Equations 18 and 19 show the output constrained input demand functions of X_{c1} and X_{c2} derived using Shephard's Lemma. Equation 20 shows the market clearing condition for copra processing where the output price equals the unit cost of output.

Coconut oil processing

Other input supply for coconut oil processing

21. $Z_{c2=f}(P_{c2}, t_8)$

Output constrained input demand functions

22. $Z_{c1} = Q * c'_{Q,P_{c1}}(P_{c1}, P_{c2})$

23. $Z_{c2} = Q * c'_{Q,P_{c2}}(P_{c1}, P_{c2})$

Coconut oil quantity and value equilibria

24. $Z_c(Z_{c1,} Z_{c2}) = Q(Q_{e1,} Q_{d1})$

25. $c_{\ Q}(P_{c1}, P_{c2}) = r_{Zc}(P_{e1}, P_{d1})$

Input constrained output supply

26. $Q_{e1} = Z_c * r'_{Zc,P_{e1}}(P_{e1}, P_{d1})$ Exports

27. $Q_{d1} = Z_c * r'_{Zc,P_{d1}}(P_{e1}, P_{d1})$ Domestic

Equation 21 is the input supply function of coconut oil processing inputs. Equations 22 and 23 are the output constrained input demand functions derived using Shephard's Lemma. Equation 24 is the multi output product transformation function where the aggregated input equals aggregated output in quantity. Equation 25 sets the unit cost incurred per unit of aggregated output (Q) equal to unit revenue (r_{Zc}) earned per unit of aggregated input (Z_c). Equations 26 and 27 show the input constrained output supply functions of Q_{e1} and Q_{d1}. Those are derived from unit revenue functions applying the Samuelson-McFadden Lemma (Chambers, 1988, p. 264).

Export marketing of coconut oil

Marketing input supply

28. $Q_{e2} = f(P_{e2,} T_9)$

Output constrained input demand

29. $Q_{e1}{=}Y_{ce} * c'_{Y_{ce,P_{e1}}}(P_{e1}, P_{e2})$ Demand for coconut oil
30. $Q_{e2}{=}Y_{ce} * c'_{Y_{ce,P_{e1}}}(P_{e1}, P_{e2})$ Demand for other marketing inputs

Value equilibrium for export marketing

31. $c_{Yc}(P_{e2,}P_{e1}) = r_{Qe}(P_{ce})$

Export demand for coconut oil

32. $Y_{ce} = f(P_{ce}, N_3)$

Equation 28 is the supply function for coconut oil export marketing inputs related to its own price P_{e2}. T_9 is a supply shifter for efficiency gains in marketing strategies that reduce the cost. Equation 29 and 30 are the output constrained input demand functions of Q_{e1} and Q_{e2} derived using Shephard's Lemma. Equation 31 shows the market equilibrium where unit cost of producing output equals the unit revenue or the output price. Equation 32 is the export demand for coconut oil related to its own price P_{ce}. N_3 is a demand shifter.

Domestic retail marketing of coconut oil

Other marketing input supply

33. $Q_{d2} = f(P_{d2,}T_{10})$

Output constrained input demand of coconut oil

34. $Q_{d1} = Y_{cd} * c_{Y_{cd,P_{d1}}}(P_{d1}, P_{d2})$
35. $Q_{d2} = Y_{cd} * c_{Y_{cd,P_{d2}}}(P_{d1}, P_{d2})$

Value equilibrium

36. $c_{Y_{cd}}(P_{d1}, P_{d2}) = r_{Qd}(P_{cd})$

Domestic retail demand for coconut oil

37. $Y_{cd} = f(P_{cd,}N_4)$

Equation 33 is the retail marketing input supply of coconut oil related to its own price P_{d2}. T_{10} is a supply shifter, that may change due to more efficient use of marketing inputs that reduce the marketing margin, for example lower the cost storage, handling and distribution. Equations 34 and 35 are the output constrained input demand functions of Q_{d1} and Q_{d2} derived from unit cost functions. Equation 36 shows the value equilibrium where unit revenue (unit price of output) equals unit cost of producing output. Equation 37 is the retail demand for coconut oil related to its own price P_{cd} and N_4 is a demand shifter.

Other export products

Supply of other processing inputs

38. $X_{d2}{=}f(w_{d2}, T_5)$

Output constrained input demand functions

39. $X_{d1}{=}Y_d * c'_{Y_d,w}(w, w_{d2})$
40. $X_{d2}{=}Y_d * c'_{Y_d,w_{d2}}(w, w_{d2})$

Value equilibrium

41. $c'_{Yd}(w, w_{d2}) = r'_{Xd}(P_d)$

Export demand

42. $Y_d = f(P_{d,}N_5)$

Equation 38 is the supply function of other processing inputs used in other export products processing. w_{d2} is the own price of inputs and T_5 is a supply shifter that shifts the supply curve due to lower cost technologies in processing.

Equations 39 and 40 are the output constrained input demand functions of X_{d1} and X_{d2} derived applying Shephard's Lemma to the unit cost functions. Equation 41 is the market clearing condition for other products that equates the unit cost of producing output to unit revenue earned. Equation 42 is the export demand for other products related to its own price P_d. and N_5 is a demand shifter.

Appendix 3. Model in Displacement Form

The above model with demand and supply equations and decision making equations was totally differentiated to derive the following equations which represent the model in displacement form.

These equations were adjusted to meet the necessary integrability conditions. Mathematical integrability concerns the existence of decision making problems that can be recovered from the demand and supply functions in the displaced form using the parameters. That is, to be able to recover the underlying cost and revenue functions. This concept is a necessity when the objective of the study is to measure the welfare changes and its distribution (Zhao, 1999).

1. $EX = \varepsilon_{X,w}(Ew - t_1)$
2. $EX = \rho_{X_{a1}} * EX_{a1} + \rho_{X_{b1}} * EX_{b1} + \rho_{X_{c1}} * EX_{c1} + \rho_{Xd1} * EX_{d1}$
3. $EX_{a2} = \varepsilon_{X_{a2},w_{a2}}(Ew_{a2} - t_2)$
4. $EX_{a1} = EY_a - k_{X_{a2}} * \sigma_{X_{a1},X_{a2}} * Ew + k_{X_{a2}} * \sigma_{X_{a1},X_{a2}} * Ew_{a2}$
5. $EX_{a2} = EY_a + k_{X_{a1}} * \sigma_{X_{a1},X_{a2}} * Ew - k_{X_{a1}} * \sigma_{X_{a1},X_{a2}} * Ew_{a2}$
6. $k_{X_{a1}} * EX_{a1} + k_{X_{a2}} * EX_{a2} = EY_a$
7. $EY_a = \eta_{Y_a,P_a}(EP_a - n_1)$
8. $EX_{b2} = \varepsilon_{X_{b2},w_{b2}}(Ew_{b2} - t_3)$
9. $EX_{b1} = EZ_{b1} - k_{X_{b2}} * \sigma_{X_{b1},X_{b2}} * Ew + k_{X_{b2}} * \sigma_{X_{b1},X_{b2}} * Ew_{b2}$
10. $EX_{b2} = EZ_{b1} + k_{X_{b1}} * \sigma_{X_{b1},X_{b2}} * Ew - k_{X_{b1}} * \sigma_{X_{b1},X_{b2}} * Ew_{b2}$
11. $k_{X_{b1}} * Ew + k_{X_{b2}} * Ew_{b2} = EP_{b1}$
12. $EZ_{b2} = \varepsilon_{Z_{b2},P_{b2}}(EP_{b2} - t_6)$
13. $EZ_{b1} = EY_b - k_{Z_{b2}} * \sigma_{Z_{b1},Z_{b2}} * EP_{b1} + k_{Z_{b2}} * \sigma_{Z_{b1},Z_{b2}} * EP_{b2}$
14. $EZ_{b2} = EY_b + k_{Z_{b1}} * \sigma_{Z_{b1},Z_{b2}} * EP_{b1} - k_{Z_{b1}} * \sigma_{Z_{b1},Z_{b2}} * EP_{b2}$
15. $k_{Z_{b1}} * EP_{b1} + k_{Z_{b2}} * EP_{b2} = EP_b$
16. $EY_b = \eta_{Y_b,P_b}(EP_b - n_2)$
17. $EX_{c2} = \varepsilon_{X_{c2},w_{c2}}(Ew_{c2} - t_4)$
18. $EX_{c1} = EZ_{c1} - k_{X_{c2}} * \sigma_{X_{c1},X_{c2}} * Ew + k_{X_{c2}} * \sigma_{X_{c1},X_{c2}} * Ew_{c2}$
19. $EX_{c2} = EZ_{c1} + k_{X_{c1}} * \sigma_{X_{c1},X_{c2}} * Ew - k_{X_{c1}} * \sigma_{X_{c1},X_{c2}} * Ew_{c2}$
20. $k_{X_{c1}} * Ew + k_{X_{c2}} * Ew_{c2} = EP_{c1}$
21. $EZ_{c2} = \varepsilon_{Z_{c2},P_{c2}}(EP_{c2} - t_7)$
22. $EZ_{c1} = EQ - k_{Z_{c2}} * \sigma_{Z_{c1},Z_{c2}} * EP_{c1} + k_{Z_{c2}} * \sigma_{Z_{c1},Z_{c2}} * EP_{c2}$
23. $EZ_{c2} = EQ + k_{Z_{c1}} * \sigma_{Z_{c1},Z_{c2}} * EP_{c1} - k_{Z_{c1}} * \sigma_{Z_{c1},Z_{c2}} * EP_{c2}$
24. $k_{Z_{c1}} * EZ_{c1} + k_{Z_{c2}} * EZ_{c2} = \gamma_{Q_{e1}*}EQ_{e1} + \gamma_{Q_{d1}*}EQ_{d1}$
25. $k_{Z_{c1}} * EP_{c1} + k_{Z_{c2}} * EP_{c2} = \gamma_{Q_{e1}*}EP_{e1} + \gamma_{Q_{d1}*}EP_{d1}$
26. $EQ_{e1} = EZ_c - \gamma_{Q_{d1}} * \tau_{Q_{e1},Q_{d1}} * EP_{e1} + \gamma_{Q_{d1}} * \tau_{Q_{e1},Q_{d1}} * EP_{d1}$
27. $EQ_{d1} = EZ_c + \gamma_{Q_{e1}} * \tau_{Q_{e1},Q_{d1}} * EP_{e1} - \gamma_{Q_{e1}} * \tau_{Q_{e1},Q_{d1}} * EP_{d1}$
28. $EQ_{e2} = \varepsilon_{Q_{e2},P_{e2}} * (EP_{e2} - t_8)$
29. $EQ_{e1} = EY_{ce} - k_{Q_{e2}} * \sigma_{Q_{e1},Q_{e2}} * EP_{e1} + k_{Q_{e2}} * \sigma_{Q_{e1},Q_{e2}} * EP_{e2}$
30. $EQ_{e2} = EY_{ce} + k_{Q_{e1}} * \sigma_{Q_{e1},Q_{e2}} * EP_{e1} - k_{Q_{e1}} * \sigma_{Q_{e1},Q_{e2}} * EP_{e2}$
31. $k_{Q_{e2}} * EP_{e2} + k_{Q_{e1}} * EP_{e1} = EP_{ce}$
32. $EY_{ce} = \eta_{Y_{ce},P_{ce}}(EP_{ce} - n_3)$
33. $EQ_{d2} = \varepsilon_{Q_{d2},P_{d2}}(EP_{d2} - t_9)$
34. $EQ_{d1} = EY_{cd} - k_{Q_{d2}} * \sigma_{Q_{d1},Q_{d2}} * EP_{d1} + k_{Q_{d2}} * \sigma_{Q_{d1},Q_{d2}} * EP_{d2}$
35. $EQ_{d2} = EY_{cd} + k_{Q_{d1}} * \sigma_{Q_{d1},Q_{d2}} * EP_{d1} - k_{Q_{d1}} * \sigma_{Q_{d1},Q_{d2}} * EP_{d2}$
36. $k_{Q_{d1}} * EP_{d1} + k_{Q_{d2}} * EP_{d2} = EP_{cd}$
37. $EY_{cd} = \eta_{Y_{cd},P_{cd}}(EP_{cd} - n_4)$
38. $EX_{d2} = \varepsilon_{X_{d2},w_{d2}}(Ew_{d2} - t_5)$

39. $EX_{d1} = EY_d - k_{X_{d2}} * \sigma_{X_{d1},X_{d2}} * Ew + k_{X_{d2}} * \sigma_{X_{d1},X_{d2}} * Ew_{d2}$
40. $EX_{d2} = EY_d + k_{X_{d1}} * \sigma_{X_{d1},X_{d2}} * Ew - k_{X_{d1}} * \sigma_{X_{d1},X_{d2}} * Ew_{d2}$
41. $k_{X_{d1}} * Ew + k_{X_{d2}} * Ew_{d2} = EP_d$
42. $EY_d = \eta_{Y_d,P_d}(EP_d - n_5)$

These 42 equations represent the EDM of the Sri Lankan coconut market. Table 1 in the txt describes the variables and parameters in the model.

Appendix 4. Previous Parameter Estimates

Function	Variables	Value	Source	Data period	Notes
Consumer demand for culinary coconut	Own price	-0.11 (p<0.05)(-3.88)	(Samarajeewa, 2002a)	1970-2000	elasticity
	Income	0.38 (p<0.05) (2.00)			elasticity
Consumer demand for coconut oil	Own price Palm oil price	-45.758 (p=0.025) 65.921 (0.011)	(Samarajeewa, 1999)	1978-1997	Linear relationship There is no long run equilibrium relationship among the model variables
Fresh coconut supply	Supply elasticity (own price)producer price	0.195 (p<0.05) (5.00)	(Samarajeewa, 2002b; Samarajeewa et al., 2002)	1970-2000	
	Supply elasticity (input price-fertilizer)	-0.079 (-0.75)			
Fresh coconut demand	Demand elasticity (own price)Retail price	-0.11 (p<0.05) (-2.25)			
	Demand elasticity (income)	0.3 (p<0.05) (2.39)			
Fresh coconut Price at the producer level	Fresh coconut price at the retail level	0.77 (11.14)			
Coconut oil supply	Supply elasticity coconut oil (own price-producer)	0.512 (p<0.05) (5.16) 0.21 0.01	(Samarajeewa et al., 2002) (Jayalath et al., 2014)	1970-2000 1990-2009	- Single equation Simultaneous equation analysis
	Supply elasticity (input price-fresh coconut)	-0.362(p<0.05) (-2.36) -1.16 -0.19	(Samarajeewa et al., 2002) (Jayalath et al., 2014)	1970-2000 1990-2009	- Single equation Simultaneous equation analysis
Coconut oil demand	Demand elasticity (own price)Retail price	-0.479(p<0.05) (2.51) -0.32 -0.19	(Samarajeewa et al., 2002) (Jayalath et al., 2014)	1970-2000 1990-2009	- Single equation Simultaneous equation analysis
	Per capita income	-0.054 (0.35) 0.13 0.01	(Samarajeewa et al., 2002) (Jayalath et al., 2014)	1970-2000 1990-2009	- Single equation Simultaneous equation analysis

Function	Variables	Value	Source	Data period	Notes
	Price of palm kernel oil	0.51 (2.82)	(Samarajeewa et al., 2002)	1970-2000	
	Price of soy oil	0.079 (0.38)	(Samarajeewa et al., 2002)	1970-2000	
	Palm oil price	0.20 0.25	(Jayalath et al., 2014)	1990-2000	Single equation Simultaneous equation analysis
Coconut oil price at the producer level	Coconut oil price at the retail level	0.739 (2.81) 0.78	(Samarajeewa et al., 2002) (Jayalath et al., 2014)	1970-2000 1990-2009	- Single equation Simultaneous equation analysis
Supply elasticity desiccated coconut	DC price at the Producer level	0.048 (0.806)	(Samarajeewa, 2002b)	1970-2000	
	Supply elasticity (input price-fresh coconut)	-0.22 (p<0.05) (-3.27)	(Samarajeewa, 2002b)	1970-2000	
Export Demand elasticity	DC price at the border	-0.041 (-0.69)	(Samarajeewa, 2002b)	1970-2000	
DC price at the producer level	DC price at the border	0.75 (7.5)	(Samarajeewa, 2002b)	1970-2000	

Appendix 5. Details of Price and Quantity Changes

Appendix Table 5.1: Percentage changes in prices and quantities for different scenarios

	Scenario 1 (t_x=1%)	Scenario 2 (t_{xa2}=-0.1%)	Scenario 3 (t_{xb2}=-0.1%)	Scenario 4 (t_{xc2}=-0.1%)	Scenario 5 (t_{xd2}=-0.1%)	Scenario 6 (t_{Zb2}=-0.1%)	Scenario 7 (t_{Zc2}=-0.1%)
Quantities							
X	-0.13	0.00	0.00	0.00	0.02	0.01	0.00
Xa1	-0.04	0.00	0.00	0.00	-0.01	0.00	0.00
Xa2	0.00	0.10	0.00	0.00	0.00	0.00	0.00
Xb1	-0.51	-0.01	0.05	0.00	-0.13	0.13	-0.01
Xb2	-0.45	0.00	0.15	0.00	-0.12	0.13	-0.01
Xc1	-0.13	0.00	-0.01	0.01	-0.03	-0.01	0.01
Xc2	-0.09	0.00	0.00	0.10	-0.02	-0.01	0.01
Xd1	-0.51	-0.01	-0.02	0.00	0.87	-0.05	-0.01
Xd2	-0.45	0.00	-0.02	0.00	0.93	-0.04	-0.01
Yd	-0.48	0.00	-0.02	0.00	0.90	-0.05	-0.01
Ya	-0.03	0.03	0.00	0.00	-0.01	0.00	0.00
Zb1	-0.50	-0.01	0.06	0.00	-0.13	0.13	-0.01
Zb2	-0.45	0.00	0.05	0.00	-0.12	0.22	-0.01
Zc	-0.13	0.00	-0.01	0.00	-0.03	-0.01	0.02
Zc1	-0.13	0.00	-0.01	0.00	-0.03	-0.01	0.01
Zc2	-0.09	0.00	0.00	0.00	-0.02	-0.01	0.11
Yb	-0.50	0.00	0.06	0.00	-0.13	0.14	-0.01
Q	-0.13	0.00	-0.01	0.00	-0.03	-0.01	0.02
Qe1	-0.11	0.00	0.00	0.00	-0.03	-0.01	0.02
Qe2	-0.09	0.00	0.00	0.00	-0.02	-0.01	0.01
Yce	-0.10	0.00	0.00	0.00	-0.03	-0.01	0.02
Qd1	-0.13	0.00	-0.01	0.00	-0.03	-0.01	0.02
Qd2	-0.09	0.00	0.00	0.00	-0.02	-0.01	0.01
Ycd	-0.13	0.00	0.00	0.00	-0.03	-0.01	0.02
Prices							
w	0.34	0.00	0.01	0.00	0.09	0.03	0.01
wa2	0.00	-0.95	0.00	0.00	0.00	0.00	0.00
wb2	-0.23	0.00	-0.93	0.00	-0.06	0.06	0.00
wc2	-0.05	0.00	0.00	-0.95	-0.01	0.00	0.01
wd2	-0.23	0.00	-0.01	0.00	-0.53	-0.02	0.00
Pd	0.10	0.00	0.00	0.00	-0.18	0.01	0.00
Pa	0.23	-0.30	0.01	0.00	0.06	0.02	0.00
Pb1	0.31	0.00	-0.03	0.00	0.08	0.04	0.01
Pb2	-0.23	0.00	0.02	0.00	-0.06	-0.89	0.00
Pc1	0.33	0.00	0.01	-0.01	0.09	0.03	0.01
Pc2	-0.05	0.00	0.00	0.00	-0.01	0.00	-0.95
Pb	0.25	0.00	-0.03	0.00	0.06	-0.07	0.00
Pe1	0.14	0.00	0.01	-0.01	0.04	0.01	-0.02
Pe2	-0.05	0.00	0.00	0.00	-0.01	0.00	0.01
Pce	0.05	0.00	0.00	0.00	0.01	0.01	-0.01
Pd1	0.32	0.00	0.01	-0.01	0.08	0.03	-0.05
Pd2	-0.05	0.00	0.00	0.00	-0.01	0.00	0.01
Pcd	0.26	0.00	0.01	-0.01	0.07	0.03	-0.04

Appendix Table 5.2: Percentage changes in prices and quantities for different scenarios

	Scenario 8 (t_{Qe2}=-0.1%)	Scenario 9 (t_{Qd2}=-0.1%)	Scenario 10 (n1=0.1%)	Scenario 11 (n2=0.1%)	Scenario 12 (n3=0.1%)	Scenario 13 (n4=0.1%)	Scenario 14 (n5=0.1%)
Quantities							
X	0.00	0.00	0.02	0.06	0.00	0.02881	0.04
Xa1	0.00	0.00	0.10	-0.03	0.00	-0.01579	-0.02
Xa2	0.00	0.00	0.10	0.00	0.00	-0.00096	0.00
Xb1	-0.01	-0.03	-0.19	1.26	-0.01	-0.22113	-0.33
Xb2	-0.01	-0.02	-0.17	1.23	-0.01	-0.19653	-0.29
Xc1	0.01	0.05	-0.05	-0.13	0.02	0.39321	-0.09
Xc2	0.01	0.05	-0.03	-0.09	0.02	0.38910	-0.06
Xd1	-0.01	-0.03	-0.19	-0.49	-0.01	-0.22091	2.17
Xd2	-0.01	-0.02	-0.17	-0.43	-0.01	-0.19632	2.09
Yd	-0.01	-0.02	-0.18	-0.46	-0.01	-0.21034	2.13
Ya	0.00	0.00	0.10	-0.02	0.00	-0.01113	-0.02
Zb1	-0.01	-0.03	-0.19	1.26	-0.01	-0.21989	-0.33
Zb2	-0.01	-0.02	-0.17	1.23	-0.01	-0.19653	-0.29
Zc	0.01	0.05	-0.05	-0.13	0.02	0.39345	-0.08
Zc1	0.01	0.05	-0.05	-0.13	0.02	0.39371	-0.09
Zc2	0.01	0.05	-0.03	-0.09	0.02	0.38910	-0.06
Yb	-0.01	-0.03	-0.18	1.26	-0.01	-0.21722	-0.32
Q	0.01	0.05	-0.05	-0.13	0.02	0.39345	-0.08
Qe1	-0.08	0.05	-0.04	-0.11	-0.17	0.46765	-0.07
Qe2	0.11	0.05	-0.03	-0.09	0.02	0.38910	-0.06
Yce	0.01	0.05	-0.04	-0.10	-0.08	0.43006	-0.07
Qd1	0.01	0.05	-0.05	-0.13	0.03	0.39013	-0.08
Qd2	0.01	0.14	-0.03	-0.09	0.02	0.38910	-0.06
Ycd	0.01	0.06	-0.05	-0.12	0.03	0.38997	-0.08
Prices							
w	0.00	0.02	0.12	0.33	0.01	0.14774	0.22
wa2	0.00	0.00	0.05	0.00	0.00	-0.00048	0.00
wb2	0.00	-0.01	-0.08	0.62	-0.01	-0.09827	-0.15
wc2	0.01	0.02	-0.02	-0.05	0.01	0.19455	-0.03
wd2	0.00	-0.01	-0.08	-0.22	-0.01	-0.09816	1.04
Pd	0.00	0.00	0.04	0.09	0.00	0.04207	0.57
Pa	0.00	0.01	0.10	0.22	0.01	0.10114	0.15
Pb1	0.00	0.02	0.11	0.34	0.01	0.13533	0.20
Pb2	0.00	-0.01	-0.08	0.62	-0.01	-0.09827	-0.15
Pc1	0.00	0.02	0.12	0.32	0.01	0.14842	0.22
Pc2	0.01	0.02	-0.02	-0.05	0.01	0.19455	-0.03
Pb	0.00	0.01	0.09	0.37	0.01	0.10861	0.16
Pe1	0.86	-0.07	0.05	0.14	1.98	-0.59094	0.09
Pe2	-0.95	0.02	-0.02	-0.05	0.01	0.19455	-0.03
Pce	-0.01	-0.03	0.02	0.05	1.04	-0.21503	0.03
Pd1	-0.03	0.02	0.12	0.31	-0.08	0.18427	0.21
Pd2	0.01	-0.93	-0.02	-0.05	0.01	0.19455	-0.03
Pcd	-0.03	-0.13	0.10	0.25	-0.07	0.18587	0.17