Malaysian Journal of Economic Studies 52(2): 205-226, 2015 ISSN 1511-4554

A Comparative Static, Partial Equilibrium, Multi-Commodity Model for Malaysian Agriculture

Yaghoob Jafari*
Islamic Azad University, Shiraz Branch

Jamal Othman**
Universiti Kebangsaan Malaysia

Abstract: Most models for the analysis of Malaysian agricultural policies have been based on partial equilibrium and econometrics. Such models have their own unique strengths but they are not capable of examining factor markets, outputs, trade, and policy linkages across sub-sectors, explicitly and simultaneously. The aim of this paper is to develop a multi-commodity, comparative statics model for the Malaysian agricultural sector with multiple stages of production that links explicitly factor markets, related outputs and agri-environment policy. An illustration of the comparative static effects of a change in export tax for Malaysian crude palm oil is presented.

Keywords: Agri-environment policies, comparative statics, Malaysian agriculture, partial equilibrium

JEL classification: Q10, Q11, Q18, Q58

1. Background and Objectives

Contemporary Malaysian agriculture is confronted with a number of daunting challenges such as scarcity of land supply, labour shortages, public awareness of biodiversity loss, environmental quality degradation and food safety. Aggregate land supply into agriculture has been virtually on a standstill since the mid-1990s, due to strict environment-forest policy enforcement in light of global and domestic concerns related to large scale deforestation and climate change effects. However, clear shifts in the allocation of existing agricultural land use can be seen across the major cultivated crops. Oil palm expansion continues steadily over the years, while the other crops suffered a gradual decline, especially from early 2000 (Figure 1). This somewhat suggests that oil palm expansion to some extent has been fueled by deforestation. Casson (2000) and Corley and Tinker (2003) assert that oil palm expansion in Malaysia has been at the expense of both forest area and shifts in pre-existing crops. Additionally, Koh and Wilcove (2008) argue that during the period 1990 to 2005, 55–59 per cent of oil palm expansion in Malaysia was at the expense of forests where the conversion of pre-existing cropland such as rubber accounted for 41 – 45 per cent of land that went into oil palm plantation. Consequently, they suggest that significant land cover change is a cause of significant biodiversity loss. To date, researchers are yet to empirically quantify the linkages between land use allocation, output markets and policy changes.

* Department of Economics and Management, Shiraz Branch, Islamic Azad University, Shiraz, Iran. Email: *yaghoob.jafari@gmail.com* (Corresponding author)

** Faculty of Economics and Management, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia. Email: *jortman@ukm.edu.my*

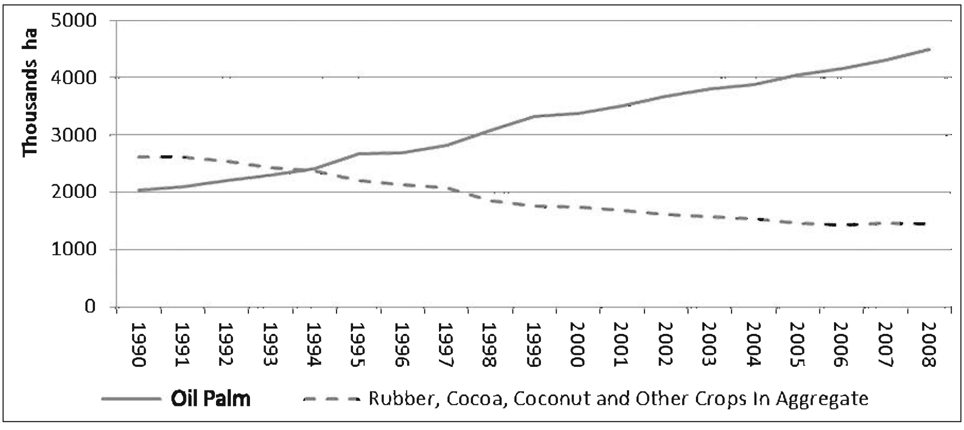

Figure 1. Land reallocation among the main agricultural crops in Malaysia
Data Source: Ministry of Plantation Industries and Commodities (2010).

The second major issue relates to labour shortages. While it has been evident that the contribution of agricultural employment (including livestock, forestry and fishing) has declined substantially from 26 per cent of total employment in 1990 to 12 per cent in 2008, there also has been a clear shift in terms of employment proportion within the various agricultural sub-sectors. For instance, the proportion of labour employed in the oil palm sub-sector increased remarkably, while employment figures in other sub-sectors (rubber, cocoa, and other crops including pepper and tobacco) declined pronouncedly (Ministry of Plantation Industries and Commodities 2010). A related issue is the potential imposition of minimum wage policy and migration reforms within the agricultural sector, especially in the oil palm and rubber sub-sectors. As to how such policies affect Malaysian agricultural competitiveness is not known empirically.

The third daunting challenge relates to the increasing public concerns of biodiversity loss, environmental degradation and food safety. The haze externalities, changes from chemical-based fertilisers to organic supplies, and the well debated food-fuel dilemma are some of the notable examples. Again, to what extent these issues affect the competitiveness of Malaysian agriculture, especially the oil palm sub-sector, is rather unknown.

Undoubtedly, there is a clear need to tract the inter-subsectoral effects of agricultural policies (output, inputs and trade) and changes in other pertinent exogenous variables such as shifts in domestic and export demand on related markets. Contemporary agricultural policy issues, as noted earlier, encompass the rising public concerns of environmental degradation, food safety, as well as labour supply rigidity and minimum wage policy. Traditional econometric-based models are rather deficient when it comes to addressing such multifaceted issues and especially the sectoral or inter-subsectoral effects. It will be a modelling challenge to model the simultaneous effects of policy and pertinent exogenous shifts on interrelated output and input markets, as well as on Malaysia's trade position. Such intricacies constitute the prime motivation of this paper.

Economic models that have been used to appraise Malaysia's agricultural policy issues have been mainly based on partial-equilibrium and econometrics. Such models focus mainly on a single commodity and ignore related markets, including factor markets. Most of the models are associated with the analyses of demand and supply of the major agricultural commodities such as palm oil, rubber, rice, and cocoa. While such models have a distinct advantage in explaining and predicting demand and/or supply factors, they lack the capability to examine related markets simultaneously. General equilibrium models, on the other hand, are able to examine the repercussions emanating from a certain policy change on the entire economy; however, the results are often minute and intractable, due to the emphasis on multi-sectoral aggregation.

This paper aims to construct and apply a comparative static, multi-commodity, exogenous policy model for the Malaysian agricultural sector. In this paper, we highlight the development of a two-commodity model and present an empirical illustration on the case of a tax on Malaysia's crude palm oil exports. As will be clear in the subsequent sections, the model can easily be generalised to incorporate multiple commodities and capture a multitude of policy shocks and exogenous shifts.

2. Literature Review

The earliest work measuring the impact of different agricultural support measures on prices and quantity of agricultural primary factors is that of Floyd (1965). Floyd developed a two-factor model (land and one non-land input including labour and capital) which were combined in a constant return-to-scale production function to produce a single agricultural output. In his model, output and input market clearing conditions determine the equilibrium prices. Then he employed his model to compare the impact of price supports with output restrictions and mandatory land retirement. Although input-based payments have become increasingly common in recent years, Floyd's model does not consider the possibility of producer payments based on land use. Hertel (1989) used Muth's (1964) idea[1] to enlighten on the joint importance of agricultural technology and factor mobility in determining the impact of altering the existing level of agricultural support policies. In so doing, he developed a long run comparative static and partial equilibrium model in determining the impacts of alternative farm policies including output, input and export subsidies; and land retirement on price and quantity of factors demanded and outputs produced. Then he applied his model to the United States agricultural sector. Later, Jamal (1994) and Gunter *et al.* (1996) expanded Hertel's model to develop a model that was able to simulate the effect of changes in input market and government policies on production, returns to input consumption and trade. Jamal's model was applied to the international wheat market (Jamal 1994). Jamal also (i) appraised the link between trade policies and its environmental consequences in Malaysia (Jamal 1997); (ii) assessed the impact of currency depreciation on agricultural land demand with special focus on the Malaysian oil palm sub-sector (Jamal 2000); and (iii) estimated the effect of alternative agricultural policies on the oil palm sector of South-east Asia (Jamal 2003). Models from Hertel (1989), Jamal (1994) and Gunter *et al.*(1996) and their extensions ignored the interaction among the agricultural sub-sectors, and existence of different stages of production.

---

1 Muth (1964) formulated the problem concerning equilibrium in housing and urban land use. The basic framework of Hertel's (1989) model is due to Muth (1964).

Extensive bodies of literature exist on the appraisals of agricultural policies. The most common approaches for the analysis of agricultural policies are econometrics and market equilibrium models including partial and general equilibrium models. Econometric models can be distinguished from the general and partial equilibrium models by the critical role that data plays in informing the structure of the model (Capron and Cincera 2002). In this context, the basic characteristic of econometrics models is that they use historical data to calculate the parameters of the model through various estimation techniques. In contrast, partial equilibrium (PE) and computable general equilibrium (CGE) models are theoretical structures where their parameters are calibrated or obtained from other studies (Brettell 2003). Pollitt *et al.* (2007) argue that econometric models are very resource-intensive and in order to estimate reliable parameters, the use of these models requires the construction of a time series database with the necessary disaggregation which covers a sufficient time period. For this reason the use of econometric models tends to be somewhat limited. According to Pollitt *et al.* (2007), another common criticism of econometric models which base their outcomes on empirically-estimated parameters is that such models are subject to the Lucas Critique. This states that it is a naivety to attempt to estimate the effect of future policy experiments using the estimated results from historical data.

This is even more debatable in bottom-up models when they are highly disaggregated and behaviour in a particular sector could change significantly in a short time. In contrast to this, market equilibrium models to some extent rely on historical data (usually only a single year) to calibrate their parameters and such models are not generally subject to the Lucas Critique as their results tend to be formed by their underlying theory.

The CGE models, compared to partial equilibrium models that study the different sectors separately, consider all linkages within the economy. Therefore, these models are able to capture the direct effect of policy shock on a relevant market, on the other markets and to capture their feedback to the original market. In contrast, in partial equilibrium modeling, one sector is modeled in isolation with others, assuming that prices and quantities in other sectors remain unchanged and hence the possibility that events in these market affect other market equilibrium prices and quantities is ignored. However, the nature of a partial equilibrium model compared to CGE models makes it possible to model a particular sector in a highly-detailed manner. Although partial equilibrium models do not account for as many linkages between product groups as CGE models do, they can provide a transparent and focused analysis of how a limited number of products is affected by the imposition of policy changes and restrictions. Besides, the main criticisms addressed to computable general equilibrium compared to partial equilibrium models are that the CGE models are too aggregate and typically lack a detailed representation of the economy. Consequently, their results fail to address the sectoral relevant issues (Junior and Galvao 2008).

The methodology used in partial equilibrium modeling is commonly of three types, namely single sector models, multi-sectoral models and inter-sectoral models (Winters 1987). The simplest appraisals of an agricultural policy are related to those of single sectors where the entire sector is aggregated to one output and then the impacts of alternative agricultural policies are assessed. Studies on a multi-sectoral set are conceptually identical to the aggregated single models, but because of their wider coverage have attracted greater attention. In a multi-sectoral framework, one can imply the simple partial equilibrium approach to several sectors simultaneously but without modeling the interactions between the sectors explicitly. The inter-sectoral PE models the relationships among the different subsectors explicitly by the cross price elasticities in both demand and supply sides of the sector.

To date, studies on the effect of agricultural policies have focused on individual commodities in Malaysia and ignored the analysis of factor markets and their linkages with output markets. However, the Malaysian agricultural sector, particularly the crop sector comprises important sub-sectors such as oil palm, rubber, paddy and other crops including vegetables which are interlinked through their use of limited primary resources. The paper aims to propose an alternative approach to the econometric and general equilibrium models for agricultural modeling. In particular, the objective of the study is to develop a multi-commodity partial equilibrium model which is capable of taking into account the inter-sectoral linkages, factor markets as well as output and trade markets simultaneously. Appendix A introduces Hertel's model (1989) which will be expanded into a two-commodity model. Interested readers are referred to the paper for detailed construction of the single commodity model.

3. The Development of the Two-Commodity Model

This study constructs a modelling framework where the use of primary inputs and outputs produced within and between agriculture sub-sectors are inter-linked. The model can be used to examine the inter sub-sectoral, comparative static effects of alternative agricultural support policies encompassing input, output and trade policies on the magnitude and direction of changes in a number of variables of interest, including land allocation, labour flows, agrochemical uses, commodity outputs, prices and trade. In this paper, we will first illustrate the development of the comparative static, exogenous policy, partial equilibrium model for two commodities with two subsequent stages of production. The framework can be generalised into a full fledged, multiple commodity model with multiple stages of production. The basic framework for our two-commodity model stems from the theoretical construct of Hertel's (1989) partial equilibrium, comparative statics, and single commodity model for one country.

Figure 2 depicts the conceptual framework that is used to guide the development of the model in this study. In a two-commodity framework, the Malaysian agricultural sector is represented by two competing sub-sectors. The first sector represents the oil palm sub-sector which is Malaysia's most important agricultural sub-sector. The other is an aggregate of all other sub-sectors that compete for the pre-existing resources including land, labour, agrochemicals, and other inputs. As noted in the figure, the primary outputs of the oil palm sub-sector and other subsectors are fresh fruit bunches (FFBs), and other primary outputs (OPP), respectively. The primary output in the oil palm sub-sector (FFB) is destined to produce crude palm oil (CPO), while OPP is intended to produce other final products in aggregate (OFP). Symbols shown in brackets in Figure 2 will be used for mathematical construction of the model. Both CPO and OFP are tradable in the world market place. Since both outputs utilise the same inputs base, any policy shocks or exogenous changes affecting either sub-sector, will have repercussions in all related markets - primary inputs, primary and final outputs as well as trade.

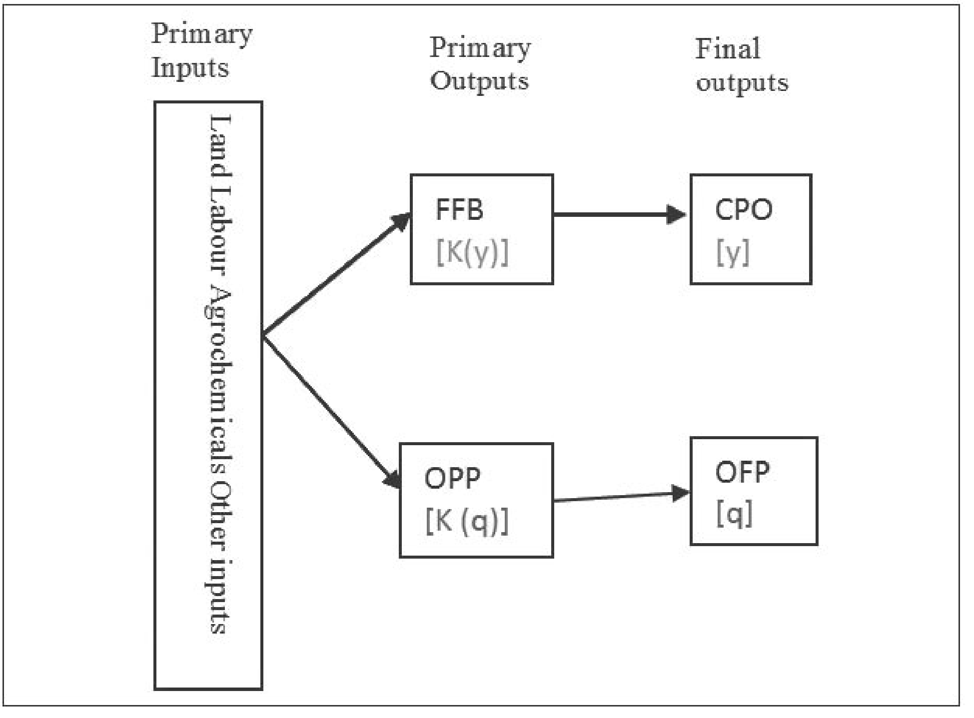

Figure 2. Schematic model of the partial equilibrium, two commodity model for the Malaysian agricultural sector

Table 1 presents the complete system of equations for a long run partial equilibrium for the model as derived from the basic Hertel's model and follows the general conceptual framework shown in Figure 2. Appendix B depicts the notations and descriptions of all the endogenous and exogenous variables in the two-commodity model. Further, Appendix C shows a detailed and systematic explanation on how the model is developed. It is worthwhile to note that this approach can also be generalised for the case of *n* commodities.

Equations 1 and 2 in Table 1 represent the changes in demand for the two final outputs, $\widehat{D}_y^M$ and $\widehat{D}_q^M$, i.e, CPO and OFP, which are functions of domestic and export demand. A notable difference of these equations, relative to Hertel's (1989) basic model, apart from its expansion to a two commodity equation, is the need for incorporation of structural shifts in both domestic and export demand schedules. The extension of the model to capture the demand schedule is due to Jamal (2003). These functions are especially incorporated into the model to capture the impact of alternative agricultural policies on Malaysia's agricultural sector Equation 3 and 4 describe the derived demand for primary outputs *k(y)* and *k(q)* being used in production of *y* and *q* respectively, while Equations 5 and 6 refer to the derived demand for primary inputs, $\widehat{D}_{i,k(y)}$ and $\widehat{D}_{i,k(q)}$, which go into the production of *k(y)* and *k(q)*. Equation 7 portrays the aggregated demand for primary inputs. These equations, relative to Hertel's basic model, apart from its expansion to a two

Table 1. Two commodity partial equilibrium model of the agricultural sector market

Market demand equations	
$\widehat{D}_y^M = \alpha_y^D \varepsilon_{y,y}^D(\hat{P}_y^M - \widehat{U}_y^D) + \alpha_y^D \varepsilon_{y,q}^D(\hat{P}_q^M - \widehat{U}_q^D) + \alpha_y^E \varepsilon_{y,y}^E(\hat{P}_y^E - \widehat{U}_y^E) + \alpha_y^E \varepsilon_{y,q}^E(\hat{P}_q^E - \widehat{U}_q^E)$	1)
$\widehat{D}_q^M = \alpha_q^D \varepsilon_{q,q}^D(\hat{P}_q^M - \widehat{U}_q^D) + \alpha_q^D \varepsilon_{q,y}^D(\hat{P}_y^M - \widehat{U}_y^D) + \alpha_q^E \varepsilon_{q,q}^E(\hat{P}_q^E - \widehat{U}_q^E) + \alpha_q^E \varepsilon_{q,y}^E(\hat{P}_y^E - \widehat{U}_y^E)$	2)
Derived demand under locally constant return to scale condition	
$\widehat{D}_{k(y)} = \varepsilon_{k(y)} \hat{P}_{k(y)}^D + \hat{S}_y^D$	3)
$\widehat{D}_{k(q)} = \varepsilon_{k(q)} \hat{P}_{k(q)}^D + \hat{S}_q^D$	4)
$\widehat{D}_{i,k(y)} = \sum_{j=1}^{n} C_{j,k(y)} \sigma_{ij,k(y)} \hat{P}_{j,k(y)}^D + \hat{S}_{k(y)}^D$	5)
$\widehat{D}_{i,k(q)} = \sum_{j=1}^{n} C_{j,k(q)} \sigma_{ij,k(q)} \hat{P}_{j,k(q)}^D + \hat{S}_{k(q)}^D$	6)
$\widehat{D}_{i,T} = \theta_{i,k(y)} \widehat{D}_{i,k(y)} + \theta_{i,k(q)} \widehat{D}_{i,k(q)}$	7)
Long run zero profit condition	
$\hat{P}_{k(y)}^S = \sum_{i=1}^{n} C_{i,k(y)} \hat{P}_{i,k(y)}^D$	8)
$\hat{P}_{k(q)}^S = \sum_{i=1}^{n} C_{i,k(q)} \hat{P}_{i,k(q)}^D$	9)
$\hat{P}_y^S = C_{k(y),y} \hat{P}_{k(y)}^D$	10)
$\hat{P}_q^S = C_{k(q),q} \hat{P}_{k(q)}^D$	11)
Input supply equations for two sub-sectors	
$\hat{S}_{i,k(y)} = v_{i,k(y)k(y)} \hat{p}_{i,k(y)}^S + v_{i,k(y)k(q)} \hat{p}_{i,k(q)}^S$	12)
$\hat{S}_{i,k(q)} = v_{i,k(q)k(y)} \hat{p}_{i,k(y)}^S + v_{i,k(q)k(q)} \hat{p}_{i,k(q)}^S$	13)
Ad valorem equivalent output policies	
$\hat{P}_y^S = \hat{P}_y^M - \hat{t}_y$	14)
$\hat{P}_q^S = \hat{P}_q^M - \hat{t}_q$	15)
$\hat{P}_{K(y)}^S = \hat{P}_{K(y)}^M - \hat{t}_{K(y)}$	16)
$\hat{P}_{K(q)}^S = \hat{P}_{K(q)}^M - \hat{t}_{K(q)}$	17)
Ad valorem equivalent input policies	
$\hat{P}_{i,K(y)}^S = \hat{P}_{i,K(y)}^D - \hat{l}_{i,K(y)}$	18)
$\hat{P}_{i,K(q)}^S = \hat{P}_{i,K(q)}^D - \hat{l}_{i,K(q)}$	19)
$\hat{P}_{K(y)}^S = \hat{P}_{K(y)}^D - \hat{l}_{K(y)}$	20)
$\hat{P}_{K(q)}^S = \hat{P}_{K(q)}^D - \hat{l}_{K(q)}$	21)
Ad valorem equivalent export policies	
$\hat{P}_y^E = \hat{P}_y^M - \hat{e}_y$	22)
$\hat{P}_q^E = \hat{P}_q^M - \hat{e}_q$	23)
Factor market clearing conditions	
$\widehat{D}_{i,k(y)} = \hat{S}_{i,k(y)}$	24)
$\widehat{D}_{i,k(q)} = \hat{S}_{i,k(q)}$	25)
$\widehat{D}_{k(y)} = \hat{S}_{k(y)}$	26)
$\widehat{D}_{k(q)} = \hat{S}_{k(q)}$	27)
Commodity market clearing conditions	
$\widehat{D}_y^M = \hat{S}_y^D$	28)
$\widehat{D}_q^M = \hat{S}_q^D$	29)

Note: The hat notation denotes percentage changes in variables.

commodity model, explicitly show the two-step production function model while Hertel (1989) considered a single step production function in his model. An incorporation of a two-step production function allows more detailed analysis of agricultural policies and also allows the researcher to be more accurate should agricultural policies be implemented at midstream activities. Appendix A reveals assumptions used along with supporting theories in the construction of derived demand equations. Equations 8 through 11 depict the zero profit conditions for the production of primary and final outputs. These equations which feature the long-run assumption ensure that in the long run, there is zero profit for firms. Equations 11 and 12 describe the responsiveness of land and non-land supply factors to a change in rents or return under the assumptions that $0 < v < \infty$. The nature of the two-commodity model requires capturing the rigidity of primary inputs among sub-sectors and the degree of input supply responsiveness to relative price changes between the sub-sectors. Hertel's input supply equations are expanded to capture primary input movements among the sub-sectors. The value of primary inputs supply cross-price elasticity (e.g. the elasticity of land supply in the oil palm sector with respect to changes in land rent in other agricultural sectors in aggregate) that determine the movement of inputs across sectors. These equations are especially formulated to capture the heterogeneity of land inputs. Land inputs are heterogeneous in the sense that they have their own biological characteristics which are crop specific. Agricultural land under the cultivation of perennial crops, in this case the oil palm sub-sector, is somewhat different from that of other crops in aggregate. In order to capture the varying rigidity of land supply across sub-sectors, a methodology which is able to capture such characteristics of land is incorporated into the model. The standard version of Global Trade Analysis Project (GTAP) of Hertel (1997) addresses this need by determining the supply of land across different uses through a constant elasticity of transformation supply function. Equations 14 through 23 incorporate exogenous sectoral *ad valorem* output, input, and trade policy variables into the model. Here, $\hat{t} < 0, \hat{l} < 0, \hat{e} < 0,$ reflect the percentage changes in output, input and export subsidies, respectively. The last six equations describe the market clearing conditions, where no surpluses or deficits in inventory of outputs and inputs are assumed.

4. Solving Strategy and Database

Mathematically, Equations 1 - 29, form a linear system that can be solved given the non-singularity of coefficients matrix condition. The necessary and sufficient condition for non-singularity of the matrix is that the matrix shall satisfy the squareness and linear independence equations. A convenient way of solving a linear equation system is by using the well-known Cramer's rule. The system of equations in the model can be written in a matrix form, so that the general system of algebraic equations can be represented compactly as follows:

$$AX = C$$

Here A is the Jacobean matrix (coefficient of the endogenous variables of the model), X represents the matrix of endogenous variables (prices and quantities) while the right hand side matrix denotes the exogenous variables (policy shocks). Thereafter, we can apply Cramer's rule to solve for the endogenous variables.

Before any simulation is performed, it is imperative that the baseline parameters or coefficients for the endogenous variables are obtained. The present model contains

Table 2. Distribution share of primary inputs in different sub-sectors

Primary inputs	Oil palm	Other crops in aggregate	Source
Land	0.758	0.242	Ministry of Plantation Industries and Commodities (2010a)
Labour	0.8878	0.1122	Department of Statistics (2008)
Capital	0.83	0.17	
Agrochemicals	0.841	0.159	Mohammad Ali Sabri (2009)

Table 3. Allen elasticities of substitution between primary inputs in oil palm plantation

	Land	Labour	Agrochemical	Capital
Land	-0.3	0.078	-0.042	0.645
Labour	0.078	-0.79	0.492	0.895
Agrochemicals	-0.042	0.492	-1.007	0.378
Capital	0.645	0.895	0.378	-4.147
Factor cost share	0.36	0.31	0.19	0.14

Source: Mahendra Romous (2006)

61 parameters. This includes the Allen elasticities of substitution between inputs for the various primary outputs, factor shares, factor cost shares, and demand and supply elasticity values. Likewise many partial and general equilibrium models include a large number of parameters with some of the parameters being obtained, calibrated, guestimated, or assumed (see Salhofer 2000). In this study, primary input market shares are calculated based on raw data from various sources (See Table 2). This study assumes that the relative level of Allen elasticities and input cost share in the palm oil sub-sector in Malaysia and Indonesia are fairly comparable and hence, the Allen elasticity of substitution parameters and input market share values employed for the oil palm sub-sector are sourced from estimations for Indonesia's oil palm (Table 3). The value of input cost share and own price elasticities as an aggregate of other agricultural crops sub-sector is borrowed from OECD PEM model (Salhofer 2000; OECD 2003). Input market shares between sub-sectors and own input price elasticities are not defined for Malaysian agriculture and therefore, despite the heterogeneity that might exist between EU region and Malaysia's agricultural practices, we assumed that the values of such parameters are fairly comparable. Such assumptions are common in partial and general equilibrium when researchers want to overcome the problem of data gathering. Consequently we used Binswanger (1974) equations to calibrate Allen elasticities of substitution as an aggregate of all other crops subsector (Table 4).

The primary input supply elasticities in Malaysia, as defined in the model, are not directly available from the literature, but have to be deduced from the review of studies of this kind. Salhofer (2000) reviewed microeconomic studies on farm level primary factor supplies and recommended the use of the mean value of maximum and minimum points as benchmark data. Following Salhofer (2000) and OECD (2003), we assigned the values

Table 4. Allen elasticities of substitution between primary inputs in other crops in aggregate

	Land	Labour	Capital	Agrochemicals
Land	-4.2	0.3	0.1	2.7
Labour	0.3	-7.35	0.4	1.3
Capital	0.1	0.4	-2.27	0.6
Agrochemicals	2.7	1.3	0.6	-1.322
Factor cost share *	0.3	0.1	0.15	0.45

Source: Factor cost shares and own price elasticities are obtained from OECD (2003); Salhofer (2000) while other parameters are calibrated.

of 0.6 and 1 for land and non-land input supply elasticities, respectively. The elasticity of transformation value for land input based on GTAP-AGR model of Keeney and Hertel (2005) is 0.25 while the value of 1 is assigned to the elasticity of transformation for other inputs. Following GTAP Policy Evaluation Model (OECD 2003) the transformation elasticities have been calibrated to the land cross-supply elasticities.

With regard to the value of CPO export elasticity, we used an average of -0.3236 from Shri Dewi *et al.* (2011) and -0.457 from Basri Talib and Zaimah Darawi (2002). Accordingly, the value of -0.39 is assigned for CPO export elasticity, while the value of CPO domestic demand elasticity is taken from FAPRI elasticities database. The value of OPP own price elasticities (-0.19) is taken from GTAP database (Betina *et al.* 2006); and we assumed that the aggregated elasticity is normally distributed between foreign and domestic market, and therefore the value of -0.19 is assigned to own export and domestic demand elasticities. The value of other parameters, including CPO export and domestic demand share (0.122, 0.878), and OFP export and domestic demand share (0.133, 0.867) are calculated based on *Statistics of Commodities* (Ministry of Plantation Industries and Commodities, 2010a) and *Agricultural Statistics Handbook* (Ministry of Plantation Industries and Commodities, 2010b), respectively. It is important to note that although changes in the baseline coefficients of the endogenous variables in the model may lead to changes in the magnitude of exogenous variables, our sensitivity analysis[2] reveals that the direction and relative order of impacts of the result would be still reliable, provided that the meaningful sign is given to substitution or complementary possibilities.

5. Model Application - A 10 Per cent Export Tax on CPO Exports

The constructed model is capable of appraising a wide range of agri-environmental policy issues. This includes input, output and trade taxes (subsidies). Effects of shifts in domestic and export demand schedules due to some exogenous factors (e.g. changes in consumer preference and increases in disposable incomes) can also be simulated. As an illustration, this paper considers a 10 per cent tax on Malaysia's exports of CPO. Recall that in this paper, CPO is modeled as the only final output from the use of FFB. In reality this is never the case, as CPO is further processed into processed palm oil and oleo chemicals. This implies the model here will not show the effects of any policy changes on any CPO-derived products.

[2] The sensitivity analyses are not presented in the paper to save space.

Next, the model was validated by its ability to replicate the initial value of endogenous variables when baseline policies were implemented. Section 4 presented all the required baseline coefficients and parameters, including data sources. Simulation results, i.e., effects of the policy change on the endogenous variables are listed in Appendix D. It shall be noted here, that the major focus of this type of appraisals is on the direction and relative order of impacts. Given the uncertain nature of the various baseline values, examination of fine tune numbers will be immaterial. The results generally show an inverse relation of long-run impacts among the endogenous variables representing each sub-sector. An increase in export taxes on CPO increases its export price by 9.46 per cent and decreases its export demand by 3.69 per cent. Besides, an increase in export taxes on CPO decreases its market price by 0.53 per cent and hence increases its domestic demand by 0.22 per cent.

Although, an increase in the domestic demand for CPO somewhat offsets the decline in its export demand of 3.69 per cent, its market demand (sum of export and domestic demand) decreases by 0.25 per cent. This in turn, directly decreases the demand for FFBs by 0.25 per cent and the price of FFBs or/and CPO by 0.53 per cent. The decline in demand for FFBs has a straight forward impact of reducing the demand for primary factors in oil palm plantation through derived factor demand functions when constant returns to scale conditions are assumed. On the other hand, the lower demand for primary inputs in the oil palm sub-sector is associated with a decrease in market price for the respective primary inputs within the sub-sector. Consequently, factor owners will reallocate their inputs to other sub-sectors to obtain higher factor returns. Further, changes in the price of primary factor inputs will lead to changes in input combinations in each sub-sector. These linkages are provided through the Allen elasticities of substitution. Accordingly, the use of primary factors including, land, agrochemicals, employment and other inputs are estimated to decrease by 0.22, 0.28, 0.25, and 0.24 per cent, respectively. The decrease in the use of primary inputs in the oil palm sub-sector will provoke a decline in the use of primary inputs in other sub-sectors. The lower demand for the primary factors of production in the oil palm sub-sector makes the price of these factors cheaper in this sub-sector relative to OPP sub-sector. The relatively higher price of primary factors in other crop sub-sectors motivates the farmers to reallocate the use of these factors from oil palm to the OPP sub-sector. As a result, the use of land, labour and other inputs is anticipated to be reduced in the oil palm sub-sector, while increased in OPPs sub-sectors. The total use of primary inputs in the agricultural sector is estimated to decrease slightly as the oil palm sub-sector has the highest share of each primary input use in the Malaysian agricultural sector. The relative percentage changes in the demand for primary factors are very small especially when it comes to land input which is almost zero.

Generally, the results of the study demonstrate clear opposite relationships of impacts amongst variables that signify each sub-sector. As FFB and CPO outputs fall due to export taxes, prices fall, consequently demand for the corresponding factors declines, thus depressing factor prices within the sub-sector. In a two sub-sector framework, inputs can be seen flowing into the competing sub-sector. Hence, output of the competing sub-sector (OPP) increases along with increases in demand for primary inputs. Total demand for inputs going into the agriculture can also be appraised. For instance, while demand for land going into the oil palm sub-sector declines by 0.22 per cent and land demand in the competing sub-sector increases by 0.71 per cent, total land demand within the entire agricultural economy remains unchanged. This is attributable to the much larger share of land use by the oil palm sub-sector.

Drawing upon the direction and order of impacts affecting the various endogenous variables, one can draw insights on the usefulness of the comparative statics and the multi-commodity modelling framework, especially in providing tractable endogenous results for a set of closely related and/or competing commodities. The main purpose of this study is to construct a two commodity model which is valid for application to the Malaysian agricultural sector. However, more meaningful insights and implications of the results could be derived by conducting sensitivity analyses to examine the effects of varying assumptions of the baseline coefficients of the endogenous variables in the model.

6. Conclusion and Future Research

Malaysia's agricultural sub-sectors are inevitably linked due to resource constraints, especially land and labour. Contemporary Malaysian agriculture is also associated with environmental issues such as loss of biodiversity, environmental degradation, and food safety. Additionally, the sector is subjected to a myriad of domestic and trade support measures. Changes in any such policy in one sub-sector would affect inputs use, production, price of crops and exports within and other related sub-sectors. This study developed a two-commodity, comparative statics, partial equilibrium model which can be used to simulate the effects of alternative agricultural policies and pertinent exogenous shifts on output markets, inputs and trade. The model can be further generalised and expanded to consider multiple commodities or sub-sectors and also to incorporate policy changes and exogenous shifts associated with rising public concerns on biodiversity loss, climate change, minimum wages, migration reforms and food-fuel issues. Welfare function representing the various interest groups can also be incorporated into the model framework.

Acknowledgements

We are very grateful to anonymous referees whose constructive comments have helped to improve the quality of the paper.

References

Basri Talib and Zaimah Darawi. 2002. An economic analysis of the Malaysian palm oil market. *Oil Palm Industry Economic Journal* **2(1)**:19-27.

Betina V. D., R.A. McDougal and T.W. Hertel. 2006. *GTAP 6 data base documentation - Chapter 20: Behavioral Parameters*. Center for Global Trade Analysis, Purdue University.

Binswanger, H. P. 1974. A cost function approach to the measurement of elasticities of factor demand and elasticities of substitution. *American Journal of Agricultural Economics* **56(2):** 377-386.

Brettel, S. 2003. Econometric modelling in the evaluation of regional sustainable development. Paper presented at the *3rd workshop of the EU Thematic Network project REGIONET*, UK, Manchester, 11-13 June.

Capron, H. and M. Cincera. 2002. Econometric models: Macroeconomic modelling and simulation approaches. In *European Commission RTD Evaluation Toolbox.* Institute for Prospective Technological Studies and Joanneum Research.

Casson, A. (2000) *The Hesitant Boom: Indonesia's oil palm subsector in an area of economic crises and tropical change.* CIFOR Program on the underlying Causes of Deforestation.

Chizmar, J.F. and T.A. Zak. 1983. Modeling multiple outputs in educational production functions. *The American Economic Review* **73(2)**:18-22.

Corley, R. and P. Tinker (Eds.). 2003. *The Oil Palm*. 4th Edition. Oxford: Blackwell Publishing.

Department of Statistics, Malaysia. 2008. *Economic Census of 2006*. Putrajaya: Department of Statistics.

Floyd, J.E. 1965. The effects of farm price supports on returns to land and labour in agriculture. *Journal of Political Economy* **73**:148-158.

Food and Agricultural Policy Research Institute (FAPRI). Elasticities database. *http://www.fapri.iastate.edu/.*

Gunter, L.F., K.H. Jeong and F.C. White. 1996. Multiple policy goals in a trade model with explicit factor markets. *American Journal of Agricultural Economics* **78(2):** 313-330.

Hertel, T. W. 1997. *Global Trade Analysis: Modeling and Applications.* Cambridge: Cambridge University Press.

Hertel, T.W. 1989. Negotiating reductions in agricultural support: implications of technology and factor mobility. *American Journal of Agricultural Economics* **71(3):** 559-73.

Jamal Othman. 1994. *A comparative static, game theoretic trade model with explicit cross-country policy linkages.* Ph.D dissertation, Department of Agriculture and Applied Economics, University of Georgia, Athens.

Jamal Othman. 1997. Linking factor markets, environment and trade: The case of oil palm in Malaysia. *Jurnal Ekonomi Malaysia* **31:** 53-69.

Jamal Othman. 2000. Linking exchange rates, market failures and agricultural land demand. *Jurnal Ekonomi Malaysia* **34**: 21-27.

Jamal Othman. 2003. Linking agricultural trade, land demand, and environmental externalities: Case of oil palm in Southeast Asia. *ASEAN Economic Bulletin* **3(20):** 244-55.

Junior, F. and R.Galvão. 2008. *Are CGE models still useful in economic policy making*? Economics Working Papers No. 674 (Ensaios Economicos da EPGE). Graduate School of Economics, Getulio Vargas Foundation (Brazil).

Just, R., D. Zilberman and E. Hochman. 1983. Estimation of multi crop production functions. *American Journal of Agricultural Economics* **65(4)**:770-80.

Keeney, R. and T.W. Hertel. 2005. *GTAP-AGR: A framework for assessing the implications of multilateral changes in agricultural policies*. GTAP Technical Papers. Center for Global Trade Analysis, Purdue University, USA.

Koh, L.P and D.S. Wilcove. 2008. Is oil palm agriculture really destroying tropical biodiversity. *Conservation Letters* **1(2):** 60-64.

Mahendra Romous. 2006. *Input substitution elasticities, technology changes and economy of scale: Case study of oil palm in Indonesia*. Ph.D Dissertation. Universiti Kebangsaan Malaysia, Bangi.

Ministry of Plantation Industries and Commodities. 2010a. *Handbook of Agricultural Statistics.* Kuala Lumpur, Malaysia.

Ministry of Plantation Industries and Commodities. 2010b. *Statistics on Commodities 2009.* Kuala Lumpur, Malaysia

Ministry of Plantation Industries and Commodities. 2010. *Statistics on Commodities 2009.* Kuala Lumpur, Malaysia.

Mohamed Ali Sabri. 2009. Evolution of fertilizer use by crops in Malaysia: recent trends and prospects. Paper presented at the *IFA Crossroads Asia-Pacific 2009 Conference,* Kota Kinabalu, Malaysia, 8-10 December.

Muth, R.F. 1964. The derived demand curve fora productive factor and the industry supply curve. *Oxford Economic Papers* **16(2):** 235-261.

OECD. 2003. *OECD's Policy Evaluation Model.* Paris: OECD.

Pollitt, H., U. Chewpreecha and P. Summerton. 2007. *E3ME: An energy–environment– economy model for Europe: A technical description.* Cambridge: Cambridge Econometrics Limited.

Salhofer, K. 2000. Elasticities of substitution and factor supply elasticities in European agriculture: A review of past studies. In *Markets Effects of Crop Support Measures*, ed. OECD, pp. 89-119. Paris: OECD.

Shri Dewi Applanaidu, Fatimah Mohamed Arshad, Mad Nasir Shamsudin & Amna Awad Abdel Hameed. 2011. An econometric analysis of the link between biodiesel demand and Malaysian palm oil market. *International Journal of Business and Management* **6(2)**:35-45.

Winters, L.A. 1987. The political economy of the agricultural policy of industrial countries. *European Review of Agricultural Economics* **14 (3):**285-304.

Appendix A: A Brief Introduction to Hertel's (1989) Model

Hertel (1989) used Muth's (1964) idea to enlighten on the joint importance of agricultural technology and factor mobility in determining the impact of altering the existing level of agricultural support policies. In so doing, he developed a long run comparative static and partial equilibrium model in determining the impacts of alternative farm policies such as output, input and export subsidies, land retirement on price and quantity of output produced and factors demanded. Then he applied his model to the United States agricultural sector. Hertel's system of equations for a long run partial equilibrium model of the farm sector is presented in Table A.

Table A. Hertel's equations for a long run partial equilibrium model of the farm sector

Commodity demand equation

$$\hat{q}_O^M = (1-\alpha)\, E_D^D \hat{p}_0^M + \alpha E_D^E \hat{p}_0^E \quad \text{(A.1)}$$

Derived demand under locally constant return to scale

$$\hat{q}_j^F = \sum_{i=1}^{n} c_i\, \sigma_{ij}\, \hat{p}_i^F + \hat{q}_O^S \quad \text{(A.2)}$$

Zero profit condition

$$\hat{p}_O^F = \sum_{i=1}^{n} c_i \hat{p}_i^f \quad \text{(A.3)}$$

Non land supply function

$$\hat{p}_j^M = 0\ (j \neq L) \quad \text{(A.4)}$$

Land supply function

$$\hat{q}_L^M = v_l\, \hat{p}_L^M \quad \text{(A.5)}$$

Ad valorem Equivalent Output policy

$$\hat{p}_O^S = \hat{p}_O^M - \hat{t}_O \quad \text{(A.6)}$$

Ad valorem Equivalent Input Policy

$$\hat{p}_j^F = \hat{p}_j^M - \hat{s}_j \quad \text{(A.7)}$$

Ad valorem Equivalent Export Policy

$$\hat{p}_O^E = \hat{p}_O^M + \hat{e}_O \quad \text{(A.8)}$$

Commodity market clearing condition

$$\hat{q}_O^M = \hat{q}_O^S \quad \text{(A.9)}$$

Land market clearing condition

$$\hat{q}_L^M = \hat{q}_L^F \quad \text{(A.10)}$$

Source: Source: Hertel (1989)

The *hat* notation represents the relative change in the relevant variable. The scripts *q* denotes the quantity and script *p* denote the price of output and inputs, while *i* and *j* refer to inputs. The superscript *M* and *O* denote market quantity or price, while subscript *F* refers to the farm supply. Superscripts *D* and *E* refer to domestic and export demands. Equation (A.1) represents demand for aggregate commodity. Here, E_D^D , E_D^E are the elasticity of domestic and export demand for aggregate commodity. Additively, $\hat{P}_0^M$, $\hat{P}_0^E$ denotes the relative changes of output price in domestic and export market. Coefficient α refers to the quantity share of export in total demand and (1 - α) shows the quantity share of domestic demand with respect to the market demand. This equation shows the price responsiveness of market demand $\hat{q}_O^M$, for an aggregated agriculture product. Equation A.2 represents the derived demand function under the locally constant return to scale condition. The variables c and α stand for cost share of each input and Allen partial elasticity of substitution, respectively. Here, $\hat{q}_j^F$, $\hat{p}_i^F$ and $\hat{q}_O^F$ represents the percentage changes in input quantities, input prices and the quantity of an aggregated agricultural output, respectively. The assumption of zero profits for the aggregate farm sector is given by equation A.3. This equation states that in the long run firm output price moves in the same direction as input prices, implying that firms will achieve the zero economic profit in the long run. Equation A.4 depicts the supply of non-land factors to the farm sector at an exogenously determined price. In this equation, the infinite availability of non-land factor inputs are assumed. Equation A.5 describes the responsiveness of total farmland supply to a change in land rents under the assumptions that $0 < v < \infty$. In other words, the finite availability of land resources is assumed in this equation. Here, v, $\hat{q}_L^M$ and $\hat{p}_L^M$ represent land demand responsiveness of rent, changes in land demand, and land prices. Equations A.6 through A.8 incorporate exogenous sectoral ad valorem output, input, and trade policy variables into the model. In these equations, $\hat{t}_0$, $\hat{s}_j$ and $\hat{e}_0$ are percentage changes in output, input, and export subsidies, respectively. In this respect, $\hat{t}_0 < 0$ and $\hat{e}_0 < 0$ reflect the output subsidies, while $\hat{s}_j > 0$ shows the input subsidies. Equations A.9 and A.10 describe the market clearing conditions for output, and land. Commodity market clearing represents that the farm product price must adjust to equilibrate supply and demand for farm product. Input market clearing condition represents that land rent must adjust in order to equilibrate supply and demand in the land market. In other words, the last two equations show that the excess demand for the output produced and input demanded are zero.

Appendix B. Definitions of Variables for the Two Commodities Exogenous Policy Model

The superscripts *M* and *E* respectively, represent the market and export demand for commodities while superscript *D* denotes the domestic demand for or supply of commodities. Scripts *D, S* and *P* refer to the demand, supply and price of inputs or outputs respectively, while scripts *t*, *e* and *I* refer to the output, export and input subsidies (taxes), correspondingly. Subscripts *i* and *j* signify primary factors of production including land, labor, agrochemicals, and an aggregate of other primary inputs (*i, j* =1, 2, 3, 4). Subscripts *y* and *q* denote the production of each agricultural subsector, while *k(y)* and *k (q)* refer to primary output being used in the production of the two final outputs, *y* and *q*, respectively.

Endogenous variables	
D_y^M, D_q^M	Market demand for final outputs (y and q), e.g., CPO and OFP
$D_{k(y)}, D_{k(q)}$	Derived demand for primary outputs k(y) and k(q), e.g., FFB, OPP
D_y^E, D_q^E	Export demand for final outputs (y and q)
D_y^D, D_q^D	Domestic demand for final outputs (y and q)
$D_{i,k(y)}, D_{i,k(q)}$	Derived demand for i^th primary input being used in production of k(y) and k(q)
S_y^D, S_q^D	Domestic supply of agricultural outputs (y and q)
$S_{i,k(y)}, S_{i,k(q)}$	Supply of i^th primary input being used in production k(y) and k(q)
P_y^S, P_q^S	Supply price of agricultural outputs (y and q)
$P_{k(y)}^S, P_{k(q)}^S$	Supply price of k(y) and k(q)
P_y^M, P_q^M	Market price of final outputs (y and q)
$P_{k(y)}^M = P_{k(y)}^D, P_{k(q)}^M = P_{k(q)}^D$	Market(Demand) Price of primary outputs k(y) and k(q)
P_y^E, P_q^E	Export price of final outputs (y and q)
Parameters	
D_y^M, D_q^M	Own price elasticity of domestic demand for final outputs (y and q) when (y=q) / Cross price elasticity of domestic demand for final outputs y and q) when (y≠q)
$D_{k(y)}, D_{k(q)}$	Derived demand elasticity of k(y)and k(q)
D_y^E, D_q^E	Allen substitution elasticity between input i and j being used in production of k(y)and k(q).
D_y^D, D_q^D	Share of export demand for y and q with respect to their market demand
$D_{i,k(y)}, D_{i,k(q)}$	Share of domestic demand for y and q with respect to their market demand
S_y^D, S_q^D	The cost share of i^th primary input with respect to total cost of producing k(y) and k(q)
$S_{i,k(y)}, S_{i,k(q)}$	Share of i^th input employed in production of k(y) and k(q)
P_y^S, P_q^S	Own supply elasticity of i^th input in the production of k(y) and k(q)
$P_{k(y)}^S, P_{k(q)}^S$	Cross supply elasticity of i^th input in the production of k(y) and k(q)
P_y^M, P_q^M	
$P_{k(y)}^M = P_{k(y)}^D, P_{k(q)}^M = P_{k(q)}^D$	
P_y^E, P_q^E	
Exogenous variables (policy shocks)	
e_y, e_q	Export subsidy(tax) on final outputs, y and q, (ad valorem)
t_y, t_q	Output subsidy(tax) on final outputs, y and q, (ad valorem)
$t_{k(y)}, t_{k(q)}$	Output subsidy(tax) on production of primary outputs, k(y) and k(q), (ad valorem)
$l_{i,k(y)}, l_{i,k(q)}$	Inputs subsidy(tax) on i^th input being used in production of k(y) and k(q)
$l_{k(y)}, l_{k(q)}$	Input subsidy on use of k(y) and k(q) as an input in production of y and q
U_y^D, U_q^D	Shift in domestic demand schedules for y and q
U_y^E, U_q^E	Shift in export demand schedules for y and q

Appendix C: Mathematical Framework for the Two-commodity Model

Following Hertel (1989), the mathematical formulation in this study is specified for a long run partial equilibrium model under the assumption of perfect competition in the market.

Commodity Market Demand Module

Suppose that there are two commodities, *y* and *q* which are produced by the firms in domestic market and are consumed by the consumers in domestic and foreign markets. The demand for these two commodities could be either separable or related. Besides, it is assumed that consumers have the homothetic preferences, implying that the budget share that the consumers allocate to the commodities is independent of their total expenditure. The market demand for output *y*, is the function of the domestic and export demand (D_v^D, D_v^E) (Therefore, the market demand function in implicit form is:

$$D_y^M = D_y^M\left(D_y^D, D_y^E\right) \quad \text{(C.1)}$$

Additionally, the domestic demand for output *y*, D_y^D is the function of own and cross prices in the domestic market (P_y^M, P_Q^M); while, export demand for output *y*, Q_y^E is a function of own and the cross prices in export market (P_y^E, P_Q^E). Therefore, under the assumption that domestic demand for commodity y is not the function of its own and cross export prices and the export demand for commodity *y* is not function of own and the cross prices in domestic market, the domestic and export demand functions for commodity *y* are defined as:

$$D_y^D = D_y^D(P_y^M, P_Q^M) \quad \text{(C.2)}$$

$$D_y^E = D_y^E(P_y^E, P_Q^E) \quad \text{(C.3)}$$

Considering equations A.1 through A.3 and providing that demand function is the summation of market and export demand, the demand function for commodity *y* is:

$$D_y^M = D_y^D(P_y^M, P_q^M) + D_y^E(P_y^E, P_q^E) \quad \text{(C4)}$$

By total differentiation of Equation A.4 and manipulating it for obtaining the elasticities and market shares, the market demand function for commodity *y* would be defined as follows:

$$\widehat{D}_y^M = \alpha_y^D \varepsilon_{y,y}^D \widehat{P}_y^M + \alpha_y^D \varepsilon_{y,q}^D \widehat{P}_q^M + \alpha_y^E \varepsilon_{y,y}^E \widehat{P}_y^E + \alpha_y^E \varepsilon_{y,q}^E \widehat{P}_q^E \quad \text{(C.5)}$$

Here, *hat* notation denotes the percentage changes in the variable (e.g. $\widehat{D}_y^M = \frac{dD_y^M}{D_y^M}$).). It should be noted that, this study considers the Marshalian demand elasticities to capture the demand relationships between the commodities. The market demand function for commodity *q* is similar to that of *y*. Following Jamal (2003), market demand equations can be further extended to incorporate shifts in domestic and export demand. By some simple manipulation of market demand equations for *y* and *q*, shifts in the domestic and export demand for the two commodities can be expressed, respectively, as the shifts in the direction of price axis:

$$\widehat{P}_y^M = \frac{\widehat{D}_y^M - \alpha_y^D \varepsilon_{y,q}^D \widehat{P}_q^M + \alpha_y^E \varepsilon_{y,y}^E \widehat{P}_y^E + \alpha_y^E \varepsilon_{y,q}^E \widehat{P}_q^E}{\alpha_y^D \varepsilon_{y,y}^D} + \widehat{U}_y^D \quad \text{(C.6)}$$

$$\widehat{P}_y^E = \frac{\widehat{D}_y^M - \alpha_y^D \varepsilon_{y,y}^D \widehat{P}_y^M + \alpha_y^D \varepsilon_{y,q}^D \widehat{P}_q^M + \alpha_y^E \varepsilon_{y,q}^E \widehat{P}_q^E}{\alpha_y^E \varepsilon_{y,y}^E} + \widehat{U}_y^E \quad \text{(C.7)}$$

$$\widehat{P}_q^M = \frac{\widehat{D}_q^M - \alpha_q^D \varepsilon_{q,y}^D \widehat{P}_y^M + \alpha_q^E \varepsilon_{q,q}^E \widehat{P}_q^E + \alpha_q^E \varepsilon_{q,y}^E \widehat{P}_y^E}{\alpha_q^D \varepsilon_{q,q}^D} + \widehat{U}_q^D \quad \text{(C.8)}$$

$$\widehat{P}_q^E = \frac{\widehat{D}_q^M - \alpha_q^D \varepsilon_{q,q}^D \widehat{P}_q^M + \alpha_q^D \varepsilon_{q,y}^D \widehat{P}_y^M + \alpha_q^E \varepsilon_{q,q}^E \widehat{P}_q^E}{\alpha_q^E \varepsilon_{q,y}^E} + \widehat{U}_q^E \quad \text{(C.9)}$$

where $\widehat{U}_y^D$ and $\widehat{U}_y^E$ and represent percentage shifts in domestic output and export demand schedules for commodity *y*, $\widehat{U}_q^D$ and $\widehat{U}_q^E$ represent percentage shifts in domestic output and export demand schedules for commodity *q*. Considering equations C.6 through C.9, the market demand functions which incorporate shifts in domestic and export demand schedules can be expressed in the forms of equations 1 and 2 in Table 1.

Derived Demand Functions under Locally Constant Return to Scale

There are three basic ways to model production of more than one output by the same firm. One can use separate production functions for each output, a single joint production functions, or simultaneous production functions for the outputs. Chizmar and Zak (1983) suggest that both the relationship among the outputs and the issue of input exhaustion must be considered in determining which modeling technique is appropriate. Input exhaustion is complete if using an input to produce the output completely exhausts that input, so that it cannot be used to produce other outputs. The approach of treating each output separately with its own production function is appropriate when the outputs are produced by separate production processes with complete input exhaustion and no causal relationship among the outputs exist. Besides, Just *et al.* (1983) also pointed out that the method of specifying separate production function for each commodity is appropriate when the productions of each output occur separately and the required information to show the input allocation among the outputs is available. Therefore, this study considers specifying a separate production function for each output to model the two output production function. Therefore, one can derive the separated factor demand function in order to define the aggregated factor demand function. The individual conditional factor demand function may be derived by a dual approach, which relies on the assumption of the cost minimisation behaviour, concave and twice differentiable product transformation curve, non-increasing return to scale and excluding the fixed cost that would introduce discontinuity and non-differentiability. Therefore, separate conditional factor demand functions, in the absence of supply shift parameters and the assumption that production functions are well behaved mathematically such that the first and second order conditions for a constrained minimum are fulfilled can be defined as follows.

$$D_{k(y),y} = D_{k,y}\left(P_{k(y),y}^D, \mathrm{S}_{\mathrm{y}}^{\mathrm{D}}\right) \quad \text{(C.10)}$$

$$D_{k(q),q} = D_{k,q}\left(P_{k(q),q}^D, \mathrm{S}_{\mathrm{q}}^{\mathrm{D}}\right) \quad \text{(C.11)}$$

$$D_{i,y} = D_{i,k(y)}\left(P_{i,k(y)}^D, P_{j,k(y)}^D, \ldots, P_{n,k(y)}^D, \mathrm{S}_{k(y)}^{\mathrm{D}}\right) \quad \text{(C.12)}$$

$$D_{i,q} = D_{i,k(q)}\left(P_{i,k(q)}^D, P_{j,k(q)}^D, \ldots, P_{n,k(q)}^D, \mathrm{S}_{\mathrm{k(q)}}^{\mathrm{D}}\right) \quad \text{(C.13)}$$

By total differential of the above equations and assuming that firms produced under the condition of locally constant return to scale, we get equation 3 through 7 in Table 1. Considering equations C.12 and C.13, changes in total factor demand can be written as the sum of changes in individual factor demand functions.

$$\Delta D_{i,T} = \Delta D_{i,k(y)} + \Delta D_{i,k(q)} \quad \textbf{(C.14)}$$

By total deferential of above equation, and some algebraic manipulation, and writing this equation for percentage changes and parameter shares, the equation will turn into equation 7 in Table 1.

Zero Profit Conditions

The logic for zero profit condition in two commodity model is similar to that of a single commodity model. Since the commodities are produced under separate production function, the zero profit condition is imposed on the production of individual outputs. Moreover, as the model is linearised, the zero profit condition for the production of each output is modeled as the change of each output price. In this respect, the changes of all input prices are weighted with their cost shares and added to ensure that output prices of each commodity moves in the same direction of their associated input prices. This would ensure that in the long run the firms are achieving normal profits. Alternatively, under the assumption of perfect competition and constant return to scale in the long run, firm's profit is equal to zero. In order to ensure that firms achieve zero profit in the long run, unit cost function for each output must be equal to its respective prices, under the assumption that full factor employment is assumed and factor intensity reversal does not occur. The following equations represent such situations when the price of each output is equal to the cost of production of one unit of that output.

$$P^S_{k(y)} = C_{k(y)}\left(P^D_{i,k(y)}, P^D_{j,k(y)}, \ldots, P^D_{n,k(y)}\right) \quad \textbf{(C.15)}$$

$$P^S_{k(q)} = C_{k(q)}\left(P^D_{i,k(q)}, P^D_{j,k(q)}, \ldots, P^D_{n,k(q)}\right) \quad \textbf{(C.16)}$$

$$P^S_y = C_y\left(P^D_{k(y),y}\right) \quad \textbf{(C.15)}$$

$$P^S_q = C_q\left(P^D_{k(q),q}\right) \quad \textbf{(C.16)}$$

Here, $C_{k(y)}$. $C_{k(q)}$, C_y and C_q refer to the associated unit cost production of commodity ***k(y), k(q), y*** and ***q***, respectively.

Total differential of above equations and employing the *Young theorem*, the zero profit condition for production of each commodity is defined as equations 8 to 11 in Table 1.

Factor Supply Equations

Supply of i[th] input for being used in production of commodity ***y*** and ***q*** $(S_{i,y}, S_{i,q})$ is function of its own and cross prices $(p^S_{i,y}, p^S_{i,q})$. Therefore, the supply function of i[th] input for producing ***y*** and ***q*** can be specified as:

$$S_{i,y} = g_y(p^S_{i,y}, p^S_{i,q}) \quad \textbf{(C.175)}$$

$$S_{i,y} = g_y(p^S_{i,y}, p^S_{i,q}) \quad \textbf{(C.18)}$$

Here, g^y and g^q refers to the primary supply function of ***y*** and ***q*** activities, respectively. Taking the total differential of equations, and using some algebra to get elasticities we have Equations 12 and 13 in Table 1.

Ad Valorem Equivalent Policies

Following Hertel (1989), it is straightforward to show that output, input, and export policies can be defined as Equations 18 through 23 in Table 1.

Factor Market Clearing Conditions

The rental rate of production factors must adjust to equating supply and demand in the factor markets. Further, market clearing condition requires that demand and supply of each goods should be equal in the equilibrium, thus prices of goods will be adjusted to equating supply and demand in the commodity market .This conditions leads to the Equations 24 through 29 in Table 1.

Appendix D: Effect of 10% CPO export tax on endogenous variables

Notation	Definition of Variables	Percentage Changes
D^M_{FFB}	*Market Demand for FFB*	-0.249094
D^M_{OPP}	*Market Demand for OPP*	0.631106
$D_{land.FFB}$	*Demand for Land in Production of FFB*	-0.226975
$D_{land.OPP}$	*Demand for Land in Production of OPP*	0.710939
$D_{Che.FFB}$	*Demand for Agrochemicals in Production of FFB*	-0.28231
$D_{Che.OPP}$	*Demand for Agrochemicals in Production of OPP*	0.884261
$D_{lab.FFB}$	*Demand for Labour in Production of FFB*	-0.256174
$D_{lab.OPP}$	*Demand for Labour in Production of OPP*	0.802398
$D_{oth.FFB}$	*Demand for Other inputs in Production of FFB*	-0.244377
$D_{oth.OPP}$	*Demand for Other inputs in Production of OPP*	0.765446
$D_{land.T}$	*Total Demand for Land*	-0.0000001880
$D_{che.T}$	*Total Demand for Agro Chemical*	-0.0968254
$D_{lab.T}$	*Total Demand for Labour*	-0.137403
$D_{oth.T}$	*Total Demand for Other Inputs*	-0.0727072
P^S_{FFB}	*Supply Price of FFBs*	-0.533276
P^S_{OPP}	*Supply Price of OPP*	0.779143
$P^M_{land.FFB}$	*Market Price of Land in Production of FFBs*	-0.743611
$P^M_{land.OPP}$	*Market Price of Land in Production of OPP*	0.819579
$P^M_{che.FFB}$	*Market Price of Agrochemicals in Production of FFBs*	-0.271839
$P^M_{che.OPP}$	*Market Price of Agrochemicals in Production of OPP*	0.894732
$P^M_{lab.FFB}$	*Market Price of Labour in Production of FFBs*	-0.441611
$P^M_{lab.OPP}$	*Market Price of Labour in Production of OPP*	0.616961
$P^M_{oth.FFB}$	*Market Price of Other Inputs in Production of FFBs*	-0.550194
$P^M_{oth.OPP}$	*Market Price of Other Inputs in Production of OPP*	0.459629
$S_{land.T}$	*Total Supply of Land*	-0.0000001880
$S_{che.T}$	*Total Supply of Agro Chemical*	-0.0968254
$S_{lab.T}$	*Total Supply of Labour|*	-0.137403
$S_{oth.T}$	*Total Supply of Other Inputs*	-0.0727072
$P^D_{land.FFB}$	*Firm's Demand Price of Land in Production of FFBs*	-0.743611
$P^D_{che.FFB}$	*Firm's Demand Price of Agrochemicals in Production of FFBs*	-0.271839
$P^D_{lab.FFB}$	*Firm's Demand Price of Labour in Production of FFBs*	-0.441611
$P^D_{oth.FFB}$	*Firm's Demand Price of Other Inputs in Production of FFBs*	-0.550194
$P^D_{land.OPP}$	*Firm's Demand Price of Land in Production of OPP*	0.819579
$P^D_{che.OPP}$	*Firm's Demand Price of Agrochemicals in Production of OPP*	0.894732
$P^D_{lab.OPP}$	*Firm's Demand Price of Labour in Production of OPP*	0.616961
$P^D_{oth.OPP}$	*Firm's Demand Price of Other Inputs in Production of OPP*	0.459629
P^M_{FFB}	*Market Price of FFBs*	-0.533276
P^M_{OPP}	*Market Price of OPPs*	0.779143
$S_{land.FFB}$	*Supply of Land for FFBs Production*	-0.226975
$S_{land.OPP}$	*Supply of Land for OPP Production*	0.710939
$S_{che.FFB}$	*Supply of Agrochemicals for FFBs Production*	-0.28231
$S_{che.OPP}$	*Supply of Agrochemicals for OPP Production*	0.884261
$S_{lab.FFB}$	*Supply of Labour for FFBs Production*	-0.256174
$S_{lab.OPP}$	*Supply of Labour for OPP Production*	0.802398
$S_{oth.FFB}$	*Supply of Other Inputs for FFBs Production*	-0.244377
$S_{oth.OPP}$	*Supply of Other Inputs for OPP Production*	0.765446
S^D_{FFB}	*Domestic Supply of FFBs*	-0.249094
S^D_{OPP}	*Domestic Supply of OPP*	0.631106
D^E_{CPO}	*Export Demand for CPO*	-3.69202
D^M_{CPO}	*Market Demand for CPO*	-0.249094
D^D_{FFB}	*Domestic Demand for FFB*	-0.249094,
P^D_{FFB}	*Domestic Price of FFB*	-0.533276
P^S_{CPO}	*Supply Price of CPO*	-0.533276
P^M_{CPO}	*Market Price of CPO*	-0.533276
P^E_{CPO}	*Export Price of CPO*	9.46672
D^M_{OFP}	*Market Demand for OFP*	-0.148037
D^D_{OFP}	*Domestic Demand for OPP*	0.631106
P^S_{OFP}	*Supply price of OFP*	0.779143
P^M_{OFP}	*Market Price of OFP*	0.779143
P^E_{OFP}	*Export Price of OFP*	0.779143
P^D_{OFP}	*Domestic Price of OPP*	0.779143
S^D_{OFP}	*Domestic Supply of OFP*	-0.148037
D^D_{CPO}	*Domestic Demand for CPO*	0.229309
S^D_{CPO}	*Domestic Supply of CPO*	-0.249094