INTEGRATING AGRICULTURAL INPUT EXPENDITURE INTO A PARTIAL EQUILIBRIUM MODEL OF THE SOUTH AFRICAN AGRICULTURAL SECTOR

Y. Gebrehiwet*, F. Meyer** and J.F. Kirsten***

ABSTRACT

Most partial equilibrium models of the agricultural sector have not incorporated a dynamic and interlinked module for agricultural input expenditure. The South African Bureau for Food and Agricultural Policy (BFAP) model, which models a major share of agricultural output in South Africa, has also up to now not integrated input expenditure into the modelling framework. In most models, input costs are treated as exogenous and the recursive link between the input and output sides of the sector is overlooked in the models that attempt to incorporate input expenditures. This article addresses both issues by integrating agricultural input expenditures into the South African sectoral partial equilibrium model by endogenising input costs and recursively linking both the input and output sides of the agricultural sector. Thus, the impact of increasing the input cost may not only signal a fall in the gross value added and net farming income, but also a growth in subsequent years when the recursive effect of the impact is fully accounted for.

Keywords: input costs, partial equilibrium model, recursive link

1 INTRODUCTION

In reviewing most agricultural partial equilibrium models, Conforti (2001) notes that few of these models incorporate the input components of the sector. Thus, most of the analyses of these models are limited to simulating the impact of economic policies on the output side of the agricultural sector, which includes area planted, commodity prices, production levels and gross income. Hence, the implication of economic policies on the net farming income and the value added of

* Researcher, The Bureau for Food and Agricultural Policy (BFAP), Department of Agricultural Economics, Extension and Rural Development, University of Pretoria. Email: Yemane.gebrehiwet@up.ac.za

** Director: Bureau for Food and Agricultural Policy (BFAP), Department of Agricultural Economics, Extention and Rural Development, University of Pretoria. Email: Ferdie.Meyer@up.ac.za

*** Professor, Head: Department of Agricultural Economics, Extension and Rural Development, University of Pretoria. Email: Johann.Kirsten@up.ac.za

the sector is largely unaddressed. Furthermore, some of the models that estimate net farm income, such as the FAPRI-CARD model, do not recursively link the agricultural input and output sides due to the treatment of the variable input costs that affect production, an exogenous variable in the model (Westhoff *et al.,* 1990; Westhoff, 2008).

The general review of the United States Department of Agriculture (USDA) net farming income model, which is well documented by McGath *et al.* (2009), also indicates that input expenditure and other components are estimated by adjusting the previous year's value using the index derived from the output model and input price index forecasts. Hence, input and output models are not recursively linked to enable the model to generate a medium-term outlook of net farm income and evaluate the recursive effect of input prices on the commodity production.

Since agricultural producers generally respond to a higher input cost by reducing the area devoted to production (Gafar, 1997; Mushtaq & Dawson, 2002; Meyer, 2006), the total amount of production may be reduced and, depending on the size of the output reduction, the output prices may be affected. Area reduction by producers in response to higher input costs could subsequently reduce agricultural input demand, which may then affect the prices of some agricultural inputs. An increase in input costs also affects the total input expenditure. The size of the impact, however, largely depends on the price elasticity of the agricultural input demand. For price inelastic input demands, a rise in input costs results in a higher input expenditure. Thus, with a change in input markets, there is a recursive effect on commodity production and vice versa. Hence, an attempt to investigate their impact should incorporate this recursive process in order to appropriately assess the effect of policies on the sector.

Thus, the main objective of this article is to extend the existing South African multi-market model by recursively linking the input and output sides of the agricultural sector and endogenising the input costs so as to improve its ability to evaluate comprehensively the net impact of economic policies on the agricultural sector.

The article is organised as follows. Section two reviews the partial equilibrium model and section three describes how inputs are treated in partial equilibrium models. Section four presents the conceptual framework methodology of the study. The results and discussion of the study are given in section five and the conclusion of the study is presented in section six.

2 PARTIAL EQUILIBRIUM MODELS

Partial equilibrium models are the models most widely used to assess the effect of various policy interventions on the agricultural sector. They are specifically justified in cases where the sector is relatively small in the economy, inputs are mainly specific to the sector, and competition for factors with other sectors is limited (Conforti, 2001). In these cases, therefore, the agricultural sector's effect on the whole economy can safely be considered negligible. The effect of the economy on the agricultural sector, however, is captured using exogenous variables.

Though there are various classifications of partial equilibrium models, they are mainly categorised according to the estimation method used to obtain the parameters that measure the relationship between the explanatory and dependent variables, and how the dynamics of the model are specified (Van Tongeren *et al*., 2001). There are two approaches to estimating the parameters that measure the relationship between the explanatory and dependent variables, namely, the econometric and calibration approaches. In the econometric approach, coefficients are estimated using various econometrics techniques (single equation, simultaneous equation, two stages least square, etc.), depending on the availability of data and the appropriate techniques for a given situation. With the calibration approach, which is also called the synthetic approach, parameters are obtained from the benchmark data and the model's theory (Van Tongeren *et al*., 2001). In this approach, estimated elasticities from other sources are calibrated according to the functional form and initial equilibrium data set to obtain the coefficient. One of the limitations of this approach is that the parameter estimated cannot be statistically assessed (Conforti, 2001).

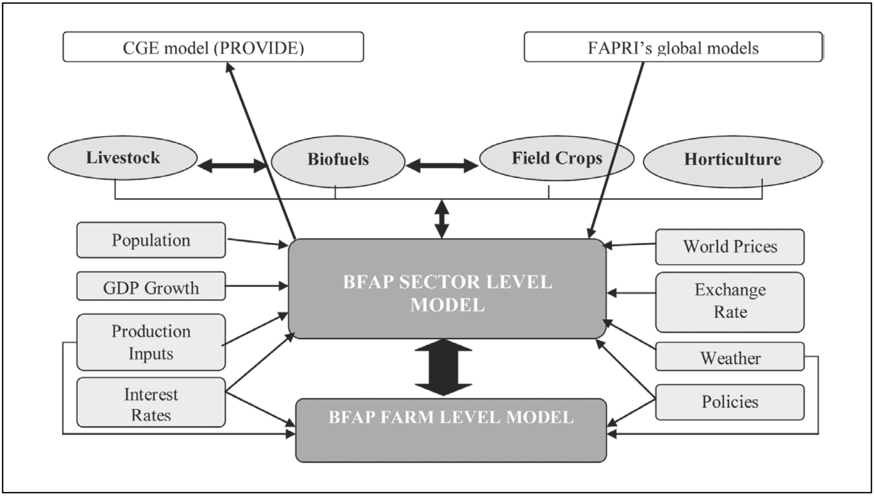

Figure 1: Basic structure of the BFAP system of models
Source: BFAP (2010)

The first partial equilibrium multi-market commodity model for the South African agricultural sector has been developed and is maintained by the BFAP. The system of models used by the BFAP is composed of three levels, namely, the international, sectoral and farm levels (see figure 1). Analysing these tiers is important in determining the impact of any major policy or market changes at the international and sectoral levels on the gross market of producers.

At the international level, the model is linked to the Food and Agricultural Policy Research Institute's (FAPRI) global model, which generates projections for a range of agricultural commodities for many countries worldwide. The BFAP model incorporates the FAPRI world price projections into the South African system of equations to generate medium- to long-term projections for the South African market. The BFAP model also links to the computable general equilibrium (CGE) model developed by the Provincial Decision-Making Enabling Project (PROVIDE) when agricultural shocks or policies are to be evaluated on the overall South African economy. Since the PROVIDE model is a static model and the BFAP sector model is a dynamic time series model, there is no direct link between these two models and the output of each model has to be adapted and interpreted before it can be incorporated into the other level.

At the sectoral level, domestic macro-economic variables, such as the exchange rate and GDP growth, are incorporated. In addition, the model takes into account the impact of population dynamics, consumer trends and weather on the South African grain and livestock sector. Table 1 illustrates the primary commodities and other products included in the BFAP sectoral model. These commodities encompass around 70 per cent of the primary commodities of the agricultural sector.

Table 1: Products included in the BFAP econometric system of equations

Field crops	Animal products	Horticulture	Other
White maize	Pork	Wine	Ethanol
Yellow mkmaize	Chicken	Apples	Biodiesel
Wheat	Beef	Potatoes	DDGs
Sorghum	Mutton	Table grapes	
Barley	Eggs		
Sunflowers	Dairy		
Soybeans			
Canola			
Sugarcane			

Source: BFAP (2010)

3 TREATMENT OF INPUTS IN PARTIAL EQUILIBRIUM MODELS

In general, producers consider various issues when making production decisions. These include expected prices of the output and competing output, the costs of inputs for both the output and competing output, as well as government policies and weather variables. Accordingly, producers choose the enterprise and the proportion to be produced by reacting to these determinant variables. However, since the level of production is affected by factors outside of the control of producers, the area planted is often used in policy analysis to gauge the response of the crop farmers. The number of trees, on the other hand, is used for perennial fruit in the horticulture sub-sector and the number of livestock (volume of animal production) is used to measure producers' responses in the animal product sub-sector.

The general model specification of the main determinants for the area planted for a given crop consists of all the factors that affect the variable input costs. Separating the impact of individual variables on the supply response in the above equation becomes statistically unfeasible due to the multicollinearity and low degrees of freedom, which preclude the validity of most statistical inferences. Thus, in most partial equilibrium models, gross margins and ratios are used to address these problems (Ferris, 1998).

The real expected gross margin for the product per hectare (REGMP) is computed as follows:

$$\text{REGMP} = [\text{P*Y} - (a\text{FUP} + b\text{FP} + c\text{SP} + d\text{CP})]/\text{CPI} \qquad [1]$$

where P and Y are respectively output price and yield; FUP stands for fuel price; FP represents the fertiliser price; SP denotes the seed price and CP stands for chemical/pesticide price; and CPI is a deflator and a, b, c and d respectively denote the amount of inputs applied per hectare of the product. In a similar fashion, the gross margin per hectare for the competing products is computed and the area response equation is estimated using the equation below:

$$\text{AREA} = f(\text{REGMP}, \text{REGMP}c, \text{GOV}, \text{OTHERS}) \qquad [2]$$

where REGMPc denotes the real expected gross margin of the competing product; GOV refers to various government policies; and OTHERS represents technology and all the factors excluded in the model. The merits of introducing the gross margin in the above equation include incorporating priori information and reducing multicollinearity. Moreover, this approach conserves the degrees of freedom and it is able to provide projections of the profit indicator for various enterprises (Ferris, 1998). However, this approach demands more data, especially on the cost side, and it often produces a low adjusted R square. Furthermore, when the variables are collapsed as a single variable, the response to the adjustment to lags of output and input prices also cannot easily be differentiated (Ferris, 1998).

In computing the gross margin equation, variable costs are often used since they play a determinant role in influencing the decision-making for short-term horizons, which extend to five years. Moreover, the compilation of data on variable costs displays less inconsistency across a country than fixed costs. Thus, variable costs are more preferable than the fixed or total cost in computing the gross margin (Ferris, 1998). The latest BFAP output model uses the following equations and elasticities to estimate the area response for the summer and winter regions (BFAP, 2010). The proxies used for the variable costs in estimating the area response equation are fuel and fertiliser prices.

Table 2: Estimated equation in the BFAP model for summer grain area harvested

Variable	Coefficient	Elasticity
Summer grain real expected weighted gross market return (lag)	0.62	0.3
Real fuel price (lag)	–126.49	–0.05
Real fertiliser price (lag)	–733.13	–0.07
Rainfall (summer region)	1.49	0.13

Table 3: Estimated equation in the BFAP model for winter grain area harvested

Variable	Coefficient	Elasticity
Winter grain real expected weighted gross market return (lag)	0.075	0.29
Real fuel price	−10.88	−0.04
Real fertiliser price	−21.39	−0.07
Rainfall (winter region)	0.235	0.13
Real mutton auction price (lag)	−0.074	−0.17

The real expected weighted gross market return refers to the weighted sum of the expected gross market return for six types of grains for the summer area and three types of grains for the winter area. The weight for each commodity is given according to the share of its area to the total grain area. The expected gross market in the equation is obtained from the products of the trend yield and price of each commodity. Input cost prices that determine the winter area are expected to affect the current area response since the production and harvesting time generally occurs in the same year, unlike the summer region. Once the total area response of the whole grain sector has been estimated, the share of the area devoted to each crop is estimated. For yellow maize, for example, the model is specified as follows (Meyer, 2006):

$$YMAH = f\,(YMRGMSA\ (-1)) \qquad [3]$$

where YMAH refers to the yellow maize's percentage share of the total grain area; and YMRGMSA (–1) stands for the ratio of the lagged value of the yellow maize's expected gross market return to the weighted sum of the expected gross return of the remaining crops. A similar model specification is also used for the other commodities.

As shown in tables 2 and 3, fuel and fertiliser prices are used as proxies to capture the effect of variable costs on the area planted; this is done due to the lack of data that can be used for computing the net return of each commodity. However, since these input costs are not endogenised in the model, the effects of factors that affect input costs, such as the price of crude oil and the world price for fertiliser, could not be assessed.

4 CONCEPTUAL FRAMEWORK AND METHODOLOGY

Incorporating agricultural inputs into the multi-market modelling framework basically utilises the theory of the derived demand, which states that demand for inputs exists as a result of consumer demand for the final output. If a given product does not have a demand, then all factors of production necessary to produce the item will not be in demand. Thus, a change in agricultural output markets (like gross income, commodity and animal products prices, the volume of production and the area planted) plays an instrumental role in determining agricultural input demand. Input demand is also determined by its own price and other factors.

In general, three factors are the main drivers of domestic input prices, namely, the oil price, exchange rate and world price. Hence, these variables are used to estimate the model of input prices. The impact of increasing demand for inputs by producers on input prices is also incorporated. A feed cost index, which is computed for each animal product by applying various weights for the field crops and other relevant cost indicator variables in the sectoral output model, is used to estimate the aggregate feed price index to determine the feed demand.

Figure 2 presents the schematic view of how the existing output model and input modules developed in the study are recursively linked. The figure also displays the common exogenous variables that influence both the input and output sides of the integrated model. As shown in the figure, the area planted, which affects the production and hence the price and income in the output model, determines the quantity of inputs to be applied in the production process. Together with exogenous variables, such as the exchange rate and oil price, the quantity of input demand also influences some of the domestic input prices. The domestic input price subsequently determines the area planted for the next season. Thus, there is a recursive link between the output and input models whereby a shock introduced in one model will have a recursive effect on the other model.

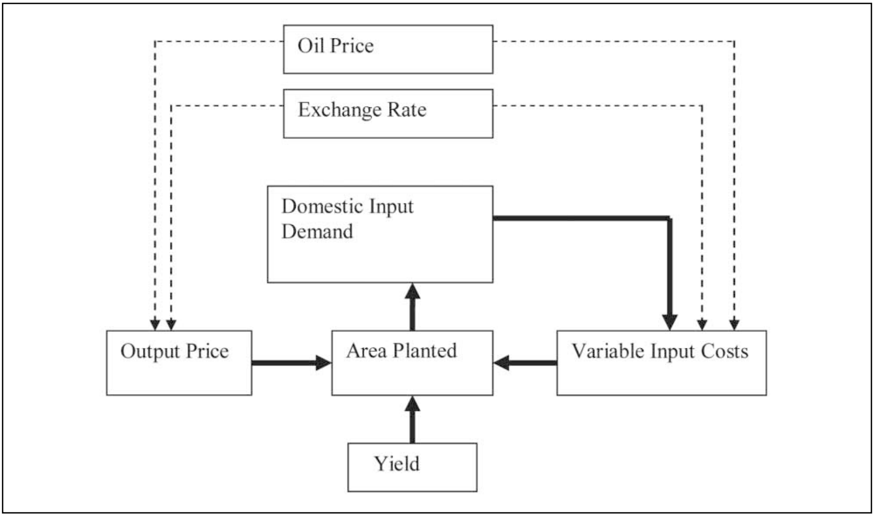

Figure 2: The schematic view of the recursive link between the output and input models

The general direction of the linkage between the input and agricultural output markets flows from the output side to the input markets. This arises because input demand is derived from demand that is largely dependent on the agricultural output market, particularly on changes in the gross income, output price and planted area. However, the effect of agricultural input markets on outputs in the model is largely captured by the input costs. Among the input costs that are recursively affected by the output market is the fertiliser price, which is linked with the output market through the gross income of field crops. However, the fuel price, which is regarded as a proxy for the variable cost in the area response, is not recursively linked with agricultural markets since it is determined exogenously by the international oil price and exchange rate, and agricultural demand has little impact on its price.

For the recursively linked integrated model, therefore, the effect of a shock is expected to converge slowly in the integrated model instead of coming to an abrupt halt. To compare the recursively linked and unlinked integrated models and to test the hypothesis of a slow and cyclical convergence of a shock's effect in a recursively linked model, the recursive link between the input and output models would be “switched off” and domestic input prices would remain exogenous so that the shock’s effect could be compared in both versions of the model.

This recursive link between field crops and inputs introduced in this study is similar to the recursive link between animal production and field crops in the BFAP output model. Both sub-sectors in the output model are recursively linked through feed equations. Thus, a rise in the commodity price augments the feed (input) cost for animal production. As a result of a lower ratio of the output price to input costs, animal production subsequently declines. The fall in production consequently brings about a fall in the feed demand. The fall in the feed demand, therefore, results in lower feed consumption and domestic use of the commodity, which may ultimately affect the domestic commodity prices.

By setting the input model as mentioned above, the net effect of some exogenous variables (like the exchange rate and oil prices) on the sector can be unlocked, as their parallel effect on output and input will be taken into account. Moreover, using the aggregated values from the sectoral output and input models, the key indicators of the agricultural sector’s role in the economy, which is the gross value added, are computed using the following formula:

$$GVA = GINC - INTEXP - OCONS + CLI \qquad [4]$$

where GVA denotes the gross value added (agricultural GDP); GINC refers to the gross income of the agricultural sector; INTEXP refers to the intermediate input expenditure; OCONS refers to own construction, which is the erection of new buildings and works, and making additions and alterations to existing buildings and works by the agricultural producers; and CLI refers to a change in the value of the livestock inventory.

In this study, a change in the livestock inventory is assumed to have a negligible effect on the gross value added, as evidenced by its average value over the past decades, which is close to zero. Once the gross value added has been obtained with equation [4], the following formula is used to calculate the net farming income:

$$NFI = GVA - INTPAID - LREMU - RENPAID - DEPRE \qquad [5]$$

where NFI stands for net farming income; GVA denotes the gross value added; INTPAID, LREMU, RENPAID and DEPRE are respectively expenditures on capital (interest paid), labour (labour remuneration), land (rent paid), and the depreciation value of assets.

To estimate the aggregate variables, the gross income of the sector is obtained from the output model. The total intermediate input expenditure is the sum of expenditures on feed, fuel, fertiliser, maintenance and repairs, farm services and others (which encompasses all expenditures on dips and sprays, electricity, land tax, licences, packing material, seeds and plants, insurance and water tax). The first five intermediate inputs that will be estimated in this model comprise more than 74 per cent of the expenditure on intermediate inputs.

A projected variable from the sectoral model, such as the area planted, is used to estimate the rent paid by the agricultural sector. The model for own construction is also indirectly determined by the variable from the output model, which is gross income, through its effects on the gross capital formation of the sector. The depreciation value for the sector's asset value is computed using the annual depreciation rate used by the Department of Agriculture, Forestry and Fisheries (DAFF). The model for interest paid is largely determined by the amount of debt and the real interest rate. The wage rate and employment figure will also be used to estimate the amount of labour remuneration.

Once all input expenditure equations have been estimated, using projections of exogenous variables from other sources such as FAPRI and Global Insights, a baseline projection is presented for all the variables, including the net farming income and gross value added for the period 2010 to 2015. Then the baseline is used as a benchmark to evaluate the effect of alternative scenarios.

Due to the flexibility it offers in modelling policy-oriented models, Hendry's (1995) methodology of general-to-specific is used to estimate the demand for each equation. This approach, which follows a single-equation framework, is more suitable than other approaches when constructing these models because it accommodates many explicit policy variables and ensures that the exogenous variables have a projected value. Furthermore, the approach is conducive when there is a limited data set on agricultural input expenditures (McQuinn, 2000).

Most of the data is sourced from DAFF and includes all intermediate input expenditures and their respective price indices; own construction; change in livestock inventory and the components of net farming income, which are depreciation value, labour remuneration, rent paid and interest paid. The same source is also used to obtain the data for the asset value, gross capital formation and total debt value of the sector. The data for the interest rate, consumer price index, producer price index and exchange rate are obtained from the Reserve Bank and the quantity, domestic and world price of fertiliser demand is sourced from Grain SA.

5 RESULTS AND DISCUSSION

The results of the estimation of the variable costs, which are linked with the area response equation of the output model, are given in the appendix. The forecasted values of the selected exogenous variables of the model used to produce the baseline are provided in table 4. The data sources for most of these variables are from Global Insight and FAPRI projections.

Table 4: Projected values of selected exogenous variables

Exogenous variable	2010	2011	2012	2013	2014	2015
Exchange rate (R/USD)	7.44	7.80	8.14	8.47	8.80	9.09
Average annual prime rate (%)	11.10	12.00	12.50	13.00	13.00	13.00
Oil price (USD)	79.60	90.00	80.77	86.43	86.00	80.65
Inflation (%)	6.8 %	6.6 %	6.3 %	6.3 %	5.7 %	6 %
Yellow maize, US No. 2, FOB, Gulf ($/t)	170.57	169.75	176.38	177.72	183.81	186.81
Wheat US No. 2, HRW FOB, Gulf ($/t)	210.77	206.57	215.40	225.53	229.47	228.81
Sorghum, US No. 2, FOB, Gulf ($/t)	159.34	159.50	165.90	168.79	174.31	177.72
Cheese, FOB, N. Europe ($/t)	2 432.8	2 618.8	2 747.7	2 802.4	2 879.1	2 969.4
Chicken, US 12-city wholesale ($/t)	1 467.9	1 820.6	1 846.3	1 873.5	1 907.7	1 937.7
WMP, FOB, N. Europe ($/t)	1 988.4	2 183.6	2 225.3	2 283.3	2 365.2	2 462.4

Using the forecasted values of the above exogenous variables, a baseline is generated for key agricultural variables. To test the hypothesis that a recursively linked agricultural sector model converges slowly to subdue the effect of exogenous shocks introduced in the model, two versions of the integrated model are used. In the first version, both sides of the sector are recursively linked and the domestic input prices are endogenised; the second version "switches off" the recursive link and the domestic input prices remain exogenous.

5.1 The shock of a 50 per cent increase in the world fertiliser price

Tables 5 and 6 respectively show the results of the single shock of a 50 per cent increase in the world fertiliser price in 2010, which was introduced in both the recursively linked and unlinked models. As shown in the table, the impact greatly increased the intermediate input expenditures due to the rise in the cost of the fertiliser input. However, there was a fall in the area planted and the gross income due to the impact of the current input prices on the winter area planted. As a result, both the gross value added and the net farming income of the sector fell in the recursively linked model in 2010.

Following the year of the shock, however, the area planted and the gross income in the recursively linked model fell in 2011 due to the recursive impact of the rise in input costs on the summer area planted. The gross income fell due to the fall in the percentage of production, which exceeded the rise in the price for most of the field crops. However, since the input expenditure fell following the decline in the area planted in 2011, the recursively linked model showed little change in the gross value added and net farming income of the sector in 2011. The rise in output prices in 2011 also causes an increase in the area planted and the gross income in 2012 and, following a small change in the intermediate input expenditure, the gross value added and net farming income shows a slight increase. Thereafter, the effect of the shock on the gross value added and net farming income slowly converges in a cyclical pattern until the effect eventually disappears (see figures 3 and 4).

For the recursively unlinked model, however, the effect of the shock was a rise in the input expenditure, which induced a fall in the gross value added and net farming income in 2010. The shock did not impact the area response, as domestic input prices are exogenous in the model. Furthermore, due to the lack of the recursive effect of the shock on the output side, the subsequent impact of the shock disappears in 2011 and thereafter. Thus, using the recursively linked model, the effect of the rise in world fertiliser price on the gross value added and net farming income shows a presence of a positive impact, rather than a once-off plummeting effect implied by the recursively unlinked model.

Table 5: Results of the recursively linked model for the shock of a 50 per cent increase in the world fertiliser price in 2010

Variable	2010	2011	2012	2013	2014	2015
Area planted	–0.21 %	–2.03 %	0.34 %	0.03 %	0.06 %	–0.03 %
Gross income	–0.06 %	–0.29 %	0.17 %	0.00 %	0.07 %	–0.06 %
Intermediate input expenditure	2.06 %	–0.64 %	–0.05 %	0.09 %	–0.04 %	0.02 %
Gross value added	–1.84 %	0.03 %	0.36 %	–0.08 %	0.17 %	–0.12 %
Net farming income	–3.42 %	0.09 %	0.82 %	–0.17 %	0.48 %	–0.32 %

Table 6: Results of the recursively unlinked model for the shock of a 50 per cent increase in the world fertiliser price in 2010

Variable	2010	2011	2012	2013	2014	2015
Area planted	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
Gross income	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
Intermediate input expenditure	2.14 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
Gross value added	–1.79 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
Net farming income	–3.32 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %

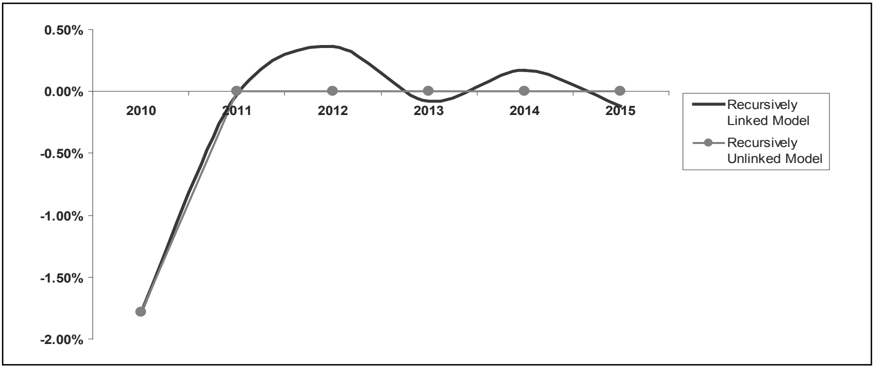

Figure 3: The impact of the shock of a 50 per cent increase in the world fertiliser price on the gross value added in the agricultural sector

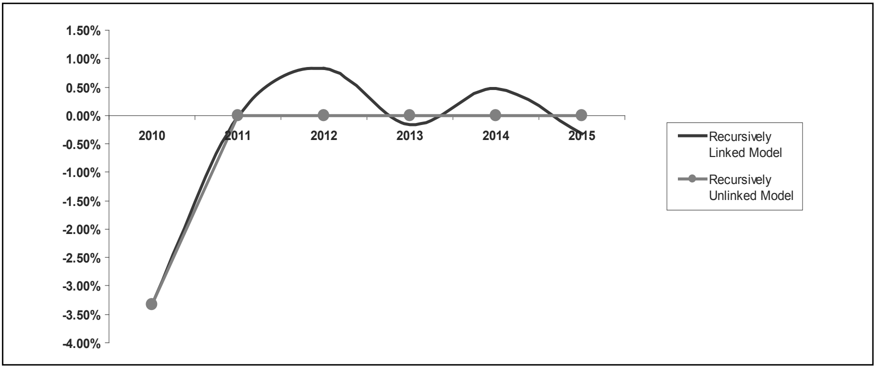

Figure 4: The impact of the shock of a 50 per cent increase in the world fertiliser price on the net farming income

5.2 The shock of a 50 per cent increase in the world crude oil price

Tables 7 and 8 respectively present the results of the impact of a single 50 per cent increase in the crude oil price in 2010 on the agricultural sector using the recursively linked and unlinked models. The impact of the shock entails a fall of the gross value added and net farming income due to the rise in input expenditure. Unlike with the effect of the shock of the world fertiliser price, the crude oil price shock showed a marginal increase in the gross income of both versions of the model in 2010. This is because the shock raised the domestic prices of some commodities by increasing the transport cost, which is captured in both models.

In 2011, the unlinked model shows a marginal increase in the area planted and the gross income due to an increase in output prices in 2010, but the area planted and gross income fall in the recursively linked model since it takes into account the full effect of the change in fuel prices during 2010, when the summer planting area decision was made for 2011. Similar to the above scenario, the gross income falls because the fall in the percentage of production exceeds the rise in the percentage of price for most of the field crops. However, the reduction in input expenditure following the decline in the area planted augments the gross value added and net farming income. In 2012, the gross value added and net farming income also grows after the effect of the change in gross income and input expenditures are taken into account. Gross income rises in 2012 due to the rise in the area planted following the rise in price in 2011. Thereafter, the impact of the shock on the gross value added and net farming income slowly converges in a cyclical pattern until it slowly disappears (see figures 5 and 6). Thus, the effect of the rise in the crude oil price on the agricultural sector may not be a once-off fall in the gross value added and net farming income when the recursive effect is fully taken into account.

Table 7: Results of the recursively linked model for the shock of a 50 per cent increase in the crude oil price in 2010

Variable	2010	2011	2012	2013	2014	2015
Area planted	–0.29 %	–2.51 %	0.74 %	–0.07 %	0.12 %	–0.06 %
Gross income	0.24 %	–0.06 %	0.25 %	–0.03 %	0.11 %	–0.09 %
Intermediate input expenditure	2.75 %	–0.75 %	–0.01 %	0.07 %	–0.07 %	0.03 %
Gross value added	–1.86 %	0.56 %	0.46 %	–0.11 %	0.26 %	–0.19 %
Net farming income	–3.46 %	1.17 %	1.02 %	–0.28 %	0.70 %	–0.58 %

Table 8: Results of the recursively unlinked model for the shock of a 50 per cent increase in the crude oil price in 2010

Variable	2010	2011	2012	2013	2014	2015
Area planted	0.00 %	0.38 %	0.07 %	0.00 %	0.00 %	0.00 %
Gross income	0.34 %	0.18 %	0.02 %	0.00 %	0.00 %	0.00 %
Intermediate input expenditure	2.83 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
Gross value added	–1.77 %	0.34 %	0.04 %	0.00 %	0.00 %	0.00 %
Net farming income	–3.29 %	0.70 %	0.10 %	0.00 %	0.00 %	0.00 %

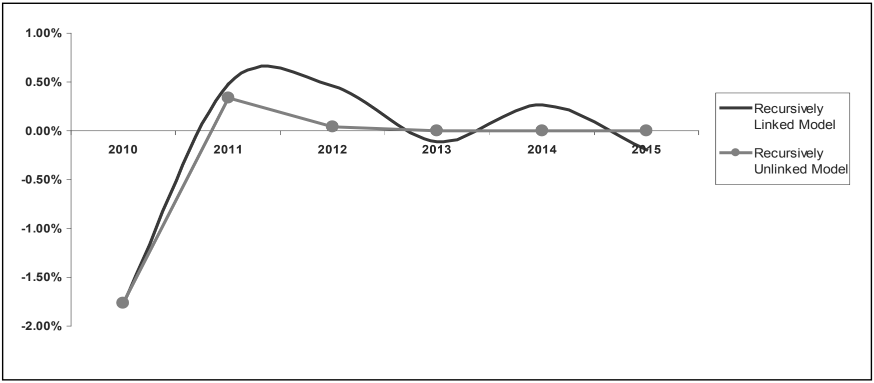

Figure 5: The impact of a 50 per cent increase in the crude oil price on the gross value added in the agricultural sector

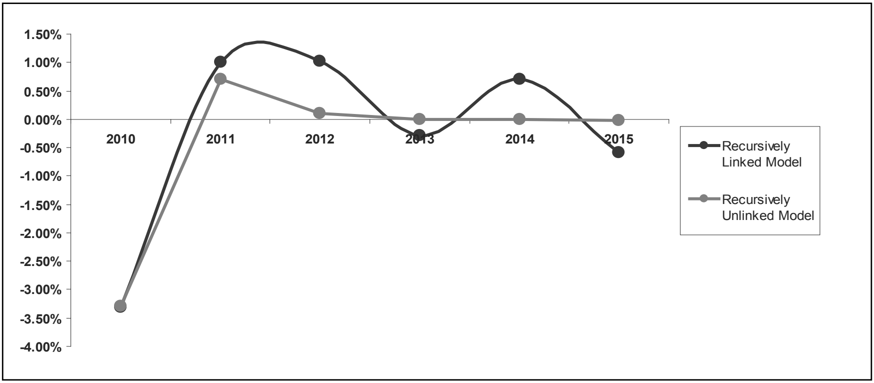

Figure 6: The impact of a 50 per cent increase in the crude oil price on the net farming income

6 CONCLUSION

The study integrated the agricultural input expenditure model into the existing South African multi-market partial equilibrium model and tested the hypothesis that embracing the recursive effect of the agricultural input side to the output side (and vice versa) and endogenised input costs in a partial equilibrium models helps to evaluate the impact of exogenous variables on the agricultural sector and replicates the dynamics of the agricultural sector by converging the effect of exogenous shocks on the sector. To test the hypothesis, a shock of increasing the world fertiliser and crude oil prices was introduced into the model.

Comparing the results of the recursively linked and unlinked versions of the integrated model showed that the effect of the exogenous shocks on the recursively unlinked model quickly diminish after the year of the shock due to the lack of the recursive effect between the input and output sides and by treating the domestic input prices as exogenous in the model. For the recursively linked model, however, the effect slowly converges in a cyclical manner until it disappears, which can be accounted for by the recursive effect between the input and output sides. Thus, the impact of increasing the input cost may not only be a fall in the gross value added and the net farming income, as shown by the recursively unlinked model, but also a growth in subsequent years when the recursive effect of the impact is fully accounted for.

REFERENCES

Bureau for Food and Agricultural Policy (BFAP). 2010. *Focus area: Commodity modelling*. http://www.bfap.co.za/commodtiy.html (accessed 4 May 2010).

Chembezi, D.M. 1991. Modelling acreage response with risk consideration: The case of state tobacco in Malawi. *Agricultural Systems* 36:427–438.

Conforti, P. 2001. *Common agricultural policy in main agricultural partial equilibrium models*. National Institute of Agricultural Economics (INEA). Rome, Italy.

Gafar, J. 1997. The supply response of aggregate agricultural output in Jamaica. *Agricultural Economics* 16:205–217.

Ferris, J.N. 1998. *Agricultural prices and commodity market analysis*. 1st ed. New York: McGraw-Hill

Hendry, D.F. 1995. *Dynamic Econometrics,* 1st ed. New York: Oxford University Press.

McGath, C., McElroy, R., Strickland, R., Traub, L., Covey, T., Short, S.D., Johnson, J., Green, R., Ali, M. and Vogel, S. 2009. *Forecasting farm income: Documenting USDA's forecast model.* USDA, Economic Research Service. Technical Bulletin, No. 1924.

McQuinn, K. 2000. *Modelling Irish inputs*. FAPRI-Ireland Working Paper.

Meyer, F. 2006. *Model closure and price formation under switching grain market regimes in South Africa*. Unpublished PhD dissertation, University of Pretoria, Pretoria, South Africa.

Mushtaq, K. and Dawson, P.J. 2002. Acreage response in Pakistan: A co-integration approach. *Agricultural Economics* 27:111–121.

Van Tongeren, F., Van Meijl, H. and Surry, Y. 2001. Global models applied to agricultural and trade policies: A review and assessment. *Agricultural Economics* 26:149–172.

Westhoff, P., Baur, R., Stephens, D.L. and Meyers, W.H. 1990. *FAPRI US crops model documentation.* Technical Report 90-TR17. Iowa: Centre for Agricultural and Rural Development, Iowa State University.

Westhoff, P. 2008. Personal communication. FAPRI.

APPENDIX: ESTIMATED RESULTS OF VARIABLE COSTS IN THE INTEGRATED MODEL

Fuel Price Equation

The result of the static model specified for the price transmission equation of the fuel price is given in equation [6]. All variables are statistically significant with the expected signs. As expected, the domestic fuel price increases with the rise in the world crude oil price (USD) and the depreciation of the exchange rate. The real domestic fuel price elasticity of the crude oil price and exchange rate is 0.55. Hence, a 10 per cent increase in the international oil price in local currency causes a 5.5 per cent increase in the real domestic fuel price.

The fuel price equation plays a pivotal role in linking the input and output models. The variable cost used in the area response of the output model will now be linked with equation 6. Hence, the implications of all the determinant factors of fuel prices on the output side of the sector are captured and endogenised in the integrated model.

$$\underset{}{RFUELP} = \underset{(11.64)}{46.75} + \underset{(10.25)}{0.27}\ OIL^{*}\ EXC - \underset{(-3.98)}{19.41}D06 \qquad [6]$$

Adj.R^2 = 97.2 T = (1991–2008)

Real Feed Price Equation

The result of the estimated model of the real feed price is given in equation [7]. The variable included in the model is statistically significant and displays the expected signs. As expected, the feed cost for animal production computed in the sectoral model effectively explains the aggregate feed price index of the agricultural sector. The elasticity of the aggregate feed price to the cost of the feed for animal production taken from the sectoral model is 0.65. Hence, a rise of 10 per cent will increase the aggregate price index by 6.5 per cent.

$$RFEEDP = 73.95 + 0.06\ RTFEEDC \quad [7]$$
$$(5.13) \quad (2.40)$$

Adj.R^2 = 0.54 T = (1990–2007)

This equation links the output model with the aggregate feed cost index, which is also used to determine the feed demand. Hence, the impact of all the variables that determine the feed cost in the output model, such as domestic commodity prices (which are also related to the world prices and exchange rate), are indirectly factored in to determine the feed expenditure by the agricultural sector.

Potassium Price Equation

The result of the price transmission of the domestic potassium price equation is presented in equation [8]. A rise in the world price and depreciation of the exchange rate will increase the domestic potassium price. Moreover, the effect of producers' "cash availability" on the domestic price is positive. Hence, it indicates that input providers have the market power to charge more for inputs if they realise that producers have acquired enough cash during the previous season. The price elasticity for the transmission and cash availability are 0.56 and 0.24, respectively. Thus, a 10 per cent increase in the world potassium price (in terms of Rands) and in the gross income of field crops would cause the domestic price to increase by 5.6 and 2.4 per cent, respectively.

$$RPOTP = 415.14 + 1.34\ RWPP*EXCH + 0.034RGINCFC\ (-1) \quad [8]$$
$$(3.01) \quad (30.34) \quad (3.58)$$

Adj. R^2 = 0.98 T = (1995–2008)

Phosphorus Price Equation

The estimated result of the model specified for the price transmission of the domestic phosphorus price equation is given in equation [9]. The rise of the world price, depreciation of the rand and producers' cash availability increase the domestic price. Thus, as with the domestic potassium fertiliser prices, the results show that the input suppliers respond to the higher income by setting domestic prices higher, which could be attributed to the market structure for fertiliser producers in the country. The price transmission elasticity is higher than with the other fertiliser prices. A 10 per cent increase in the world price would cause a 7.7 per cent increase in the phosphorus price. Moreover, a 10 per cent increase in cash availability would cause a simultaneous 1.7 per cent per cent increase in the domestic phosphorus price.

$$RPHOSP = 146.46 + 1.48\ RPHWP*EXC + 0.03\ RGINCFC\ (-1) \quad [9]$$
$$(0.79) \quad (33.3) \quad (2.77)$$

Adj.$R^2 = 0.99$ T = (1996–2008)

Nitrogen Price Equation

The estimated result of the specified model for the price transmission of the domestic nitrogen price equation is given in equation [10]. As expected, a rise in the world price or depreciation of the exchange rate increases the domestic price. Moreover, farmers' cash availability, though statistically insignificant, shows a positive effect on the domestic price, which suggests that input prices are set higher in response to cash availability. The elasticity of the price transmission from the world price (in terms of rands) is 0.59 and is 0.114 from the "cash availability". Thus, a 10 per cent increase in the world price (in terms of Rands) and cash availability would cause the domestic price to increase by 6 and 1.14 per cent, respectively.

$$RNP = 589.60 + 1.31\ RWNP*EXCH + 0.012\ RGINCFC\ (-1) \quad [10]$$
$$(3.06) \quad (15.52) \quad (1.3)$$

Adj. $R^2 = 0.96$ T = (1995–2008)

Real Fertiliser Price Equation

The result of the estimated model for the real aggregate fertiliser price index is given in equation [11]. As expected, the aggregate price for all fertilisers, which was constructed using a weight based on the consumption share of each fertiliser, displays the expected signs and is highly significant.

$$RFERTINDEX = 22.87 + 0.04AFERTP \quad [11]$$
$$(4.87) \quad (19.65)$$

Adj. $R^2 = 0.96$ T = 1991–2008

This equation links the input model with the output model. The area response equation used in the output model uses fertiliser prices as its determinant. The model specified in this equation, therefore, will be linked with the area response equation in the output model. Thus, all of the effects of the determinants of each fertiliser price (the world price, exchange rate and cash availability) on the output sector are captured and endogenised in the integrated model.