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RESOURCES USE, TECHNICAL EFFICIENCY OF MAIZE INDUSTRY AND PERFORMANCE OF THE SOUTH AFRICAN ECONOMY

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Abstract

Given the significance of maize within the overall food security strategies in Sub- Saharan Africa including South Africa, it is important to analyse the technical efficiency of the maize industry for the overall development of the economy. This article analyzes the impact of labor productivity, import price of the world, research and development on technical efficiency of maize industry in South Africa using a Computable General Equilibrium model and South Africa Social Accounting Matrix. The result revealed that maize producers used less intermediate inputs, value-added drops, increased export and reduced import due to an increase in production. Despite the rise in maize output, the demand for labour reduced. This was due to the indirect effect than a direct effect of the maize sector technical efficiency improvements. The study recommends that the improvement of technical efficiency directly related to competitiveness and welfare, therefore, in spite of employment reducing effect, the government should pursue to increase the rate of technical development.

Keywords: Labour productivity; Research and Development; Maize industry; Technical efficiency

1. Introduction

Maize is the main staple crop in Southern Africa including South Africa. The correct application of production inputs is the main determinant of a successful maize production and sustaining the diverse environment. Approximately 2.5 million hectares of land, realising 10-12 million tons of maize grain, is produced in South Africa annually. White

maize for human food consumption, accounts for 50 % of maize production (Syngenta, 2014).

The South African agricultural sector has not performed well in terms of gross output value during the last four decades. Accordingly, the decline in the gross value of agricultural production can be ascribed to decreasing commodity prices (Pauw *et al*., 2007). Limited research reports, which focused on the technical efficiency of the maize industry in South Africa using a SAM - CGE methodology, were found. Thurlow and van Seventer (2002) used a CGE model and 1998 SAM to simulate the economic impact of a 1 % improvement in total factor productivity in the South Africa agricultural sector. They found that an increase in total factor productivity was growth enhancing. Pauw *et al*. (2007) and McDonald *et a*l. (2014) examined the efficiency and welfare of agriculture in South Africa using a CGE model. Their finding suggested that despite a negative impact on employment, technological advances in agriculture should not be resisted. Punt (2013) assessed the impact of a 1 % increase in technical efficiency in the South African agricultural sector using a 2007 SAM and a CGE model. The author's finding indicated an increase in the gross domestic product (GDP: 0.27 %), employment (0.16 %), export (0.30 %), and import (0.25 %) at nominal prices.

Given the importance of maize within the overall South African food security strategies, this study analyses the impact of improved technical efficiency in the maize industry on the South African economy. The results can apply to not only South Africa, but also Southern Africa and globally. A recent South African Social Accounting Matrix (SAM) was used as the main database for the application of a Computable General Equilibrium (CGE) model. The maize sector was disaggregated from agriculture to demonstrate the numerous effects of maize technical efficiency improvements. The policy scenarios were selected from different studies, literature and the 2011 South African National Development Plan (NPC, 2011). Improvement of domestic and international technical efficiency will have policy implications on how the government can enhance maize technical efficiency in particular, and food crop production in general.

2. Methodology

This study used an economy-wide CGE model and a 2009 South African SAM database to explore the effect of technical efficiency improvement on the maize sector on the South African economy. The SAM was developed by the IFPRI (2014).

Besides a SAM, the elasticities for selected agricultural and non-agricultural products were obtained from different studies, which were summarised by Gibson (2003). The production elasticities were set at 1.2 and 0.6. To determine the overall implications of labour productivity in the maize sector, labour categories were aggregated. Fourteen income class categories were aggregated into three categories, namely poor households (below 40 % income), middle class (40-80 % income), and rich households (above 81 % income). Household income elasticities were thus set for respectively rich, middle and poor households as follows: agricultural products at 0.5, 0.6 and 0.7, mining products at 0.7, 0.8 and 0.9, industry at 0.8, 0.85 and 0.9, and other service sectors at 1.3, 1.4 and 1.5. Rich households show lower income elasticities than poorer households, which is consistent with the literature where a larger consumption share of subsistence expenditure is reflected (Philippidis *et al*., 2011; Punt 2013). Elasticities for export demand were set at 0.9 and 2 for rich and poor households respectively. The Frisch parameter, which allows for the determination of a subsistence floor in household expenditure, was set to a constant across all household deciles at 2.

The original SAM provided a comprehensive representation of the South African economy with 85 commodities and 49 activities; households were disaggregated by per-capita expenditure deciles, and labour by education level (Rob and Thurlow, 2013). However, adjustments were made for the sectors *Non - ferrous metals*, *General machinery,* and *Aircrafts*. The three sectors showed lower outputs than export figures, which implied negative domestic supply of domestic produce. This episode indicated re-export of imported goods, because the economy exported more than the produced gross output. The three export figures were netted and their respective import figures were lowered by equivalent values.

The South African SAM does not comprise detailed accounting for the maize sector. A maize sector was included in the *Agriculture* account. In order to analyse the impact of labour productivity, research and development on technical efficiency of the

maize industry, it was separated from the aggregated *Agricultural* account. The maize sector was disaggregated using different data sources. The share of gross output to total agricultural output used DAFF (2014) data. The share of maize gross output (gross value of output) in 2009 was 11.51 % to total agricultural output. The share of export and import to total agricultural export and import used data from the ITC (2014) and the NAMC (2014). The share of maize export in 2009 was 8.18 % to total agricultural export, and the share of maize import in 2009 was 0.51 % to total agricultural import. Information on import tariff was obtained from the ITC (2005) and information on household expenditure was sourced from income and expenditure of Statistics South Africa (2005). Data inconsistencies resulted that the SAM was unbalanced and to balance the SAM, a cross-entropy method was used (Robinson *et al.,* 2000; Fofana *et al*., 2005; Lee and Su, 2014; Bahta *et al.,* 2014).

In order to simulate the model, the selected macroeconomic closure rules are based on the South African economic environment, which is characterized by:

- the consumer price index (CPI) was the numeraire and was fixed, while domestic producer index (DPI) was flexible;
- investment driven savings – uniform marginal propensity to save (MPS) rate for selected institutions;
- flexible government savings with fixed direct tax;
- flexible exchange rate with fixed savings;
- capital fully employed and labour mobile and unemployed (fixed wages).

2.1.Descriptions of policy scenarios

To assess the effect of technical efficiency improvement in the maize sector on the South African economy, a set of policy simulations were explored. These examinations were driven by perceptions on how the improvement of technical efficiency in South African maize sector contributes to the overall objectives of the South African government growth policy. Additionally, the examinations were driven by the broad argument that an understanding of how economic systems might respond to changes in the production climate is important in the development of economic policies. Some of the scenarios analysed in this study were derived from the National Development Plan for South Africa (NPC, 2011), namely technical efficiency improvements through continued research and development.

The scenarios focus on domestic and international technical efficiency changes within the maize industries. Thus, two sets of simulations were done, which included the domestic and the international maize sector technical efficiency:

- Domestic maize technical efficiency: an increase in labour productivity. These simulations were done by increasing the efficiency parameter for labour with the value added function of the maize sector by 2 %. The attention on labour can be partially justified as labour is largely immobile, but capital is mobile (Edwards and Golub, 2002).
- Domestic maize technical efficiency: efficiency improvements through continued research and development in the maize industry with an increase of 1 %. Punt (2013) highlighted that multi-factor productivity for South Africa is estimated at 1.49.
- International technical efficiency changes affect the domestic economy via the impact on world import prices (PWM) of maize commodities, because of technical efficiency improvement in international maize production. These simulations were done by reducing world maize import by 2 %.

The major assumptions underlying the simulatiuons is based on the Ricardian model assumes a single factor of production, which is labour. However, other factors of production, particularly capital, are also important determinants of output and costs. The focus on labour can be partially justified by the argument that labour is largely immobile internationally, but capital is mobile, so that labour costs are likely to diverge much more across countries than costs of capital. Nonetheless, allowing for capital could still be important in interpreting labour productivity, because labour productivity depends on capital input (Edwards and Golub, 2002).

Based on the study of different researcher the scenarios of 1 percent increase in research and development derived. Multi-factor productivity for South Africa between 1947 and 2008 is estimated at 1.49 percent (Liebenberg and Pardey, 2010 cited by Punt, 2013). An increase in technical efficiency would require research and development, but there are already institutions in place to ensure this and the level of increase is assumed to be low enough to ensure that this can take place within current budgets allocated for this purpose (Punt, 2013).

3. Results and discussion

3.1. Domestic maize technical efficiency: an increase in labour productivity

Table 1 reports a percentage change in various prices and quantities arising from technical efficiency gains with a 2 % increase in labour productivity for the maize industry. Technical efficiency improvement through labour productivity leads to less intermediate inputs used by maize producers and value-added declines. Producer prices decline by 0.50 %, because improvement of efficiency lowers the cost of a unit of output. The differences in output mainly cause the inverse relationship between producer prices and domestic production.

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Table 1 Percentage changes in intermediate inputs, value added and domestic production for the simulation of aggregate labour, world import price, and research and development for the maize sector

	Aggregate labour						World import price						Research and development					
	Intermediate inputs		Value added		Output/Production		Intermediate inputs		Value added		Output/Production		Intermediate inputs		Value added		Output/Production	
	QINTAXP	PINTAXP	QVAXP	PVAXP	QXXP	PXXP	QINTAXP	PINTAXP	QVAXP	PVAXP	QXXP	PXXP	QINTAXP	PINTAXP	QVAXP	PVAXP	QXXP	PXXP
Agriculture, forestry and fishery	-0.25	0.0007	-0.25	-0.54	0.16	-0.23	0.0009	0.001	0.0009	0.005	0.00007	0.003	0.0005	0.0001	0.0005	0.001	0.0005	0.0006
Maize	2.60	0.0006	2.602	-0.95	2.00	-0.5	-0.005	0.001	-0.005	-0.004	0.003	-0.06	0.0004	0.0001	0.0004	0.0008	0.0005	-0.000007
Mining	-0.01	0.016	-0.014	0.01	-0.01	0.01	-0.0003	0.003	-0.0003	0.003	-0.0003	0.003	0.0001	0.0002	0.0001	0.0003	0.0001	0.0003
Manufacturing	0.01	-0.01	0.008	0.04	0.008	-0.0007	-0.0002	0.003	-0.0002	0.003	-0.0002	0.003	0.0007	-0.0002	0.0007	0.0006	0.0007	0.00002
Electricity and water	0.003	0.02	0.003	0.04	0.003	0.03	0.00004	0.003	0.00004	0.003	0.00004	0.003	0.0005	0.0004	0.0005	0.001	0.0005	0.0007
Construction	0.002	0.012	0.002	0.03	0.0007	0.02	-0.00005	0.003	-0.00005	0.003	-0.000009	0.003	-0.00006	0.0001	-0.00006	0.00006	0.0001	0.00007
Trade and accommodation	0.01	0.018	0.009	0.04	0.008	0.03	-0.000045	0.003	-0.00005	0.003	-0.00003	0.003	0.0003	0.0002	0.0003	0.0003	0.0005	0.0003
Transport and communication	0.005	0.018	0.005	0.04	0.005	0.03	-0.000009	0.003	-0.000009	0.003	-0.0000002	0.003	0.0006	0.000001	0.0006	0.001	0.0006	0.0005
Research and development	0.001	0.02	0.001	0.03	0.001	0.02	0.0001	0.003	0.0001	0.003	0.0001	0.003	0.051	-0.016	0.051	-1.071	0.05	-0.5
Financial and business services	0.0006	0.024	0.0006	0.03	0.001	0.03	0.00007	0.003	0.00007	0.003	0.00007	0.003	0.0007	-0.0008	0.0007	0.001	0.0008	0.0002
Other services	0.002	0.018	0.002	0.03	0.002	0.03	0.0002	0.003	0.0002	0.003	0.0002	0.003	0.001	-0.003	0.001	0.0007	0.001	-0.001

Note: QINTXP: percentage change of quantity intermediate aggregate input, PINTAXP: percentage change of price of intermediate aggregate inputs, QVAXP: percentage change of quantity value added, PVAXP: percentage change of price of value added, QXXP: percentage change of quantity of production/output, and PXXP- Percentage change of output price.

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The model indicates that improving the technical efficiency of maize industries increases its exports and reduces exports of other commodities (Table 2). The rise in export is due to a rise in domestic output level. The 2.98 % maize export is evidence of maize producers' greater competitiveness. A rise in domestic demand for domestically produced goods caused by lower domestic maize commodities prices, result in domestic maize production increases by about 0.82 %. The composite domestic commodity (imported and domestically produced goods) increased by 0.40 % for maize commodities due to an income effect. The results also show that improving maize technical efficiency results in reducing its import by 0.16 % due to an increase in output level.

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Table 2 Percentage changes of commodity flows for the simulation of aggregate labour, world import price, and research and development for the maize sector

Industries	Aggregate labour				World import price				Research and development			
	QDXP	QMXP	QEXP	QQXP	QDXP	QMXP	QEXP	QQXP	QDXP	QMXP	QEXP	QQXP
Agriculture, forestry &fishery	0.12	-0.156	0.695	0.103	0.0001	0.0002	-0.005	0.0001	0.0006	0.001	-0.0007	0.0006
Maize	0.82	-0.159	2.984	0.402	-0.15	1.56	0.12	0.58	0.000636	0.0006	0.00031	0.0006
Mining	0.003	0.014	-0.026	0.007	-0.0002	-0.0001	-0.0003	-0.0002	0.0006	0.0009	-0.0002	0.0007
Manufacturing	0.014	0.008	-0.015	0.011	0.00003	0.0002	-0.001	0.0001	0.000743	0.0006	0.0007	0.0007
Electricity and water	0.003	0.021	-0.061	0.003	0.00005	0.0003	-0.0008	0.00005	0.000518	0.001	-0.001	0.0005
Construction	0.0007	0.01	-0.033	0.0007	-0.000008	0.0002	-0.0006	-0.000008	0.000126	0.00005	0.00035	0.0001
Trade and accommodation	0.011	0.029	-0.053	0.011	0.000002	0.0002	-0.0008	0.000008	0.000504	0.0006	0.0002	0.0005
Transport and	0.007	0.026	-0.04	0.01	0.00003	0.0003	-0.0005	0.00006	0.00064	0.001	-0.0001	0.0007
Research and development	0.002	0.017	-0.035	0.003	0.0001	0.0003	-0.0004	0.0001	0.022	-0.46	1.11	0.002
Financial and business	0.002	0.02	-0.04	0.002	0.00008	0.0004	-0.0006	0.00009	0.0008	0.0008	0.0007	0.0008
Other services	0.002	0.074	-0.027	0.003	0.0002	0.002	-0.0003	0.0002	0.001	-0.005	0.004	0.001

Note: QDXP: percentage change of quantity of domestic sales, QMXP: percentage change of quantity of import, QEXP: percentage change of quantity of export, and QQXP percentage change of quantity of composite goods supply.

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The effect of technical efficiency gains on factor demand is shown in Table 3. Fewer workers are needed to produce a unit of output, because marginal productivity increases. In spite of a rise in maize output, the demand for factor labour is reduced. There is also a reduction in demand for labour in the maize sector. However, this was due to indirect effects (changing relative prices of intermediate inputs and value-added) rather than the direct effect of the maize sector technical efficiency improvements. Given the assumption that labour is mobile between sectors, the labour that is released from the maize industries is absorbed elsewhere by other sectors of the economy. This findings with line to the finding of Thurlow and van Seventer (2002) an increase of total factor productivity enhances growth.

Table 3 Effect of technical efficiency gains on factor demand in aggregate labour, world import price, and research and development simulations (percentage change)

Industries	Aggregate labour	World import price	Research and development
Agriculture, forestry and fishery	-0.926	-0.003	0.002
Maize	-1.795	-0.014	0.001
Mining	-0.036	-0.00071	0.0004
Manufacturing	0.014	-0.00041	0.001
Electricity and water	0.009	0.00014	0.002
Construction	0.005	-0.0001	-0.0001
Trade and accommodation	0.017	-0.00009	0.0006
Transport and communication	0.014	-0.00003	0.002
Research and development	0.001	0.00011	-1.04
Financial and business services	0.002	0.0002	0.002
Other services	0.003	0.00035	0.002

Results for the macroeconomic indicators are shown in Table 4. An improvement of maize technical efficiency improves the GDP, private consumption, export, and import. An increase in South African labour productivity efficiency in the maize sector leads to an increase in GDP by 0.012 % in real value. An increased share in the real value of total exports and imports were observed in the economy.

Table 4 Percentage change of macroeconomic indicators for aggregate labour, world import price, and research and development simulations

	Aggregate labour	World import price	Research and development
Real GDP	0.012	0.0004	0.0008
Private consumption	0.020	0.002	0.001
Exports	0.010	-0.0003	0.0006
Imports	0.009	0.002	0.0005

Note: GDP: gross domestic product

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A rich household's real income is less compared to other household categories due to labour productivity simulation. The highest real income improvement was observed in poor households followed by middle-income households (Table 5).

Table 5 Household income (YIXP) as a result of aggregate labour, world import price, and research and development in the maize sector

	Aggregate labour	World import price	Research and development
Poor households	0.026	0.003	0.0002
Middle-class households	0.025	0.003	0.0005
Rich households	0.022	0.003	0.0009

3.2. Technical efficiency gains as a result of a 2 % reduction in world maize import price

Table 2 reports a percentage change in price and quantity arising from efficiency improvement as a result of a decline in the world import price of maize. A 2 % decline in the world import price of maize shows that the output of maize industries increases by 0.003 % and reduces production costs, as inputs are more effectively transformed into outputs. There is a small impact on output quantity and price in other sectors.

The commodity flow effects of a 2 % reduction simulation in world import price of the maize commodity price shown in Table 3. A 2 % reduction in the world import price leads to a rise of domestic demand for imports by 1.56 % in the maize sector, thus putting further pressure on the exchange rate to depreciate. The general impact of the decline in world import price on the exchange rate is rather minimal, mainly because the actual magnitude of maize trade is small in relation to total trade. The international and domestic demand movements put pressure on demand for domestically produced commodities, as reflected in the decline in production of the maize sector by 0.15 % (Table 3). Despite this overall decline in production, the impact is not all negative for domestic producers. Some producers benefit from the lower import prices as a component of intermediate inputs imported. This is reflected in the prices of intermediate inputs that decline in the maize sector.

Results for selected macroeconomic indicators for a simulation of a reduction of world import price (Table 4) reveals that a reduction improves the GDP, private

consumption and import at a minimum rate, however, export also declines at a minimum rate. A decrease in a world import price leads to an increase in South African GDP by 0.0004 % in real value. A rise in the real value of total import and a decline in total export is observed in the economy. The real income of households is similar in all categories, and as a result, there is a reduction of maize import price. The finding of this study concurred with the finng of Punt (2013) who assessed the impact of a 1 % increase in technical efficiency in the South African agricultural sector using a 2007 SAM and a CGE model. The author finding indicated an increase in the gross domestic product (GDP: 0.27 %), employment (0.16 %), export (0.30 %), and import (0.25 %) at nominal prices.

3.3. Technical efficiency gains as a result of a 1% increase in research and development

Table 2 also reports a percentage change on prices and quantities from technical efficiency gains when research and development is increased by 1 %. Consequently, the output of the maize industry increases by 0.0005 % and production costs are reduced as inputs are more effectively transformed to outputs. There is little impact on output quantity and price for other sectors.

Maize export and import increases, whereas trades of other sectors are only affected indirectly through the relatively small change in the exchange rate. The increase in export is due to increase in domestic output. The composite domestic commodity (imported and domestically produced goods) increased by 0.0006 % for maize commodities (Table 3), due to an income effect. Technical efficiency gains do not affect factor demands much (Table 4) and the change is insignificant. Results for selected macroeconomic indicators for a simulation of research and development are shown in Table 5 and reveals that an increase in research and development improves the GDP, private consumption export, and import. This findings in line with thr finding of Punt (2013).

4. Summary, conclusion and recommendations

This study assesses the impact of the maize industry's technical efficiency improvement on the South African economy using a CGE model, SAM, and other economic behavioural parameters. The maize sector was disaggregated from agriculture to demonstrate the numerous effects of maize efficiency improvements. The policy scenarios were based on different studies, literature and the 2011 South African National Development Plan (NPC, 2011). The significance of this study with respect to policy cannot be understated; studying improvement of domestic and international technical efficiency will have policy implications on how the government can enhance maize technical efficiency in particular, and food crop production in general.

There is a decline in producer prices in the maize sector when there are technical efficiency improvements through labour productivity, because technical efficiency improvements cause a unit of output to be produced at a lower cost. The differences in output cause an inverse relationship between domestic production and producer prices. The result indicates that improving technical efficiency in maize industries increases its export, reduces exports of other commodities, and reduces maize import due to an increase in output level. Improving technical efficiency of maize industries through labour productivity increases export and reduces exports of other commodities. The increase in export is due to an increase in domestic output level. The 2.98 % rise in maize export is evidence of maize producers' greater competitiveness. Due to a income multiplier income effect, the composite domestic commodity increases for maize commodities. The results also show that improving maize technical efficiency results in a reduction in maize import due to an increased output level. A macroeconomic indicator, because of labour productivity improvement reveals that improvement of maize technical efficiency improves the GDP, private consumption, export, and import.

Due to a reduction in the world prices of maize imports, the output of maize industries increases and a rise in domestic demand for imports by 1.56 % in the maize sector is observed. As a result, production costs are reduced as inputs are more effectively transformed into outputs. There is a small impact on output quantity and prices in other sectors. The magnitude of maize, trade is small in relation to total trade, and thus the overall impact of the decline in world import prices on the exchange rate is minimal. Macroeconomic indicators reveal that a reduction in world import price improves the

GDP, private consumption and import at a minimum rate, however, exports decline at a minimum rate as well.

The impact of an increase in research and development on the maize industry shows that the output in the maize industry increases. Production costs are reduced as inputs are more effectively transformed into outputs. There is a small impact on output quantity and price for other sectors. Maize export and import increases, whereas trades of other sectors are only affected indirectly through the relatively small change in the exchange rate. The increase in export is due to increase in domestic output. Simulated research and development results for selected macroeconomic indicators reveal that an increase in research and development improves the GDP, private consumption export, and import.

This study shows that the improvement of technical efficiency is directly related to competitiveness and welfare. Therefore, in spite of an employment reducing effect, government and policymakers are recommended to increase the rate of technical development. As long as South Africa's trading partners become progressively more efficient then policies, which include efforts to maintain employment levels by resisting technical efficiency improvement will fail, despite reduction of world import prices and incremental research and development gains.

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