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The Welfare Impacts of Domestic and International Agricultural Efficiency Gains – A South African Case Study

Scott McDonald, Kalie Pauw and Cecilia Punt *

Kalie Pauw, PROVIDE Project, Private Bag X1, Elsenburg 7607, Republic of South Africa.
Phone: +27-21-8085206, Fax: +27-21-8085021, Email: kaliep@elsenburg.com

Abstract: A large proportion of the on-going reductions in global food prices are attributable to the efficiency gains associated with various 'green revolutions'. Unfortunately the welfare gains associated with such productivity growth are unevenly distributed, with many African states reaping relatively few benefits. One possible reason for this is the failure of African agriculture to retain its relative competitiveness in global agricultural and food markets, and hence, the welfare gains associated with reductions in consumer prices are largely offset by the welfare losses associated with reductions in producer prices. The analyses reported in this paper explore how changes in domestic and international agricultural efficiency will impact upon the welfare of households and the profitability of agricultural and food industries in South Africa. The results are generated from a computable general equilibrium (CGE) model for South Africa with highly disaggregated food and agricultural sectors. The scenarios reported focus on three dimensions of domestic technology change; changes in the efficiencies with which intermediate inputs, primary inputs and land are used, and one international dimension; changes in the world prices of agricultural and food products. The results indicate that both domestic and international efficiency gains have positive net welfare effects for South Africa. In the case of domestic efficiency gains the net benefit is marginally greater, mainly because of the smaller negative welfare consequences for domestic producers. This can be explained by domestic producers' increased penetration of export markets, which offsets the negative welfare effects associated with a reduction in producer prices. The paper concludes with an assessment of the differential impacts upon the agronomic regions of South Africa and the different household types. These results suggest that while the distribution of the consumer benefits is biased towards poorer households, the distribution of the producer benefits is biased towards relatively richer agricultural areas.

1. Introduction

A large proportion of the on-going reductions in global food prices are attributable to the efficiency gains experienced in agricultural industries. The resulting consumer welfare gains have done much to combat poverty throughout the world. However, such gains are offset by the producer welfare losses associated with reductions in producer prices. A further concern is the impact of efficiency gains on employment levels, and especially in the agricultural industry the losers are either low-income subsistence farmers who fail to compete or low paid agricultural workers who lose their jobs.

As the role-players in the agricultural sector, policymakers and farmers have to face the challenges of rapid changes in technology, domestic and international prices and consumer demand patterns. Recent advances in microeconomic theory and empirical methods have enabled researchers to simulate and evaluate the impact of such economic shocks on the agricultural industry as well as the economy as a whole. The

* Kalie Pauw is the corresponding author and presenter at the AAAE Inaugural Symposium, Nairobi, December 2004. Contact details: PROVIDE Project, Private Bag X1, Elsenburg, 7607, South Africa. Tel: +27-21-8085023. Fax: +27-21-8085210. Email: kaliep@elsenburg.com. Scott McDonald is from the Department of Economics, University of Sheffield, U.K. Cecilia Punt is also associated with the PROVIDE Project.

analyses reported in this paper explore how changes in domestic and international agricultural efficiency will impact upon the welfare of households and the profitability of agricultural industries in South Africa. As a small economy South Africa is modelled a price-taker in international markets and hence foreign agricultural efficiency gains thus affect the prices faced by domestic importers and exporters.

Estimates of the socio-economic impacts of domestic and international efficiency changes are generated with a computable general equilibrium (CGE) model for South Africa. The CGE model is calibrated with a Social Accounting Matrix (SAM) with highly disaggregated food and agricultural sectors. The scenarios simulated focus on various dimensions of international and domestic technology change.

The paper is structured as follows. Section 2 gives a theoretical overview of technical change and its welfare effects via employment, prices and output levels within the context of the CGE model used in the study. Section 3 describes the CGE model and the SAM, while section 4 explains the policy scenarios and closure assumptions and discusses the results of the various policy simulations. Section 5 concludes the paper.

2. Technical Change and Welfare Effects

2.1 Theoretical underpinnings

Productivity, broadly defined as the amount of output produced per unit of input, should not be confused with total factor productivity (TFP), which is the output per "generalised unit of input" (Hall and Taylor, 1993:79). Such a generalised unit of input also includes intermediate inputs used in the production process over and above the normal factors of production such as capital and labour. TFP growth (or efficiency gains/technical change) can be defined as the rate of change of the technology used in the production process, and enable producers to produce a unit of output using fewer inputs than before. In a competitive market environment the benefits of efficiency gains are typically realised as reductions in real commodity prices. This may have a demand-side impact, in which case the gain is also associated with an increase in output.If output (Q) is defined by a linearly homogenous production function $Q = f(K, L, A)$, where K and L denote factors capital and labour respectively, and A the technology parameter, the standard growth accounting method can be used to decompose output growth (dQ/Q) into components relating to the growth of capital (dK/K) and labour (dL/L), as well technical progress (dA/A) (see Chiang, 1984, Dornbusch et al., 1998). In the equation below MPL and MPK refer to the marginal productivities of capital and labour respectively.

$$\frac{dQ}{Q} = \left(\frac{MP_K.K}{Q}\right)\frac{dK}{K} + \left(\frac{MP_L.L}{Q}\right)\frac{dL}{L} + \frac{dA}{A}.$$

Modifications to the growth accounting model may include the use of a human capital index to account for possible increased growth in output due to growth in the quality of labour over time (see Hartzenberg and Stuart, 2002). The approach can also be extended to include multiple inputs, such as land and intermediate inputs.

The CGE model used in this study makes use of a two-tier production structure that incorporates both intermediate and primary inputs. This production structure allows for the analysis of various types of technical change. At the top-level of the production structure (see Figure 1) aggregate primary inputs (referred to here as 'value added', or *QVA*) and aggregate intermediate inputs (*QINT*) are combined using a Constant Elasticity of Substitution (CES) function to form final output (*QX*). At the second level primary inputs, in this example capital (*K*) and labour (*L*), are combined in a CES production function to form *QVA*.

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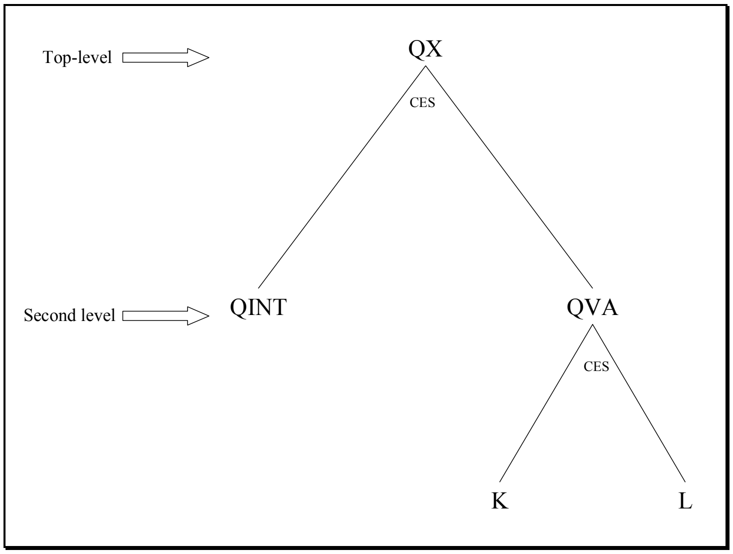

Algebraically, the production structure can be expressed as follows, with the 'value added' CES production function (f_{VA}) embedded in the top-level CES production function (f_Q):

$$QX = f_{QX}\left(QINT, QVA, A_{QX}\right) \text{ and } QVA = f_{QVA}\left(K, L, A_{QVA}\right)$$

In these equations the technology parameters A_{QX} and A_{QVA} are the standard CES shift parameters that define the current production technologies. Domestic technical change can now be defined either as growth in A_{QX}, growth in A_{QVA} or combined growth in both these parameters. Since South Africa acts as a price taker in international markets international efficiency changes will impact on the domestic economy via changes in world prices of imports and exports. Consequently, in the CGE model, international efficiency gains are simply modelled as reductions in the world prices of imports and exports.

2.2 The green revolution and technical change in South African agriculture

The term 'green revolution' was coined in the 1960s to denote rapid technological change that resulted from large investments globally in agricultural research and development from the 1940s onwards (Wikipedia, 2004). Although the green revolution was extremely successful at reducing world hunger through reduction in purchaser prices, some concerns have been raised about its wider impact. These range from concerns about a loss in biodiversity and food quality, greater fossil fuel dependence, pollution, and land degradation. The green revolution also favoured large-scale industrial agriculture and as a result many small-scale farmers, who relied on subsistence agriculture, and farm workers often lost their only source of income.

Although the South African agricultural sector has not performed exceptionally well during the last four decades as measured in terms of gross value of output, there is evidence that the volume of output has not declined during the last decade. Consequently the decline in the gross value of agricultural production can be attributed to declining commodity prices (Vink, 2000). This warrants further investigation into productivity changes of the agricultural sector as a possible source of these price declines. Hartzenberg and Stuart (2002) find that total factor productivity (TFP) growth for the economy as a whole was negative between 1960 and 1975 (-1.0%) and remained unchanged between 1976 and 1989 (0.0%). However, TFP growth recovered during the 1990s (0.8%). A sectoral decomposition reveals that agriculture was one of only a few sectors that experienced positive TFP growth over all the time periods examined by Hartzenberg and Stuart (see Table 1). Vink (2000) and Thirtle *et al*. (2000) also find evidence of a recovery in agricultural TFP growth during the 1990s.

This revival in agricultural production was necessitated by the 'cost-price squeeze' experienced by agricultural producers: producer prices were increasing over time, but at a lower rate than the increase in input prices (Vink, 2000). Many factors contributed to these price effects. The depreciating domestic currency increased the cost of imported intermediate inputs, while increased labour market regulation increased the non-wage cost of employing workers during the 1990s (Nattrass, 2000). At the same time domestic food and agricultural commodities did not enjoy the same levels of protection as before (Vink, 2000). Producers were forced to react to the cost-price squeeze by reducing the area of land planted and switching to higher quality land, and by reducing the amount of capital and intermediate goods used in production. This had the effect of increasing productivity and average industry yields (Vink, 2000).

Table 1: TFP growth estimates for South Africa (1960 – 1999) (percentage change)

(Vink, 2000)		(Thirtle *et al.*, 2000)		(Hartzenberg and Stuart, 2002)		
Period	**TFP growth (Agriculture)**	**Period**	**TFP growth (Agriculture)**	**Period**	**TFP growth (Agriculture)**	**TFP growth (Total)**
1960-1980	2.05	1965-1981	2.15	1960-1976	1.00	– 1.00
1980-1990	0.96	1981-1991	2.88	1976-1989	1.70	0.00
1980-1996	1.19					
1990-1996	1.56			1990-1999	N/A	0.80
1960-1996	1.66					

While consumers have benefited from price declines the South African agricultural sector could not avoid the job losses associated with efficiency gains. Vink (2000) finds evidence of an unambiguous bias towards capital in the technological change experienced in agriculture between 1970 and 1990, which has led to a decrease in employment in agriculture.

This brief discussion raises some complex policy issues relating to the interaction between price changes and welfare impacts, and between consumers or employees and producers. Such complex matters are best analysed within an economy-wide model such as a CGE model that takes into account the actions, reactions and interactions of all agents in the economy.

3. Computable General Equilibrium Model and Data

3.1 CGE model

The PROVIDE standard computable general equilibrium (CGE) model is a member of the class of single country computable general equilibrium (CGE) models that are descendants of the approach to CGE modelling described by Dervis *et al*. (1982), and more recently by Robinson *et* al. (1990), Kilkenny (1991) and Devarajan *et al*. (1994). The model is based on a Social Accounting Matrix (SAM) for South Africa, which serves to identify the agents in the economy, provide the database with which the model is calibrated and identify the transactions that took place in the economy.

The behavioural relationships in this model are a mix of non-linear and linear relationships that govern how the model's agents will respond to exogenously determined changes in the model's parameters and/or variables. In brief, households are assumed to maximise utility subject to a Stone-Geary utility function while producers maximise profits subject to the two-stage production structure described in section 2.1. The modelling of trade flows follows the Armington assumption that domestically produced and imported commodities are imperfect substitutes (CES function) (Armington, 1969). In a similar way imperfect transformation is assumed between domestic demand and export demand (CET function). For a detailed description of the price and quantity structures and the mathematical statement in the model, see PROVIDE (2003).

3.2 Data

The data used for this study are arranged in two groups, namely a SAM that records all transactions between agents in the economy, and a series of elasticities that control the operation of some of the model's behavioural functions. The SAM is a 115 account aggregation of the PROVIDE SAM for South Africa in 2000. For a full description of this SAM, see PROVIDE (2004). A list of the SAM accounts and their descriptions appear in Table 9.

In the SAM agricultural activities are defined by reference to provinces of the country. Ideally this would be by agronomic region but the agricultural census data are by magisterial district and hence this geographical distinction has to be followed. This SAM classification as well as the model code allows that each agricultural activity can produce a range of commodities.

4. Policy Analysis

4.1 Policy scenarios

The policy scenarios examined in this study represent explorations of the impact of domestic and international efficiency gains in agricultural production upon the South African economy. These explorations are not driven by the immediate and/or imminent pressures of current policy questions but are rather inspired by the general argument that an understanding of how economic systems might react to changes in the economic and technological climate is an important input to the development of economic policies.

Three sets of simulations are explored:

1. *SIMSET1*: An improvement in the efficiency with which the South African agricultural industry uses intermediate and primary inputs. This is implemented as an increase in the technology parameter (A_{QX}) of industry's top-level CES production function. Five simulations (*sim11* to *sim15*) are implemented that increase the shift parameter by between 0.5% and 2.5% (0.5 percentage point increments). Technology changes at the second level of the production structure fall beyond of the scope of this particular paper.
2. *SIMSET2*: A reduction in the world prices of imported (*pwm*) and exported (*pwe*) food and agricultural commodities due to efficiency gains in international agricultural production. Five simulations (*sim21* to *sim25*) are implemented that directly reduce the world prices of imports and exports by a series of magnitudes. The world prices of agricultural commodities are reduced by between 0.5% and 2.5% (0.5 percentage point increments), while the world prices of food commodities are reduced by between 0.25% and 1.25% (0.25 percentage point increments) (see section 4.3.2 for more detail).

3. *SIMSET3*: This simulation set is a combination of *sim24* and *SIMSET1*. This means that five simulations (*sim31* to *sim35*) are implemented that increase the shift parameter in the top-level CES production function of the agricultural industry by between 0.5% and 2.5% (0.5 percentage point increments), while for each of these simulations the world prices of agricultural commodities are reduced by 2% and the world price of food commodities by 1%.

The simulations all assume that the origins of these technological changes are exogenous, i.e., the model provides no explanation of how these changes in technology originate nor does the model include allowances for the research and development costs of new technology. Table 10 provides a summary description of all the simulation sets and their member simulations.

4.2 Model closure rules

The model closure rules were selected with the objective of providing a realistic representation of the South African economy. Mathematically speaking, closure rules ensure that the number of variables and equations in the model are consistent, which is a necessary condition for the model to solve. In economics closure rules define perceptions of how economic systems operate. The closure rules for this study are summarised in Table 11.

4.3 Results and analyses

4.3.1 Domestic efficiency gains

The range of efficiency gains simulated in *SIMSET1* is consistent with the TFP growth estimates reported in Table 1 and thus represent a realistic expectation of the level of TFP growth that can be expected to materialise in South Africa. As a result of the efficiency gains all agricultural producers use fewer intermediate inputs (*QINT*), while value added (*QVA*) declines. This has a number of knock-on effects in the economy.

The greater efficiency allows producers to reduce the production price (*PX*), and as a result purchaser prices (*PQD*) of agricultural commodities also fall. The price effect also feeds through to the food commodities, since food industries use agricultural commodities are intermediate inputs in the production of food. The price effect on food commodities is, however, significantly lower than the effect on agricultural commodities since (roughly one quarter), since food commodities 'only' spend about 25% of their budget on agricultural commodities that are now cheaper. The remainder is spent on other intermediate inputs and factors of production, the cost of which remains largely unchanged.

Lower agricultural and food commodity prices directly lead to an increase in demand for domestically produced goods, both from within the economy (domestic demand, *QD*) and externally (exports, *QE*), which generally leads to an increase in domestically produced commodities (*QXC*). At the same time since domestically produced goods are now relatively cheaper consumers tend to favour these over imports (*QM*). Since QM declines and QD increases, the net impact on the composite commodity (*QQ*) is very small, which also suggests that income changes of consumers are not very significant. These commodity flow changes are summarised in Table 2 (only results for *sim14* are shown).

Table 2: Commodity flows (sim14, percentage changes)

	QXC	QQ	QD	QE	QM
CCEREAL	1.040	0.194	0.569	2.604	-1.427
COFIELD	0.693	-0.012	0.499	2.426	-1.392
CPOTVEG	0.795	0.577	0.759	7.245	-5.335
CFRUIT	1.094	0.354	0.371	3.029	-2.218
COHORT	0.801	-0.051	0.409	1.531	-0.700
CLSTOC	0.735	0.720	0.729	7.207	-5.357
CLPROD	1.063	0.629	0.744	5.033	-3.370
COANIM	0.808	0.559	0.645	8.441	-6.591
CAGOTHER	1.018	0.421	0.964	4.660	-2.601
CMEAT	0.956	0.557	0.803	3.566	-1.886
CVEG	0.299	0.212	0.237	0.530	-0.054
COILS	0.428	0.193	0.401	0.961	-0.156
CDAIRY	0.356	0.286	0.346	1.189	-0.490
CGRAIN	0.373	0.255	0.356	1.135	-0.417
CAFEED	-1.249	-1.352	-1.257	0.148	-2.643
CBAKE	0.231	0.225	0.230	0.528	-0.067
CCONFEC	0.339	0.278	0.307	0.763	-0.147
CFOOD	0.746	0.466	0.673	2.005	-0.641
CBEVT	0.275	0.226	0.252	0.625	-0.121

Notes: Comparisons should be made with care since time periods, data sources and growth decomposition methods used may differ between researchers. The underlying message that is conveyed here is an apparent recovery in both agricultural and total (economy-wide) TFP growth from the 1990s onwards. Hartzenberg and Stuart (2002) were unable to estimate agriculture's TFP growth for the period 1990 to 1999 due to missing data in their dataset.

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Efficiency gains also have a direct impact on factor demand. Since the marginal productivity of factors increase, fewer workers are needed to produce a unit of output. All agricultural producers reduce the demand for skilled and unskilled workers. Due to the labour market closures selected in the model, the decrease in labour demand leads to a fall in employment of unskilled workers in the agricultural sector, while the higher productivity of skilled workers is reflected in the higher wages of these workers.

Under the full-employment assumption skilled factors are absorbed elsewhere in the economy. The joint effect of higher marginal productivity of skilled workers and increased factor demand in non-agricultural sectors ensure that the average skilled wage (*WF*) increases. Demand for unskilled labour also increases in non-agricultural sectors due to increased overall economic activity. As a result the economy-wide level of unskilled employment (*FS*) increases despite the decrease in the agricultural sector. These positive effects in other industries allow average factor incomes of all skilled and unskilled workers to increase marginally (see Table 3). It is important to realise that these results depend crucially upon the assumption that skilled workers are fully mobile. It is also not possible to say whether those workers that have been released from the agricultural sector necessarily fill the additional unskilled jobs that have been created in non-agricultural sector. It may be that unemployment in the agricultural industry increases, while unemployment in other industries decreases due to factor immobility between sectors.

Table 3: Changes in factor supply, wages and factor income (sim14, percentage changes)

Unskilled labour			Skilled labour		
Categories	**Factor supply (FS)**	**Factor income (YF)**	**Categories**	**Wages (WF)**	**Factor income (YF)**
FAFUSKIL	0.262	0.262	FAFSKIL	0.314	0.314
FCOUSKIL	0.264	0.263	FCOSKIL	0.323	0.322
FASUSKIL	0.308	0.304	FASSKIL	0.315	0.314
FWHUSKIL	0.322	0.321	FWHSKIL	0.291	0.291

In conclusion, although efficiency gains in the agricultural industry have a negative welfare impact for producers via declining producer prices and employment levels, gains experienced elsewhere allow overall employment levels and wages to increase. Consumers are also better off due to lower purchaser prices, while incomes also increase slightly due to higher factor returns.

4.3.2 International technical change

International efficiency gains are modelled by reducing the world prices of imports and exports. This is not ideal since one effectively has to assume a price impact of a notional technical change in a foreign market. *SIMSET1* has shown that efficiency gains in the agricultural sector have a significant impact on domestic agricultural prices, and, to a lesser extent, on food commodity prices. Based on this evidence *SIMSET2* only reduces international food commodity prices by half that of agricultural commodity prices.

A reduction in the world price of exports (*pwe*), *ceteris paribus*, will cause domestic producers to shift output towards the domestic market (*QD*) away from the export market (*QE* declines). This causes the trade balance to deteriorate, leading to an exchange rate depreciation. If at the same time we also have a reduction in the world price of imports (*pwm*), domestic demand for imports (*QM*) will rise, thus putting further pressure on the exchange rate (*ER*) to depreciate. Despite the compounding effect of these two scenarios the overall impact of the world trade price declines is minimal, mainly because the actual magnitude of the international price changes are fairly small. The exchange rate depreciates by between 0.02% and 0.098% in simulations *sim21* to *sim25*. The impact of *sim24* on commodity flows is shown in Table 4. As before the impact on domestic consumption (*QQ*) is small due to the small income effect. The international and domestic demand movements put pressure on demand for domestically produced commodities, and we see a decline in production of virtually all the food and agricultural commodities (*QXC*).

Table 4: Commodity flows (sim24, percentage changes)

	QXC	QQ	QD	QE	QM
CCEREAL	-0.531	-0.020	-0.251	-1.473	0.987
COFIELD	-0.310	-0.103	-0.254	-0.814	0.309
CPOTVEG	-0.302	-0.140	-0.278	-4.864	4.530
CFRUIT	-0.611	-0.101	-0.114	-1.962	1.769
COHORT	-0.316	-0.083	-0.210	-0.514	0.096
CLSTOC	-0.335	-0.325	-0.332	-4.569	4.095
CLPROD	-0.541	-0.222	-0.311	-3.476	2.959
COANIM	-0.353	-0.253	-0.290	-3.430	2.952
CAGOTHER	-0.481	0.045	-0.437	-3.557	2.785
CMEAT	-0.337	-0.060	-0.234	-2.120	1.689
CVEG	-0.442	-0.012	-0.139	-1.573	1.316
COILS	-0.190	0.024	-0.166	-0.675	0.345
CDAIRY	-0.115	0.009	-0.097	-1.564	1.391
CGRAIN	0.073	0.134	0.081	-0.322	0.486
CAFEED	-0.461	-0.417	-0.457	-1.049	0.138
CBAKE	0.027	0.053	0.032	-1.130	1.207
CCONFEC	-0.115	0.019	-0.044	-1.043	0.965
CFOOD	-0.293	-0.025	-0.225	-1.486	1.053
CBEVT	-0.126	0.035	-0.049	-1.265	1.182

Since demand for domestically produced food and agricultural commodities declines, production levels of most agricultural producers and food activities fall. The percentage changes are generally very small, especially for food activities, which face a smaller decline in international prices of competing food commodities than agricultural producers. Producers do however benefit from the lower import prices since a component of intermediate inputs may be imported. This is reflected in the price of intermediate inputs (*PINT*) that declines for virtually all agricultural and food activities.

The decline in production impacts negatively on employment, with factor demand declining in virtually all the food and agricultural industries, although by not as much as in *SIMSET1*. This either impacts on the average wage or on the actual employment level, depending on the factor market closure (see Table 5). Of the 'unemployed' factor groups, only Coloured workers experience a marginal increase in unemployment at an economy-wide level, with unemployment rising by between 0.02% and 0.09% under the various simulations (0.07% in Table 5). Many of these workers are employed as agricultural workers in the Western Cape (*AGWC*) region. This region experiences the largest decline in production of all the agricultural industries (results not shown).

Demand for all other unskilled factors actually increases at the economy-wide level, thanks to increased production and labour demand in some other non-agricultural and non-food industries. The only overall losers are Coloured unskilled workers, who face a decline in factor income (*YF*) of 0.069%. All other factors experience an increase in factor income, although changes are marginal and considerably lower than in *SIMSET1*.

Table 5: Changes in factor supply, wages and factor income (sim24, percentage changes)

Unskilled labour			Skilled labour		
Categories	**Factor supply (FS)**	**Factor income (YF)**	**Categories**	**Wages (WF)**	**Factor income (YF)**
FAFUSKIL	0.055	0.055	FAFSKIL	0.031	0.032
FCOUSKIL	-0.070	-0.069	FCOSKIL	0.024	0.024
FASUSKIL	0.021	0.022	FASSKIL	0.029	0.030
FWHUSKIL	0.095	0.095	FWHSKIL	0.019	0.019

In conclusion, a reduction in world prices of both imports and exports has a very limited effect on the domestic economy. Production levels in the food and agricultural sectors decline, leading to a fall in the demand for factors in these industries. However, most of these losses are made up through increases in production and factor demand in other industries. As a result the welfare effects of the simulations are very small, with the only real benefit going to consumers who can import goods at a lower price.

4.3.3 Combined domestic and international efficiency gains

In *SIMSET3* a combined experiment is performed to evaluate the outcome of simultaneous domestic and international technical changes. As with *SIMSET2* the world trade price declines cause the exchange rate to depreciate. These trade price changes induce consumers to shift consumption towards cheaper imports, while domestic producers tend to allocate more of their production to the domestic market where prices are now relatively higher.

However, there is also a domestic price impact associated with the efficiency gains in the agricultural sector. Consider Figure 2 and Figure 3. Producer prices (*PX*) of agricultural activities fall as a result of the efficiency gains. This has a direct impact on agricultural commodity prices (*PQD*). Since food activities spend a fairly large share of their budget on agricultural commodity inputs, they are able to reduce their production costs and, as a consequence, food prices also drop, although not by the same degree as agricultural commodity prices. These domestic price movements have two important impacts. Firstly, it counteracts the movement along the CES aggregation function caused by cheaper imports; and, secondly, it counteracts the movement along the CET allocation function caused by cheaper exports. The impact on the trade balance is thus greatly reduced (see Table 6, compare Table 2 and Table 4). We also see that the change in the quantity of domestically produced commodities (*QXC*) is lower than under the domestic efficiency gain simulation due to the negative impact of the international price declines.

Figure 2: Production prices (*PX*): agricultural and food activities (percentage changes)

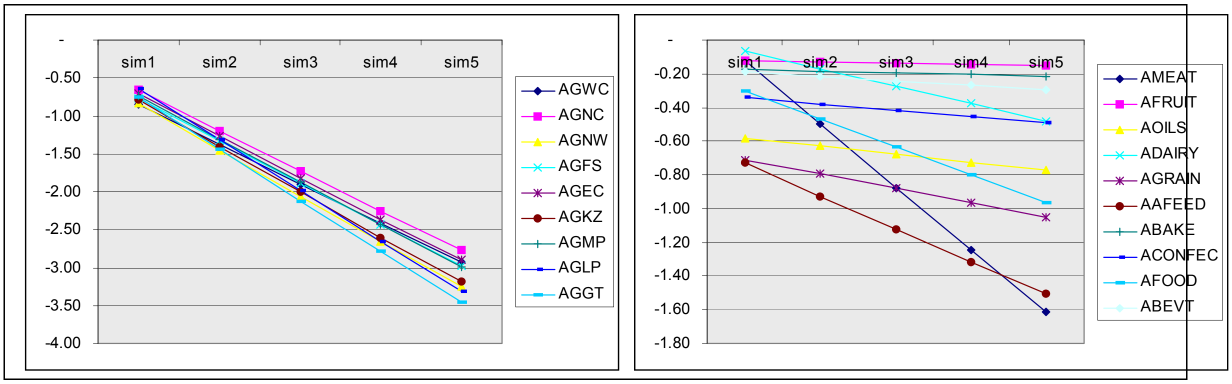


Figure 3: Domestic prices (PQD): agricultural and food commodities (percentage change)

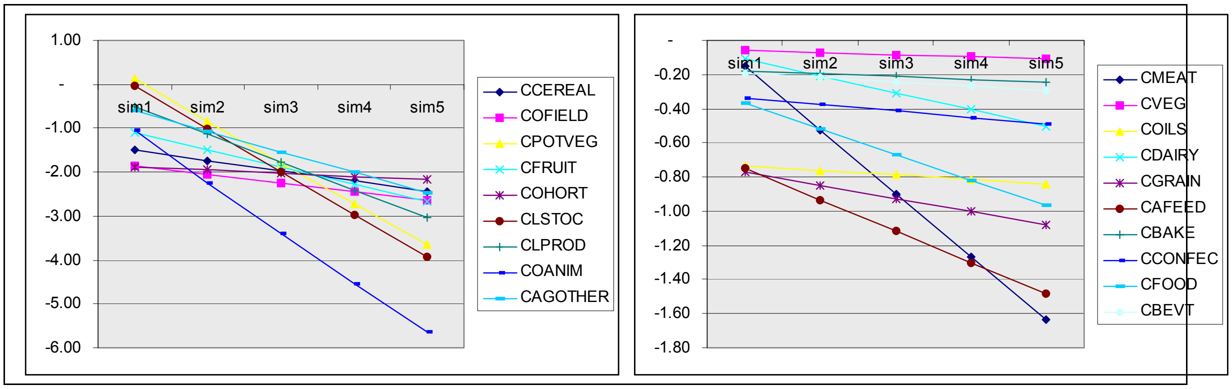


Table 6 only reports on the results of a 2% increase in efficiency, it is important to look at the entire range of productivity changes to understand that the level of the efficiency gain will determine whether the overall production effect is positive. The results in Table 7 indicate that only at a 2% efficiency gain will all domestic agricultural producers experience production growth that is sufficient to counteract the 2% decline in the world prices of exports (*sim34*).

Table 6: Commodity flows (sim34, percentage changes)

	QXC	QQ	QD	QE	QM
CCEREAL	0.490	0.169	0.312	1.083	-0.453
COFIELD	0.377	-0.119	0.241	1.593	-1.093
CPOTVEG	0.477	0.426	0.469	1.963	-1.002
CFRUIT	0.458	0.250	0.255	1.006	-0.490
COHORT	0.464	-0.140	0.187	0.982	-0.601
CLSTOC	0.388	0.384	0.387	2.217	-1.410
CLPROD	0.500	0.401	0.428	1.400	-0.535
COANIM	0.438	0.298	0.347	4.744	-3.865
CAGOTHER	0.523	0.461	0.518	0.894	0.143
CMEAT	0.607	0.492	0.564	1.355	-0.221
CVEG	-0.146	0.198	0.097	-1.053	1.260
COILS	0.231	0.215	0.230	0.270	0.190
CDAIRY	0.241	0.294	0.249	-0.386	0.887
CGRAIN	0.444	0.389	0.436	0.800	0.073
CAFEED	-1.719	-1.779	-1.724	-0.914	-2.527
CBAKE	0.258	0.277	0.261	-0.610	1.140
CCONFEC	0.221	0.295	0.260	-0.295	0.819
CFOOD	0.447	0.439	0.445	0.483	0.406
CBEVT	0.147	0.260	0.201	-0.650	1.060

Table 7: Domestic agricultural production (QX) (percentage change)

	sim31	*sim32*	*sim33*	*sim34*	*sim35*
AGWC	-0.592	-0.224	0.146	0.517	0.891
AGNC	-0.494	-0.327	-0.161	0.003	0.166
AGNW	-0.341	-0.107	0.129	0.365	0.601
AGFS	-0.349	-0.065	0.220	0.504	0.789
AGEC	-0.159	0.135	0.429	0.722	1.014
AGKZ	-0.173	0.002	0.177	0.352	0.527
AGMP	-0.122	0.158	0.438	0.716	0.994
AGLP	0.312	0.295	0.278	0.260	0.242
AGGT	0.304	0.377	0.454	0.535	0.620

Due to increased productivity, factor demand declines in agricultural industries, but despite this the economy-wide level of employment (*FS*) of virtually all unskilled workers increases as a result of greater demand for factors in other expanding non-agricultural sectors. This is true for all factor groups except Coloured unskilled workers in *sim31* (see Table 8). The demand for skilled workers also increases at the economy-wide level, as reflected by the positive wage impact for these workers in all the simulations. The returns to factors therefore increase under all circumstances (except Coloured unskilled workers in *sim1*).

Table 8: Changes in factor supply, wages and factor income (percentage changes)

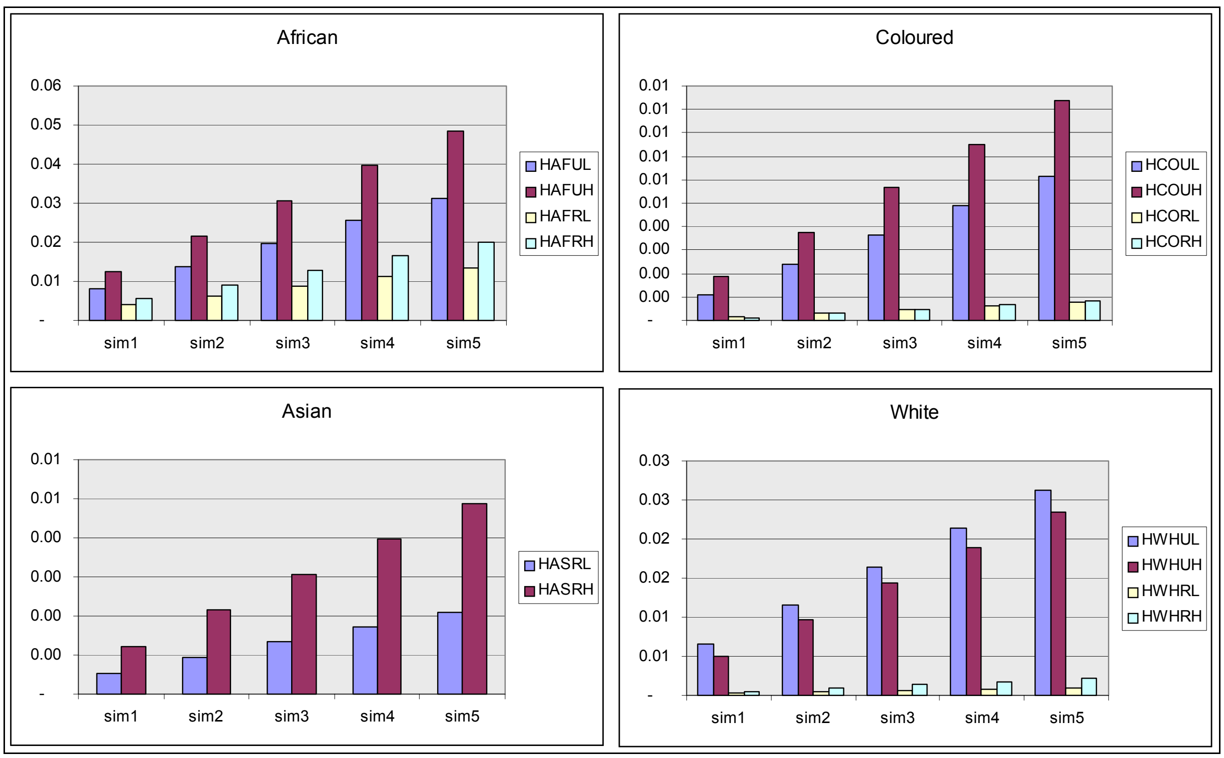
		sim31	*sim32*	*sim33*	*sim34*	*sim35*
FS	FAFUSKIL	0.122	0.187	0.252	0.317	0.380
	FCOUSKIL	-0.004	0.061	0.126	0.191	0.255
	FASUSKIL	0.099	0.176	0.253	0.328	0.403
	FWHUSKIL	0.177	0.257	0.337	0.416	0.495
WF	FAFSKIL	0.111	0.189	0.267	0.344	0.420
	FCOSKIL	0.105	0.186	0.266	0.345	0.424
	FASSKIL	0.109	0.188	0.266	0.343	0.420
	FWHSKIL	0.092	0.165	0.237	0.308	0.379
YF	FAFSKIL	0.111	0.189	0.267	0.344	0.420
	FAFUSKIL	0.122	0.187	0.252	0.317	0.380
	FCOSKIL	0.105	0.186	0.266	0.345	0.423
	FCOUSKIL	-0.003	0.062	0.126	0.191	0.255
	FASSKIL	0.109	0.188	0.265	0.342	0.419
	FASUSKIL	0.099	0.175	0.251	0.326	0.400
	FWHSKIL	0.092	0.165	0.237	0.308	0.379
	FWHUSKIL	0.176	0.257	0.337	0.415	0.493

While the consumer welfare effects in terms of price changes and income changes are very small in all the simulation sets, it is interesting to compare the relative welfare effects between different household groups in the model. One of the results parameters generated by the CGE model is welfare measure based on the equivalent variation (*EV*) (for more, see Gravelle and Rees, 1992:117-119). Figure 4 shows the percentage changes in consumer welfare for each household group. The separate graphs for each racial group compare the welfare change between low and high-income urban and rural households.

The positive relationship between greater levels of technical change (*sim31* to *sim35*) and welfare is significant. Also apparent is the relative disadvantage of rural households across all racial groups. This is due to the adverse effects of fewer agricultural employment opportunities associated with domestic and international efficiency gains, which affects income levels and hence consumer welfare. Urban households, on the other hand, benefit from the combined effect of lower consumer prices and increased employment opportunities in non-agricultural sectors.

Also significant is the relative disadvantage of low-income households compared to high-income households, even within rural and urban areas. One possible explanation is the strong link between skilled workers and high-income households, and unskilled workers and low-income households. The returns to skilled workers are slightly higher on average (Table 8), which causes household income of low-income households to increase, on average, by less than that of high-income households. Although everyone is better off under all the scenarios reported, combined domestic and international efficiency gains are biased against low-income rural households, which may have important policy implications given the already skew distribution of income in South Africa.

Figure 4: Welfare effects by household groups (percentage changes)



5. Conclusions

Moderate domestic and international efficiency gains have small but important welfare effects in the South African economy. Under all the scenarios reported here, whether international trade prices of food and agricultural commodities decline, or whether domestic agricultural producers experience efficiency gains, consumers benefit from lower prices of especially agricultural goods, and, to a lesser extent, food products. For the economy as a whole, households also typically see their incomes increasing, which implies that the welfare effect associated with lower prices and higher income is unambiguously positive.

Producers, and in particular agricultural producers, face production declines when international efficiency increases. One way to counteract this is through domestic efficiency gains, which allows greater penetration of export markets, while price reductions further allow domestic demand increases. However, domestic and international agricultural efficiency gains cause this industry to shed labour. Although the results indicate that employment of unskilled workers at the economy-wide level increases, this positive outcome depends on the assumptions of inter-industry factor mobility of skilled and unskilled workers.

Although all households experience welfare gains, urban households and high-income households gain relatively more than their rural and low-income counterparts. It is therefore crucial that domestic efficiency gains, which are important for the industry to remain competitive in foreign markets, be supplemented with job creation programmes in rural areas to allow low-income households to recover from the adverse effects of job losses in the agricultural sector.

References

Armington, P.S. 1969. "A theory of demand for products distinguished by place of production," *IMF Staff Papers,* Vol. 16.

Chiang, A.C. 1984. *Fundamental Methods of Mathematical Economics,* 3rd Edition. McGraw-Hill: Singapore.

Dervis, K., de Melo, J. and Robinson, S. 1982. *General Equilibrium Models for Development Policy*. Cambridge University Press: New York.

Devarajan, S., Lewis, J.D. and Robinson, S. 1994. "Getting the Model Right: The General Equilibrium Approach to Adjustment Policy," *Mimeo*.

Dornbusch, R., Fischer, S. and Startz, R. 1998. *Macroeconomics,* 7th Edition. McGraw-Hill: New York.

Gravelle, H. and Rees, R. 1992. *Microeconomics,* 2nd. Prentice Hall: London.

Hall, R.E. and Taylor, J.B. 1993. *Macroeconomics,* 4th Edition. W.W. Norton & Company: New York.

Hartzenberg, T. and Stuart, J. 2002. "South Africa's Growth Performance since1960: A Legacy of Inequality and Exclusion," *Report prepared for the AERC Growth Project*. University of Cape Town.

Kilkenny, M. 1991. "Computable General Equilibrium Modeling of Agricultural Policies: Documentation of the 30-Sector FPGE GAMS Model of the United States." USDA ERS Staff Report AGES 9125.

Nattrass, N. 2000. "The Debate about Unemployment in the 1990s," *Studies in Economics and Econometrics,* 24: 73-90.

PROVIDE. 2003. "The PROVIDE Project Standard Computable General Equilibrium Model," *PROVIDE Technical Paper Series,* 2003:3.

PROVIDE. 2004. "A Social Accounting Matrix for South Africa: 2000," *PROVIDE Technical Paper Series,* Forthcoming.

Robinson, S., Kilkenny, M. and Hanson, K. 1990. "USDA/ERS Computable General Equilibrium Model of the United States." USDA ERS Staff Report AGES 9049.

Thirtle, C., Van Zyl, J. and Vink, N. 2000. *South African Agriculture at the Crossroads: An empirical analysis of effiency, technology and productivity*. MacMillan Press, Great Britain.

Vink, N. 2000. "Farm profitability and the cost of production inputs in South African agriculture," *A Report to the National Department of Agriculture*. http://www.agriinfo.co.za.

Wikipedia. 2004. "Green Revolution," published online at http://en.wikipedia.org/wiki/Green_revolution.

Appendix

Table 9: SAM Accounts for this study

SAM Name	Description	SAM Name	Description	SAM Name	Description	SAM Name	Description
CSCER	Summer Cereals	CELMACH	Electrical machines	ABEVTA	Beverages & tobacco	WHUSKIL	White unskilled labour
CWCER	Winter Cereals	CVEHIC	Vehicles	ATEXTIL	Textile and leather products	WHMAN	White manual labour
COSEED	Oilseeds	CMISC	Miscellaneous manufactures	AWPAP	Wood and Paper	HAFUL	African urban low
CSCANE	Sugarcane	CUTIL	Utilities	ACHEM	Chemical Products	HAFUH	African urban high
COFIELD	Other Field Crops	CCONSTR	Construction	ARUBPL	Rubber and Plastic	HAFRL	African rural low
CPOTVEG	Fruit and vegetables products	CTRADE	Trade services	ANONMET	Non metal products	HAFRH	African rural high
COHORT	Other Horticulture	CTRANS	Transport services	AMETAL	Metal products	HCOUL	Coloured urban low
CLSTOC	Livestock Sales	CSERV	Other services	AMACH	Machinery	HCOUH	Coloured urban high
CLPROD	Livestock products	CGOVT	Government services	AELMACH	Electrical machines	HCORL	Coloured rural low
COANIM	Other Animals	CDSERV	Domestic Services	AVEHIC	Vehicles	HCORH	Coloured rural high
CAGOTHER	Other agriculture	AGWC	Western Cape	AMISC	Miscellaneous manufactures	HASRL	Asian low
CMINES	Mining	AGNC	Northern Cape	AUTIL	Utilities	HASRH	Asian high
CMEATA	Meat products	AGNW	North West	ACONSTR	Construction	HWHUL	White urban low
CFRUITA	Fruit and vegetables products	AGFS	Free State	ATRADE	Trade	HWHUH	White urban high
COILSA	Oils fats and dairy products	AGEC	Eastern Cape	ATRANS	Transport services	HWHRL	White rural low
CGRAINA	Grain mill products	AGKZ	KwaZulu-Natal	ASERV	Other services	HWHRH	White rural high
CAFEEDA	Animal feeds	AGMP	Mpumalanga	AGOVT	Government services	IMPTAX	Import duties
CBAKEA	Bakery products	AGLP	Limpopo	ADSERV	Domestic Services	EXPTAX	Export taxes
CSUGAR	Sugar products	AGGT	Gauteng	GOS	Gross operating surplus	SALTAX	Sales taxes
CCONFEC	Confectionery products	AMINES	Other mining	AFSKIL	African skilled labour	INDTAX	Production taxes
CFOODA	Other food products	AMEATA	Meat	AFUSKIL	African unskilled labour	FACTTAX	Factor taxes

CBEVTA	Beverages and tobacco products	AFRUITA	Fruit	AFMAN	African manual labour	DIRTAX	Direct income taxes
CTEXTIL	Textile and leather products	AOILSA	Oils and dairy	COSKIL	Coloured skilled labour	GOVT	Government
CWPAP	Wood and Paper	AGRAINA	Grain mills	COUSKIL	Coloured unskilled labour	ENT	Enterprises
CCHEM	Chemical Products	AAFEEDA	Animal feeds	COMAN	Coloured manual labour	KAP	Savings
CRUBPL	Rubber and Plastic	ABAKEA	Bakeries	ASSKIL	Asian skilled labour	DSTOC	Stock Changes
CNONMET	Non metal products	ASUGAR	Sugar	ASUSKIL	Asian unskilled labour	ROW	Rest of World
CMETAL	Metal products	ACONFEC	Confectionery	ASMAN	Asian manual labour	TOTAL	Account Totals
CMACH	Machinery	AFOODA	Other food	WHSKIL	White skilled labour		

Table 10: Description of simulation sets and simulations

Simulation set	**Simulation number and description**				
	sim11	*sim12*	*sim13*	*sim14*	*sim15*
SIMSET1	adx (agric) up (0.50%)	adx (agric) up (1.00%)	adx (agric) up (1.50%)	adx (agric) up (2.00%)	adx (agric) up (2.50%)
	sim21	*sim22*	*sim23*	*sim24*	*sim25*
SIMSET2	pwe & pwm down: agric (0.50%) & food (0.25%)	pwe & pwm down: agric (1.00%) & food (0.50%)	pwe & pwm down: agric (1.50%) & food (0.75%)	pwe & pwm down: agric (2.00%) & food (1.00%)	pwe & pwm down: agric (2.50%) & food (1.25%)
	sim31	*sim32*	*sim33*	*sim34*	*sim35*
SIMSET3	pwe & pwm down: agric (2.00%) & food (1.00%); adx (agric) up (0.50%)	pwe & pwm down: agric (2.00%) & food (1.00%); adx (agric) up (1.00%)	pwe & pwm down: agric (2.00%) & food (1.00%); adx (agric) up (1.50%)	pwe & pwm down: agric (2.00%) & food (1.00%); adx (agric) up (2.00%)	pwe & pwm down: agric (2.00%) & food (1.00%); adx (agric) up (2.50%)

Table 11: Closure rules

Closure	Description of closure assumption
Foreign exchange market	The external balance is assumed fixed and equilibrium is obtained via a flexible exchange rate. All world prices of imports and exports are fixed based on the small country assumption.
Capital account	The share of investment expenditure in total final domestic demand remains is assumed constant. The equilibriating variable is the savings rate of all households and incorporated business enterprises, which are allowed to vary equiproportionately to ensure that savings equal investments in the economy.
Government account	Government savings (budget deficit or surplus) is variable. All tax rates are assumed to remain constant and the government is assumed to consume a fixed share of total final domestic demand. The impact of the policy shocks evaluated in this paper upon government revenue is small. Consequently the impact of allowing the government savings to vary is marginal.
Factor market	Skilled labour is assumed to be fully employed and mobile across various sectors (activities) in the economy, and hence the equilibriating variable is the wage rate. The supply of unskilled labour is assumed to be perfectly elastic, based on the assumption that there is excess capacity (unemployment) of this type of labour in the economy. Activities can increase employment of unskilled workers by any margin as long as they are willing to pay the constant wage. For physical capital a short run scenario where the quantity of capital used by each activity is fixed is assumed. This means that the industry-specific return to capital adjusts to maintain the employment level in the sector.
Numéraire	The model numéraire is the consumer price index (CPI). Consequently, all the value results of the model are expressed in real terms.