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The role of improved livestock technologies in poverty alleviation in sub-Saharan Africa A multi-region, economy-wide analysis *

by

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Introduction

Sub-Saharan Africa is the most important development challenge of the 21st century. According to the 1997 World Development Report of the World Bank, the production of Sub-Saharan Africa amounted to $300 billion. Take off South Africa, and you are left with $160 billion. Nor are most African markets growing particularly fast. In 1980, the economy of Sub-Saharan Africa was larger than that of Brazil; today it is about 4/10th the size of Brazil's.

Furthermore, poverty is higher in most African countries than elsewhere in the developing world – about 40 percent of the citizens of Sub-Saharan Africa lives on less than single U.S. dollar a day; those most vulnerable to poverty live in rural areas, in large households, which are often headed by women; education is low for these most vulnerable groups, and they are also most likely to live in those countries with real growth rates of less than 5 percent (World Bank).

The combination of low economic growth, the highest rate of population increase in the world (at an annual rate of 2.8 percent), and a high burden of dependents to workers, puts Africa low on the rankings for those most critical indicators of social progress: longevity, education, and access to resources for improving their standard of living. Thus, the challenge is not only to achieve sustainable growth but also to focus that growth on poverty alleviation.

Recent African growth statistics have begun to show, however, the first signs of economic revival in several countries, after decades of stagnation. In 1997, economic growth was estimated at 4.6 percent, compared to 4.8 percent in 1996 and 3.3 percent in 1995. Last year, 21 countries (out of a total of 48) had a GDP growth rate of 5 percent or more and at least

38 countries had positive GDP per capita growth rates (World Bank). But growth may not be sustained if it is not supported by investments in human and social infrastructure, especially in the rural areas. Expanding Africa's trade and foreign investment in Africa are important to accelerating growth in Africa. About 70 percent of Africa's poor live in rural areas, however, and the rural population is expected to outnumber the urban population for the next three decades (World Bank). Thus agriculture needs to be an engine of growth for the economy as a whole, rural areas and the poor.

This paper assesses the potential impacts of technological change in livestock research on poverty alleviation in Sub-Saharan Africa (SSA)[1]. We address the poverty issues by examining the impact of livestock research on growth (welfare gains), trade, employment of unskilled labor, prices of food products and returns to owners' factors of production. We also investigate the impacts of different types of technical change namely Hicks-neutral and biased technical change in the livestock sector. We also examine the impacts of technological spillovers (that is when a technology not only benefits SSA but also other regions of the world) as well as the impacts of technological retardation in livestock research in SSA.

To quantify those impacts of technological change we employ a global, applied general equilibrium (AGE) framework. A multi-region AGE model is a general, internally consistent framework, which is convenient for analysis of policy options that affect several regions and sectors as it avoids under- or over-estimating of welfare effects of policy options.

[1] Our definition of SSA excludes North Africa but includes South Africa. However in the analysis South Africa is separated from the Rest of SSA

The role of the livestock sector in poverty alleviation

It is interesting to examine the question of impact of livestock research and poverty alleviation in SSA for many reasons. This region (excluding South Africa for the moment) is one of the poorest regions of the world, accounting for less than 2 percent of global GDP and more than 10 percent of the world's population (World Bank, 1998). Since the early 1980s, there has been a persistent downward trend in GDP per capita in SSA, in contrast to other regions. Between 1979-81 and 1989-91 per capita food consumption declined most in SSA, while it increased in the rest of the developing world (Pinstrup-Andersen and Pandya-Lorch, 1994). Table 1 shows that in 1993 nearly 220 million people in SSA (representing almost 40 percent of the population) were living below the poverty line. Table 1 also shows that the degree of poverty in SSA is greater than in any other world region and increased steadily between 1987 and 1993 (Holst and Hartnett, 1997). Since agriculture accounts for 30 percent of GDP, 40 percent of exports, and 70 percent of employment in the region, technological improvements that simultaneously raise agricultural productivity and incomes of the rural poor and lower food prices have great scope for reducing the overall incidence of poverty. The majority of the poor in SSA live in rural areas, employed largely in agriculture or related occupations. The scarcity of capital in the region makes it impossible in the short run to absorb more than a small proportion of the poor people outside the rural sector. Consequently, growth in food production and agriculture in general is the only means by which employment and incomes of the poor can be increased (Mellor, 1989). In fact Hertel et al. (1998) show that although SSA is likely to loose when the Uruguay Round is implemented, the cost to the region can be outweighed significantly from potential gains in agricultural productivity and in transport costs. However Hertel et al. (1998) focussed only on grains.

In SSA, like in many developing countries livestock are central to the livelihood of the rural poor. They are an important source of cash income and are one of the few assets available to the poor, especially poor women. Research results show that for all categories of farmers more cash is derived from the livestock sub-sector than on the crop sub-sector (Ehui et. al., 1998).[2] Livestock manure and draft power are essential to the preservation of soil fertility and sustainable intensification of farming systems. In addition livestock products enable farmer to diversify income, helping to reduce income variability, especially in semi-arid systems characterized by one cropping season per year (Delgado et.al. 1999).

As per capita income grows, people tend to prefer a more diverse diet, and expenditures on some food items such as meats tend to grow faster than for food staples such as cereals and legumes (Canfields, 1998, Hertel et al. 1999). Recent work by Cranfield *et al.* (1998) suggests that demand side forces are indeed in place to fuel such growth. Figure 1 reports fitted budget shares (at mean prices) for food products, from an AIDADS demand system estimated using 1985 data from the International Comparisons Project. The vertical bars show real income levels for six focus countries in 1985 in the following order (left to right): Ethiopia, Pakistan, Senegal, Korea, France and the United States. While grain's budget share is declining over the full range of the sample, the budget shares for livestock, horticulture and vegetable and other food products increase at lower levels of per capita expenditure (section I), reach a maximum, and then decline as per capita expenditure grows. Note that the importance of grains relative to livestock products changes dramatically as per capita expenditure increases (section II). The latter has the largest budget share of the food products when per capita expenditure exceeds an

[2] In semi-arid Mali, livestock contributed 78 percent of cash income in smallholder mixed farming (Deborah et. al Sissoko, 1990). Gryseels (1988) showed that the sale of livestock and livestock products contributed 83 percent of cash income per year in the Ethiopian Central highlands.

average level of per capita expenditure roughly equal to that of Pakistan in 1985. At lower income levels, the increasing budget share for livestock products derives from an income elasticity of demand in excess of one. This means that livestock demand can be expected to grow as fast, or faster than the economy at large, thereby potentially fueling strong import demand. In fact, Cranfield *et al.* (1998) project annual growth in per capita livestock product demand in Ethiopia (the poorest country in the sample) over the period 1995 to 2020 to be double that in the richer countries (3.4% vs. 1.8% in France). When population growth is factored in, the annual growth in livestock demand is three times higher in Ethiopia (Cranfield *et al.*, 1998, Table 3).

Growth in livestock demand in SSA is projected to increase due to expected population and income growth. From the beginning of the 1970s, total meat consumption in Sub-Saharan Africa grew by 2.2 percent per year despite a decline in GNP per capita of 1.3 percent per year between 1980 and 1995. Between 1970 and 1995 total and urban population grew at 2.9 and 5 percent per year in SSA and these were the highest in the world (UNDP, 1998 cited in Delgado et. al. 1999). Thus population growth and urbanization fueled the increase in meat consumption in SSA. This trend is expected to continue as populations and incomes are expected to increase. Meat and milk consumption is expected to grow at 3.5 and 3.8 percent annually between 1993 and 2020. It is also expected that meat and milk production will grow annually by 3.4 and 4 percent over the same period (Delgado et. al. 1999). In order to achieve this growth level, significant investment in livestock research and development will be necessary.

Prospects for improvements in livestock technology

A number of technologies are available which can help increase livestock productivity in Sub-Saharan Africa. Modern science has developed, and continues to develop a large number of technologies for enhancing the productivity of livestock production, processing and marketing activities. The use of exotic breeds has enabled genetic improvement within herds and flocks to be speeded up. Artificial insemination (AI) is a well-known reproductive technology. Its spread in SSA is likely to occur through market processes. But recent developments in embryo transfer raise the possibility that it might replace AI. A range of associated techniques have been developed. The transfer of embryos from donor to recipient animals allows the build-up of genetically-superior animals using lower-grade and inexpensive recipients. Thus herd improvement can be achieved at faster rates than with natural mating or artificial insemination. But this form of reproduction will not become widespread in the developing countries within the next 20 years (Cunningham, 1997). Other techniques include the splitting of embryos to produce multiple copies of genetically identical animals, embryo cloning, *in vitro* fertilization and sex determination. Recent advances in cloning of embryos could potentially have a large impact on livestock production, particularly of dairy cattle in the developed world. But this is still an area where a number of complex ethical issues have yet to be resolved (Cummingham, 1997). In the tropics, it has become a common practice to cross local breeds with highly productive varieties from the developed world. Advances in genetics also offer new means to improve livestock. For example marker-assisted selection and detection of quantitative traits loci combine results from molecular and quantitative genetics research (Delgado et al., 1999).

Genetic improvement has been enhanced even further with the aid of biotechnology. The latter involves the use of living organisms to produce improvements within animals, such as the various genetic engineering (DNA) techniques to manipulate genetic material and to transfer genes from one organism to another. In such ways, animal quality may be rapidly upgraded through improvements in genetic make-up and in the rate of reproduction. It has become possible during the past ten years to produce maps of genetic linkages in order to identify the gene locations of economically important traits such as disease resistance and performance. Biotechnology has also aided improvements in feed efficiency, milk production, and in the development of vaccines. Numerous compounds have been developed to promote faster growth and improved feed efficiency, such as the use of anabolic steroids in cattle as a growth promotant. Also becoming well known is the elevation of natural levels of somatotropins (naturally-occurring protein hormones) in cattle, pigs, poultry and sheep. Growth rates, feed efficiency and milk yields may all be increased (CAST, 1999).

In the area of animal health, biotechnology offers promise for the improved diagnosis and treatment of animal disease. Livestock health research benefits from greater resources available to human health research. For example, genomics is a new science is a new science applicable to humans and livestock and livestock that permits sequencing and mapping of the genome (a genetic map of a living organism). Genomics takes advantage of the work of the genomes of disease organisms and permits the development of new generations of vaccines, including those that use recombinant antigens to pathological agents (Fitzhugh, 1998; Delgado et. al. 1999). Farmers in the developing regions typically lack low-cost, easy-to-use diagnostics, vaccines, and control strategies for disease organisms and vectors. Among the parasitic diseases, trypanosomiasis (sleeping sickness) transmitted by tsetse flies, poses an enormous constraint to cattle production in most of the humid and sub-humid zones of Africa. Other important parasitic diseases groups include helminthiasis and tick-borne diseases. Although helminths are rarely fatal, they become a limiting factor in the intensification stage. Ticks have the capacity to transmit diseases notably theleiriosis (or East Coast Fever) in Eastern and Southern Africa effective vaccine for this disease may soon be available with a potentially large impact in ruminant productivity in those countries (Delgado et. al. 1999).

To improve Feed quantity and quality, research to reduce costs and improve efficiency will have to be highly targeted. The identification of suitable traits and their molecular markers help improve the quality of tropical feeds derived from crops breeders use the markers to develop dual purpose crops with improved grain and protein content for humans and non-ruminants and higher quality crops residues for ruminants. Plant genomics and phytochemistry will tackle antinutritional factors, some of which can be poisonous to ruminants. Microbial techniques exit that can help enrich ruminant ecosystems with microbes that can better detosify antinutritional factors.

The success with which these technologies can be brought into commercial use and the rate and success, with which they may be adopted, will be influenced by many factors including policy, socioeconomic, and institutional factors. Delgado et al. (1999) have identified such factors in four broad categories: (1) removing the policy distortions that promote artificial economies of scale, (2) building institutions for incorporating poor producers in the benefits of livestock development, (3) creating public goods (technologies) for livestock development and (4) regulating environmental and public health concerns.

Economic framework, and experimental design

In this section, we discuss briefly the economic framework that we employ to conduct our policy simulations and we specify those simulations.

Economic model: An applied general equilibrium (AGE) model provides a general framework for analysis of productivity and trade-policy changes. Research-induced technical change in agriculture can have economy-wide implications for employment and returns to factors of production, including the non-agricultural sectors. Through output-market adjustments, technical change in agriculture affects the relative prices of agricultural and non-agricultural products, even if they are not directly affected by new technology. Induced changes in product markets lead to further changes in factor markets. Thus, agricultural productivity changes can affect foreign exchange earnings by affecting terms of trade between countries or regions; labor and land use in agriculture and non-agricultural productions; and relative factor and product prices (Alston et al., 1995).

A multi-region AGE model also provides an internally consistent framework which avoids the pitfalls of under- or over-counting welfare effects in a multi-market setting, by avoiding partial equilibrium errors when evaluating the impact of technological change across multiple agricultural (Frisvold, 1997). In this paper, we use the Global Trade Analysis Project (GTAP) model which is fully documented in Hertel, 1997.

Furthermore, the GTAP version used here embodies a Constant Elasticity of Substitution (CES)–Constant Elasticity of Transformation (CET) technology. This provides an exact and theoretically consistent measure of producer gains to research. Finally, AGE models specify the structure of primary factor markets explicitly, permitting the direct examination of impacts of technology change on returns to owners of land, accounting for shifts in land and labor use and differential returns by type of sector.

Sectoral and regional specification: The GTAP framework consists of a global database and an economic model for performing simulations of policy initiatives. The database represents economic conditions in 1995 and it covers 50 sectors (or commodities) in 45 countries (or regions). In version 4 of the database, Africa is divided into five sub-regions that permit us a disaggregated analysis (McDougall et al.,1998).

Experiments in this paper are based on a thirteen-commodity seven-region design using a full multi-region, general equilibrium closure. SSA is divided into two major regions: the Rest of SSA and Southern Africa. Our commodity and regional aggregations are shown in Table 2. A multi-region specification allows us to consider open economy effects of technical change. This aggregation also allows for explicit examination of the transmission of effects of technological change among livestock grains, non-grains, processed food, meat and dairy sectors of the economy. Grains output are intermediate inputs in both livestock and food production. Livestock is a major input to processed meat, dairy and other processed foods.

Experiment specification:

Experiment 1(E1): Three percent Hicks-neutral technical change in animal products with no spillovers

Our first experiment consists of implementing a 3 percent technical change in animal products in the Rest of SSA (E1A) and Southern Africa (E1B) separately and with no spillovers in other regions. This shock is similar to reducing the costs of animal product production in the two regions. It uniformly reduces the input requirements associated with producing a given level of output. The 3 percent growth rate is below the projected growth rate of 3.4 percent in meat production in SSA (Delgado et. al. 1999). The shock is implemented as a 3 percent increase in the output augmentation parameter for the animal products sector.

Experiment 2 (E2): Three- percent Hicks-neutral with technical change in animal products with spillovers

This second experiment considers the case where research results are adopted by other regions. Since agricultural research results in SSA are international public goods, other regions without restriction can adopt them. Thus research reduces costs not only in the innovating region, but also in other regions. Specifically, it is assumed that livestock research carried out in SSA reduces cost in all other regions by 3 percent. The shock is implemented as a 3 percent increase in the animal product augmentation parameters, corresponding to the animal products sector of all seven regions.

Experiment 3 (E3): Impacts of lagged technology adoption in SSA

This experiment represents the case of SSA falling behind technologically in livestock research. We consider a three-percent output-augmenting technical change in the animal products sector of all regions except the two regions in SSA. We compare this experiment with Experiment 1 and 2 in order to examine the implications of technological retardation in SSA.

Experiment 4 (E4): Three percent cost-reducing technical change in the livestock sectors though a labor-augmenting technical change.

This experiment examines the impact of reducing the cost of production of animal products through unskilled labor-augmenting technical change (biased technical change). We study this technical change because labor is often perveived as a main constraint in African agriculture and improving the productivity of labor is often perceived as an appropriate policy strategy. In addition unskilled labor constitutes the largest share of total endowment costs in the animal products sector (71% for Rest of SSA and 49% for Southern Africa). The three percent cost reduction was implemented by shocking the labor augmentation parameter, afe[32] by 3 percent divided by labor's cost share in the animal product sectors in SSA. That is, the efficiency of unskilled labor input increases but leaves unchanged the efficiency of other inputs.

Experiment 5 (E5): Three percent cost reduction through a grain- augmentation technical change in the animal products sector.

Experiment 5 serves to assess the impact of a biased technical change that increases the efficiency of converting grains into livestock. The GTAP database shows that grains contribute only 4% and 2.4% of the intermediate inputs in animal production in SSA. However, there are concerns that rapid increases in livestock production will increase grain prices and therefore divert good away from the poor. Total use of cereals as feed rose by 5.2% percent annually in SSA between 1982 and 1994 and is projected to increase by 3.5 percent annually between 1993 and 2020 (Delgado et. al. 1999).

Simulation Results

Table 3 presents the results of Experiment 1 (3 percent output-augmenting technical change in livestock in SSA). When there are no technological spillovers (E1), domestic welfare gains amount to US$ 225 and US$ 139 million for the Rest of SSA and Southern Africa, respectively. Rest of SSA and Southern Africa capture 97 and 80 percent of the total global gains as a result of the technical change in the two regions. Aggregate exports of animal

[3] The parameter afe is defined as the proportional change in labor input. If labor =L, then afe = $\Delta L/L$

products in the Rest of SSA and in Southern Africa increase from US$216 to US$256 million and from US$140 to US$164 million, respectively. In percentage terms this represents an increase of about 18% and 17% for Rest of SSA and Southern Africa, respectively. Exports of meat products also increase as a result by 6.25% and 7.39% for the two regions, respectively.

Output prices for all food products fall. In particular prices for animal products fall by over 3 percent in the two regions. Meat product prices fall by 1.46% in the Rest of SSA and by 1.75% in Southern Africa. Although returns to land decline, wage rates of unskilled labor increase. Thus the ratio of wage rates to food prices increases, thereby enhancing the purchasing power of the poor. Employment decreases in the animal product sectors by 2.11 percent and by 1.54 percent in the Rest of SSA and Southern Africa, respectively; employment increases, however, by 1.88 and 1.16 percent in the meat products sectors. That employment decreases in the animal and meat product sector despite technological change dismisses the usual argument that greater competitiveness in a sector leads to increased employment in that sector.

In the presence of technological spillovers (Experiment 2 in Table 3), the gains for SSA are very modest. Welfare gains amount to US$196 and US$134 million for the Rest of SSA and Southern Africa, respectively. But these gains represent only about 1% of the total global gains. Exports of food products either decrease or increase only marginally. All returns to factors of production decline. Employment declines in the agricultural sectors or increase marginally. Those results imply that poverty cannot be reduced unless SSA catches up technologically with the rest of the world. It will be important that technical progress in livestock moves faster than in other region in SSA in order for SSA to capture the domestic benefits of the global gains.

The situation is worse when SSA lags behind technologically (Experiment 3 in Table 4). SSA looses in terms of welfare gains a result of technological retardation while global welfare gains increase by over US$16 billion. Actual GDP in the Rest of SSA declines by over US$ 11 million dollars. Employment in all the agricultural sectors, exports, and returns to factors of production decline. Although food prices fall, the decline in wage rates wipe out the potential gains from the fall in food prices.

When the same cost reduction in animal products is achieved through a labor augmenting technical change (Experiment 4 in Table 5) welfare gains increase to US$133 and US$66 million for the Rest of SSA and Southern Africa, respectively. Exports of animal products increase by 9.24% and 6.70% for both regions respectively. Exports of meat products increase by 3.29% and 2.96% respectively. Wage rates decreases slightly but returns to land in grains, non-grains and animal products increase. Output prices for grains and non-grains increase marginally. Although animal product prices and meat product prices fall, the decline in wage rate is not likely to give increased access to food for the unskilled rural labor as in the case of Experiment 1.

In the case of a grain-augmenting technical change (Experiment 5 in Table 5) welfare gains increase to US$78 million and US$ 66 million in the Rest of SSA and Southern Africa respectively. Exports of animal products increase by 5.56%and 6.92% for the two regions respectively. Employment in the grain sector decreases by 0.36% and 2.45 % respectively but increases in the non-grain, animal and meat products sectors respectively. Returns to land in non-grains fall while wage rates and returns to land in animal product increase. Output prices for all food products fall thereby increasing the purchasing power of the poor unskilled citizens in rural areas.

3. Conclusions

Sub-Saharan Africa is the most important development challenge of the 21st century. Poverty is higher in most Sub-Sahara African countries than elsewhere in the developing world. Thus, the challenge is not only to achieve sustainable growth but also to focus that growth on poverty alleviation. Recent African growth statistics have begun to show, however, the first signs of economic revival in several countries, after decades of stagnation. But growth may not be sustained if it is not supported by investments in human and social infrastructure, especially in the rural areas. Expanding Africa's trade and foreign investment in Africa are important to accelerating growth in Africa. About 70 percent of Africa's poor live in rural areas, however, and the rural population is expected to outnumber the urban population for the next three decades. Thus agriculture needs to be an engine of growth for the economy as a whole, rural areas and the poor.

This paper focused on the impact of technological change in the livestock sector in Sub-Saharan Africa. We derived implications for poverty alleviation by examining the impact of livestock research on growth, trade, employment, and returns to factors of production. The cause of hunger is lack of purchasing power of the poor. Thus examination of the impact of livestock research on food prices and purchasing power reveals interesting insights for poverty alleviation. A multi-region, economy-wide model with thirteen commodities and seven regions was used to conduct simulations. The simulations generated the following conclusions:

(1) Factor-neutral technical change (without spillovers) have the highest potential to reduce poverty in SSA according to a number of criteria: (a) global welfare gains (b) domestic capture of the gains, (c) trade, and (d) raising the ration of wage rates to prices of food.

Since the poor spend relatively more of their income on food, the latter has significant implications for poverty alleviation.

(2) SSA will have to catch technologically in order to take advantage of the benefits of research. When the rest of the world benefits from the technological innovation in SSA, the gains to SSA are quickly are quickly eroded with a negative consequence for poverty alleviation. The situation becomes worse when SSA lags behind technologically. SSA experiences welfare losses with a negative impact on gross domestic product.

(3) Technological change biased towards labor reduces employment in animal product sector and wage rates declines. Employment does not increase in the other sectors of the economy. To absorb the excess labor. Therefore it seems that a strategy that will continue to use the rural unskilled labor rather than displacing offers more potential than a strategy geared toward more a labor-augmenting technology.

(4) Grains represent a small proportion of the intermediate products in the production in SSA. Nevertheless a technical change biased toward a grain augmenting technical change appear to generate benefit from a poverty reduction viewpoint. Output prices decline while wage rates increase or remain unchanged. Except for the grain sector, employment increases in the other agricultural sectors. SSA also captures a large share of the global welfare gains due to the technical change.

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Table 1: Population living below US$1/day in developing and transitional economies, 1987-93[a]

Region	Population Covered[b] %	No. of poor (millions)			Headcount index (%)[c]			Poverty gap (%)[d]		
		1987	1990	1993	1987	1990	1993	1987	1990	1993
East Asia & Pacific	88	464	468	446	28.2	28.5	26.0	8.3	8.0	7.8
(excluding China)	(62)	(109)	(89)	(74)	(23.2)	(17.6)	(13.7)	(3.8)	(3.1)	(3.1)
E.Europe & Central Asia	86	2	n.a.	14	0.2	n.a.	3.5	0.2	n.a.	1.1
Latin Amer.&Caribbean	84	91	101	110	22.0	23.0	23.5	8.2	9.0	9.1
Middle East & N.Africa	47	10	10	11	4.7	4.3	4.1	0.9	0.7	0.6
South Asia	98	480	480	515	45.4	43.0	43.1	14.1	12.3	12.6
Sub-Saharan Africa	66	180	201	219	38.5	39.3	39.1	14.4	14.5	15.3
Total	85	1,227	n.a.	1,314	30.1	n.a.	29.4	9.5	n.a.	9.2
Total excluding ECA[a]	85	1,225	1,261	1,299	33.3	32.9	31.8	10.8	10.3	10.5

Source: World Bank 1996. (Cited in Holst and Hartnett, 1997).

[a] There are many differences between these estimates and previous estimates, including those in World Bank 1993a and World Bank 1990. Unlike past estimates, these numbers are based on survey data, rather than extrapolations, and on new purchasing power parity estimates,

[b]) By at least one survey.

[c]) Share of population below the poverty line.

[d]) Mean distance below the poverty line expressed as a percentage of the poverty line.

[e]) East Europe and Central Asia.

Table 2. Regional and Commodity Aggregation

Regional Aggregation	Commodity Aggregation
1. **North Africa and Middle East (NAFR_MEAST)** Morocco, Turkey, Rest of North Africa, Rest of Middle East	1. **Grains** Paddy rice, Wheat, Cereal; other grains
2. **Southern Africa (SothernAfrica)** South African Countries Union, Rest of Southern Africa	2. **Non grains** Vegetables, fruits, nuts, oil seeds, sugar Cane, soya bean, plant based fibers, other Crops
3. **Rest of Sub-Saharan Africa (RestSSA)**	3. **Animal products (Animal Prod)** Ruminants, other animal products
4. **Asia (Asia)** South and Southeast Asia	4. **Raw milk (Rawmilk)**
5. **Western Hemisphere (Whemisph)** Canada, U.S.A., Mexico, Latin America and the Carribbean	5. **Other livestock (OthLvstk)** Wool, silk-worm cocoons
6. **European Union (EU)**	6. **Natural Resource Industries (NatResInd)** Forestry, coal, oil, gas, minerals
7. **Rest of the World (ROW)**	7. **Processed food (Procfood)** Veg.oils and fats,processed rice,sugar,other food products
	8. **Meat Product (Meatprod)** Meat,meat products
	9. **Dairy Products(Dairyprod)** Dairy products
	10. **Fishing** Fishing
	11. **Beverages** Beverages and tobbacco pdts
	12. **Manufactures (Mnfctrs)**
	13. **Services**

Table 3: Impacts of a 3% output-augmenting technological change that reduces cost for producing animal products in Sub-Saharan Africa without and with spillovers (percent)

	Without spillovers		With spillovers	
	E1A Rest of Sub-Saharan Africa	E1B Southern Africa	E2 Rest of Sub-Saharan Africa	E2 Southern Africa
Trade (qxw), % change				
Grains	0.05	0.37	-1.36	-0.96
Non-grains	0.02	0.26	-0.68	-0.52
Animal products	18.20	17.24	-1.71	-2.15
Meat products	6.25	7.39	-0.18	1.18
Output prices (pm), % change				
Grains	-0.02	-0.08	-0.30	-0.36
Non-grains	-0.01	-0.07	-0.30	-0.36
Animal products	-3.07	-3.08	-3.38	-3.37
Meat products	-1.46	-1.75	-1.73	-2.01
Factor prices (pfe), % change				
Land in grains	-0.45	-0.93	-1.41	-3.26
Land in non-grains	-0.51	-0.87	-1.58	-3.14
Land in animal production	-2.20	-2.16	-3.66	-5.02
Wage rate (unskilled labor)	0.09	0.06	-0.19	-0.02
Employment (qfe), % change				
Grains	0.06	0	0.01	0.47
Non-grains	-0.01	0.07	-0.20	-0.32
Animal products	-2.11	-1.54	-2.81	-2.71
Meat products	1.88	1.16	0.15	0.60
Equivalent variation (EV)				
Domestic ($USm)	224.73	139.39	195.85	133.66
Total ($USm)	230.23	173.60	17082.90	17082.90
Domestic EV as % of total EV	97	80	1.15	0.78

Table 4: Impacts of Sub-Saharan Africa lagging behind technologically

	E3 Rest of Sub-Saharan Africa	E3 Southern Africa
Trade (qxw), % change		
Grains	-1.46	-1.34
Non-grains	-0.72	-0.79
Animal products	-l6.83	-16.38
Meat Products	-6.01	-5.77
Output prices (pm), % change		
Grains	-0.27	-0.27
Non-grains	-0.28	-0.28
Animal products	-0.31	-0.28
Meat products	-0.27	-0.27
Factor prices (pfe), % change		
Land in grains	-0.94	-2.29
Land in non-grains	-1.05	-2.23
Land in animal production	-1.40	-2.79
Wage rate(Unskilled labour)	-0.27	-0.08
Employment (qfe), % change		
Grains	-0.05	-0.47
Non-grains	-0.20	-0.39
Animal products	-0.63	-1.09
Meat products	-1.69	-0.55
Equivalent variation (EV)		
Domestic ($Usm)	-26.26	-5.07
Total ($USm)	16686.97	16686.97

Table 5: Impact of a 3% cost reduction in the animal product sector coming from different types of technical change in Sub-Saharan Africa (percent)

	Type of Augmenting Technical change			
	E4A Labor (Rest SSA)	E4B Labour (Southern Africa)	E5A Grains (Rest SSA)	E5B Grains (Southern Africa)
Trade (qxw), % change				
Grains	-0.01	0.03	0.09	0.07
Non-grains	-0.04	-0.05	-0.01	0.06
Animal products	9.24	6.70	5.56	6.92
Meat products	3.29	2.96	1.99	3.05
Output prices (pm), % change				
Grains	0	0.01	-0.03	-0.20
Non-grains	0.01	0.02	0	-0.01
Animal products	-1.63	-1.27	-1.00	-1.31
Meat products	-0.78	-0.72	-0.48	-0.74
Factor prices (pfe), % change				
Land in grains	0.24	0.17	-0.46	-2.34
Land in non-grains	0.23	-0.11	-0.14	-0.32
Land in animal production	0.03	-0.05	0.07	0.16
Wage rate (Unskilled labor)	-0.02	-0.01	0.03	0.04
Employment (qfe), % change				
Grains	0.09	0.11	-0.36	-2.45
Non-grains	0.07	-0.03	0.03	-0.32
Animal products	-3.26	-5.03	0.29	0.64
Meat products	1.11	0.51	0.64	0.50
Equivalent variation (EV)				
Domestic ($Usm)	133.23	65.65	97.15	66.03
Total ($USm)	131.56	74.25	99.28	81.35
Domestic EV as % of total EV	101	88	98	81