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Working Paper No. 37

THE ROLE OF LIVESTOCK IN THE KENYAN ECONOMY: Policy

Analysis Using a Dynamic Computable General Equilibrium

Model for Kenya

Ermias Engida, Paul Guthiga, Hannah Nyota and Joseph Karugia

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1. Introduction

In most African countries, the livestock sector supports livelihoods of large proportion of rural households and may have an important role to play in rural poverty reduction strategies. In livestock rich countries like Kenya, its role is even bigger nationally and stronger for large proportion of most rural households. Similarly, a good number of urban households are directly dependent on income they earn by selling livestock products or by getting employment in livestock-related agro-processing industries such as dairy, meat, and leather. Livestock production contributes almost 90 percent of the livelihood of households and accounts for nearly 95 percent of family income in the Arid and Semi-Arid Lands (ASALs) (Kenya Ministry of Agriculture, 2008). However, national and regional development policies have rarely recognized the actual and potential roles of livestock sector development in reducing poverty among rural households in Sub-Saharan Africa.

The livestock sector in Kenya reportedly contributes 12 percent to Kenya's national GDP and 42 percent to agricultural GDP (SNV, 2008). However, there is reason to believe that its contribution is underestimated. For example, a study sponsored by Livestock Policy Initiative of the Intergovernmental Authority on Development (IGAD-LPI) (Behnke and Muthami, 2011) claimed that this figure grossly underestimates the actual contribution of the sector. "...Kenya's livestock are economically much more important than hitherto believed; in fact, only marginally less than crops and horticulture combined." In fact, this phenomenon is not unique for Kenya. A recent study on the Ethiopian economy revealed that the direct and indirect roles of the livestock sector on the wider economy have been substantially underestimated (Gelan et al, 2012).

The study by IGAD-LPI (Behnke and Muthami, 2011) reported that in 2010, 11.4 percent of the national household consumption expenditure is spent on livestock-derived food items. Additionally, between 2005 and 2010, manufacturing based on three animal product inputs– meat, milk and hides/skins – constituted about 12 percent of Kenya's total official manufacturing output. This can provide insight on how important the sector is to the Kenyan economy even though it is underestimated. In order to have a complete picture and better understanding about its uses and inter-linkage with the rest of the economy, it is necessary to make use of economy-wide models.

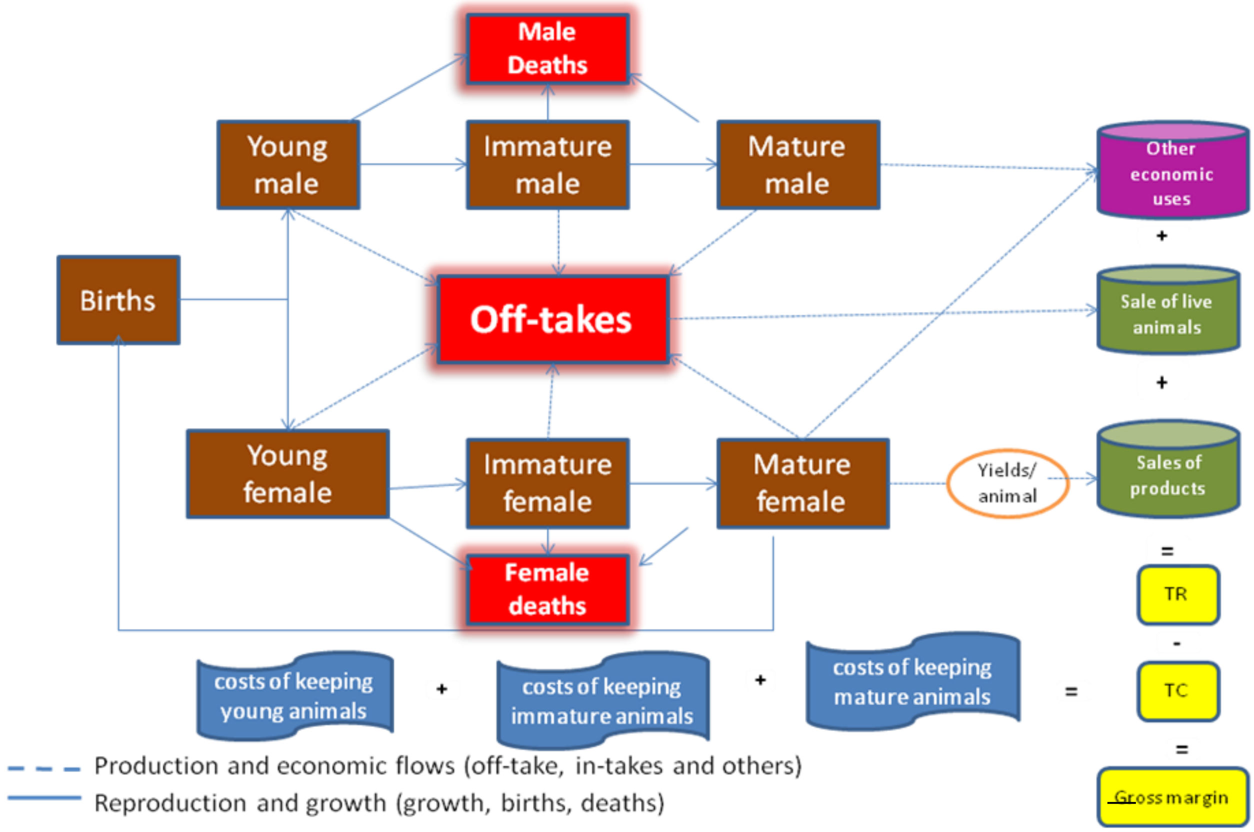
When applying economy-wide models to understand the role of the livestock sector in the rest of the economy, the model should ideally capture both the biological, dynamic relationships between the stocks and flows of livestock and the economic linkages between the sector and the rest of the economy. The existing dynamic recursive general equilibrium model for Kenya is extended to better capture this feature of the livestock sector in the economy. A separate herd dynamics module is developed which enables us to specify stock-flow relationship, distinguishing between the capital role of livestock and the flow of livestock products. The underlying system of economic accounts (i.e. the Social Accounting Matrix) is also modified to better capture breeding stocks.

The major significance of this study is thus, to give the already existing dynamic CGE model the ability to better treat the livestock sector by capturing its complete natural picture through coupling of the stock–flow feature of the sector into the model. Researchers neglect the livestock sector mainly for methodological reasons. This study set out to overcome these methodological reasons and the shortcomings in existing economy-wide modelling. Besides, this study shows the strong potential of the livestock sector to economic growth. It reveals the direct and indirect roles of the livestock sector on the wider economy, which have been substantially underestimated.

2. The herd dynamics module, the conceptual framework and data organization

The herd dynamics module is a representative one for most livestock types. In Figure 1 below, the module is displayed in stock-flow diagram. One part of the figure shows the dynamics of the stocks. Naturally, mature females give birth to young ones, which are male or female. Each sex category passes through different stages, i.e., from young to immature to mature. The proportion that passes to the next stage depends on survival rates, which in turn are determined by death rates and off-take rates. This stock dynamics is represented by the solid lines in the figure.

Figure 1. Schematic representation of herd dynamics and productivity



Source: A.Gelan et al. 2012

Figure 1 is a simple diagrammatic exposition of stock-flow relationships that captures deeper economic logic too. A typical dairy cow continues to yield milk for over a decade until it is culled due to reductions in productivity at old age. Similarly, layer hens continue producing eggs until they reach age of zero productivity. The sales of these livestock products are one part of the economic flows in the sector. Moreover, during their lifetime, breeding stocks give birth to many off-spring that are sold year after year as finished stocks or products. The sale of live animals at different stages of growth is represented by off-takes. The sum total of sales of live animals and livestock products, and returns from other economic uses of livestock gives total revenue of keeping livestock. This means livestock units are themselves assets that continue to survive year after year and produce products that can be sold or accumulate wealth over several years. The figure also shows livestock costs at different stages of development. Like other sectors, livestock production requires labour, land, and capital stocks such as buildings, machinery, and equipment. The sum of these gives total costs of livestock production activity. The difference between total revenues and total costs yields gross margin of keeping livestock.

A number of equations are developed in the herd dynamics module and also in the main standard CGE model to build the system of equations in order to integrate the conceptual frameworks of the herd dynamics model presented in the figure above. This satisfies the need to establish a vital relationship between stocks (livestock numbers) and flows (livestock products). Additional data sets on different aspects of five livestock types in the Kenyan economy: cattle, sheep, goats, camel and chicken (classified as either indigenous or commercial) are used to track the stock–flow relationships in the herd dynamics model. The data is comprehensive in its coverage and consistent with the conceptual structure displayed in the herd dynamics model. It is disaggregated by sex, age group, agro-ecological zone and administrative provinces.

Livestock receipt and payment estimates in the original SAM are updated with more reliable numbers in order to make the database more suitable to the study and compatible with the separately developed livestock bio-economic module in the CGE model. This adopts the approach used in a similar study for Ethiopia (Gelan et al., 2012). However, unlike the Ethiopian study, the Kenyan SAM used in this study is disaggregated at province-level, which gives the separately developed module the capacity to handle province-level analysis.

Price, quantity and off take rates of the five livestock types is used to calculate value of off take (transactions as sales, gifts, exchanges of animals, slaughter, loans, and so on). Besides, revenue collected from sales of different livestock products is calculated. Data on milk output per lactating livestock for each type per year and lactating ratios, egg output per layer hen and laying ratios, and producer prices in Kenyan Shillings (Ksh) are used. The average of formal and informal cow milk prices is taken as the reference price. For instance, revenue from cow milk sales is calculated as a product of milk yield per lactating cow per year, lactating ratio and the stock of cows which are in milk producing age limit. The same technique is used in order to come up with the revenue amount from egg sales. The off take value and revenue from sales of livestock products calculated in the module are finally used to modify the receipts by livestock commodities of the different livestock types in the SAM based on users' original payment proportion. Moreover, investment in the livestock sector is modified by value of stock changes calculated in the module using livestock price data and quantity of stock change for each livestock type (the average of the stock changes in Kenya recorded during 2004–2007 is used).

The other very important element in this study is the identification of livestock capital as a factor of production in activities. In many economy-wide models, livestock capital is found merged together with other capital stock categories like land. The original SAM for Kenya has detailed presentation of the value addition of all factors of production including livestock and their contribution to household income. The inclusion of this makes the role of livestock sector in the economy complete.

In general, the sizes and values of the breeding stocks in each stage change through time by restocking or destocking (similar to the investment process in other capital stock categories) or appreciation in the value of breeding stocks due to investments in the maintenance of the health and body conditions of the livestock units or depreciation due to diseases and some other damages. The specification of this herd dynamics module couples the other source of dynamic changes in the livestock sector, i.e., the complex biological processes related to births, deaths, and survival rates are analyzed jointly with the dynamic economic processes.

In such a framework, exogenous shocks to the livestock production systems can be traced to the economic flows. Economic shocks that affect equilibrium relationships in the system of national accounts can also be traced back to the bio-physical level. Specifying stock–flow linkages in economy-wide CGE models like this has rarely been implemented.

3. Methodology

The model used in this study is a recursive dynamic extension of the standard CGE model of the International Food Policy Research Institute (IFPRI) modified to fit the Kenyan economy, documented in Thurlow and Benin (2008). This kind of dynamic model is based on the assumption that the behaviour of economic agents (private and public) is characterized by adaptive expectations: economic agents make their decisions on the basis of past experiences and current conditions, with no role for forward-looking expectations about the future (Lofgren, et al, 2002). Recursive dynamic CGE models are an alternative to inter-temporal dynamic models that better capture developing countries' reality. Inter-temporal strands of CGE models are explained by economic agents who have forward-looking expectations. These agents make inter-temporally optimal decisions, in which everybody knows everything about the future, and they use that information in making decisions.

The recursive-dynamic CGE model is solved one period at a time. It is a series of static CGE models that are linked between periods, the equations in this model are separated into time periods, which presents the decisions of the economic agents in each period, which governs the dynamics of the model.

The model assumes that producers maximize profits subject to production functions. In this model, a multi-stage production technology is adopted. The domestically produced output of each commodity is either domestically used or exported. Profit maximization drives producers to sell their products in domestic or foreign markets based on the potential returns. It is assumed that commodities sold domestically can only imperfectly be transformed into exportable commodities via the use of constant elasticity of transformation (CET) functions. In an analogous way, the model incorporates imperfect substitutability between domestically produced and imported goods (i.e. Armington assumption).

Domestic demand is the sum total of all the demand by economic agents: it constitutes final consumption demands by households and government, and investment demand, intermediate consumption demands by activities and transaction services demand. The model assumes households maximize utility subject to budget constraints.

The common assumption here is that the economy observed is in general equilibrium. Equilibrium in the goods market is attained through the endogenous interaction of relative prices. In order to clear the factor market, capital is set to be fully employed and activity-specific, implying that sector-specific returns to these factors adjust to guarantee market clearing. Labour with various skill levels (i.e., skilled, semi-skilled and unskilled), land and livestock are all assumed to be fully employed and mobile across sectors.

The model includes three macroeconomic balances: the current account balance, the government balance, and the savings and investment balance. The current account balance is held constant by assuming flexible exchange rate at a fixed level of foreign savings (fixed in foreign currency). There is an implicit functional relationship between the real exchange rate and the trade balance. In the government account, the level of government expenditure, equal to consumption and transfers, is fixed in real terms while government revenue is determined by fixed direct and indirect tax rates. Government savings is determined residually as the gap between revenue and expenditure. This closure is chosen since it is assumed that changes in direct and indirect tax rates, as well as in government expenditure, are exogenously determined based on the economic policy. The macro closure applied for the saving-investment balance is the savings-driven investment closure in which the value of investment is determined by the value of savings. Fixed savings rates for all non-governmental institutions and flexible capital formation are specified so that all savings are channelled into investment.

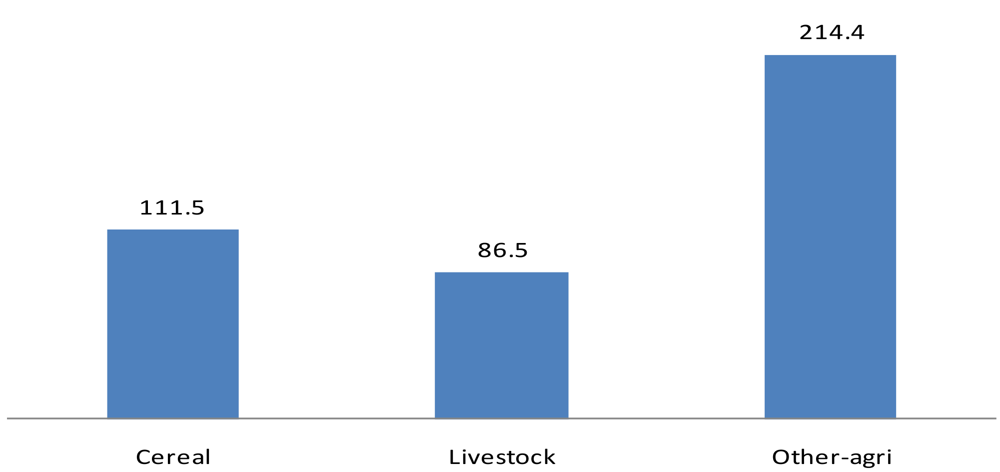
In every period of the model run, capital stock is updated with the total amount of new investment and depreciation. Total labour supply is updated by the population growth rate, i.e. as population grows, the total labour supply increases at the same rate.

The model is calibrated to a SAM developed by Mabiso et al. (2012). The SAM adopts the macroeconomic structure of the SAM originally developed by Thurlow and Benin (2008), but imposes a geographic disaggregation across by agro ecological zone (AEZ). It identifies 53 sub-sectors, 24 of which are in agriculture. Forestry and fisheries are also included in agriculture. All the remaining 29 sub-sectors are classified either as mining, manufacturing industries or service sectors. The entire activities in the model are disaggregated across Kenya's three AEZs (i.e. high rainfall, arid and semi-arid zones). The AEZ disaggregation also applies to factors of production (land, capital, livestock, and labour). Overall, there are 19 factors of production employed in the model. Household groups are disaggregated by AEZ. Households within each AEZ are classified into rural farm, rural non-farm, and urban households, and each of these is in turn disaggregated by income quintile. Thus, there are total of 45 household groups in the model.

4. Simulation specification

Total Factor Productivity (TFP) shocks are applied on three agricultural sub-sectors. These were cereals (Maize, Wheat, Rice, Sorghum, Millet including tuber crops); Livestock (Beef, Dairy, Poultry, Shoats and Other livestock); and other agriculture (Pulses, Oil seeds, Fruits and Vegetables, Cotton, Sugarcane, Coffee, Tea, Tobacco, Other cash crops, and fishing and forestry). Initially, these three major sub-sectors of agriculture had the following shares in total agricultural GDP: cereals (27 percent), livestock (21 percent), and other-agriculture (52 percent). These shares are important to look at these sectors' potential for economic growth.

Figure 2: Size of sub sectors in 2007 (in millions of Kenyan Shillings)



Source: Author's computation

The model simulation period is 2010 to 2020. There are four simulation scenarios used in this study: BASE, CEREAL, LIVESTOCK and AGRIC. A baseline scenario (BASE) replicates the growth trend experienced during 1998 to 2008. Three accelerated agricultural growth scenarios are also solved over the simulation period. The first two accelerated growth scenarios adjust Total Factor Productivity (TFP) growth rates in the cereals/tubers (CEREAL) and livestock (LIVESTOCK) sectors respectively. The third combines the CEREAL and LIVESTOCK scenarios (AGRIC). Outcomes are compared against BASE. TFP growth rates for all scenarios, including the baseline scenario, are adopted from Mabiso *et al*. (2012) who have examined the investment strategies in Kenya's Medium-Term Investment Plan (MTIP) required for achieving the goals of the Agricultural Sectoral Development Strategy (ASDS). These goals are aligned to those of the Comprehensive African Agricultural Development Program (CAADP). Further details appear below:

BASE – (business as usual or baseline scenario) draws on historical production trends for all sectors (including cereal and livestock sectors). Continuation of growth trends of the Kenyan economy observed during 1998-2008 is assumed to be applied for the period 2010-2020. These growth rates, in weighted averages, are: cereals (1.68); livestock (0), and other-agriculture (0.9). The weighted average of annual TFP growth across all agricultural activities is 0.9 percent.[1]

CEREAL – The cereal + tuber crops sub-sectors only receive accelerated TFP growth. And all other sub-sectors follow their baseline trend. Annual TFP growth rate in the cereal sub-sector rises to 4.48 on average. The weighted average of annual TFP growth across all agricultural activities is 1.68 percent.

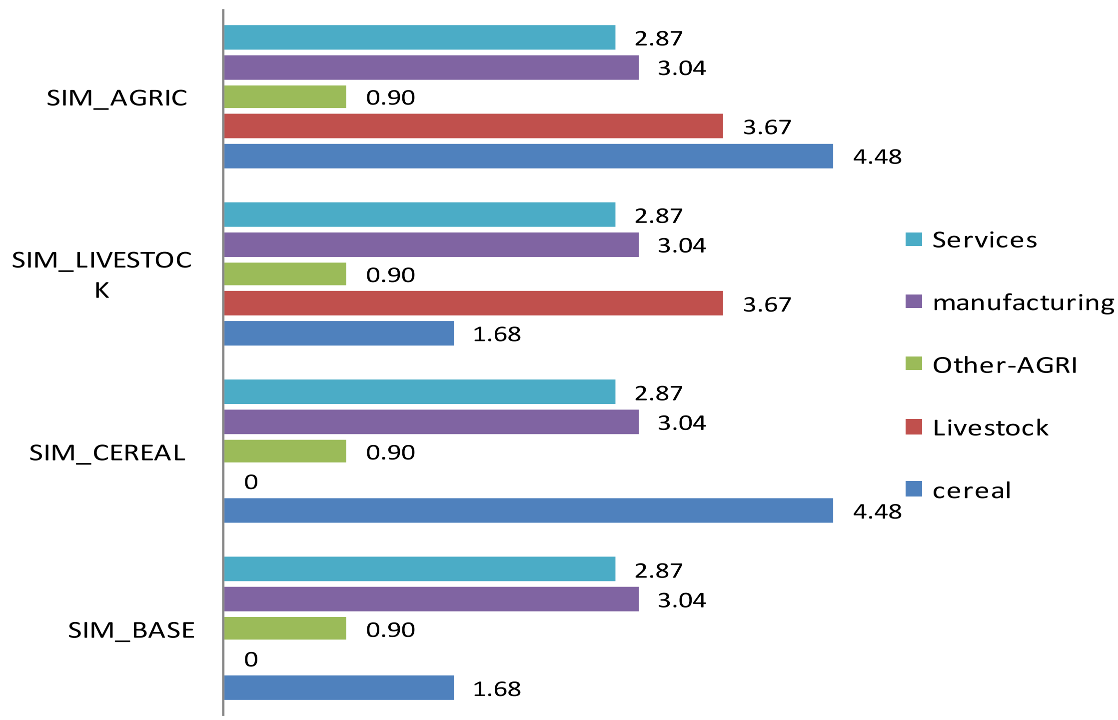
LIVESTOCK – The livestock sub-sector only receives accelerated TFP growth. And all other sub-sectors follow their baseline trend. Annual TFP growth in the livestock sub-sector rises to be 3.67 on average during the simulation period. The weighted average of annual TFP growth across all agricultural activities is 1.7 percent.

[1] Individual activities' shares of total agricultural value added in 2007 are used as weights here.

AGRIC – Both the cereal and livestock sectors receives accelerated TFP growth simultaneously. The mean annual TFP growths in the cereal and livestock sub-sectors are 4.48 and 3.67 respectively during the simulation period. All other sub-sectors follow their baseline trend. In this simulation, the weighted average of annual TFP growth across all agricultural activities is 2.45 percent.

The weighted average TFP growth rates of all the other agricultural activities, manufacturing and service sectors of the economy are similar across simulations. Activities in other-agriculture sub-sector are assumed to grow at an average TFP growth rate of 0.9. Manufacturing and service activities enjoy a 3.04 and 2.87 average TFP growth rates, respectively.

Figure 3: Weighted average TFP shocks



Source: Author's computation

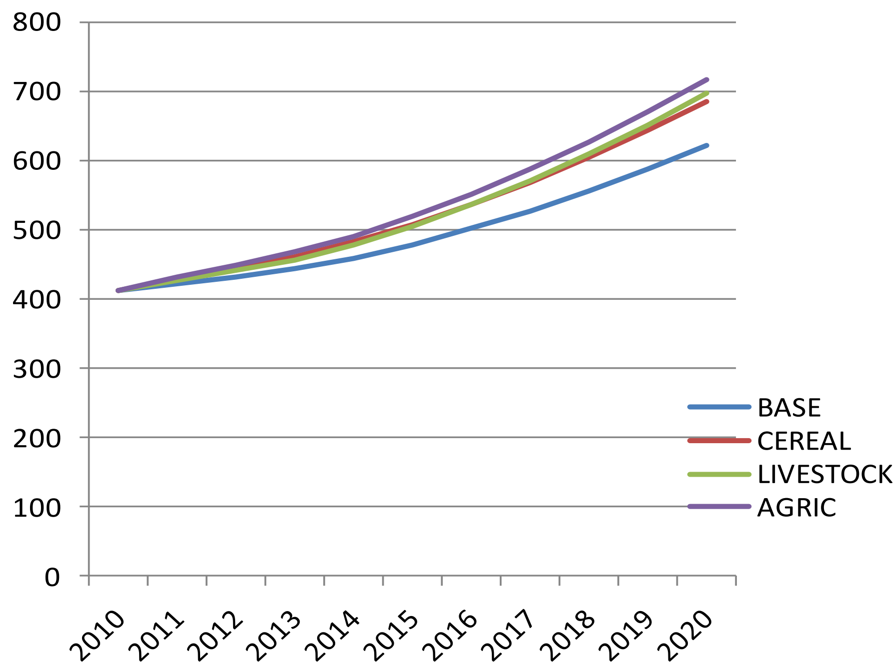
5. Results

The results reveal the importance of the livestock sector in increasing various measures of GDP and combating food insecurity. Agricultural GDP and overall GDP growth levels achieved in the livestock TFP shock scenario are significantly important to show that the sector has strong growth potential somewhat in contrast to previous thoughts that emphasized the livestock sector as auxiliary (see Dorosh and Thurlow, 2009).

In livestock simulation, land covered by cereal crops enjoy higher payments as a result of the increasing demand for it as compared to the cereal simulation in which demand for that land stagnates as there is now an accelerated increment in efficiency of that land. Land and labour are the predominant assets of poor households and hence large income gains and food consumption growth are realized under the livestock-led scenario. Whereas, livestock factors of production has got its larger income gain from CEREAL run but that of labour is similar in both simulations.

In terms of efficiency in raising aggregate quantities, results of the simulations indicate a closer effect between the various TFP-growth scenarios. Based on the assumed simulation specifications shown in Figure 3, the productivity growth shocks in LIVESTOCK simulation appear to be equally efficient in-terms of accelerating the agricultural GDP as compared to the CEREAL simulation. This is in contrast to previous literature that put the livestock sector as auxiliary.

Figure 4: Effects on agricultural GDP (in millions of Kenyan Shillings)



Source: Simulation result

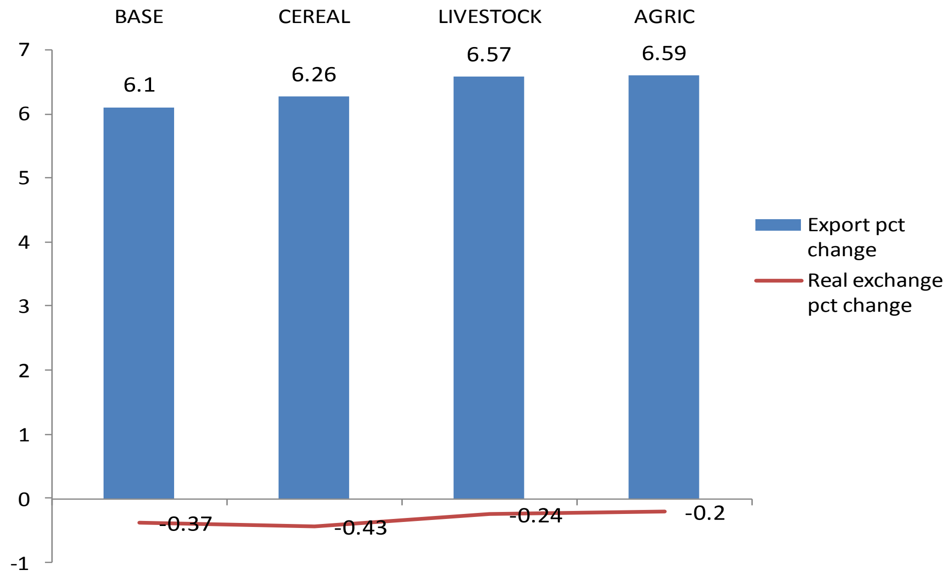
Three reasons are identified that have the very important role for the results. The re-allocation of productive resources is the first. The LIVESTOCK simulation, for example, markedly raises the productivity of livestock-related activities above its baseline trend, spurring production growth in excess of demand. As a result, the price of livestock commodities falls. Furthermore, after the TFP acceleration, less factor inputs are needed to produce a given amount of livestock commodities. Some mobile factors such as labour, livestock, and land are hence re-allocated to activities where TFP growth is less pronounced. Importantly, as factors are dynamically re-allocated between agricultural activities, the inefficiency of strategies focusing on cereal sector development alone was highlighted.

In our model, domestic output destined to domestic markets is imperfectly substitutable with output destined to export markets. An expansion in domestic supply is thus always shared among the domestic and export channels. As a result, when the domestic supply of a domestically consumed exportable rises faster than domestic demand, its equilibrium price in the model will fall. Incentives for expansion in production are thus curtailed and incentives for re-allocation of resources arise. In other words, the pace of domestic demand growth is often the binding constraint in equilibrium.

Growth in the livestock capital stock is the second mechanism. As the model solves for successive years, the livestock factor becomes more abundant and cheaply available. Livestock intensive activities benefit the most from this and so does the LIVESTOCK simulation, which concentrates TFP growth on these activities. Cereal activities are on the other hand intensive in the use of land and labour: Both are exogenously, slow-growing. Livestock-led growth thus enjoys a dynamic advantage related to its factor intensity. Again, the natural biological dynamism in livestock capital stock growth was not allowed in the original model, hence previous studies on sectors' growth contribution could not capture this point.

The third mechanism is current account balancing. Agricultural commodities constitute large exports in the economy. Accelerated agricultural TFP expansion thus results in significant export growth. Current account balance between exports and imports has to be restored through an appreciation of the real exchange rate. Growth in absorption is largest under the LIVESTOCK simulation. Consequently, demand for imports is also the largest in this simulation thus lower real exchange rate appreciation is needed under the LIVESTOCK simulation to balance the current account. As a result, total export growth is the largest. This is demonstrated in Figure 5 below:

Figure 5: Percentage change in export value and exchange rate 2010-2020



Source: Simulation result

The combined effect of these three mechanisms sustains economic growth in agriculture and the overall economy under the LIVESTOCK scenario. Even if the average TFP shock imposed in this simulation is almost similar to that of the cereal-led growth scenario, its macro effects on agricultural and overall GDP are of a strong magnitude. This shows the stronger backward and forward linkages of livestock activities with the other sectors of the economy. Thus, it has a strong potential of stimulating growth in the economy as a result of growth in its own sector.

Table 1: 2010–2020 yearly average percentage change in value added for sub-sector, agricultural sector, and overall economy

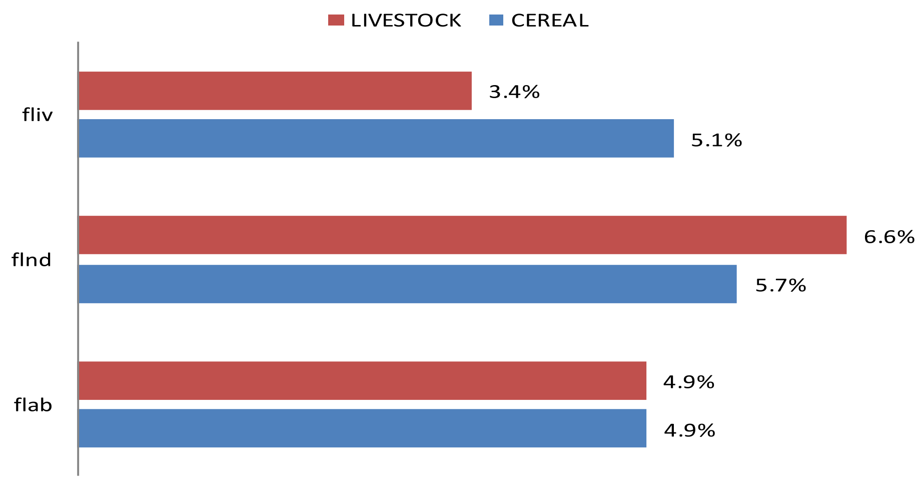
	Sub-sector	Agricultural sector	GDP
BASE		3.82%	5.09%
CEREAL	4.71%	4.73%	5.37%
LIVESTOCK	4.68%	4.88%	5.53%
AGRIC		5.14%	5.65%

Source: Simulation result

There is also a welfare aspect to our results. The reallocation in factor demands explained above favours different factors in different simulations. In LIVESTOCK, livestock-factor intensive activities experience a faster shock in productivity. Demand for existing livestock factor increases the least and so does its price and returns. Demand for land is instead quite strong which enables the factor owners enjoy better return as compared to the CEREAL run. The increase in production in the cereal sector which is motivated by the faster growth in the livestock sector now needs larger land since there is no special productivity acceleration in livestock simulation for the factors employed in cereal activities. In CEREAL, on the other hand, the accelerated cereal activities are intensive in the use of land and labour. As the price for cereal activities falls and the factors are reallocated, returns to land slows down than in the LIVESTOCK scenario. Returns to land rises by 5.7 percent which is lower than its 6.6 percent growth in the LIVESTOCK scenario. But return to livestock is growing faster in the CEREAL run. However, return to labour is equivalent in both scenarios.

As figure 6 shows, consistent with our analysis, returns to land held by poor households rises the most in the LIVESTOCK simulation. In such simulation, return to livestock grows the least. As land is relatively the major asset of the poor, the former effects more than compensates the latter. The net effect is such that poor households' incomes show fast growth when agricultural growth is livestock-led. In fact, households' income grows fast in the CEREAL run too as a result of a faster increase in returns to livestock and an increase in returns to labour.

Figure 6: Effects on factor returns (yearly average percentage change)



Source: Simulation result

As we experience from the above discussion on factors' return, there are increments for all factors in all the simulations. This directly leads to significant positive growth in households' income. As it is seen in table 2, all household types enjoy fast growing income gain. Rural households gain the faster growing income as compared to their urban counter parts. The factors that enjoy the largest income gain in all the simulations are agricultural factors. That's why rural households are enjoying faster rise in income as they are the sole owners of these factors of production. As our analysis goes down to AEZ level Semi-arid areas are getting better as compared to the others. Livestock simulations are still exhibiting strong effects on households' income too. It is stronger in Arid and Semi-arid areas as households in these areas got 95 percent of their income from livestock activities.

Table 2: Effects on households' income (yearly average percentage change)

	BASE	CEREAL	LIVESTOCK	AGRIC
Rural	4.97%	5.09%	5.33%	5.20%
Rural farming	5.01%	5.13%	5.40%	5.23%
Rural non-farming	4.70%	4.83%	4.92%	5.00%
Urban	4.69%	4.81%	4.97%	5.04%
High rain fall	4.41%	4.50%	4.72%	4.72%
Arid	4.84%	4.93%	4.54%	4.58%
Semi-arid	5.81%	5.98%	6.26%	6.11%
Total	4.84%	4.96%	5.17%	5.13%

Source: Simulation result

6. Conclusions

The livestock sector has important role in the livelihoods of a large proportion of rural as well as urban households in Kenya. The sector contributes a substantial share of total value-addition in the Kenyan economy and provides employment to a large number of people; and produces foreign exchange. Besides, it is strongly linked to other activities.

However, the importance of livestock sector has often been underestimated by policymakers as well as researchers. Researchers neglect the livestock sector mainly for methodological reasons. This study set out to overcome these methodological reasons and the shortcomings in existing economy wide modelling. The study is intended to inform policymakers regarding the economy-wide direct and indirect effects of enhancing productivity for the livestock sector in Kenya. A number of agricultural productivity growth scenarios are simulated. Significant findings are obtained both in terms of aggregate and agricultural value-added effects, various macroeconomic figures and in terms of welfare, too.

Simulation results indicate that improving productivity in the livestock sector has significantly strong aggregate economic efficiency gains measured by growth in value-added and by improvements in the external sector: a smaller real exchange rate appreciation and larger export earnings as compared to accelerated productivity growth in the cereal sector. Furthermore, although livestock is not the predominant factor owned by poor households, the accelerated productivity growth in livestock activities brings about higher returns to land and similar returns to labour than in the accelerated cereal sector scenario. Since these are the predominant factors of the poor, investing more in enhancing livestock activities' growth has huge implication in poverty reduction and narrowing the income gap. On the other hand, livestock factors enjoy larger growth of returns in the CEREAL simulation with equally growing returns to labour.

Importantly, as factors are dynamically re-allocated between agricultural activities, the inefficiency of strategies focusing on cereal sector development alone was highlighted. Thus, it is better to give equal policy priority emphasis to the livestock sector and plan livestock – cereal sub-sectors joint growth instead of cereal sub-sector growth alone. Thus, balanced agricultural growth, in which productivity gains are more evenly distributed across sub-sectors, is preferable. In Kenya, this means investing more in enhancing the productivity of livestock as it is the case for cereal sub-sector.

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