Supporting Global Livestock Advocacy for Development (GLAD project)

A framework for ex-ante impact analysis of livestock research evaluation and prioritization

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Summary

As the global development community ramps up efforts to address the world's most pressing challenges of poverty, hunger and environmental degradation, key decision-makers in the public, private and non-governmental spheres are looking to more reliable and standardized tools and approaches for prioritizing development funding. *Ex-ante* impact assessments, considered the policy maker's equivalent of business planning, have a long history as the basis for setting priorities and allocating research resources in international agricultural (and livestock) research. They are formalized principles, tools and processes that can be used in prospective analysis to identify, represent and measure drivers of change and their associated impacts. As objectives of decision makers and needs of stakeholders become more articulate, e.g., as seen in the sustainable development goals, or SDGs, there is a need to ensure that the analytical processes are being appropriately deployed to support expressed aspirations. In some cases, i.e., if they are to remain relevant, existing tools and methods for ex-ante impact assessments of international (research and) development funding may need to be upgraded to better handle the requirements of an increasingly complex global agricultural and food system.

A primary consideration for the appropriateness of existing tools and approaches of ex-ante impact assessments is the level of resolution to which they can be convincingly applied i.e., whether global, national, or sub-national. This matters as different questions are asked by the different actors or decision-makers needing ex-ante impact assessments. For a general question on what economic gains to anticipate from a research/technological, infrastructure or policy intervention in livestock, for example, a multilateral aid donor may be primarily interested in how the intervention contributes to a country's attainment of relevant goals (such as the SDGs) at the national level. A national government may in addition to this evidence want more specific information on potential winners and losers among competing sub-national regions, producers, consumers and supply or value chain actors. Different assessment frameworks will handle these questions, and the quality of policy decisions that can be derived from them, quite differently. A second consideration for an ex-ante impact assessment framework is whether, and the extent to which it can incorporate multi-objectives in its analyses, including non-economic factors such as

social, biophysical, epidemiological, or institutional ones that both mediate impact and which themselves are influenced by economic factors. For example, there is growing recognition of the role of gender and social equity in global development, and thus the need to incorporate their drivers and impacts in *apriori* assessments of investment funding. A third consideration addresses the behavioral feedbacks that link economic and non-economic factors, and which take place over time, necessitating proper incorporation of temporal issues.

In this report, two main approaches to ex-ante impact assessments of investment interventions in the livestock sector are presented. The ways in which these major approaches differ regarding the three considerations outlined above, i.e., resolution, incorporation of multi-objectives, and the treatment of feedbacks and dynamics, are outlined. Partial-equilibrium, multimarket models specify a series of supply and demand relationships for different production systems and household groups. These sets of impact assessment tools best provide information at global or national scales, although can consider pricing and trading patterns across regions and amongst a range of household typologies (income, gender, etc.). They generate commodity prices that match demand and supply and become useful for assessing outcomes such as food security and nutrition that can be inferred from these. System dynamics models, by contrast, can simulate and model the dynamics of processes and flows of specific actors in a specific or set of value chains. They thus can look more closely at the different actors and how marketing patterns change in a specific value chain, whether at national, regional, or local level. They can also more directly model the influence of non-economic factors (particularly biophysical ones like local climate or natural resource constraints) on the evolution and dynamics of the value chain.

A generic framework for practical application of ex-ante impact assessments in the context of livestock research evaluation and prioritization is developed in this report. Two case studies that represent national/sector and value chain level approaches are presented. The example from macro level ex-ante analysis covers two countries, Vietnam and Uganda, highlighting the impact of trajectories of change due to the emerging rural and agri-food systems transformation on smallholder domestic supply of pork. This analysis based on a spatial multi-market model, provides a robust evidence on the evolution and resilience of smallholder pig systems under varying agri-food system transformation including technology and policy scenarios. The contrasting example is

of a value chain analysis that captures and quantifies interactive effects along the nodes of a sub-national livestock value chain. The analysis uses participatory system dynamics and group model building to explore a commodity chain, considering how different technological interventions influence the marketing and other behavior of value chain actors such as farmers and traders. The examples demonstrate between them a range of livestock sector intervention questions that can be answered, and the tools and data needed to do so.

A framework for ex-ante impact analysis of livestock research evaluation and prioritization

Introduction

Decision-making by everyone from national policy makers to international aid organizations looking to allocate scarce resources to meeting goals for global development, will be confronted with a myriad of options. These goals are typically improved livelihoods, food security, and economic growth but also complementary aims related to gender, equity and environmental sustainability. Key decisions often need to be taken about which goals to prioritize when they cannot be simultaneously achieved, and for whom. In livestock sector development, some investments may particularly favor capital intensive systems and large private sector interests, such as promoting livestock exports, but may not be effective in reducing rural poverty or supporting gender equity. Investments in small holder-focused interventions, such as semi-scavenging poultry, may have some focused and positive impact among participating households, but may not be easily scalable and so may offer few aggregate benefits. Similarly, investment in infrastructure, technology and provision of services such as improved animal genetics delivery may be constrained by unforeseen value chain and institutional constraints.

Any such initiatives in government policies, markets, technology, and related interventions, bring about changes in the social, economic, and biophysical environments in which decision makers want to see outcomes, when faced with competing options for action. Ex-ante impact assessments provide a formalized framework for understanding these interactions and providing clearer guidance as to potential priorities and trade-offs among these choices. Ex-ante impact assessments are integral to the needs analysis and planning activity in policy making and have been described as the policy maker's equivalent of business planning (OECD, 2014). They are principles, tools and processes that can be used in prospective analysis to identify, represent and measure drivers of change and their associated impacts, and have long been used as the basis for setting priorities and allocating research resources in international agricultural (and livestock) research. Following calls to 'do more with less', public agricultural research systems in the late 1990s and early 2000s stepped up efforts to show economic value of both past and future research. The resulting quest for evidence, and for structured methodologies to guide and justify resource allocation led to the development of robust techniques for ex-post and ex-ante impact assessments in agriculture. For example, Alston, Norton & Pardey (1995), a classic text on the principles and practice of agricultural research evaluation and priority setting, was primarily motivated by the premise of growing constraints to resource funding for agricultural science.

Since the 1990s, the need for appropriate tools for assessing (past and) future research may have become even more apparent. Global agricultural and food systems are facing more intense and inter-related challenges from politics and governance, commodity markets, technological change, climate change and the environment, and these under what may be a more stringent environment for research funding. Decision-makers dealing with these evolving realities require appropriate analytical support to assess the potential impacts that decisions they make today will have tomorrow on indicators of interest. Intervention decisions needing this support include government policies at national and inter-governmental levels, and budget and grant decisions of multilateral aid donors. Managers determining the allocation of research funding between organizational programs, research activities, geographic spaces, and human resources will also benefit.

Among the diverse set of decision-makers, there may be increasing convergence around what types of impacts are anticipated from research investments, and thus on what needs to be measured. Research dollars are now generally understood to target not only technological change, as has been their traditional focus, but the attainment of universal goals of prosperity for people and the planet (CGIAR, 2015). To this end, ex-ante impact assessments of international agricultural (and livestock) research has transitioned from a somewhat narrow focus (e.g., on economic returns) to better capturing of social goals related to poverty and hunger reduction, improved nutrition and health, employment generation, and climate action such as are embodied in the Sustainable Development Goals, SDGs (e.g., Rosegrant et al., 2017).

This report outlines concepts, methods and tools applicable to assessments of the potential impacts of current or future livestock research undertaken at the International Livestock Research

Institute (ILRI). In principle, both qualitative and quantitative frameworks are employable. The report however focuses on quantitative analytical methods that may be more standardized and have capacity for increased objectivity. Alston, Norton and Pardey (1995) outlined the benefits of structured quantitative impact assessments for assessing potential impacts or setting research priorities across broad commodity programs, disciplinary (and multi-disciplinary) programs, and research problems. According to that work, ex-ante impact assessments may be less effective for decision-making regarding more detailed, disaggregated, project level decision-making. As such, the role of research evaluation and priority setting would be to help determine boundaries within which free scientific enquiry can occur.

This report maintains some agreement with the concept of more broadly applicable assessments, highlighting ex-ante methods and tools useful for answering broader questions of commodity, problem area and regional focus. An example of tools in this category will be those useful for supporting decision-making on country and national value chain site selections for global livestock research funding. Other disaggregated levels of analyses are however needed to answer such questions as what sub-sectors of the local livestock value chain to target future research efforts to, e.g., high value livestock production and marketing versus lower-resource agencies. The ex-ante impact assessment tools described are as such quite varied in the questions to which they can be applied, as well as the levels of (e.g., spatial) aggregation to which they are best suited. The details follow.

A generic modeling framework for conducting *ex-ante* impact assessment

A few important considerations are necessary in implementing ex-ante impact assessments of different technological or policy interventions. A first consideration is the level of resolution of the analysis i.e., whether at global, national, or sub-national level. This matters as different types of economic impact models, as described in detail below, may be more, or less, suitable depending on the level of aggregation and depth of analysis required. For a general question on what economic gains to anticipate from a research/technological, infrastructure or policy intervention in livestock, for example, a multilateral aid donor may be primarily interested in how the intervention contributes to a country's attainment of relevant SDGs at the national level. A national government may in addition to this evidence want more specific information on potential winners and losers among competing sub-national regions, producer or consumer types, and supply or value chain actors. A second consideration is the extent to which non-economic factors can be incorporated in the analysis, including social, biophysical, epidemiological, or institutional parameters that both mediate impact and which themselves are influenced by economic factors. For example, there is growing recognition of the role of gender and social equity in global development, and thus the need to incorporate their drivers and impacts in apriori assessments of investment funding. A final consideration is addressing the behavioral feedbacks that link economic and non-economic factors and which take place over time, necessitating a proper incorporation of temporal issues in the analysis.

Regardless of its final purpose, at the heart of a quantitative impact assessment of research innovations for the livestock sector will typically be a formalized model of the sector. Figure 1 provides a generic framework that brings together the conceptual requirements in the context of modeling the livestock sector. As the livestock sector is diverse, encompassing a range of different species and production systems, an identification of appropriate production systems for analysis is first required[1.].This can, for instance, follow the Sere and Steinfeld (1996) production system typologies or those used in the LSIPT model where comprehensive sectoral analyses are required [2]. Alternatively, where more targeted analysis is needed, the identification of production systems can be limited to a specific sector, species, or value chain(s). Regardless of the scope of production systems used, these production systems will each have different types of herd dynamics. The herd dynamics characterize how the supply of animals or birds evolves over time, based on the prevailing herd demographic structure, birth/death rates, and patterns of purchases and sales. The DynMod model (Lesnoff 2010), developed by CIRAD and ILRI, presents itself as a parsimonious means of generating herd dynamic patterns in data-scarce environments and which has been

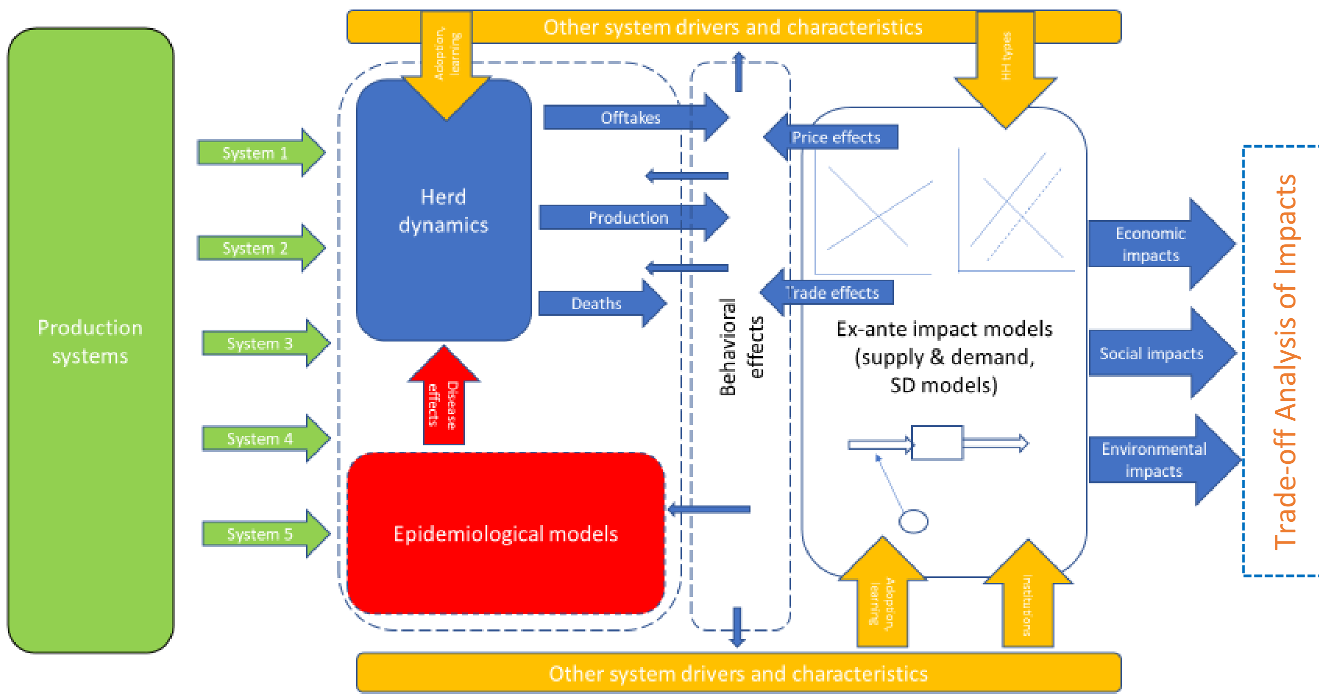
[1] The need for production-system disaggregation of the livestock sector has been emphasized even for highly aggregated models of the global agricultural and food system (see, Msangi et al., 2014).
[2] LSIPT, the Livestock Sector Investment Policy Toolkit is an analytical framework that has been used to support the livestock investment plans of many developing countries. Its development and use by countries are facilitated by the World Bank, FAO, CIRAD, ILRI and partners.

linked in several impact assessments of the livestock sector (Rich et al. 2014; Naziri et al. 2015; Toye et al., forthcoming).

The definition of production systems and use of herd dynamic models defines the supply side of the livestock sector, which can then be translated into different economic platforms to link to downstream (post-farm) dynamics and household consumption and demand. As elaborated below, two particular ways to do this are through the use of (1) partial-equilibrium, multimarket models, which specify a series of supply and demand relationships for different production systems and household groups and so generate prices which match supply and demand; and (2) the use of system dynamics methods to simulate and model the dynamics of processes and flows of specific actors in a specific or set of value chains. Both models provide insights on price, marketing, and trade dynamics which can then feedback into decisions made at the supply side, with the main difference being that of the resolution or level of detail of the analysis. Multimarket models best provide information at global or national scales, although can consider pricing and trading patterns across regions and amongst a range of household typologies (income, gender, etc.). System dynamics models, by contrast, look more closely at the different actors in the value chain and how marketing patterns change in a specific value chain, whether at national, regional, or local level. They can also more directly model the influence of non-economic factors (particularly biophysical ones like local climate or natural resource constraints) on the evolution and dynamics of the value chain.

A primary objective of the ex-ante impact assessments will be to provide information helpful for evaluating the potential outcomes and impacts of competing investments by public or private entities in technology or infrastructure, or changes in policy affecting the livestock sector. Economic modelling, which can take a variety of forms as described above, is a core component of such assessments. Irrespective of the economic modeling platform chosen, figure 1 highlights the influence of a variety of contextual factors that will shape impact that need to be accounted for in the modeling processes. The outbreak of animal diseases is a critical consideration in many contexts, as it will not only shape herd dynamics, but also influence market access, whether in the short-term through movement controls (Rich and Roland-Holst 2014) or by altering trade in export markets (Rich and Winter-Nelson 2007).

Figure 1: A conceptual modeling framework for ex-ante impact assessment



Source: Developed by the authors

There have been some efforts to directly link epidemiological models with herd dynamic models (Rich 2007; Rich and Roland-Holst 2014; Rich et al. 2014; Toye et al., forthcoming) and economic (multimarket and SD) platforms (Rich and Winter-Nelson 2007; Dizyee et al. 2017). Other drivers, including adoption and learning, gender-mediated decision making, and income-mediated consumption patterns all further influence economic impacts, with different modeling platforms handling such issues in different ways, as specified in detail below. Figure 1 also indicates the possibility of quantifying trade-offs that could occur between competing objectives.

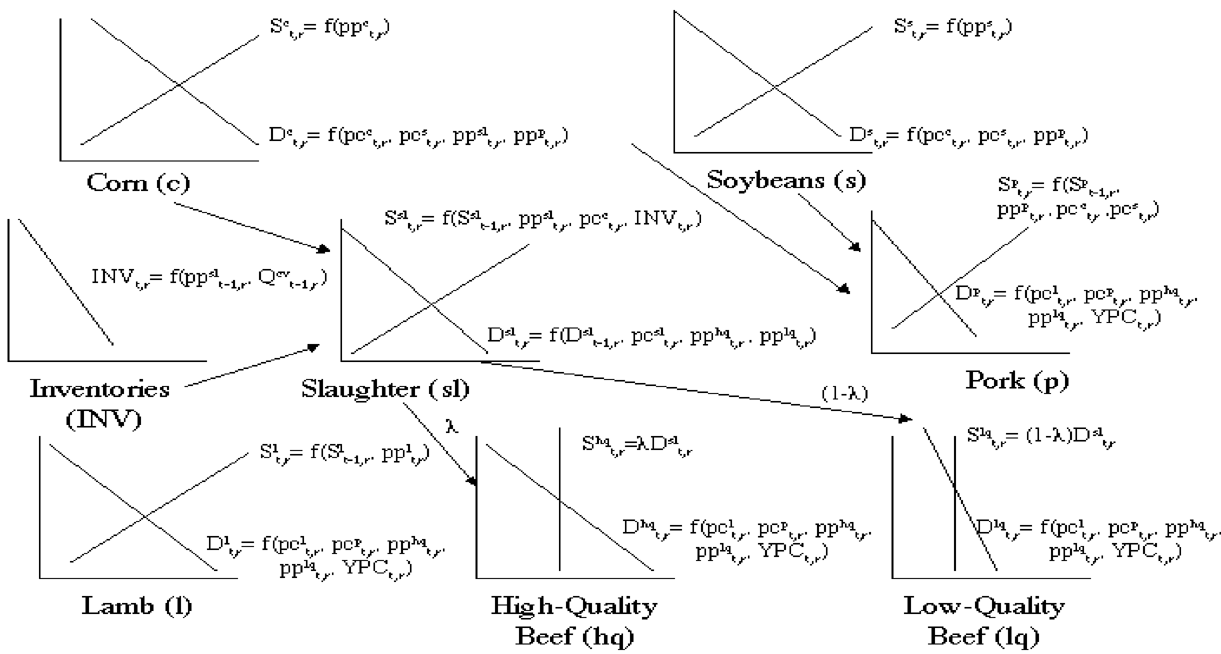
Specific modeling approaches for *ex-ante* impact assessment

Multimarket modeling at national/sectoral level

Multimarket models are a class of partial equilibrium models that specify supply and demand relationships for agricultural products across several related markets. Various types of multimarket models have been applied in the literature. The simplest models comprise of a few key aggregated agricultural and livestock markets and their interactions, and which make strong assumptions on equilibrium behavior through pre-defined tradability assumptions to ease model solution (Rich and Lundberg 2002). A second class of multimarket models are equilibrium displacement models which analyses the comparative statics of technological or policy related shocks or interventions in a set of related markets (Bhattacharya et al. 2009; Kaitibie et al. 2010). More sophisticated multimarket models endogenize price and trade behavior across regions (national and/or global) (Rich and Winter-Nelson 2007; Lapar et al. 2016), while the most complex models (such the IMPACT model developed by IFPRI) consider a wide range of agricultural and livestock sectors and countries, and their linkages with land and water use, and greenhouse gas emissions (Msangi et al. 2014; Rosegrant et al. 2017).

Figure 2 illustrates a stylized multimarket model based on Rich and Winter-Nelson (2007). This model was used to assess the impacts of foot-and-mouth disease (FMD) across a range of livestock sectors and markets in the Southern Cone of South America (Argentina, Paraguay, Uruguay). Each livestock sector (cattle and sheep) is specified as a set of supply and demand relationships across different regions in each country, which are calibrated by inventory relationships for live animals and which use and influence feed markets (corn and soybeans). Animals are further processed into meat, which in the cattle sector are sub-divided into high- and low-quality beef products to distinguish between different export market demands. This set of market relationships was adjusted to reflect epidemiological and disease control scenarios used to assess the impacts of different strategies associated with culling and vaccination policies. Each scenario (generated by use of an epidemiological model of inter-regional disease spread; see Rich 2008) will shift the supply curve of the markets for cattle to the left (given the mortality induced by culling policies e.g.) and will also close export markets for high-value beef cuts for different periods of time depending on the scenarios.

Figure 2: A multimarket analysis of livestock markets



Source: Rich and Winter-Nelson (2007)

By simulating the model over a five-year period, both short- and long-run impacts on production, prices, farm income, and exports can be quantified to contrast whether the impacts of different scenarios have different rank-ordering in the short-run versus the long-run. The model of Rich and Winter-Nelson (2007) highlighted this tension between the short-term effects of vaccination policies that minimize immediate economic losses versus the greater benefits over the long-term of stamping out (culling) policies that reduce the duration of export bans in high-value markets.

Multimarket models have been used in several livestock-related contexts, generally looking at how technology or policy-induced supply shifts impact the wider livestock sector and/or national economy. In addition to the disease example cited above, Toye et al. (forthcoming) have coupled the DynMod herd model with the global economic model IMPACT to assess different scenarios of East Coast fever vaccine adoption to generate alternative patterns of herd growth and their impacts on the livestock sector. Lapar et al. (2016) contrasted trajectories for smallholder competitiveness in the pig sector in Uganda and Viet Nam by use of a spatial multimarket model. The computation of producer and consumer surplus measures to quantify impact has long been considered the "gold standard" in impact assessment by the Standing Panel for Impact Assessment of the CGIAR and have been applied in some past ILRI studies (e.g., Kristjanson et al. 2002; see also Jutzi and Rich 2016 for a review). A novel application of a multimarket approach is that of Kaitibie et al. (2010) which uses a model of the dairy sector to consider the impact of institutional and policy processes associated with smallholder dairy policy reforms.

System dynamics modeling at value chain level

System dynamics (SD) models are simulation approaches used in the analysis of complex systems. Originally developed in the context of industrial engineering systems, they have been more widely used in a variety of management, ecological, environmental, and social science applications in the last twenty years. Within the CGIAR, ILRI has pioneered the use of SD models in the context of agri-food and livestock value chains. This has been motivated by the need to address the multi-faceted interactions and feedbacks that exist between the biology of animal production, market dynamics, epidemiology of animal diseases, institutions, and land-use patterns, all of which influence the impact and uptake of market, policy, and technical interventions. In this context, SD models have been used to test scenarios that measure the dynamic ex-ante returns of different interventions.

An attraction of system dynamics is its use of a graphical interface in building models. While SD models are systems of non-linear differential equations, they are constructed using graphical icons that represent more intuitive systems thinking concepts (stocks – accumulations of goods/services at a specific period of time; flows – inflows and outflows to/from stocks; converters – technical parameters that affect the rate of change of flows). The use of a more intuitive modelling platform facilitates the development of models across disciplines and facilitates collaboration with less technical audiences as well, potentially paving a way for increased engagement between analysts and decision-makers (and analysis and decision-making). Graphical interfaces can be hosted online that allow a wide range of participants to use and experiment with constructed models.[3] Their modularity is also an advantage in that system interactions (e.g., biophysical phenomena, livelihoods decisions, governance and institutions, climate shocks, environmental stressors, land-use patterns, food acquisition and consumption, and disease and food safety) can be integrated in ways that would be otherwise challenging for non-modular or non-dynamic models.

In an early study, Rich et al. (2009) constructed an SD model to assess the viability of a two-stage export certification system in Ethiopia that proposed using quarantine stations and feedlots to ensure disease-free status and higher quality of beef for export to markets in the Middle East. Interestingly, model results highlighted that contrary to the general belief, sanitary and phytosanitary (SPS)-associated costs were not a constraint to competitiveness; however, high feed costs would make such exports uncompetitive relative to established competitors. Since this early application, a number of other models have been developed at ILRI, including an assessment of marketing options in the sheep and goat sector of Mozambique (Hamza et al. 2014); an analysis of reforms to improve competitiveness in the beef sector in Botswana (Dizyee et al. 2017); assessments of animal disease and food safety (Grace et al. 2017; Rich et al. 2018), and dairy sector interventions in Tanzania (Dizyee and Omore, forthcoming). Research involving CIAT highlighted options to improve feeding systems supporting the dairy sector in Nicaragua (Lie et al. 2018).

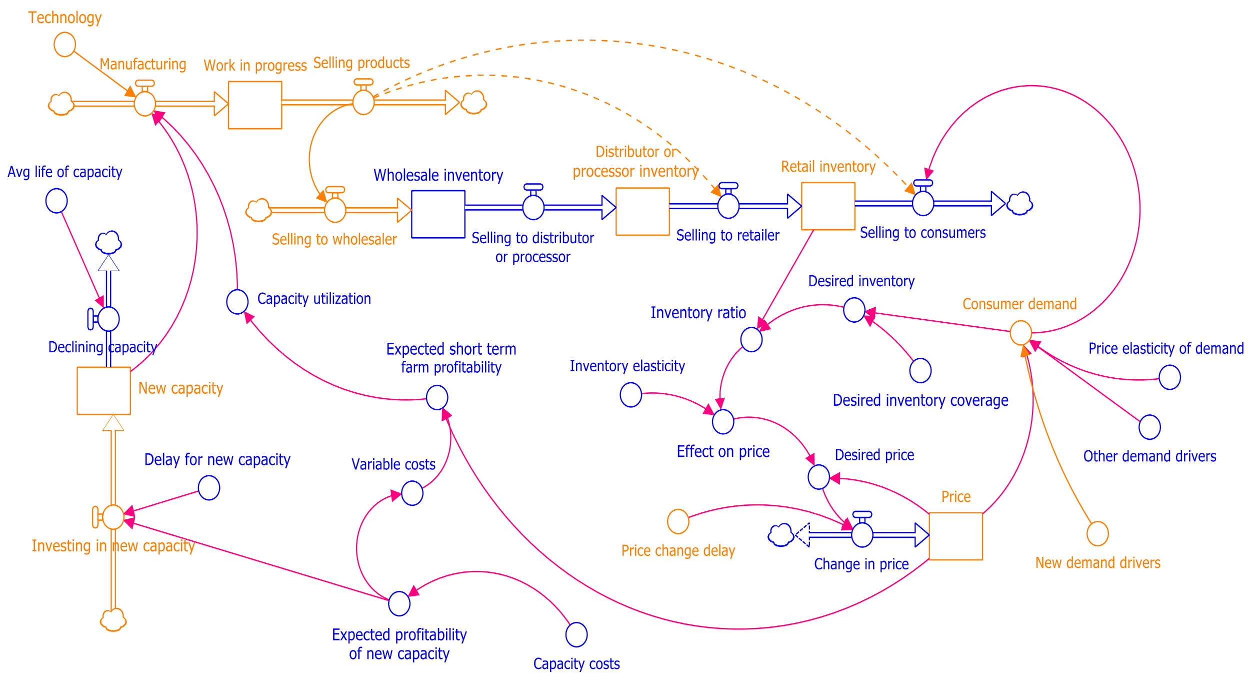
The use of SD tools in ex-ante impact assessment is illustrative by example in figures 3 and 4 using a simple, stylized value chain model developed using the STELLA modeling software.

In figure 3, reading from left to right highlights the movement of a generic product from production to consumption via different intermediaries. Each rectangular shape in the figure represents the stock of a good held by a given actor at time t while the thick arrows denote the movement of goods between stages of the value chain. Sales to consumers depend on standard demand relationships (price and income). An important difference between SD and multimarket models are how price relationships are determined. While multimarket models follow standard neoclassical economic theory in defining equilibrium, SD models of value chains use the availability

[3] See for example https://exchange.iseesystems.com/public/helene-lie/dairy-value-chain-development-in-nicaragua/index.html#page1

of inventory to calibrate price changes over time. Excess inventories push prices down, while building stocks bids prices upwards.

Figure 3: A generic value chain template



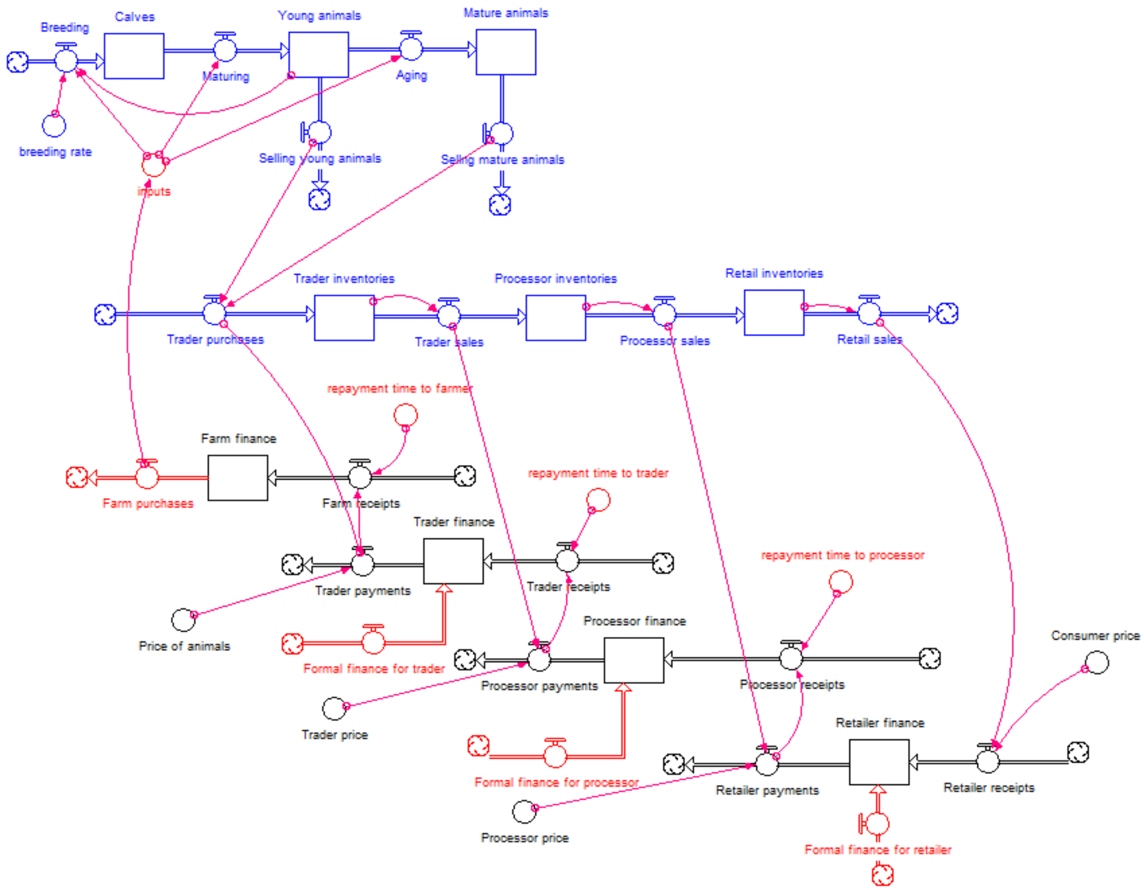
Source: Developed by the authors

As shown in figure 3, price relationships influence both short-term decision-making to produce in subsequent periods (as in multimarket models) but also in longer-term decisions to invest in new capacity or technologies. Note that while figure 3 (and subsequent figures 4-6) presents the structure of a value chain graphically, this represents an actual model that can be simulated, with mathematical relationships and parameters provided in the background.

The visualization of value chain dynamics not only adds value in model building but also in illustrating the range of different types of intervention options that could be considered along the value chain. In figure 3, new technologies at farm-level, shorter value chains (i.e., selling to fewer intermediaries), interventions in information at the demand side, or in enhanced capacity will all have dynamic impacts in the value chain that can be compared and quantified to assess their cost-effectiveness.

Figure 4 shows more specifically a livestock-oriented value chain that links herd dynamics with downstream marketing and the links with cashflow and value chain finance. In such a framework, one could consider different innovations with the availability of credit on the ability of farmers to invest in new technologies, for example.

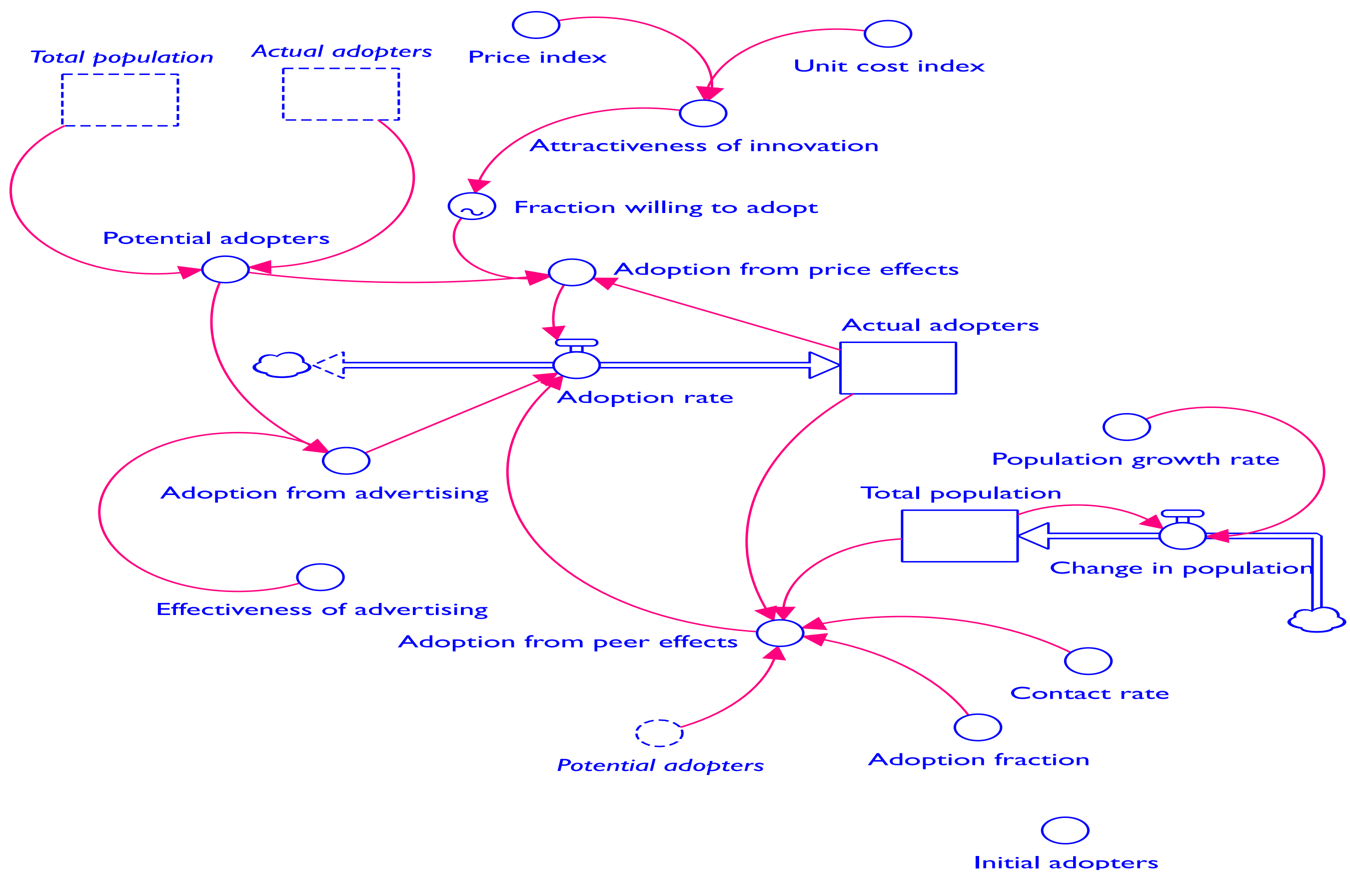
Figure 4: A generic value chain model of livestock and finance



Source: Rich (2017)

Figures 5 and 6 present models of adoption and learning effects that can be overlaid on models of livestock value chains, thus giving insights on factors and feedback effects that drive technology use and which could mediate uptake. This can provide additional guidance in improving the design of interventions that are more fit-for-purpose with the constraints that different value chain actors may face. Participatory processes can be deployed in the development of SD models. These include methods such as group model building (GMB) that construct models directly with stakeholders. The use of participatory modelling techniques has traditionally been used to foster collaboration, team-building, and learning among client groups to solve a common problem (Vennix 1996). In a value chain context, the use of participatory processes significantly eases the burden of conducting extensive value chain surveys, which are resource-intensive and often inadequate for obtaining dynamic, evolutionary data of system change.

Figure 5: Modeling adoption processes in system dynamics



Source: Developed by the authors based on Sterman (2000)

As highlighted by Lie et al. (2017), GMB sessions, complemented with strategically placed key informant discussions and secondary data, can reveal a significant amount of data on value chain structure and dynamics, while their iterative, consultative nature can improve internal validity in model results.

Figure 6: Adoption processes incorporating learning effects

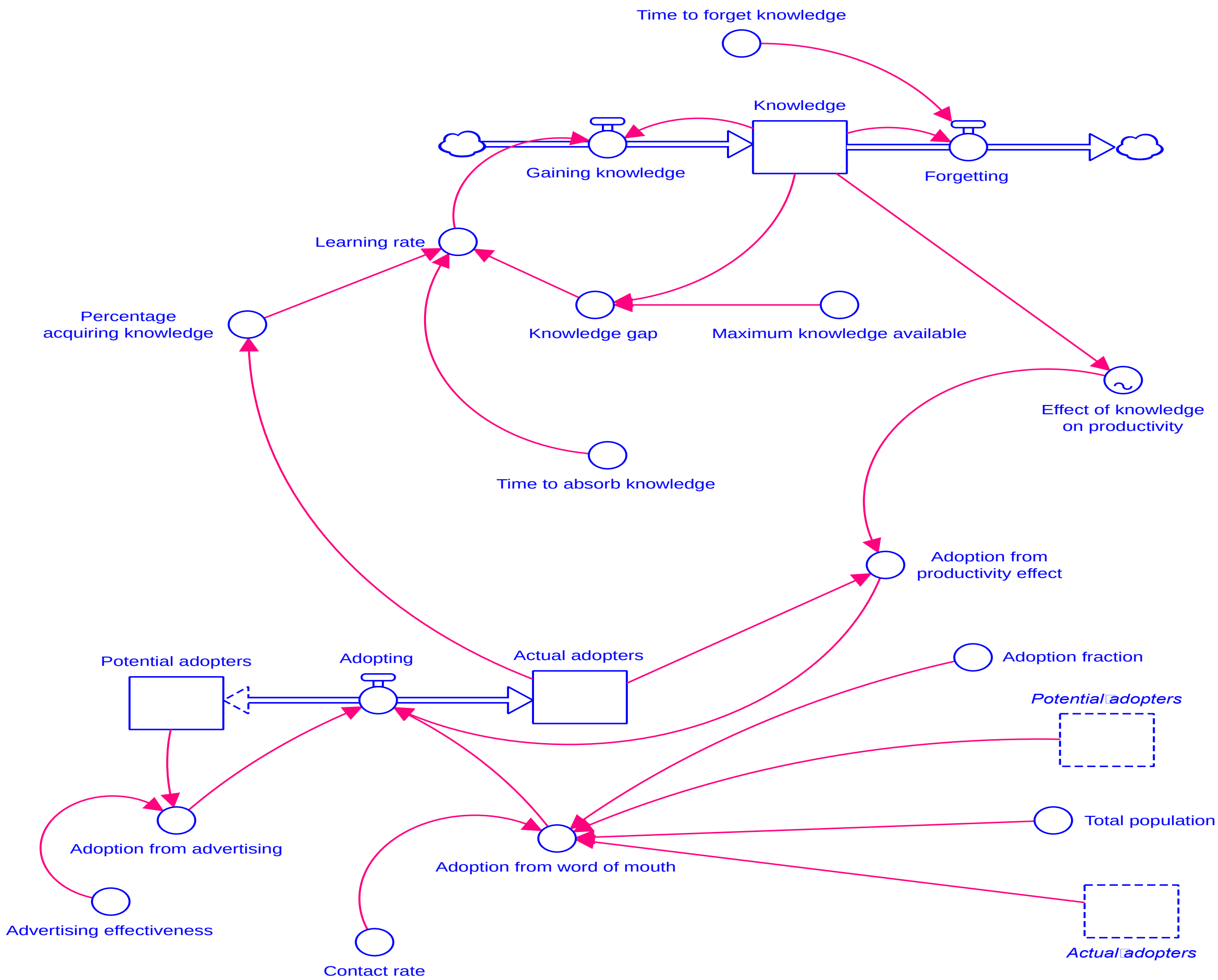


Figure 7 illustrates parts of the process followed by Lie et al. (2017) to iteratively develop a model of the dairy value chain in Nicaragua with stakeholders to explore and quantify the impacts of improving feed quality on market dynamics in the value chain.

Newly developed participatory tools (spatial group model building, or SGMB) can also be used to explicitly address the spatial aspects and drivers of livestock systems (Rich et al. 2018). The use of participatory GIS tools within SGMB is particularly useful in helping stakeholders visualize system phenomena, improving the quality of information collected and facilitating greater participation in focus group sessions. SGMB is being implemented in current ILRI projects in Bihar, Bangladesh, and Myanmar in the context of identifying sustainable, pro-poor interventions. It has proven valuable in engaging with value chain stakeholders in the context of animal disease, with Mumba et al. (2017) employing SGMB to analyze the drivers of East Coast fever control in two different districts of Zambia. The two sets of models explained above provide complementary information at different levels of resolution, with the multimarket model highlighting inter-sectoral effects across production systems and regions, and the value chain models specific details at a stakeholder level on a given commodity chain.

Both models are derived from the herd model, allowing for common data collection for supply-side information. From the standpoint of delivering advice on ex-ante impact or investment strategies, the two models provide alternative complementary perspectives, with the multimarket model focused on national/regional level investment at more macro level across the livestock sector, while the value chain models greater detail on more targeted investments for a particular priority species.

An application of the methodology is presented following.

National/sectoral and value chain level application

The type (e.g. macro or meso), intensity (e.g. single species or whole sector) and focus (e.g., investment or policy) of the ex-ante impact analysis determines the choice and application of the ex-ante impact assessment methodology, national or sector versus value chain level analysis. The choice and magnitude of ex-ante impact analysis, in turn, depends on the purpose and objectives, the types of impact dimensions of interest to the decision-maker, the resources available, and the previous knowledge of and experience with IA (perceptions of recipients regarding credibility, reliability, etc.) (IAEG, 1999).

National or sector level analyses assess aggregated impacts (economic, environmental and social) and are most suitable at the level of individual intervention being evaluated (IAEG, 1999) while value chain level ex-ante impact analysis capture and quantify interactive effects and distributional impacts along the value chain nodes (Sterman, 2000). A generic frame work is presented for practical application of ex-ante impact assessment (Figure 7) in the context of livestock research evaluation and prioritization. This has been modified from Andrade et al (2019). The seven (7) distinct steps of the framework application are identified and discussed following.

Step 1: Target site selection

Selection of target geographic area (e.g. region, country, agro-ecological zone, etc.), livestock system, technology (or suites of technologies) and policy. This selection can be identified a priori using combinations of previous mandates (e.g., of ILRI, a national government or other collaborating partner), expert knowledge of geographies and issues, and reviews of past literature.

Step 2. Mapping of livestock systems within the target region(s)

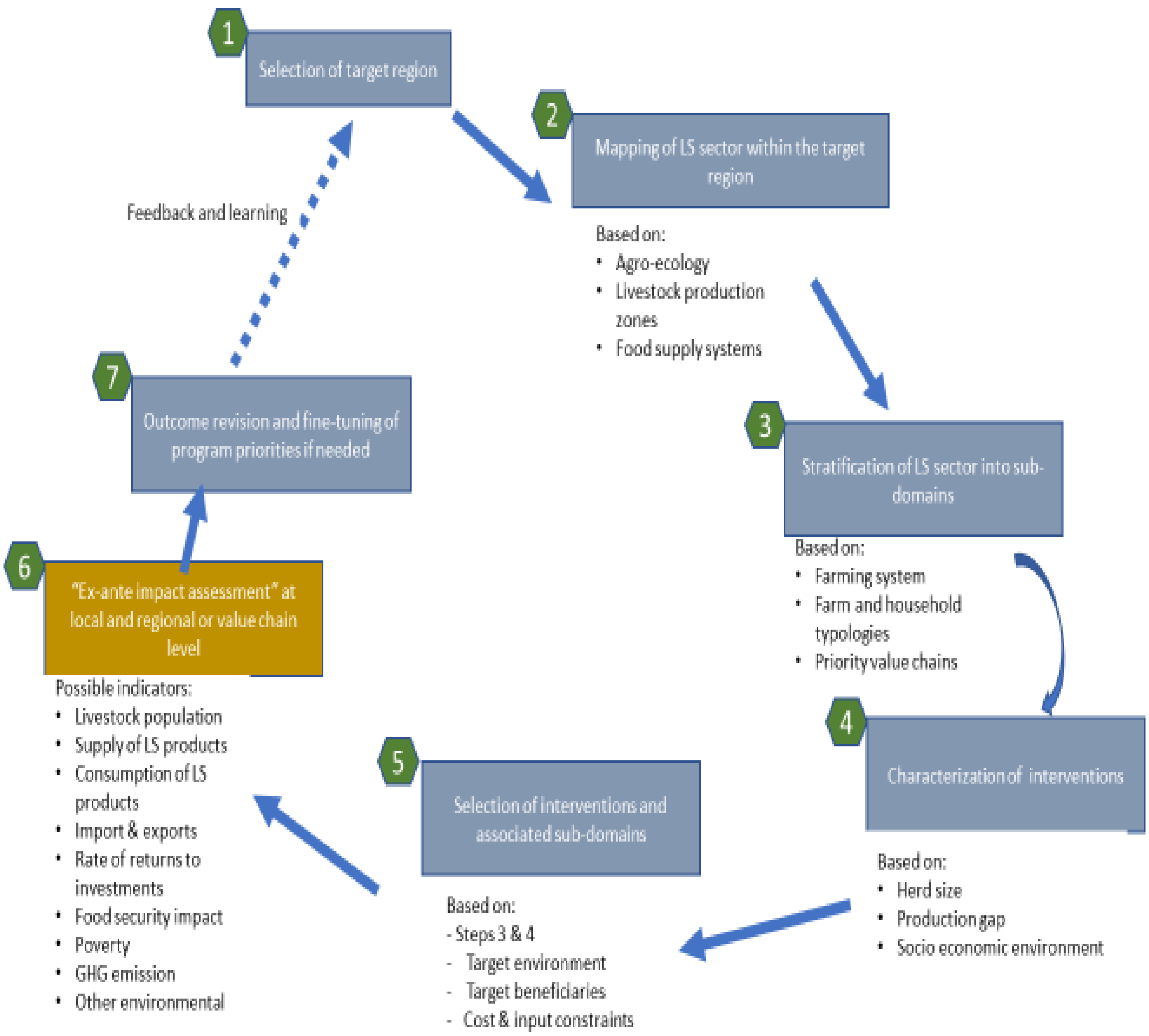
Livestock systems could be classified based on the livestock production zones which reflect a group of livestock farming practices sharing similar characteristics of climatic conditions (e.g., soil type, rainfall, altitude and temperature).

To facilitate the use of an ex-ante impact assessment analytical model, a typology of the different livestock systems is needed. Much of the work at ILRI defining livestock production systems has relied on the classification presented in Sere and Steinfeld (1996). The difficulty in translating the basically farm-level detailing of that classification to global contexts however has led to adaptation of the original classification to variations that more readily allow for the use of global spatial data (see Robinson et al., 2011).

Under the adapted classifications, the essential elements used in defining livestock production systems are defined at three levels. In the first, production is characterized by the length of growing period, human population density, land cover, (crop) irrigation area, temperature and elevation. In a second level of classification, crop and livestock distributions are accounted for, as are aquaculture, fishing and forestry. The level of intensification of production is the final determining step. These three steps together lead to a final set of four broadly defined livestock production systems that are relevant to developing countries. Two of these broad categories, i.e., pastoral/agropastoral and mixed crop-livestock systems, are land-based with their specific characterizations reflecting agro-ecological zoning.

The livestock production systems in which production methods are typically more modern and that depend mainly on the procurement of feed from commercial outlets are to a certain extent independent of the broader zonation of agro-ecological zones.

Figure 7: A generic frame work for the application of ex-ante *impact assessment*



Source: Developed by authors based on Andrade et al (2019).

These include commercial dairy, cattle and pig fattening and layer and broiler poultry systems. Smallholder livestock production serving urban/peri-urban areas may also be largely landless.

Step 3. Specification of livestock sector into sub-domains

Within the framework of the broader first level classification (production zones), further classification by the main faming system or priority livestock systems or value chains is important since interventions (technologies and policy) are strongly livestock system and value chain specific. A farming system is defined as a group of farms with a similar structure, such that individual farms are likely to share similar production functions (i.e., the formal representations of how farm inputs are turned into output). Classifying livestock production systems based on farming system gives opportunity to study, classify and group production systems into challenge and opportunity zones and simplify planning of development options/interventions. For example, the required type and scope of a policy support or technology investment interventions and associated economic and non-economic impacts are significantly different in a commercial market-oriented dairy system that uses specialized cross breeds compared to a family based low input milk-meat system reliant on local livestock breeds.

Step 4. Characterization of interventions

The framework is relatively flexible at this stage, as the characterization of the interventions will be based on the program goals (e.g. donor/research program, or national development goals). Examples of objectives and intervention combinations to which ex-ante impact assessments can be applied include: protection against drought induced catastrophic herd loss provided to farmers through covariate herd loss compensations that are predicted using the remotely sensed Normalized Differential Vegetation Index (NDVI)[4])that allows for capturing the historical relationship between livestock losses and natural vegetative cover; poverty reduction from e.g., market interventions that increase income per animal for livestock keeping households); food and nutrition security (using technological innovations that increase household herd and total herd production and the availability of Animal-source foods, ASF); increasing economic growth (by increasing livestock contributions to GDP or national income); raising export quantities or incomes (by increasing production beyond domestic demand levels which increase the potential for export of live animals and livestock products); industrialization and employment (through increased investments in ASF processing); social equity (through interventions that increase household and

4 NDVI is an indicator of vegetative cover widely used in drought monitoring programs in Africa.

post-production incomes, employment and assets of women, youth and targeted minority groups); and climate change mitigation following the introduction of higher producing and/or low greenhouse gas emitting livestock species for meat and dairy production.

Step 5. Selection of interventions and associated sub-domains

Once the interventions within the target area have been characterized based on key attributes from step 4, it is possible to rank them from most to the least important according to the programme goals or the scope and focus of the ex-ante impact analysis required. In many cases, the number of selected interventions would be determined by the required number of livestock farm types or priority value chains per sub-domain (step 3), potential impacts and the resource available. Further refinement may be needed as is deemed necessary. For example, if it is known that the technology or policy is more likely to work best in specific environments (e.g. dairy improving technologies in dairy favorable environment (highlands of SSA) and socio-economic conditions that favor adoption (e.g. access to market), specific regions within the intervention zone can be identified to meet specific criteria. After step (5), the outcome is a list of interventions explicitly selected based on priorities of research program, conditions under which the sets of technologies under evaluation are most likely to perform well and be adoptable.

Step 6. Ex-ante impact assessment at local and regional or value chain level

Indicators to evaluate potential impact of a technology or policy intervention may range from simple calculations of livestock population to more specific metrics such as the extra production that would result from the intervention, or reduction in poverty, food security gain and reduction in GHG emissions to name a few. In general, as shown in figure 1, indicators could be classified as economic and non-economic indicators. Economic indicators include changes in supply, demand, prices, trade, costs and revenues of products or activities replaced by the new technology and indirect financial and economic impacts through other spillovers.

While non-economic indicators include social and environmental indicators. Social indicators are such as, distributional consequences of the intervention, such as between consumers and producers, between different income groups of consumers and producers, and between different value chain actors, gender and employment impacts, change in poverty status and food and nutritional security. Environmental indicators include such as changes in GHG emissions, land use and natural resource base and other environmental factors.

The application framework allows ex-ante assessment across spatial scales (livestock production zones, provinces, states) and farm systems. Combining estimates of impacts on supply with investment analysis of the technology or policy intervention can provide an objective measure of return on investments (ROI), net present values (NPV) and cost benefit ratios (CBR) as well with in the same spatial structure. The quantitative framework can also allow for the analyses of trade-offs, such as beneficiaries and losers from an intervention, and the diminishing of one objective (e.g., employment generation) as a competing one increases (e.g., environmental impact). It is important to note that these can vary in the types and magnitudes of trade-offs depending on the context of the interventions and prevailing conditions.

Step 7. Outcome revision and fine-tuning of program priorities

Based upon the impact calculated in step (6), it may be necessary to re-iterate step (3) to fine tune site selection and explore different scenarios. Once the program is established, the framework can be used as a tool to monitor impact over time using the same set of indicators used in ex-ante evaluation.

Data requirements

Data layers that might be considered as overlays to the framework could vary depending on the magnitude or scale of the analysis, national versus value chain level. A good first task will be to develop the datasets for a herd dynamics model which is a basis to the baseline analysis that feeds to the multi-market models and determines the inventory and linkages to other sectors or distributional effects among other value chain nodes in system. The baseline analysis identifies the critical existing constraints and opportunities that drive the performance of the livestock sector. This leads to the identification of the spatial and farm specific intervention options.

Data required to develop the herd dynamics include production parameters (such as birth rate, offtake rate, mortality rate) and consumption parameters (both input such as feed and veterinary, and livestock products). As shown in figure 1, some of the data required at the stage of foresight or ex-ante analysis could include financial parameters, demand, trade and demographic or socio-economic factors.

An example using multi-market modeling

Application of a multi-market partial equilibrium model to evaluate the impact of technology and policy on smallholders in the pig sector of Vietnam and Uganda.
(Ma. Lucila A. Lapar, Emily Ouma, Peter Lule, Nguyen Ngoc Que, Dang Kim Khoi, and Karl M. Rich)
The study used a multi-market approach to analyze the impact of trajectories of change due to the emerging rural and agri-food systems transformation, on smallholder domestic supply of pork in Uganda and Viet Nam.

Background (steps 1-3 in Figure 7)

The study used a multi-market model framework to conduct two-country case studies to assess the impact of the trajectories of change on smallholder domestic market shares in supply of pork.

Vietnam

- Reforms in the last 20 years, shifts from a centrally planned to a state regulated market-oriented economy.
- Agriculture changed from a cooperative and state farm production system, to a system based predominantly on production by individual farmers. Household became the basic unit of agricultural production.
- Productivity of crops improved as the result of the change in institutional and policy reforms
- The livestock industry, especially poultry has also grown, creating a need for more maize to use as feed.
- The formalization of several regional economic integration and trade agreements has opened several opportunities for expanding markets for pork, but also exposes the sector to competitive pressures that demand efficient production systems and markets.
- Pork dominates meat production at approximately 77.8 percent of total livestock production compared to 14.2% of poultry and 7.9% of all other meats including beef .

- Consumption of pork estimated at 23.1 kg/person/year in 2012 is high relative to other meats.
- Pig population in Viet Nam showed a steady increase between 1995 and 2004 but started declining from 2006 due to disease challenges, especially foot and mouth disease (FMD) and Respiratory Syndrome (PRRS).
- Vietnam’s pig production is largely comprised of backyard/household operations, though the structure has changed between 2001 and 2011 with the share of smallholder farms (with less than 100 pigs) reducing from 98.1% to 82.6% and large commercial farms with 100 or more pigs increasing from 1.9 percent to 17.4 percent.
- In 2007 the government adopted policy measures aimed to increase the size of pig producing units, leading to the development of specialized registered pig farms.

Uganda

- Production and consumption of livestock and livestock products has been largely demand driven, growing rapidly as a result of increasing population, urbanization and wealth (the Livestock Revolution), and benefited from improvements in animal health control, and government projects promoting the growth of the livestock sector.
- Increase in urbanization, estimated at 5.4% per year, largely due to high population growth and rural-urban migration, and changes in consumer tastes and preferences has resulted in increased demand and consumption of pork, compared to other meats.
- Despite the demand-led growth, especially in piggery, the sector has been long neglected without public sector investment and is not among the priority enterprises selected under the Ugandan Agriculture Sector Development Strategy and Investment Plan since the 1980s.
- Piggery is only starting to gain recognition in the current 2015-2020 Agriculture sector strategic plan.
- The sector is generally underdeveloped although it has high potential for growth, given the rising demand for pork domestically and in neighboring countries such as South Sudan, Rwanda and the DRC.

- Uganda has the highest per capita consumption of pork in Eastern Africa, estimated at 3.4 Kg per person per year.
- Pig population has risen between 1980s to 2010s in response to the rise in demand for pork and pork products .
- Eighty percent of pig production is in the hands of smallholder farmers, each holding an inventory of 1–5 pigs at any given time under extensive systems, with small numbers of peri-urban small scale semi-intensive production systems.
- Pig market systems are largely informal with little devoted infrastructure.
- Available policies are either poorly implemented or lack a legal framework for implementation.

The integration of local firms into the growing urban center supply chains require substantial investments to raise business practices and quality standards to the required level, but can also yield substantial benefits in terms of improved local firm capabilities and increased market access.

To guide livestock policy and investments, there is a need for a robust evidence on the evolution and resilience of smallholder pig systems under varying agri-food system transformation including technology and policy scenarios.

The study applied a multi-market model framework to answer the following research questions:

- How will rising income and urbanization affect total pork demand and the composition of pork demand?
- How will shifts in pork demand influence pig producers, particularly small-scale producers i.e. will small-scale pig producers be squeezed out of the market?
- How will the growth of pig production affect maize markets – specifically, will imports grow?
- How would alternative policies, institutions, and technologies influence the evolution of the pig sector?

Model sectors

The multi market model for Vietnam is an eight region, four sector partial equilibrium model. For Uganda, the model is a six region, four sector, partial- equilibrium model.

Both models are designed to simulate the evolution of the pig sector over 10 years. Trade between regions with in the country and trade between the country and the rest of the world is assumed to follow the rules of spatial arbitrage in that (a) the price difference between any two regions can be less than or equal to the cost of transport and marketing between the two regions and (b) if there is trade between regions, the price difference will be equal to the cost of transport and marketing.

The direction of trade is endogenous, meaning that each region can export, import, or be self-sufficient in each commodity depending on the parameters of the simulation.

The four sectors included in the model are based on disaggregation of specific pork/pork products in addition to maize as a feed product. The model covers the following specific pork products; (1) fresh pork sold in rural wet markets produced by traditional smallholder producers, (2) fresh pork sold in urban/peri-urban wet markets produced by commercially-oriented producers, and (3) processed pork sold in formal market outlets including supermarkets produced by large, modern producers.

The model is recursive and dynamic – it simulates over 10 years (2015 – 2025). Differences in the results each year are driven by growth in income, population, and technology. These growth rates are determined exogenously outside the model based on each country estimates.

- ***Characterization of intervention (step 4 in Figure 7)***

The study analyses the impact of trajectories of change due to the emerging rural and agri-food systems transformation in Vietnam and Uganda. Changes in production, prices and other variables are tracked over space and time to understand the impacts of growth in technology and income.

Technological changes in feeds, animal health and breeds that increase productivity will help the modern and commercial pig sub-sector to increase production, meeting national demand and allowing surpluses for export. Technological changes in the traditional sector will help to reduce prices, maintain market shares, and have pro-poor impacts. In the maize sector, improving technology in crop breeding and agronomic practices will help reduce the amount of imports, despite growing pig and other livestock sectors.

Higher income elasticity indicates the increase in income of consumers and producers due to other income increasing interventions. It is expected to increase demand for pork products which in turn could drive production.

Selection of intervention & ex-ante impact assessment (step 5 & 6 in Figure 7)

The analysis compared 9 scenarios that incorporate a mix of technological and income changes across the traditional, commercial and modern pig sectors in Vietnam and Uganda.

Uganda

- The traditional pig sub-sector will retain its dominant market share (about three-fourths of total market supply) in fresh pork markets; except under the worst-case scenario of zero technical growth for the traditional pig sub-sector where its market share is reduced to only about a third of total market supply.

Vietnam

- The traditional pig sector will maintain its dominant market share (about three-fifths of total supply) in fresh pork markets. The commercial pig sub-sector will capture a dominant market share for fresh pork under two scenarios, namely 1) in high technology growth in the modern pig sub-sector and high-income elasticity for commercial and modern pork products (capturing more than half of total market supply), and 2) in the worst case scenario of no technology growth in the traditional pig sub-sector, with the latter's share being reduced to only a third of total market supply.

Technology is the most significant driver to improve the production of modern pig sub-sector. Increasing demand without technological development will lead to imports instead of developing domestic production.

Higher income elasticity and higher productivity growth in commercial and modern pig sector results in higher demand of pork products from the commercial and modern sectors compared.

In all scenarios, Viet Nam has to import maize for the animal feed industry. The imported amount depends on the production of pork and maize productivity. However, an increase in maize demand does not affect its domestic price given that supplies come from the international market at world prices.

Outcome revision and finetuning (step 7 in Figure 7)

The model results highlight that technology breakthroughs that will benefit both the traditional and modern commercial sectors will be preferable for developing the pig sectors for both countries.

Policies to regulate large producers, for example, to protect small-scale pig farmers may not be necessary.

An example using value chain level ex-ante analysis

African swine fever control and market integration in Ugandan peri-urban smallholder pig value chains: An ex-ante impact assessment of interventions and their interaction.

(Emily Ouma, Michel Dione, Rosemirta Birungi, Peter Lule, Lawrence Mayega, Kanar Dizyee)

The study used value chain level ex-ante impact assessment to assess the interacting effects and distributional impacts of biosecurity interventions to control African Swine Fever disease outbreaks and pig business hub models in Masaka peri-urban smallholder pig value chains.

- ***Background (steps 1-3 in Figure 7)***

The study analyses the peri-urban smallholder pig value chains of Masaka district based on typical production and marketing parameters agreed through consultation with local farmers and traders.

Masaka district

- has the highest pig population density in Uganda with more than 50 heads of pigs per km2 (Uganda Bureau of Statistics, 2009).
- has high pork consumption. Demand for pork is high during Christmas and Easter holidays.
- smallholder farmers sell pigs for slaughter to a variety of intermediaries (live pig traders, collectors, and butchers) through uncoordinated spot-market transactions, based on oral agreements.

- pig trading involves collection of pigs from individual pig farmers and bulking for sale or slaughter.
- about 68% are smallholders having 1–3 sows or 1–4 growers. They sell on average 1–2 growers at a time when in need of finance to local intermediaries working within larger traders' business networks.
- live pig traders and butchers dominate the trading node and each handle about 20–30 pigs per day.
- traders are largely vertically integrated, performing several functions in the value chain under single ownership. They are involved in the retail nodes of the value chain, operating pork butcheries and pork joints while also carrying out pig slaughter functions.
- the main pork trading town is Saza and has the highest number of pork joints in Greater Masaka region.
- pig supplies are from within the peri-urban as well as neighboring rural locations.
- during periods of ASF outbreaks pigs are scarce and transaction costs increase as supplies are obtained from neighboring districts.
- Pig value chain assessment surveys were conducted in Masaka district in 2012–2013 covering all value chain actors; pig farmers, pig traders, collectors, butchers, retailers, and consumers. Qualitative focus group discussion data from 600 randomly selected pig farmers were also used to complement the producer level data.

Model Sectors

Pig production sector: The production sector was constructed based on the livestock model or herd dynamics model. Based on the Group model building (GMB) exercise, the sector was further disaggregated to differentiate the pig population based on age and sex. Further details on the separate fattening process of growers was also included. The GMB process enabled identification of chain actors (collectors, traders, wholesalers, local butchers, processors, centralized pig slaughter house, and other urban butchers) involved in live pig and pork value chains.

Pig trading sector: The trading channels were mapped and quantified. Some chain actors, at local rural market level, such as producers, collectors, traders, and wholesalers trade both live pig and pork.

African swine fever (ASF) model: ASF introduced randomly into the model once a year (assumed based on past outbreaks). Once ASF outbreak occurs, both mortality increases and producers panic sales behavior occurs over a period of one month which leads to a substantial reduction in producers pig inventory. Panic sales behavior is producers risk mitigation strategy to reduce the likelihood of pigs dying in their farm or getting culled by veterinary authorities. A month after the outbreak, it is assumed that the outbreak is over, and producers begin replenishing their pig stock in which each household recommence pig production by purchasing a sow. Replenishing pig inventory occurs over a month of time after ASF outbreak is over.

- ***Characterization of intervention (step 4 in Figure 7)***

The constructed value chain level ex-ante impact assessment model run four scenarios through simulations over a 15 year and 30-year period to predict changes in pig mortalities and gross margins accruing to pig farmers and other value chain actors as a result of the ASF and pig business hub interventions relative to the current baseline situation. The details of the four scenarios are as follows:

- Baseline scenario

The baseline scenario presents the status quo of peri-urban pig value chains in Masaka district. In the baseline scenario, the model is parameterized based on data from the pig value chain assessment survey. The results of the baseline scenario are used as a benchmark to compare alternative scenarios.

- Implementation of ASF biosecurity interventions in the production sector to control ASF outbreaks

This scenario looks at the effect of implementation of biosecurity interventions in the production sector to control ASF outbreaks. The target is to reduce mortality rates due to ASF from the current 20.8% to zero. The effects of ASF in the value chain are introduced through increased mortality, home slaughter and panic selling. The cost of the biosecurity practices is estimated at Uganda Shillings 2625 per grower (pig ready for slaughter with a weight of about 30Kg carcass weight) per week. With improved biosecurity implementation, the pigs have better body condition and farmers can bargain for about 5% higher price.

- *Implementation of the pig business hub model to enhance linkages to input and output markets for better pig incomes*

The pig business hub model links pig producer collectives to dedicated input suppliers and output markets. This scenario assesses the effect of the pig business hub model on ASF control and pig incomes. The pigs are marketed collectively and collected by traders from pig collection centers. This has an effect of minimizing ASF outbreaks and spread as traders are not allowed to collect pigs on-farm. The farmers are also able to negotiate with input suppliers and pig traders for better input and pig prices due to bulk sales and purchases. At baseline, the average producer price per grower is about 150,000 Uganda Shillings. With the pig business hub, the farmers can bargain for a 24% higher price. The cost parameters associated with the pig business hub model include land rate payment to the municipal council associated with the pig collection center, ante-mortem pig inspection fees and pig loading into transport equipment. The cost is estimated at 68,540 Uganda Shillings per week.

- *Implementation of ASF biosecurity and pig business hub model*

This scenario looks at the effects of implementing both biosecurity interventions to control ASF and the pig business hub model to better link pig producer collectives to input suppliers and pig markets. With combined biosecurity and the pig business hub, farmers can bargain for 30% higher pig price.

➢ ***Selection of intervention & ex-ante impact assessment (step 5 & 6 in Figure 7)***

The analysis compared three intervention strategies with the status quo: application of ASF biosecurity measures, modification of the pig supply chain through development of business hubs and a combination of both interventions.

All the three intervention strategies: application of ASF biosecurity measures, pig business hubs and a combination of both interventions increased pig supplies by smallholders, albeit at different levels.

The rise in pig supply leads to an increase in pork supply thereby contributing to stable pork retail prices. Efforts to efficiently increase pig supplies in urban pig value chains are therefore beneficial to consumers.

Biosecurity interventions applied alone reduced ASF outbreaks but resulted in income losses to pig farmers and profit gains to other value chain actors due to stable pig supply. Although implementation of farm level biosecurity practices is justified in view of the substantial costs incurred in the event of an ASF outbreak, without an income or financial incentive to counter the high costs, farmers are unlikely to adopt the practices.

The pig business hub intervention on the other hand if applied alone, increases farmers and other value chain actors' income margins but is not as effective as the biosecurity practices in reducing mortalities due to ASF. The highest risk node for spread of ASF disease along the value chain is in the trading activities in market places. Establishment of collective marketing has a potential to significantly reduce the risk to ASF as it will prevent close contact of traders to pig farms, reducing the risk of contamination.

A win-win situation is a combination of both interventions due to their positive interactions resulting in increased income margins for all the value chain actors and reduced occurrence of ASF outbreaks. However, producers, unlike other chain actors, gain less through combining biosecurity and market hub intervention relative to market hub only intervention due to high costs of implementing biosecurity control measures. This suggests that there must be some cost sharing incentives among producers and other chain actors to make it feasible for producers to adopt biosecurity control measures.

Outcome revision and finetuning (step 7 in Figure 7)

Sensitivity analysis results that assess the reliability of the estimates show that value chain actors', except producers,' profit under pig business hub coupled with biosecurity interventions are not sensitive to +/− 10% changes in higher pig price bargain associated with the interventions and costs of policy interventions. This shows the importance of a price premium associated with policy interventions particularly implementing biosecurity measures. This is because the costs associated with biosecurity, unlike pig business hub, is high. Sensitivity analysis for other parameters (i.e. production parameters), of the model outputs were reasonable under all sensitivity tests

Application of the System Dynamics model in this study has resulted in robust estimates of the distributional impacts of the ASF biosecurity and business hub interventions along the pig and pork value chain. Most other ex-ante assessment studies utilize cost benefit analysis that focus on one node of the value chain. Such methods are unable to capture interacting effects of interventions and lack the capability to assess causal feedback effects of interventions within a system or along the value chain.

Comparing national/sectoral Vs value chain level ex-ante impact assessment

Table 1 : Comparing National/sectoral vs value chain ex-ante impact assessment

Activity	Macro level ex-ante analysis	Value chain level analysis
1. Coverage	Macro/sector level	Value chain level
2. Analysis/Assessment	assess aggregated impacts (economic, environmental and social)	capture and quantify interactive effects and distributional impacts along the value chain nodes.
3. Outcome/output	Provides sector level evidence on how prices, trade and livestock/feed markets adjust to different investment options	Considers how different technological interventions influence marketing and behavior of different value chain actors and the path of adoption
4. Tool/model	Spatial multi market partial equilibrium model	Participatory system dynamics/group model building
5. Resolution	Highlighting inter-sectoral effects across production systems and regions	Specific details at a stakeholder or value chain actor level on a given commodity chain.
6. Data	Uses herd dynamic model results from LSIPT National level aggregated data	Uses herd dynamics model from LSIPT Value chain specific detailed/disaggregated data
7. Interaction/casual feedback effects		Captures interacting effects of interventions Capable to assess causal feedback effects of interventions within a system or along the value chain.

Conclusion

As the interconnectedness between investment prioritization, socio-economic change and development outcomes become more apparent, decision-makers in public, private and non-governmental spheres are looking to more reliable and standardized tools to help focus public funding. Ex-ante impact assessments which are formalized principles, tools and processes that provide such framework, can be used in prospective analysis to identify, represent and measure drivers of change and their associated impacts. They are thus useful for setting priorities and allocating research resources. However, for *ex-ante* impact assessments to be relevant to an increasingly complex global agricultural and livestock system, several important considerations, such as the level of resolution that analytical frameworks should be, the ability to incorporate a range of non-economic factors in the analysis and the behavioral feedbacks that link economic and non-economic factors, apply. A quantitative impact assessment of research innovations for the livestock sector will typically be a formalized model of the sector.

As the livestock sector is diverse, encompassing a range of different livestock species and value chains, identification of appropriate production systems for analysis becomes a basic requirement. Another essential component of a relevant ex-ante impact assessment framework for livestock investment assessments is a well-defined model of herd dynamics that characterizes how the supply of farm animals or livestock evolves over time. To that end, this report has developed a generic framework, which includes 7 steps, for practical application of ex-ante impact assessments in the context of livestock research evaluation and prioritization.

The repot has identified two particular ways to link the quantified supply side of the livestock sector to downstream (post-farm) dynamics and household consumption and demand. The first method is partial-equilibrium or multimarket models, which specify a series of supply and demand relationships for different production systems and household groups and generate prices which match supply and demand. The second method is the use of system dynamics methods to simulate and model the dynamics of processes and flows of specific actors in a specific or set of value chains.

Appendix

Figure A1: Group model building sessions with stakeholders

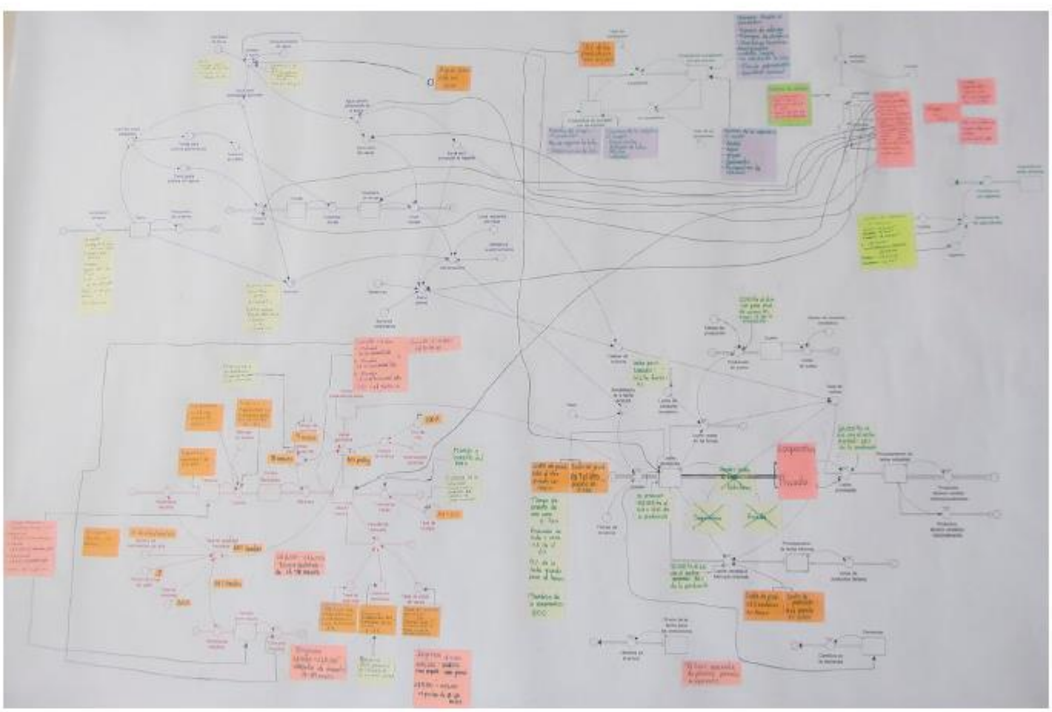
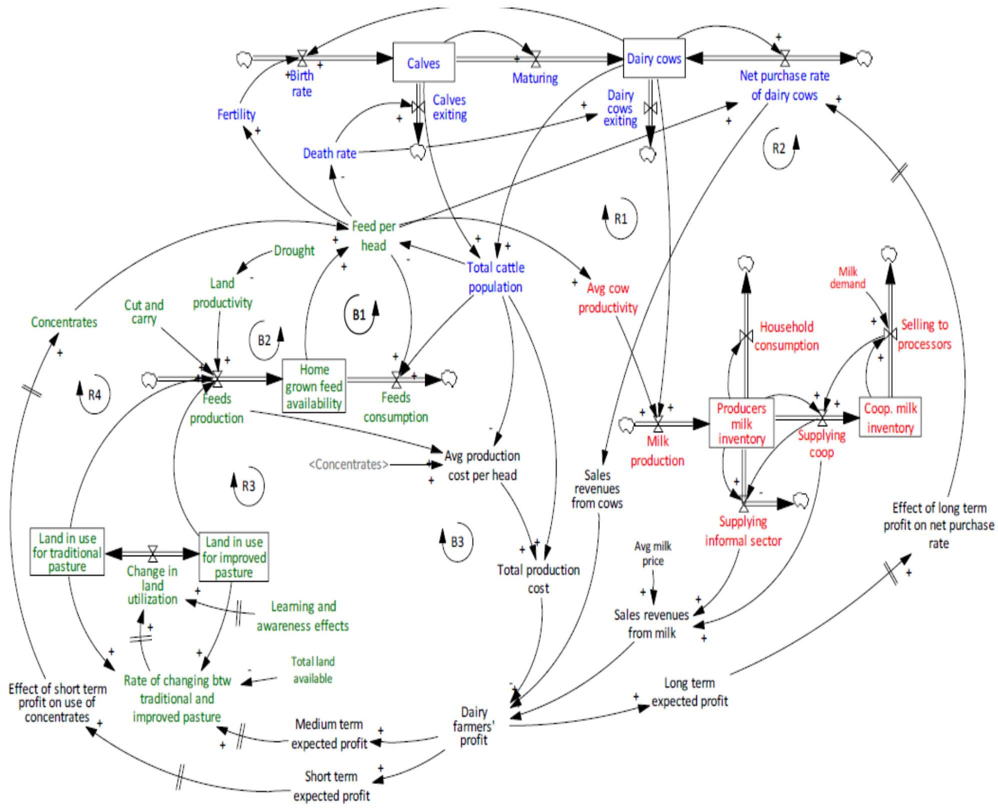


Figure A1 (cont'd)



Source: Lie et al. (2017)

Table A1: Global livestock production systems for economic modeling

Broad Category	Acronym/name commonly used	Agro-ecological classifications
Pasture-Based	LGA	Hyper-Arid/Arid/Semi-Arid
	LGH	Humid/Sub-Humid
	LGT	Temperate/Tropical Highland
Mixed crop-livestock*	MRA/MIA	Hyper-Arid/Arid/Semi-Arid
	MRH/MIH	Humid/Sub-Humid
	MRT/MIT	Temperate/Tropical Highland
Urban production	Urban	None
Production in other areas	Other	None

*****The rainfed and irrigated mixed crop systems have been collapsed when the classification is adapted to livestock economic modelling, e.g., Msangi et al., 2014.

Source: Adapted from Robinson et al., 2011.

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