Commercializing Smallholder Value Chains for Goats in Mozambique: A System Dynamics Approach

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Abstract

Goat producers in Inhassoro follow traditional management practices that lead to low supply of low quality goats. This has negative impacts on profitability, and on market access. Traders who buy in the Inhassoro locality buy only small volumes, and buyers from external markets are unaware of potential market supply in Inhassoro. This interaction of production constraints and limited information flows in the value chain was addressed using a system dynamics model for various commercialization scenarios. Simulation results show that improving goat production and animal health practices alone without concomitant improvements in market access have negative impacts on the financial performance of producers and no impact on other value chain actors. However, interventions that both improve market access and animal health have significant positive impacts on the financial performance of all value chain actors. The model's explicit treatment of herd dynamics contribute significantly to these conclusions, particularly the lagged production response inherent in livestock breeding systems.

Keywords: *Mozambique; Inhassoro; smallholders; goats; value chains; system dynamics*

1 Introduction

Goats offer a potentially strong return on investment for smallholder producers in developing countries (Van Rooyen & Homann, 2008; Devendra & Chantalakhana, 2002). Goats' reproduction rate is relatively high, taking 5-6 months for a kid to mature and be available for sale or breeding. In Mozambique, as in much of the developing world, farmers maintain stocks of goats, both for the purpose of meat consumption during special occasions and for cash needs during emergencies. The production of goats in the Inhassoro district of Mozambique uses traditional methods, with limited application and knowledge of more advanced management practices in breeding and animal health. Less than 10% of farmers report keeping goats as their main occupation (Boogaard et al. 2012). As goat raising is commonly secondary to crop production, other animal production or other economic activities, there is little attention given to goat stocks' management, nor to commercial aspects of production and marketing efficiently (imGoats Baseline Report, 2012; Peham, 2012; Boogaard et al. 2012). These features of the goat system constrain its potential as a means of sustainably contributing to Inhassoro's smallholder farmer livelihoods.

The resulting low qualities and quantities of Inhassoro's goats are of limited interest to buyers in regional and national networks such as those serving the city of Maputo to the south. Markets and trading channels are limited to the Inhassoro market, wherein a few goats per week are sold to Inhassoro butchers, and some 10-15 goats per week sold at roadsides (Peham, 2012). This isolation simultaneously limits market access for producers, and the incentives for investment and commercialization.

Thus, limitations of goat production practices in Inhassoro and information gaps among actors in larger markets (e.g. Maputo and nearby Maxixe) and Inhassoro producers constrain commercialization of the smallholder goat sector in Inhassoro district. In response, the imGoats project (www.imgoats.org) targeted Inhassoro district for improvement of the livelihoods of smallholder goat keepers. The project conducted a variety of research and field activities and workshops to design and implement interventions: improving producers' access to animal health services and better production practices, and organizing goat fairs to improve goat marketing activities and connect goat producers to goat buyers (see Boogaard et al (2012)).

Embrace of a market-oriented system offers potential for change, but this would require significant investments to boost productivity, as well as increase goat supplies and attract traders from larger markets such as Maputo and Maxixe. Such investment has been shown to be accelerated by collaboration amongst value chain actors (Devaux, et al., 2009; Cotula & Vermeulen, 2010) and other with parties (government and NGOs) (Poultonet al., 2006; Humphrey, 2006). However, Inhassoro's value chain climate is typically one where information exchange between value chain actors is scarce, and thus collaboration amongst actors is limited. At an operational level, it is not clear *ex-ante* which interventions or investments within the value chain would be most cost-effective for smallholders. Further, tradeoffs between value chain efficiency and smallholder inclusion (Warning & Key, 2002) are likely. These issues suggest a need to complement qualitative assessments of the governance patterns in the goat value chain with quantitative methods that assess tradeoffs amongst interventions.

The purpose of this paper is to evaluate quantitatively the goat production and marketing system in Inhassoro district, and guide future investment. It complements previous work in the imGoats project by developing a model that analyzes intervention strategies for enhancing livelihoods of marginalized groups in rural areas of southern Mozambique. In this application we analyze interventions aimed at raising productivity and supply (e.g. providing veterinary services to goat farmers) and enhancing information flows among value chain actors to improve producer access to large goat markets. The paper attempts to answer the following questions:

- What are the physical and financial consequences for value chain actors of interventions that provide veterinary services to improve goat productivity and quality?
- What is the impact on value chain actors of improving information flows between markets with high demand for goats, and the Inhassoro producers?

In a developing country setting such as Mozambique, understanding such impacts, particularly among smallholder producers, will have important policy ramifications for the design of successful policy reforms. Given the interaction amongst production and supply, markets and trading stages, the nature of smallholders' goat enterprises and its production lags following management decisions, and apparent constraints on information flow, a model of these elements of the system was developed. The resulting system dynamics (SD) model, calibrated to a target set of 350 farmers in 18 communities, was used to provide a framework for *ex-ante* testing of various interventions in the Inhassoro goat value chain. This allows us to conduct policy scenarios that assess both value chain performance and the potential benefits of alternative interventions on marginalized smallholder livestock producers (Rich et al. 2011). Of particular interest is the facility of the SD model to capture production lags and their implications for responses to interventions and policy reforms that are characterized by delay. These delays can lead to future uncertainty and volatility that other modeling frameworks are less equipped to address.

Although conventional wisdom suggests that shortages of supply are the main constraint in linking Inhassoro goat producers to the main market, our model results showed that interventions that focus on improving information flows between different actors could significantly improve the profitability of Inhassoro smallholder goat producers, even if productivity in the chain remains low. Productivity improvements in the absence of changes in chain-level governance would not appreciably improve market access, suggesting a re-think in the prioritization of interventions away from technical ones and more towards institutional improvements in the value chain that alter governance patterns. This would necessitate the support of NGOs and other third parties to facilitate information exchange. At the same time, model results show technical improvements in productivity would improve market access as an important second-round effect once information constraints are addressed.

2 Background to the Inhassoro goat value chain: survey and fieldwork results

This section of the paper is based on fieldwork conducted by the authors (in cooperation with imGoats project field staff) in Inhassoro, and a survey prepared by the Norwegian Institute of International Affairs (NUPI) and International Livestock Research Institute (ILRI). The survey was implemented by ILRI and CARE International in goat markets in Massinga, Maxixe, Inhambane, Zavala, Xai-Xai, Manhiça and Maputo.

Figure 1 identifies the key locations in the supply of goats to Maputo as the major consumption point. The demand for goats is reported to be higher during Christmas holidays, Independence Day, and Muslim celebrations following Ramadan. Goat trading in Maputo is significant, with traders reporting handling between 100-200 goats per trader per month, or per week, depending on the season. Survey results revealed that traders in Maputo buy goats in Tete province (Central Mozambique), despite Inhassoro's being less than half the distance from Maputo. Goat supplies in the target markets were found to come from Govuro, Mabote, Funhalouro, Machanga, Muchungue, Tete, Mabote, Gorongosa, Rio Buzi, Chissiguana, Massangena, Buzi, Mutarara, Chimoio, and Mabalane. Tete is the main supplier to large markets. Traders reported that they are able to obtain the quality and quantity of goats they need in Tete without supply shortages. In contrast, in Inhassoro the required quantity of goats was reported to be not readily available. Despite Inhassoro's being geographically close to larger markets such as Maputo and Maxixe, the lack of reliable goat supply increases organization, assembly, and transportation costs, making Inhassoro a relatively undesirable place to buy goats. An interesting finding from the survey was that Maputo traders were willing to support producers to increase their production capacity, in return for obtaining a reliable supply of goats; however traders in Maxixe and Xai-Xai reported being less interested in such arrangements. Traders in Inhorasso report that there are not enough goats available for sale, to meet their demand. Traders outside Inhassoro report, in many cases, not knowing that goats are available for sale in Inhorasso.

Figure 1. Map of goat supply chain in Southern Mozambique

On the supply side, there is a shortage of goats for sale in Inhassoro. One estimate (Baseline Report, 2012; Peham, 2012) indicates that on average goat keeper households in Inhassoro keep 8.4 goats and, on average, sell one or two goats per year depending on cash needs, season, and buyer availability. Survey results show that smallholder goat keepers in Inhassoro are willing to increase their herd size. They report insufficient financial resources as the main reason for not doing so.

Overcoming these demand and supply constraints is treated here, for the purposes of discussion, as a process of commercialization: essentially of increasing traded volumes by way of enabling transactions. On this basis, the results of the survey were communicated to local Serviços Distritais das Actividades Economicas (SDAE, the District Services for Economic Activities) staff in Inhassoro, CARE International and ILRI staff for further

validation and analysis. The authors organized a focus group discussion with SDAE officials in Inhassoro district, while an interview was conducted with the head of provincial livestock services to analyze ways of tackling the commercialization-related challenges addressed above, and to discuss feasible interventions. The following were proposed as ways forward for Inhassoro:

1. Facilitation of information flow from producers and traders: specifically on the availability of goats for sale, and their quality
2. Facilitation of information flow from traders to producers: specifically on the demand for goats throughout the season and the markets' quality requirements
3. Dissemination of information to producers on the costs inherent in the goat value chain (aggregation, transport, and goat prices), and the steps necessary to reduce them so that Inhorasso producers compete with those in other locations. Contract farming is one option to be investigated.
4. Facilitation, by SDAE, of communication among value chain actors to find locations for goat fairs and look for market opportunities outside Inhassoro district by contacting buyers in other markets
5. Organizing farmers and registering their herds to circumvent the market in stolen goats.

Based on these insights from the survey and fieldwork, we concluded that the supply of goats and lack of information flow between Inhassoro producers and larger markets are the two major constraints that impede the commercialization of the goat value chain in Inhassoro. Notably, these constraints feature some simultaneity based around high costs on the part of traders and low profitability on the part of producers. The intervention strategies examined in this paper target alleviating these two constraints.

3 Methodology and model structure

We used a system dynamics modeling approach to develop a dynamic value chain model that highlights the changes and performance of the goat value chain among involved actors over time (Rich et al. 2011). System dynamics (SD) is a methodology that studies the dynamic interactions and feedback effects among a set of variables that compose a system (Forrester 1961; Sterman, 2002; Sterman 2010). Our model relies on concepts from Sterman (2000), while our general value chain structure draws on Tchale and Keyser (2010), UNIDO (2009), FAO (2012) and Kaplinsky and Morris (2000).

Data and specific characteristics of the Inhassoro goat value chain draw on research conducted in the imGoats project and field work. We used both qualitative and quantitative data to build the model and initialize parameters and the initial state of the system. Data sources include imGoats' Baseline Report (2012), Peham (2012), imGoats' Innovation Platform meeting reports (ILRI, 2011-2012), and supplementary short reports provided by ILRI staff in Inhassoro. We complemented the sources of data through the implementation of a survey developed by NUPI and ILRI and administered by ILRI and CARE International in markets of districts/municipalities of Massinga, Maxixe, Inhambane, Zavala, Xai-Xai, Manhiça and Maputo, from 8 – 12 October 2012, and through fieldwork conducted by the authors.

The model includes two main sectors: production and market; and a policy sector. The production sector of the model was constructed based on the livestock model found in Sterman (2010). Also based on Sterman (2010), the model's market sector is an expansion to include downstream actors such as aggregators, traders, and retailers. We also attached a financial model to evaluate the profitability of the various actors in the value chain. Financial performance (i.e. changes in value chain actors' cumulative profit) is measured throughout the model for the main value chain actors. The model's policy sector simulates changes in trading and management practices. The various sectors are connected to each other through flows of information, products, and payments, and feature various feedback loops. Figure 2 is a generic portrayal of the model's main components and feedback interactions.

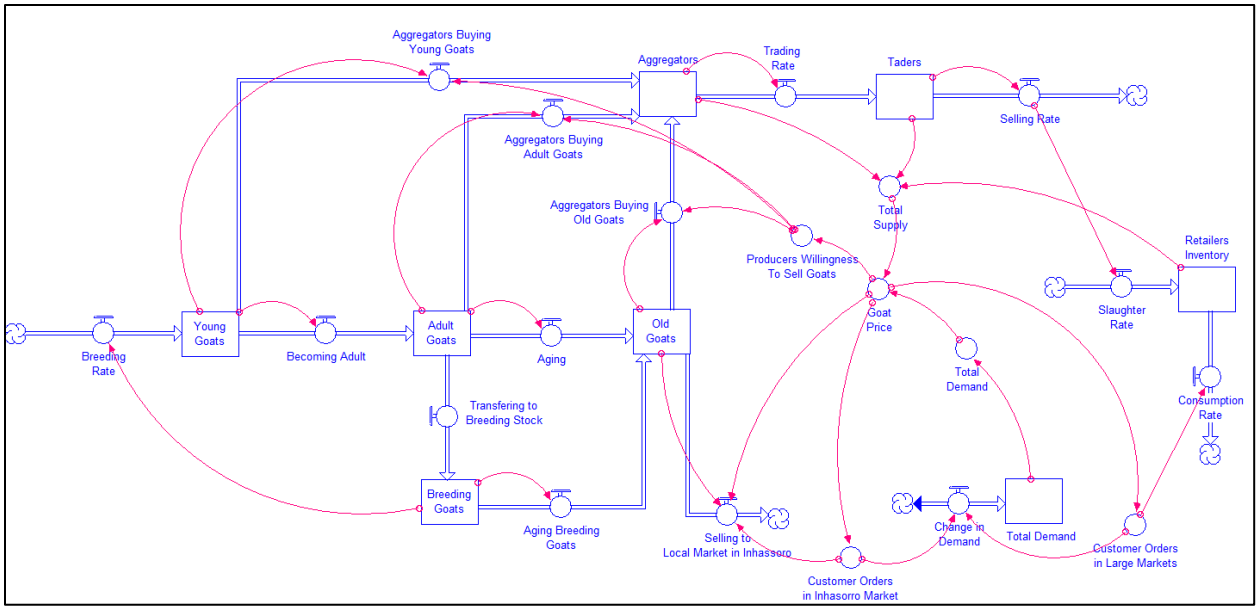


Figure 2. Portrayal of model structure

In figure 2, the stocks (boxes) represent producer stocks of goats and the inventories of animals (or meat) of the different value chain actors. For example, *"Breeding Goats"* represents the number of breeding goats in producer stocks, while "*Retailers Inventory"* represents the number of goats (and goat carcasses) in retailer inventories. Stocks change through inflows and outflows, which are governed by variables that regulate such flows: technical and/or market parameters. Connectors (arrows) between actors represent information feedback loops. Interactions between supply and demand sides of the market, and the feedback effects of price on both supply and demand, exist in all market channels. In essence, our model is an expansion of the SD supply and demand model of Whelan and Msefer (1996) in which inventory decisions by downstream actors influence prices, which subsequently affect the incentives for producers to market animals in the different market channels based on their level of market integration. Generally, goats and goat meat products flow from producers to end markets by way of value chain actors, while money flows from end markets to producers along the value chain. Information flows occur in both directions. As in all models, there are simplifications employed which introduce limitations such as the omission of input suppliers and credit providers from the model, and an all-or-nothing treatment of veterinary services and animal health which omits disease evolution. Although these simplifications ignore important elements of Inhorasso's goat value chain, the resulting focus on the abovementioned sectors allows a significant advance on previous analyses and establishes a basis for future inclusion of further detail.

4 Simulation Results and Analysis

The constructed value chain model was used to run four scenarios: (1) baseline; (2) provision of veterinary services; (3) an information intervention to link Inhassoro goat producers to targeted large markets; and (4) provision of veterinary services and linking of Inhassoro producers to large markets (i.e. a combination of scenarios 2 and 3). Scenarios' details are as follows:

1. **Baseline scenario:** we use the model to replicate the status quo of goat production and marketing in Inhassoro. Table 1 shows the values used (average column in the table) for model parameters and initial values.
2. **Scenario 2: Provision of veterinary services to enhance production**: In this scenario, we look at the effect of provision to producers of basic veterinary services on physical and financial performance, as well as on variables further downstream. This scenario targets reducing goat deaths at all stages of goats' development. Table 2 presents the changes used in model parameters and costs. We assume that producers start providing

basic veterinary services at the beginning of the simulation, taking one year to have all goats covered. Assumed veterinary services include treatments against internal and external parasites, and the treatment of wounds. This scenario is motivated by the efforts undertaken by the imGoats project to provide veterinary services and encourage producers to use such services.

3. **Scenario 3: Improvement of information links in the value chain**: In this scenario, we report the results from linking Inhassoro goat producers to larger markets such as Maputo. We simulate two channels for goat demand: (1) the local market in Inhassoro, and (2) larger markets as described above. Currently, Inhassoro goat producers have limited or no access to larger markets, and thus larger markets are targeted by our proposed information intervention. Figure 3 shows the structure of information, and flows of goats and cash between producers and goat markets. We assume that increasing goat flocks at producers stocks without addressing issues of limited information flow among chain actors has limited influence on accessing markets outside Inhassoro as traders in these markets need to be informed about goat availability in Inhassoro.

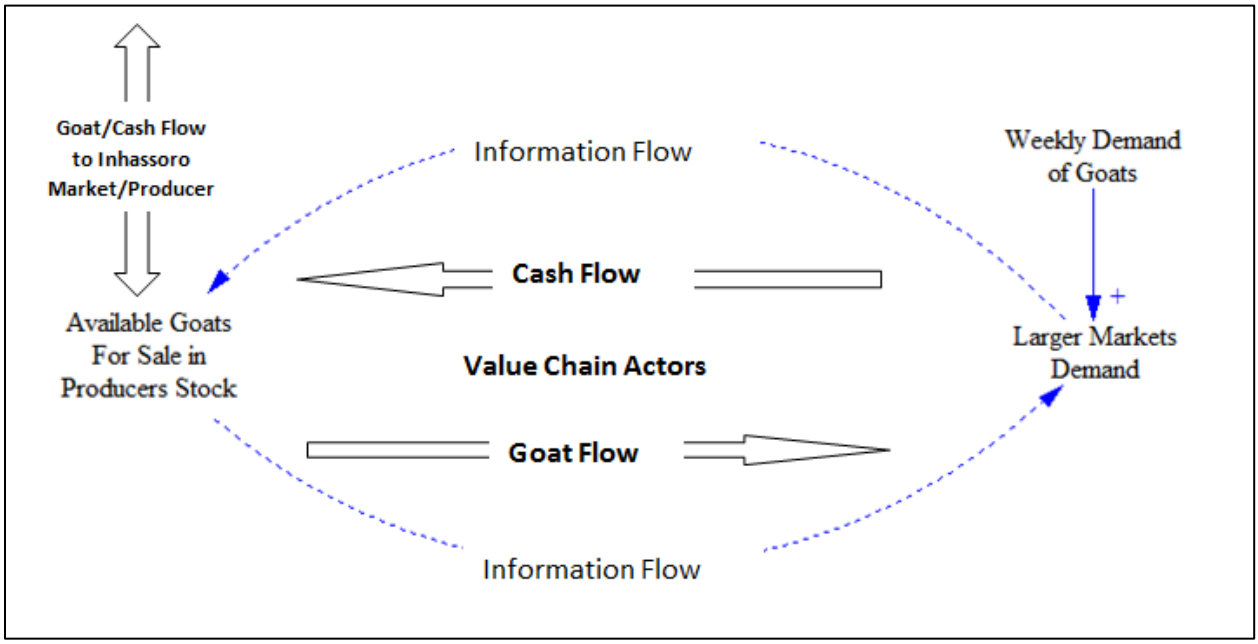


Figure 3. Information intervention to link Inhassoro producers to larger markets

In the presence of information flow among value chain actors (this can be done via SDAE to arrange goat fairs), we assume that as the number of goats in producer herds rises, the probability of attracting buyers in larger markets increases. That is, the model assumes that when the volume of goat herds increase in the targeted communities, then large traders and retailers have incentives to start obtaining parts of their supply in Inhassoro through aggregators and traders. This trading link is activated via information flow between producers and traders in larger markets. This information flow feeds goat availability in Inhassoro into a random probability function which is linked to traders demand in larger markets. We have made conservative assumption by assuming that doubling number of goats for sales in Inhassoro only increases probability of trading by 1% per time unit (week) because the targeted producers in this study are small producers (350 producers located in 18 communities, and on average each producers own 8.4 goats) located in different communities geographically far from each other. This intervention was motivated by the efforts undertaken under the imGoats project to link producers and goat buyers through goat fairs.

4. **Scenario 4: Provision of veterinary services + improvement of information links.** In this scenario, we combine scenarios 2 and 3. In scenario 4, we further assume that producers invest in veterinary services to enhance

both goat quantities and quality: this in turn improves the probability of access to the larger markets. That is, the combined effect of veterinary provisions and increased goat quantity increase the probability of trading by additional 1% to 10% (based on what portion of goat population covered by veterinary provisions, generally, it takes one year to provide veterinary services to all goats in the area from the moment producers begin investing in animal health) as animal condition is another factor that attracts buyers.

Table 1.
Goat Production parameters

Parameters	Peham (2012) + Baseline (2012) Reports	Extension officer 1 (CARE)	Extension Officer 2 (CARE)	Veterinarian (Saskia Hendrickx)	Fieldwork (author)	Average	Time unit
Breeding stock productivity	0.9*	0.9	0.95			0.9***	Unitless
Litter size	1.4	1.5	1	1	1.5	1.28	Goat/litter
Litter per year	1.05	1.5	1.5	1.3	1.5	1.37	Litter/goat/year
Gestation period	6	4	5	5	5	5	Month
Abortion Rate	0.17	0.15	0.05**			0.16	1/year
Young Goat Fractional Death Rate	0.33	0.05**	0.2		0.3	0.28	1/year
Time to Mature		6	6			6	Months
Various Consumption Rate	0.25*	0.2-0.3	0.2-0.3			0.4	1/year
Mature Fractional Death Rate	0.1					0.1	1/year
Breeding Stock Replenishment Rate		0.6-0.7	0.6-0.7			0.65	1/year
Breeding Stock Fractional Death Rate	0.1	0.03**	0.05**			0.1	1/year
Average breeding period	4*	5	3 to 4		3	3.9	Year
*	Rough estimation from reports						
**	After treatments						
***	We assume that 10% of breeding stock are males kept for breeding purposes						

Table 2.
Intervention costs (Metical) and efficacy

Scenario 2 (veterinary services) parameter changes	Before Intervention	After Intervention	Costs/Goat/Year
Abortion Rate	0.15	0.05	
Young Goat Death Rate	0.28	0.1	75
Adult Death Rate	0.1	0.05	

Table 3.
Average prices and operation costs per goat

parameter	Producers	Aggregators	Local Butchers	Traders	Retailers
Average Goat Price	830*	1050*	1450*	1350*	2000*
Production Costs Per Goat	50				
Transportation Cost Per Goat		35	70	50**	
Licenses			30		30
Inspection			50		50
Slaughter			100		100
Labor	65	65	50	150	160
Other Costs		20		35	60
Total (operation) Costs	**115**	**120**	**300**	**185**	**400**
*	These are initial prices, price changes based on supply and demand				
**	Changes depending on traded goat quantity				

5 Model runs and results

We ran the model over a five-year time horizon (260 weeks). We report the results of the investigated scenarios alongside each other to facilitate comparison of impacts. We report results of total supply, total demand, price dynamics for producers, inventories held by different value chain actors (producers, aggregators, traders, and retailers), and their respective cumulative profits. The model endogenizes price relationships following Whelan and Msefer (1996) in that as prices rise, producer willingness to sell increases, though this has an implication on the volume of animal stocks in future periods. By contrast, an increase in price reduces demand that feeds back to the market and causes supply to respond through changes in price. The pattern of price development is the same in all market channels in that price increases downstream in the chain according to assumed marketing margins between actors/stage of the chain.

In all the figures presented below, trend 1 represents scenario 1, trend 2 represents scenario 2, trend 3 represents scenario 3, and trend 4 represents scenario 4. Figures 4-6 show the supply of goats from Inhassoro, demand for Inhassoro's goats in local and external markets, and the dynamics of goat prices, respectively. In scenario 1 and 2, supply, demand, and prices exhibit regular, though relatively low amplitude, cycles. In both scenarios, we assume relatively simple marketing behavior of goats based on local (Inhassoro district) demand and some variation due to market seasonality. However, in scenario 3 and 4, we extend the goat value chain by introducing semi-frequent links between farmers and both local markets and long-distance markets such as Maputo. This requires sufficient goats in a community (or a few nearby communities) to make trading with large buyers financially economically feasible for buyers.

Scenario 3 highlights that five trading activities between Inhassoro and larger markets take place over a five-year period, while scenario 4 shows about 18 trading activities over the same time horizon. The trading events in scenario 3 and 4 are measured endogenously based on quantity and/or quality of goats in producers stocks. Scenario 3 shows fewer trading activities than scenario 4 because the number of goats and their quality is better in scenario 4 relative to scenario 3 due to the additional investment in veterinary services in scenario 4. However, trading between Inhassoro and larger markets reduces marketable goat numbers for producers, so that there is a lag in supplies from Inhassoro in future periods. As trading increases between Inhassoro and larger markets, prices in Inhassoro become more volatile and take longer to get back the levels before the trading shocks.

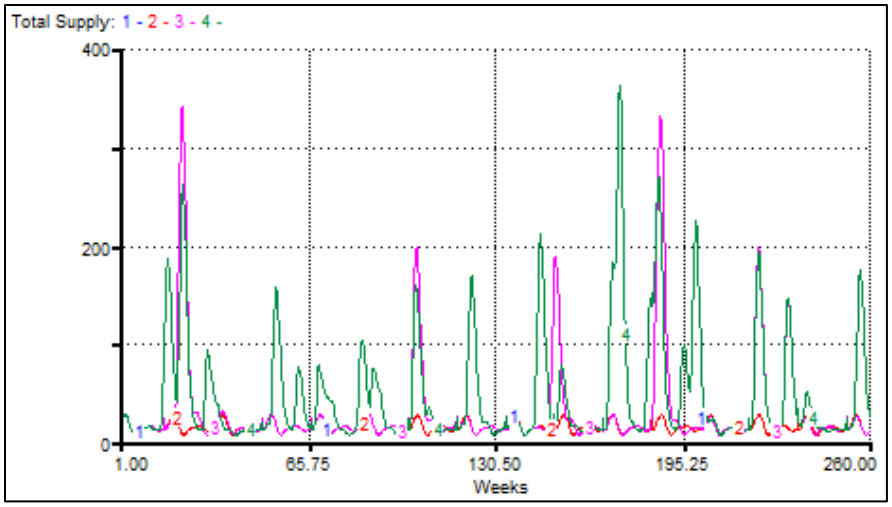
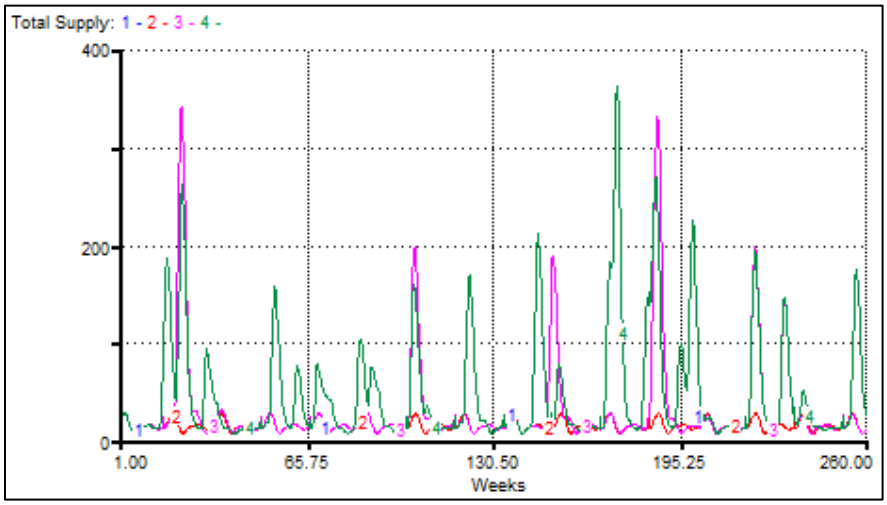


Figure 4. Total goat supply



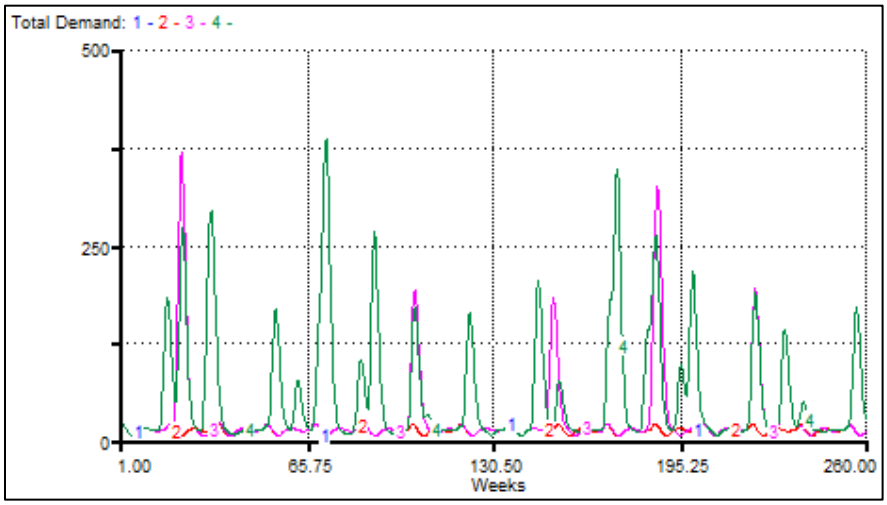


Figure 5. Total goat demand

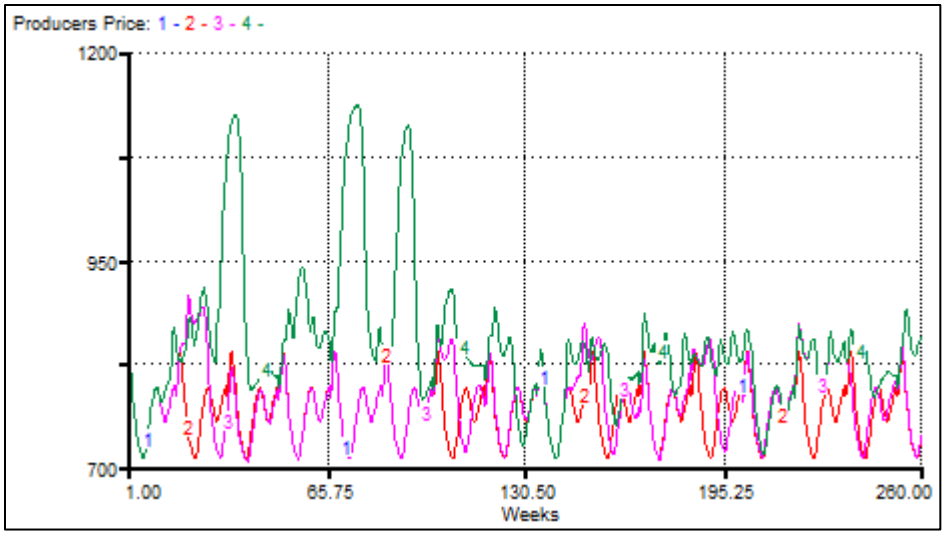


Figure 6. Price dynamics at the producer level

Figures 7 to 11 show total goats in producer stocks; potentially marketable goats in producer stocks (i.e. a fraction of total goats); and inventories of aggregators, traders, and retailers, respectively. In the baseline, goat populations rise due to low sales rates and no environmental or carrying capacity feedbacks to limit animal numbers (we do not have information about carrying capacity in the study area). In scenario 2, producers invest in veterinary services that lead to an even faster increase in population growth. However, under scenarios 3 and 4, trading channels between Inhassoro and larger markets open and create cyclical, market-based patterns of animal stocks. As traders buy large quantities of goats, producer stocks decline, while it takes some time for goat populations to rise again due to time lags in goat production from breeding to adulthood. While there is more trading under scenario 4, goat populations are higher in scenario 4 than in scenario 3 as goats are more productive due to improved veterinary services. The inventory levels of external traders and retailers are zero under scenario 1 and 2 because these actors are not engaged in the Inhassoro value chain under either scenario. Inventory levels of aggregators are very low as their trading activities are limited. However, under scenario 3 and 4, greater market activities induce a rise in inventories among downstream value chain actors.

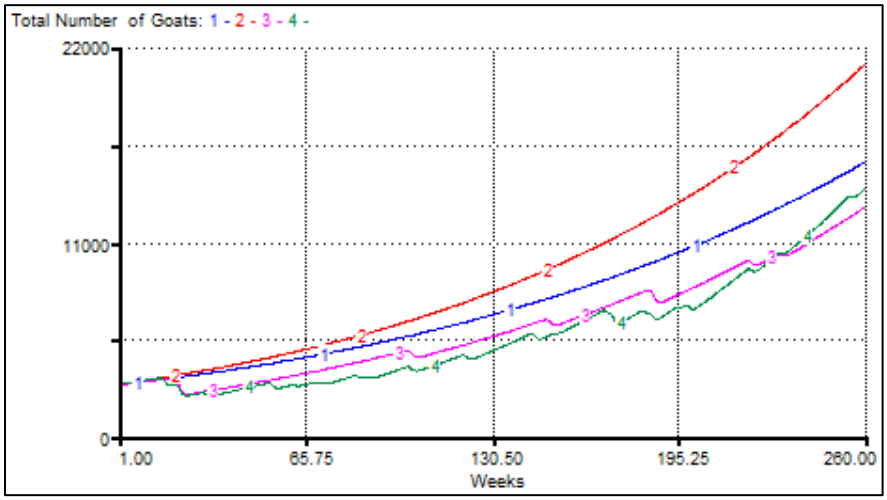


Figure 7. Total number of goats in producers stocks

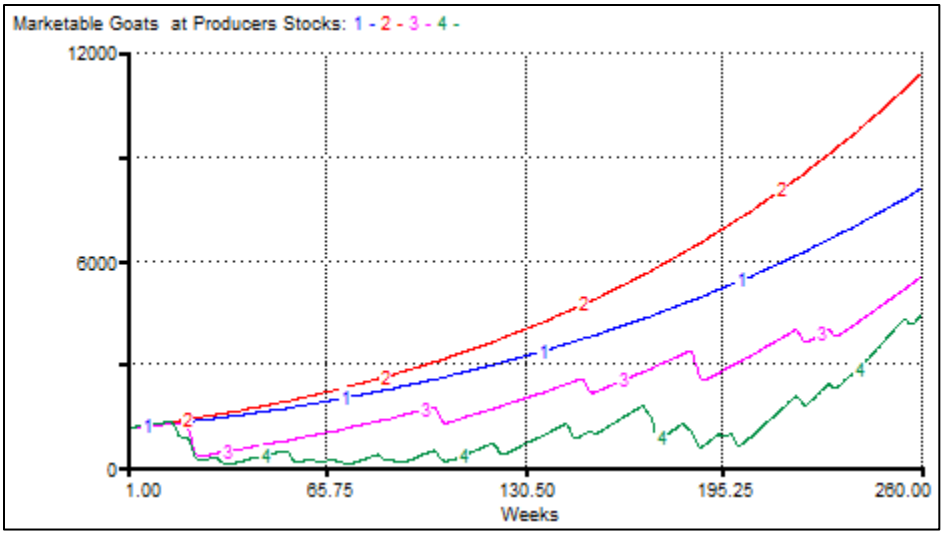


Figure 8. Marketable goats (old males and females, adult males, and young male goats) in producers stocks

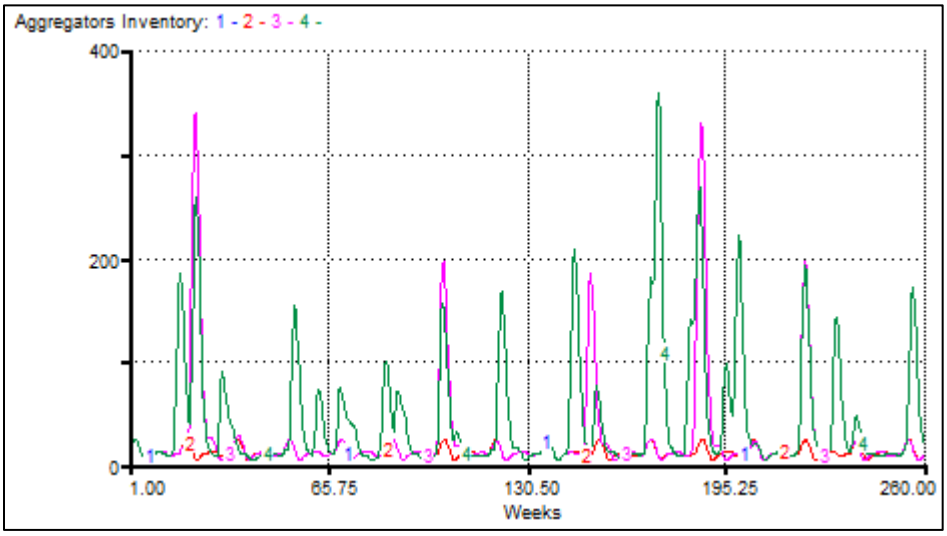


Figure 9. Goats in aggregators inventory

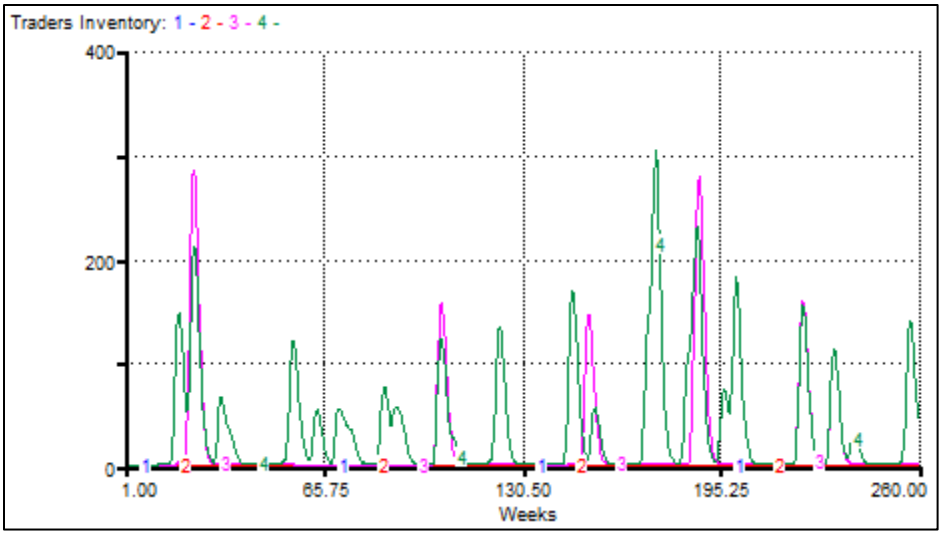


Figure 10. Goats in traders inventory

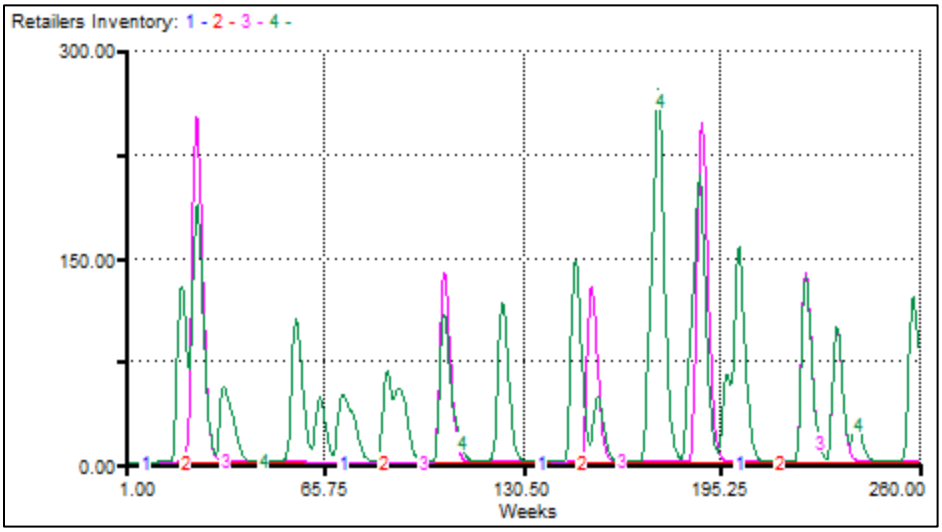


Figure 11. Goats (goat carcass) in retailers inventory

Changes in goat prices, supply and demand, and inventories influence the cumulative profits of different value chain actors. There are different costs involved in producing goats, maintaining inventories, and engaging in other activities such as renting facilities, transportation, labor costs, etc. (table 3) that affect profitability. Figures 12 to 16 show the cumulative profits of producers, aggregators, traders, retailers, and local (Inhassoro) butchers. Profits for producers in the baseline start positive and then decline to become negative after 2.5 years in the simulation period. This is because increasing producer stocks increases operational costs. Under scenario 2, producer profits decline even faster relative to scenario 1 due to even higher operational costs as a result of investments in veterinary services that result in higher volumes of animals without any extended market in which to sell them.

By contrast, under scenarios 3 and 4, the cumulative profits of all value chain actors increases significantly; this result is magnified further in scenario 4. Under scenario 4, both goat productivity and production rise to supply the

market with more goats. Table 4 summarizes the financial performance of the different value chains actors under each scenario relative to the baseline scenario.

Table 4.
Changes in value chain actors financial performance

Scenarios	Producers	Local butcher (Inhassoro)	Aggregators	Traders*	Retailers*
Scenario 2 Vs. 1	-69%	no change	no change	NA	NA
Scenario 3 Vs. 1	110%	-3%	192%	NA	NA
Scenario 4 Vs. 1	186%	3.30%	1056%	NA	NA
Scenario 4 Vs. 3*	NA	NA	NA	141%	145%

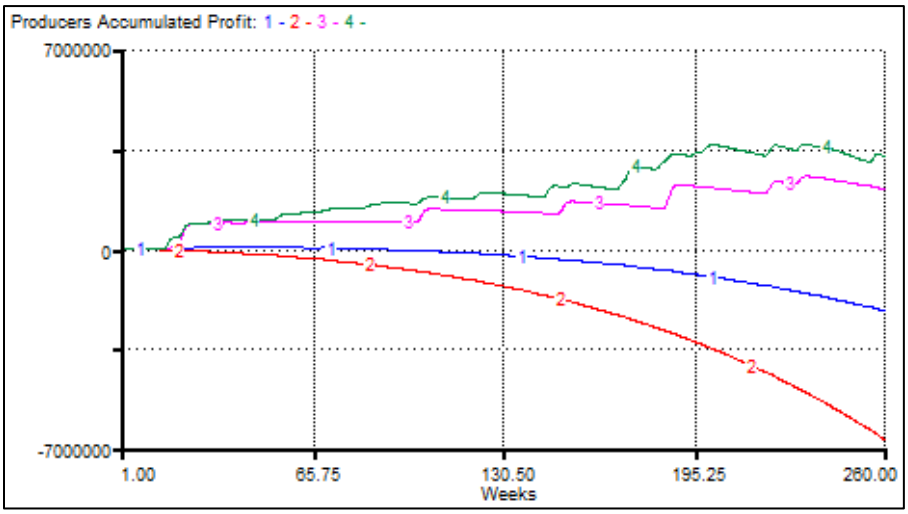


Figure 12. Producers cumulative profit

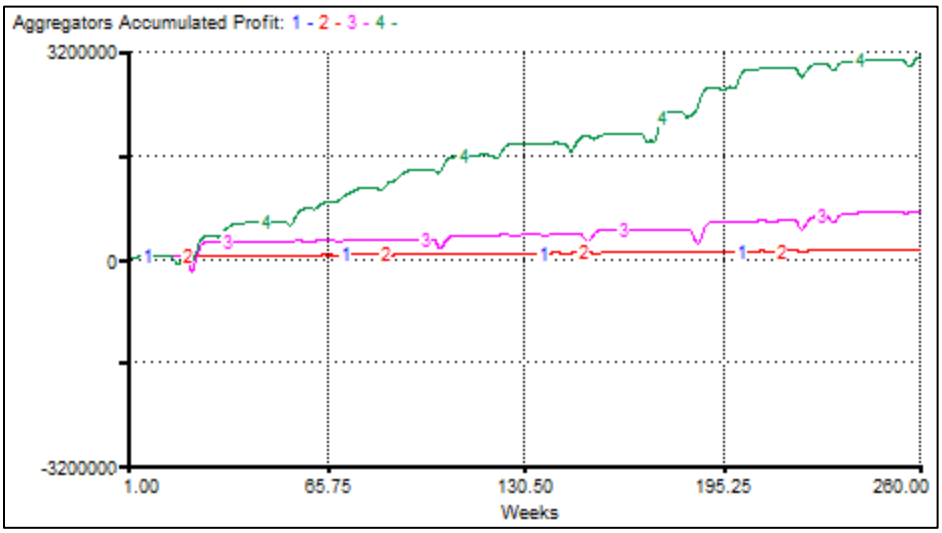


Figure 13. Aggregators cumulative profit

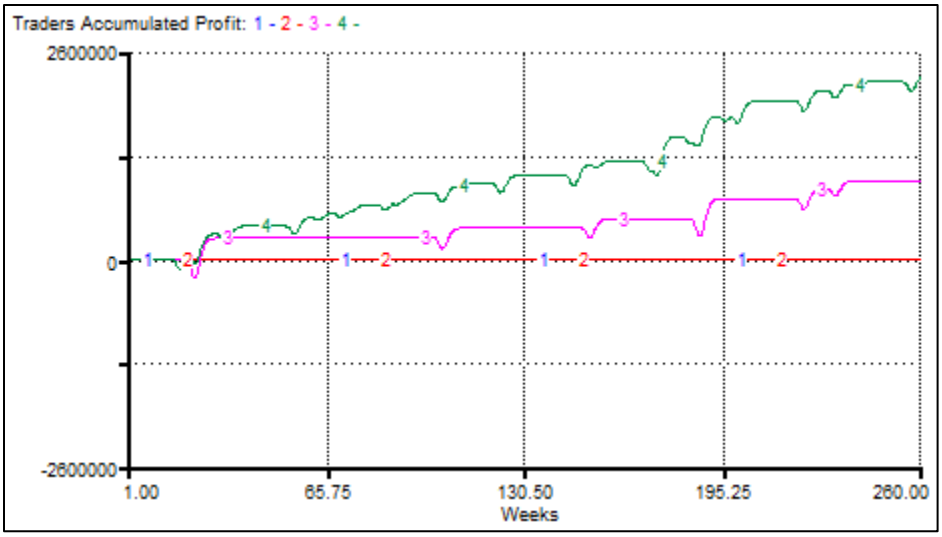


Figure 14. Traders cumulative profit

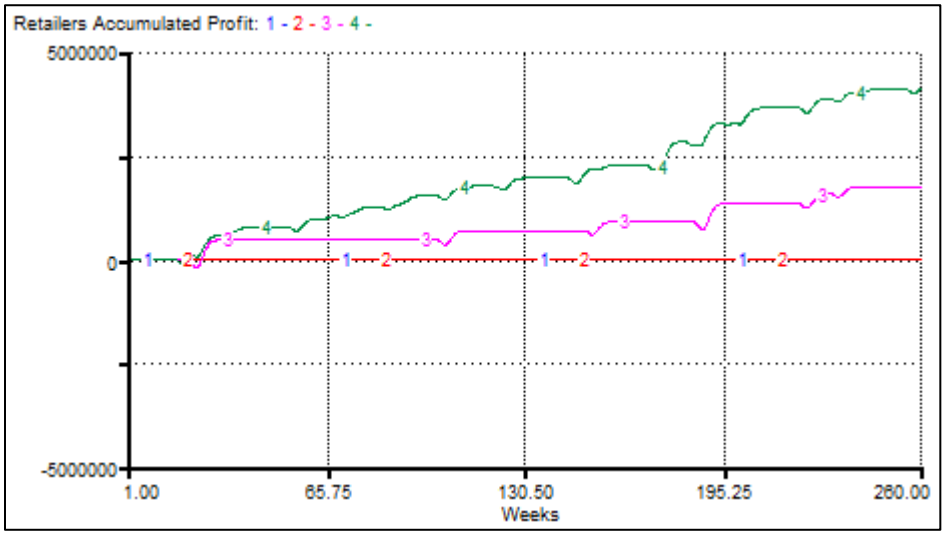


Figure 15. Retailers cumulative profit

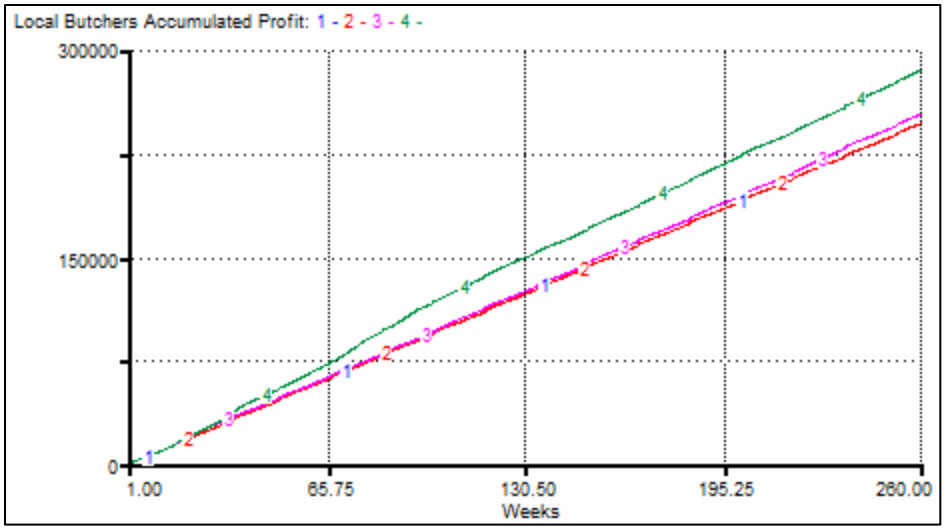


Figure 16. Local butchers cumulative profit

6 Conclusions

To our knowledge, this is the first attempt to model goat markets for isolated communities in Mozambique. The SD approach attempts to incorporate the systems related to goat production and marketing, and significantly, the lags in production and marketing response due to goat herd dynamics. Scenarios investigated center on commercialization, in the sense that connecting producers to an expanded range of marketing options is both an opportunity for improved producer welfare as well as an impetus for investments in such improvements as animal health.

Our results project that in the absence of linking Inhassoro goat producers to larger markets (such as Maputo), improving goat production and animal health practices alone would have negative impacts on the financial performance of producers and no impact on other value chain actors. This is because such a scenario raises the supply of goats without making any changes in market access. However, a more system-oriented strategy that combines improved productivity and links Inhassoro producers to larger goat markets has a significant positive impact on all value chain actors' profits. However, the rewards of such a scenario are largely dissipated among end market actors (aggregators, traders, and retailers), while the financial risks are borne solely by producers.

Our model results highlight the important distributional impacts along the value chain associated with improving veterinary services and market access to larger goat markets in Inhassoro district in Southern Mozambique. The model showed under a business-as-usual scenario (baseline scenario), that goat producers earn small profits in the short term while losing money in the medium and long term. Other value chain actors (aggregators and local butchers) have limited economic returns. Such a business-as-usual scenario is not sustainable in economic terms.

The model showed that not only are supply shortages a problem for further commercialization of the Inhassoro goat value chain, but also that there is a lack of information between producers and larger markets (and vice versa) that precludes a potentially lucrative trade. Facilitating information flows between producers and the larger market could increase producer access to larger markets outside Inhassoro district and hence increase the profitability of goat production activities for producers and other value chain actors. Moreover, it would generate, or magnify, benefits from other interventions, such as the animal health improvements simulated here. Incorporation of this interaction between markets and productivity is a strength of the SD framework used.

Improving risk- and cost-sharing across the chain is an important medium-run effect and an important area for future research and intervention. This paper contributes to the development of pro-poor, smallholder-oriented livestock policy scenarios, providing a platform for engaging government agencies, international organizations, and NGOs to better develop more sustainable livestock value chains.

Extensions to this model which would provide greater insight into approaches to such interventions include the explicit modeling of disease dynamics and an animal growth response to veterinary care. Furthermore, the model could be developed to incorporate alternative modalities for cost sharing and potential service delivery (e.g., public vs. private).

Acknowledgements

We would like to acknowledge the contributions of Dr. Birgit Boogaard from the International Livestock Research Institute for providing us with data and comments about the goat value chain in Inhassoro and arranging fieldwork for the authors. Dr. John McIntire and Dr. Steve Staal from the International Livestock Research Institute also provided valuable feedback. This study was conducted in association with the *Small ruminant value chains as platforms for reducing poverty and increasing food security in dryland areas of India and Mozambique* (imGoats, in short) project, funded by the European Commission/International Fund for Agricultural Development (IFAD) and implemented by the International Livestock Research Institute in partnership with CARE International. Funding for the design and implementation of the study, and preparation for this publication, was provided by the Policy, Institutions and Markets Research Program of the Consultative Group for International Agricultural Research.