Agricultural Systems 156 (2017) 13–24

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

A quantitative value chain analysis of policy options for the beef sector in Botswana

Kanar Dizyee[a,b,*], Derek Baker[a], Karl M. Rich[c]

[a] UNE Business School, University of New England, Armidale, NSW 2351, Australia
[b] CSIRO, Queensland Bioscience Precinct, 306 Carmody Road, St Lucia, QLD 4067, Australia
[c] Department of Agribusiness and Markets, Faculty of Agribusiness and Commerce, Lincoln University, P.O. Box 85084, Lincoln, 7647 Christchurch, New Zealand

ARTICLE INFO

Keywords:
System dynamics
Foot-and-mouth disease
Trade liberalization
Public policy
Simulation

ABSTRACT

The liberalization of beef exports in Botswana is hotly debated among policy makers and relevant value chain actors. While some policy makers argue that such a move might increase prices for producers and make beef unaffordable for consumers, others suggest an open market would reduce the profitability of the beef sector in Botswana. At the same time, these impacts will be mediated by the presence of animal disease and the availability of sufficient feed and water. In this paper, we constructed an integrated system dynamics (SD) model that captures the feedbacks between the biological dynamics of cattle production, the economics of animal and meat marketing and trade, and the impacts that environmental pressures such as rainfall and animal disease have on the system. We used this model to run a series of scenarios associated with market liberalization and animal health shocks to quantify their impacts throughout the value chain, taking into account the feedbacks between biology, markets, and environment on the value chain itself. This approach allows for a holistic evaluation of policy options on different chain actors and whole chain performance, and provides a knowledge base for prioritizing interventions. Model results suggested that although disease control policies benefit all value chain actors, gains from market liberalization come at the expense of substantial losses to Botswana Meat Commission (BMC) and its contracted feedlots. They also suggest that combining market liberalization policy reforms with better animal disease controls greatly improved the financial performance of all value chain actors.

1. Introduction

Livestock, especially cattle, make significant contributions to the livelihoods of farmers in Botswana (BEDIA, 2010). Cattle provide draught power, meat, and milk as well as being a cash-convertible, inflation-resistant asset. About 3% of Botswana's GDP is due to beef exports, with cattle accounting for most of the agricultural share of GDP. Cattle also provide important employment opportunities for rural households in Botswana, especially in communal lands (Mahabile et al., 2005) and represent one of the few enterprises well suited to the arid physical environment.

An important dimension of the cattle sector in Botswana is its significant reliance on export markets: 50% of offtake is destined for export. Over 80% of Botswana's beef exports go to the European Economic Area (EEA) under preferential trade arrangements, and to South Africa (van Engelen et al., 2013). Both markets are served at high cost. For instance, accessing EEA markets requires a cattle traceability system to comply with EU market requirements, while both markets mandate the control of diseases such as Foot and Mouth Disease (FMD) (Scoones and Wolmer, 2008). Exports from Botswana are managed by the Botswana Meat Commission (BMC), a government parastatal enterprise that enjoys a monopsony in the purchase of cattle for export and a monopoly in the sale of exported beef (van Engelen et al., 2013). This allows BMC largely to determine beef prices in the country (BIDPA, 2006). An important implication of this managed trade has been a historical inability to fill preferential EU beef quotas allocated to Botswana, which is compounded by the reliance on an open grazing oxen system which produces an animal of the desired weight at ages more advanced that of the international market standard (Ransom, 2011).

Historically, BMC has maintained its purchase prices below export parity, leading to prices in all market channels that are below those likely to be observed in a freer market (Jefferis, 2007). Divergences from market prices have varied over time: in the 1970s, producers received 70% of the price received by BMC but by 2000, this had declined to 30% (d'Allonnes, 2006). The cause of this decline has not been investigated rigorously, but contributing factors include low prices that lead to low offtake of export quality cattle from producers, which reduces the capacity utilization of BMC and thus reduce its profitability

* Corresponding author at: CSIRO, Queensland Bioscience Precinct, 306 Carmody Road, St Lucia, QLD 4067, Australia
E-mail addresses: Kanar.Dizyee@csiro.au (K. Dizyee), derek.baker@une.edu.au (D. Baker), karl.rich@lincoln.ac.nz (K.M. Rich).

http://dx.doi.org/10.1016/j.agsy.2017.05.007
Received 5 October 2016; Received in revised form 13 February 2017; Accepted 16 May 2017
Available online 01 June 2017

and raise the level of government subsidy (Stevens and Kennan, 2005). According to BIDPA (2006), reforms of the EU's Common Agriculture Policy (CAP) have resulted in beef price declines in the EU since 1999, impacting the profitability of Botswana's beef exports and reducing BMC's capacity to pay high prices. Despite BMC increasing the prices paid to producers from 2005 (d'Allonnes, 2006; Favretto et al., 2014), recent fieldwork by the authors suggests widespread dissatisfaction among producers and continued low levels of offtake for export by BMC.

Reforms of the managed trade system, both in terms of the changed roles for BMC and the diversification of export markets, have seen heated debate among Botswana's policymakers and beef industry stakeholders in recent years. Some policymakers suggest that such changes would increase prices for producers, but make beef unaffordable on domestic markets. Other commentators suggest that an open market and higher prices to producers would reduce the profitability of the beef sector in Botswana (BOPA, 2011, 2013). In particular, market liberalization that allows export of live weaners to South Africa could lead to the reduced supply of weaners and young cattle to BMC's commissioned feedlots, leading to a further reduction in Botswana's exports to the high value European market.

Since 2014, preferential quotas have been replaced by Economic Partnership Agreements (EPAs) that allow the duty-free, quota-free export of beef from Botswana to the EU. However, a number of factors conspire against the beneficial use of these market access developments. First, Botswana experienced outbreaks of FMD in 2011–2012 that restricted exports and caused industry disruption. Second, recent ratification of free-trade agreements between the EU and the Central American countries and Colombia, which have significantly lower production costs than does Botswana, is potentially problematic for Botswana once these new competitors complete implementation of the EU risk assessment protocols within the next 2–3 years. Export markets aside from the European ones are therefore of significant strategic importance for the long-term sustainability of the Botswana beef sector. Some studies suggest, however, that market diversification would not allay concerns related to the profitability of beef production and trading (Stevens and Kennan, 2005), while the high-cost model operated in Botswana might reduce the competitiveness of Botswana's beef in other export markets.

In this paper, we examine policy options for market reforms and government investments in the beef sector in Botswana. Our approach couches these impacts within their feedbacks associated with presence of animal disease and the availability of sufficient feed and water. First, we assess the impact of partial market liberalization through the removal of BMC purchasing control so as to enable the export of live weaner cattle. Second, we examine the effects of investments in disease control (specifically FMD) as a means of enabling access to high-value markets. Of particular interest in our analyses are the within-chain distributional effects throughout the value chain from different policy changes and their feedbacks with the natural environment, including the effects on profitability and decision-making for producers, intermediaries, retailers and domestic market actors, and BMC itself. The surplus generated by BMC is an important variable in our analysis because its surplus must be statutorily transferred to producers in the form of higher purchase prices for cattle. This supports the principle that increased producer profits are a policy objective for Botswana, and so forms a key measure of policy impact. Our analysis captures both the magnitude of these variables associated with policy scenarios, and the flows which transfer them between market actors.

The complex array of market and policy features of Botswana's beef industry, and the underlying cycles of livestock production suggest against a static treatment of liberalization (e.g., Cooksey, 2011). A methodological advance is offered by the use of system dynamics (SD) tools to analyze the entire value chain quantitatively, simulate the dynamic impact of various policy options, and account for underlying cycles and feedbacks in production and marketing systems (Rich et al., 2011). Our model captures the feedbacks between the biological dynamics of cattle production, the economics of animal and meat marketing and trade, and the impacts of environmental pressures such as rainfall and animal disease have on the system. SD tools are particularly relevant in this context given the lags inherent in livestock production, and thus in measurable production responses to incentives, including those associated with policy reforms. Such lags, and the large number of interactions among the variables in question, can increase uncertainty and volatility and this is less able to be captured by other modeling methods. In a developing country setting such as Botswana, understanding such impacts, particularly among smallholder producers, can improve the design of successful policies both for adding value to livestock production and for economic growth and development more generally.

2. An overview of Botswana's cattle production, market structures, and marketing channels

Botswana is home to about 77,000 cattle producers who collectively own about 2.64 million head of cattle. A large proportion of producers are smallholders: 50% of producers maintain herd sizes of less than 20 head, 75% less than 40 head, and 96% of herds have less than 150 head (van Engelen et al., 2013; CSO, 2010; World Bank, 2006). Some 85% to 90% of cattle in Botswana are raised on communal lands, with the remaining 10% to 15% held in cattle holding enterprises that are considered commercial. The differences between the commercial and traditional sectors are mainly based on land tenure, and not on herd size or any other criteria such as management procedures. Traditional cattle systems graze on open (unfenced) pasture range lands which are customarily shared, while the commercial sector's cattle graze on fenced pasture range lands where owners have exclusive grazing rights (Bahta and Malope, 2014).

Botswana is one of the few African countries to export beef to high-value international markets. According to the UNCOMTRADE database, the export value of Botswana's beef in 2014 was approximately $115 million, making it Africa's largest beef exporter: Namibia's beef export value was about $70 million in the same year. In total, from 2010 to 2014, although the export value of beef from Botswana was lower than Namibia from 2011 to 2012, Botswana's cumulative export value was USD 35.5 million more than Namibia. However, Botswana's share of global beef exports is relatively small compared to beef producers like Argentina, Paraguay, and Uruguay, and major players like Brazil and Australia, and its exports are not growing. According to the UNCOMTRADE database, the total cumulative export value of beef from Botswana from 2010 to 2014 was about 10%, 11%, 8%, 2%, and 2.2% of that of Argentina, Paraguay, Uruguay, Australia, and Brazil, respectively, for the same period. Even if Botswana were to double or triple its beef production, it would remain a small player. The barriers to expansion include institutional aspects such as disease management and BMC market power, and the inherent physical, institutional and social nature of grazing systems. The dynamic nature of the effects of these institutional constraints of grazing systems on value chain actors is widely recognized, in terms of the incentives for sustainable management of communal grazing lands. They lead to unhealthy herds, poor quality of animals and meat, depressed calving rates, and elevated mortality in those communal grazing areas. Privately-owned grazing lands do not face these problems because the benefit of any investment is internalized, essentially by fencing (Mahabile et al., 2005).

A variety of cattle trading channels, both domestic and export, are present in Botswana (Bahta, 2013). Van Engelen et al. (2013) shows that BMC's purchases represent around 57% of offtake, at 180,000 head (equivalent to 28,000 metric tons of boneless beef). These cattle were purchased from large ranches, feedlots, BMC agents, and smallholder producers. Of this number, about 90% were exported (mostly to the EU and South African markets), with the remaining 10% sold to “modern domestic” (a quality-driven channel that consists of feedlot operations,

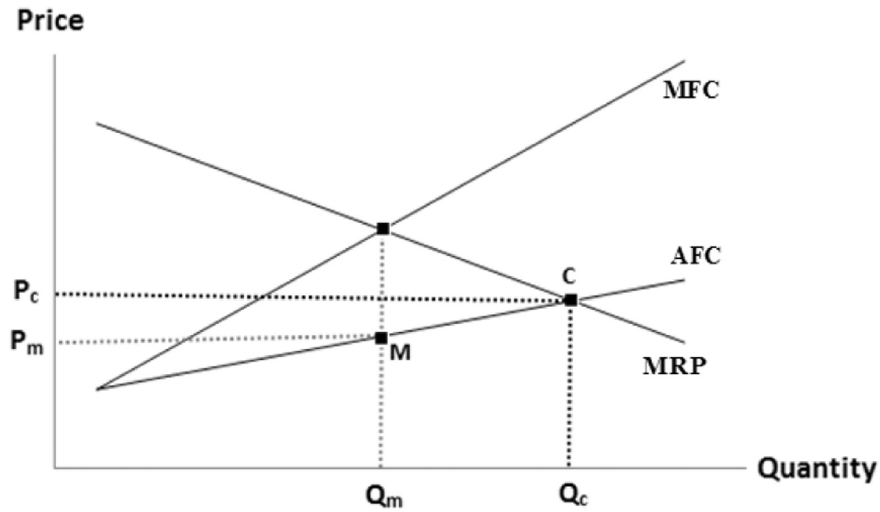

Fig. 1. Graphical representation of BMC monopsony power and its implication on price and supply.

modern processing facilities and modern retail formats) markets (van Engelen et al., 2013, and see also ICRISAT and ILRI (2005) on similar historical estimates).

Van Engelen et al. (2013) estimated that 9% of beef offtake (27,750 head) went to the modern domestic channel, which is the fastest growing in Botswana. The same study suggests that a further 26% of offtake (83,250 head) went to the traditional domestic butchery channel, which primarily uses informal and/or small scale actors at slaughter, and traditional retail arrangements. Farmers also sell cattle to individuals, government programs that distribute livestock (for example, a rural youth empowerment program), butcheries, and feedlots. Some 8% (25,000 head) of offtake was consumed by producers themselves. Cattle sales may be mediated by BMC purchasing agents or other intermediaries, particularly facilitating weaner and other cattle's entry to feedlots. A further administrative aspect of Botswana's cattle trading environment is that animals are not traded between zones of the country with different FMD status, and in particular BMC does not source cattle from Botswana's FMD vaccination zones (where the disease is endemic), but only from FMD-free zones. More details about allocation of product throughout the various channels are available in Support document 1.

3. Materials and methods

3.1. Modeling approach

Analyses of market liberalization in an agricultural setting typically employ partial or general equilibrium modeling approaches. From a partial equilibrium standpoint, we can theoretically illustrate the impacts of BMC's monopsony control over the purchase of live weaner cattle as shown in Fig. 1. In this figure, BMC as a monopsony[1] faces an upward sloping supply curve that represents the average factor cost of cattle purchases. The maximization of BMC's profit occurs at a price and output determined by equating marginal revenue product (MRP, or the demand curve) and the marginal factor cost (MFC), shown as the point where MFC intersects MRP. At the associated quantity (Q_m), the monopsony price, P_m, is thus determined by BMC at point M, being lower than the price determined under competitive markets, P_c, at point C. BMC's monopsony also restricts the quantity supplied by producers, which has further negative consequences for producer profitability.

[1] A corresponding analysis could be made of the monopoly BMC maintains in the export of beef from Botswana.

In a value chain setting, the welfare impacts associated with market liberalization become somewhat more complex, as multiple horizontal and vertical linkages are implicated. Prima facie, multi-market (Minot and Goletti, 1998; Rich and Winter-Nelson, 2007) and equilibrium displacement models (Kaitibie et al., 2010) provide potential frameworks for the analysis of policy changes in value chains within a partial equilibrium setting. Indeed, Gardner (1975) illustrated algebraically the comparative statics associated with changes in policy in a system comprised of retail food, farm output, and marketing services. Similarly, Bhattacharya et al. (2009) used an equilibrium displacement model to analyze the horizontal and vertical relationships within the U.S. ethanol sector.

As noted by Rich et al. (2011), purely partial equilibrium approaches may miss important dynamic structural, technical, and institutional responses that policy changes might engender. These are especially important in livestock markets, where biological delays and features of the production and marketing decision mechanisms could influence how the system evolves over time. From an analytic standpoint, it is difficult or impossible to parameterize neatly the relationships among intermediaries within the value chain in a partial equilibrium framework. These difficulties are compounded in data-scarce developing country contexts where most of the data on agricultural value chains generally come from qualitative, descriptive mapping exercises of the value chain.

In this paper, we developed a framework that examines elements of the value chain as they actually structured and composed the whole chain, and allows for the modeling of intervention options. In particular, we constructed a quantitative model of the livestock value chain in Botswana using system dynamics (SD). SD is a methodology that examines the dynamic interactions and feedback effects among different components (and sub-components) of a system (Sterman, 2000). It has been applied extensively in modeling inter alia businesses, environmental phenomenon, public policy, fisheries, and agribusiness (see e.g. Sterman, 2000, Mowat et al., 1997; Cloutier and Sonka, 1999; Fisher et al., 2000; Ford, 2010; Moxnes, 2000, 2004; Jones et al., 2002; Saysel et al., 2002; Arquitt et al., 2005; Hamza et al., 2014a, 2014b). More recently, SD has been applied in a number of livestock value chain studies, including Rich et al. (2009), McRoberts et al. (2013), Hamza et al. (2014a) and Naziri et al. (2015). This method allows us to incorporate the sensitivity of the system to dynamic and evolutionary feedback effects, and leverages and complements existing data resources.

The central concepts of SD are stocks, flows, and feedback loops. Stocks reflect the state of the system at a given point in time, and

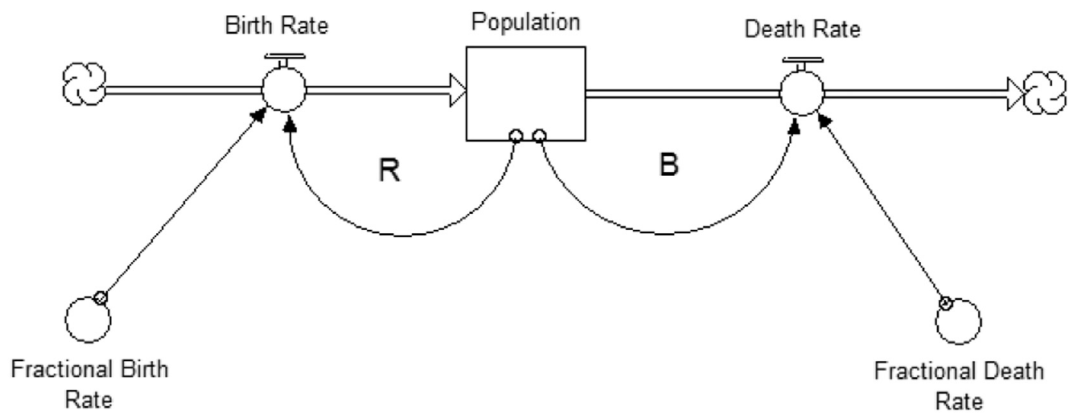

Fig. 2. Stock and flow diagram.
Source: Hamza et al. (2014a, 2014b)

represent an accumulation of services, goods, funds, or knowledge. Flows denote changes over time and regulate the inflow and output of goods or services from a stock. An example of a stock is the number of animals on a farm on a given day, while flows would include births or purchases (inflows), or deaths or sales (outflows). Feedback loops are circular causalities that regulate flows through delayed circular causal (and often nonlinear) relationships among model components (Hamza et al., 2014a, 2014b). Fig. 2 provides a representation of a stock-and-flow diagram.

Extending our earlier example into Fig. 2, the box named *population* represents the stock of *population*, e.g. cattle population. The stock of *population* changes through the entry of new cattle, through the inflow *birth rate*, and the exit of cattle, through the outflow *death rate*. A reinforcing feedback loop (R) governs the behavior of the inflow *birth rate*. In a reinforcing feedback loop, we observe either exponential growth or decay. In our example, as the number of animals in the stock of *population* increases, this leads to a larger number of births, which in turn leads, via the inflow *birth rate*, to a larger cattle *population* in subsequent time periods. In contrast, a balancing feedback loop is a self-adjusting loop that seeks to balance the system to some level of stasis. In our example, as the number of animals in the stock of *population* rises, this leads to higher deaths, which in turn through the outflow *death rate* balances the stock of *population* over time (Hamza et al., 2014a, 2014b).

3.2. Model structure and data

In Fig. 3, we provide a conceptual illustration of the model. The model is composed of a number of inter-related modules including production, the domestic and export markets, policy, and institutions and environment. A performance module generates profit for the main value chain actors by deducting costs from revenues and distributing the differences among value chain actors according to parameters derived from the available data. Fig. 3 presents these main components as well as the feedback interactions among the model components that are employed by the SD formulation.

Fig. 3's *production module* includes the cattle production and aging model (for commercial and traditional –FMD and non-FMD zones –producers). Arrows linking one module to another represent the flows of material and information: cattle flow from the *production module* to the *market module* via various value chain actors – feedlots, BMC, traditional butchers, and modern butchers and retailers. The model transforms live cattle to carcasses, and then to meat as it passes downstream through the chain. The symbol "//" denotes delays in the system, such as the biological cycles of cattle, and trading delays in the passage of products between chain actors. Information flows (e.g. changes in market conditions or in price) are also modeled so that market actor decisions occur after a time lag: from the *market module* via chain actors to the *production module*.

Changes in both the *market module* and *production module* transmit information (e.g. on cash flow and on cattle inventory) to the *performance module* to measure the profit performance (profit over time and cumulative profit) for chain actors and (by aggregation) the whole chain. The *performance module* provides an information feedback to the *policy module* that presents an assessment of the effectiveness of alternative policy options. Given feedback effects between these modules, the latter then affects both *production* and *market modules*. Similarly, changes in production affect performance (e.g. changes in cattle inventory) which in turn affects the *environmental module*, as the larger quantity of cattle reduces feed availability in pasture range lands, which in turn reduces cattle productivity (e.g. fertility, mortality and weight).

Both the *performance module* and the *environment module* feed information to *institution module.* This in turn affects the effectiveness of the chain governance structure (e.g. market power). Risk factors, such as climate variability and disease outbreaks, affect the *environmental module*, *market module* (price volatility, and trade bans due to transboundary diseases), and *policy module*. More details of each *module* of Fig. 3, and key feedback loops in the model are available in Support document 1. Further details of model equations and codes are available from the author.

The model endogenizes price, based on the applied supply and demand parameters from BMC's monopsony behavior as discussed above. Price is also affected by cattle weight, changes in the exchange rate,[2] and BMC's surplus that is statutorily transferred to producers in the form of a higher cattle purchase price. Prices motivate both production and consumption (throughout the value chain, this includes purchase) in a dynamic manner: as price rises due to supply and/or demand shifts, producer willingness to sell increases, which affects animal numbers held and in turn, numbers produced and sold. In contrast, price reductions due to demand and/or supply shift affect market incentives so as to put long term downward pressure on future prices.

Our model covers a significant part of Botswana's beef value chain from producers to end markets in Botswana, and to processed products ready for export. To our knowledge this is the first such model with such an exhaustive and disaggregated coverage, and its SD formulation and reference to monopsony market structures offer further novelty. Limitations to be addressed in future extensions are that: (1) input suppliers and credit providers are not included in the model; (2) disease outbreaks (limited to FMD) are introduced using a random function by way of Monte Carlo simulation rather than using an epidemiological model of FMD outbreaks at local and national levels (see Rich, 2008); and (3) broader policy liberalization issues are not addressed (such as competition on EU markets with exports from Brazil and Australia).

[2] Especially exchange rate of Botswana pula (BWP) to South African rand (ZAR), BMC sets cattle price based on prices in South Africa. Exchange rate is introduced as an exogenous parameter to our model.

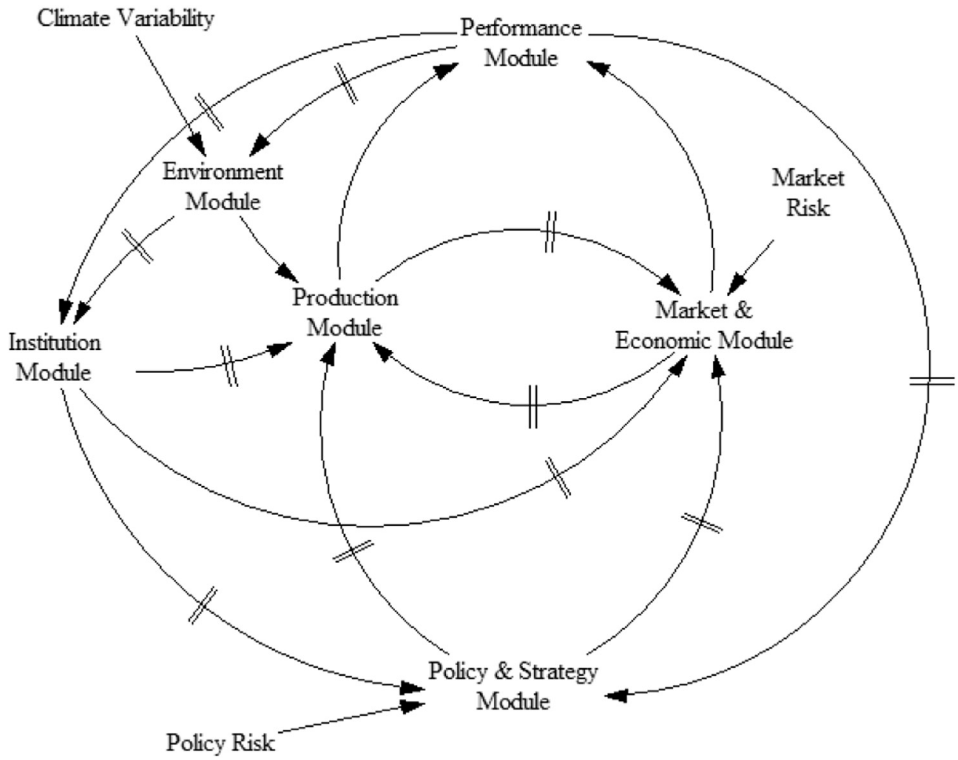

Fig. 3. Conceptual illustration of the model structure.

Data and specific characteristics of the Botswana beef value chain (as model parameters) are presented in Appendix 1 and were drawn from a snapshot survey and focus group discussions conducted in three regions (Taupye, Thabala, and Serowe) in Botswana's Central District during December 2012 (Bahta, 2013). In each of these regions, a group of 15 to 25 farmers (as well as other stakeholders) participated in focus group discussions and individual interviews. The snapshot survey covered about 60 cattle producers in two villages and one suburb in the survey area. The survey data were supplemented by national level data (BIDPA, 2006; van Engelen et al., 2013; Mahabile et al., 2005; Stevens and Kennan, 2005; World Bank, 2006; Statistics Botswana, 2011, 2013, 2014)) and information provided by the Smallholder Livestock Competitiveness Project (Bahta, 2013).[3]

3.3. Model validation

Following Forrester and Senge (1980) and Sterman (2000), we conducted several validation tests, which were duly passed (for further details see Appendix 2). An important parameter in our model is the incidence of FMD outbreaks. We include the occurrence of FMD outbreaks on cattle production and marketing because they arise frequently in parts of Botswana, with significant effects on trade and market access that resonate between seasons in a manner captured well by an SD model. Our scenario includes the actual FMD outbreak in early 2011: the resulting trade suspension lasted for 18 months (The Technical Centre for Agricultural and Rural Cooperation, 2012; Boy, 2013). We randomly introduce an FMD outbreak to the model based on the frequency of past FMD outbreaks (see Rich et al. (2009) for a similar approach) for the remainder of the simulation period (2016 and onwards). FMD outbreaks were assumed to interrupt cattle production (by way of morbidity and mortality, as well as movement controls) and reduce demand (by way of trade suspension) in the export market channel. Table 1 provides description of baseline run and policy interventions.

4. Results and discussion

4.1. Summary of results

We ran the model over a 15-year time period from 2010 to 2025 (780 weeks). The initial years from the 2010 simulation results were used to replicate historic data (see Table A.2. in Appendix 2), with policy intervention scenarios beginning from the year 2017. We report model results to compare the impacts of each of four runs (see Table 1) representing policy scenarios. We report the results of total cattle population, cattle price (BMC price), weaner prices, profits over time, cumulative profit, and percentage changes in cumulative profit for each chain actor – producers, feedlots, BMC, modern butchers and retails, and traditional urban and rural butchers. The four runs, as summarized in Table 1, are the following:

(1) business as usual
(2) removal of BMC's monopsony (particularly, allowing the sale of live weaners to South Africa by producers)
(3) control of an FMD outbreak maintaining prevailing BMC policy; and
(4) combined market liberalization (run 2) with control of FMD outbreaks (run 3).

Tables 2 and 3 summarize results for accumulated profits by each value chain actor over the 15-year period discounted by 5.6% which is the average annual inflation over recent years. Table 2 presents values of cumulative profits and Table 3 expresses these as percentage departures from the baseline (run 1-business as usual), as well as presenting a comparison of runs 3 (business as usual and FMD control) and 4 (market liberalization and FMD control).

In general, cumulative profits are raised (producers: + 26%; BMC: + 101%; feedlots: + 9%; traditional butchers: + 0.5%; modern retailers: + 4%, see Table 3) in scenarios with reduced FMD: run 3 (business as usual and FMD control) vs. run 1 (business as usual). Although all chain actor cumulative profits decline during an FMD

Table 1
Description of model runs.

Run	Key assumptions
Run 1: business as usual	A representation of normal market and production conditions and unchanged policy. FMD outbreaks (large enough in scale to interrupt export marketing) were projected to occur randomly once each 7 years (based on historical data) (BIDPA, 2006; Mapitse, 2008). The reported simulation introduced an FMD outbreak in late 2016 (week 350). The actual 2011 (week 60) FMD outbreak was included to ensure replication of past events.
Run 2: market liberalization.	During FMD outbreaks, exports to the EEA (over 50% of export market share) are blocked for two years (OIE: Terrestrial Animal Health Code – Article 8.8.3). Thus, we assume that demand from the export market declines by over 50% for two years based on lost access to the EEA markets, and then returns to normal. A partial market liberalization, allowing export of weaners to South Africa.
Run 3: business as usual + FMD freedom.	We evaluate the effect of exporting about 2000 weaners per week starting from 2017 (week 364) (2000 is a random initial value; the model endogenously develops weaner prices and demand – on average, only 55% of 2000 weaners per week are exported due to limited supply). This scenario is motivated by the policy debate in Botswana on the positive and negative effects of reducing or removing BMC's market power in the beef industry (BOPA, 2011, 2013). An FMD-free scenario for cattle production and marketing, which features an uninterrupted flow of cattle to the export market.
Run 4: market liberalization + FMD freedom.	This scenario is motivated by the fact that large scale FMD outbreaks, and outbreaks in the EU export zones in Botswana - unlike small regional outbreaks - do not occur as frequently as outbreaks in FMD-endemic and FMD-vaccinated zones (Mapitse, 2008; BIDPA, 2006). We assume a two-round FMD vaccination each year for all cattle located in FMD ones in Northern Botswana. Vaccination (funded by the Government of Botswana) is assumed to generate the FMD-free scenario. In this scenario, we assess how FMD freedom combined with market liberalization will influence market dynamics within the beef value chain.

Table 2
Value chain actors' cumulative profit (in 1,000,000 BWP).
(Source: simulation results)

Runs	Producers	BMC	Feedlots	Traditional butchers	Modern butchers and retailers	Whole chain
Run 1	1557	− 179	173	1295	520	3366
Run 2	2870	− 857	124	1305	495	3937
Run 3	1966	0.96	188	1301	540	3996
Run 4	3748	− 895	127	1312	506	4800

outbreak (see Figs. 7–11), the losses of BMC and producers are pronounced due to the accompanying reductions in farm offtake rates. The extent of the improvement brought about by reduced FMD is due to a smoother production and marketing flow of cattle, and uninterrupted trading activities in both domestic and export markets.

The market liberalization scenarios (runs 2 – market liberalization – and 4 – market liberalization and FMD control), however, have differential effects on the cumulative profits of chain actors. This is positive for producers and traditional butchers, but negative for modern butchers and retailers, feedlots, and BMC. Under run 2 (market liberalization), the cumulative profits of producers increased (+ 84%) relative to run 1 (business as usual). Further downstream, BMC experienced substantial reductions, relative to run 1, (− 379%) in its cumulative profit. This contrast occurs because exporting weaners to South Africa leads to reductions in BMC's market share and as well as having to pay higher weaner prices (see Fig. 6). The cumulative profit of traditional butchers increased slightly (+ 1%), while that of modern retailers and butchers declined (− 5%), relative to run 1. As noted above, this indicates that there is unutilized capacity in traditional domestic market channels, because producers evidently can meet extra demand in the South African market channel without needing to reduce supply to traditional butchers and, to a lesser extent, modern butchers and retailers. As observed for BMC, the cumulative profit for feedlots declines (− 28%) under run 2 relative to run 1 due to reduced animal numbers in this channel.

Under run 4 (market liberalization and FMD control), where markets are liberalized and FMD is controlled, the performance of producers increased significantly (+ 141%). However, the cumulative profits to BMC decline (− 399%), as BMC loses market share and has to pay a higher price for weaners to compete with the export market to South Africa. Similarly, the cumulative profits of feedlots decline (− 26%) due to reduced market share. The performance of modern and traditional butchers and retailers decreased (− 3%) and increased (+ 1%), respectively. In general, whole chain performance (sum of cumulative profit of all chain actors), increased in runs 2, 3, and 4 relative to baseline (run 1) (+ 17%), (+ 19%), and (+ 43%), respectively. This result is due increased cattle prices in all policy runs. For BMC, run 4 (market liberalization and FMD control) is more damaging than is run 2 (market liberalization alone), but the converse is true for feedlots. This is because maintained cattle numbers due to FMD control (see Fig. 4) mean that a more continuous flow to feedlots can be achieved as they serve modern processors and retailers, while BMC is displaced from export markets as weaners flow to South Africa.

The partial removal of the BMC monopsony by allowing live weaner exports to South Africa has been shown to be beneficial to producers and to traditional domestic market actors. However, such gains to producers come at the expense of other actors: losses to BMC and feedlots exceed producer gains. Such trade-offs provoke consideration of

Table 3
Value chain actor financial performance relative to baseline scenario.
(Source: simulation results)

Runs	Producers	BMC	Feedlots	Traditional butchers	Modern butchers and retailers	Whole chain performance[a]
Run 2 vs. 1	84%	− 379%	− 28%	1%	− 5%	17%
Run 3 vs. 1	26%	101%	9%	0.5%	4%	19%
Run 4 vs. 1	141%	− 399%	− 26%	1%	− 3%	43%
Run 4 vs.3	NA	NA	NA	NA	NA	20%

[a] % sign means per cent change relative to baseline (e.g., 17% in the first row means Run 2 is 17% more profitable than run 1.

whole chain performance (see Table 3), measured by comparing the sum of all value chain actors' cumulative profit under each scenario. The percentage cumulative losses/gains presented in Table 3 are for the entire 15-year duration of the simulation.

Freedom from FMD outbreaks is shown to improve significantly the performance of chain actors and the whole chain (by 19%). However, in the case of partial market liberalization, producer gains are partially offset by losses by feedlots and BMC to deliver a whole chain gain of 17% (see Table 3). The nature of these trade-offs and reinforcements of gains and losses among value chain actors reflects the monopsony structure of cattle purchases in Botswana, as well as the dynamics of cattle production. Under a perfectly competitive market structure, costs and benefits of shocks are shared between market actors according to elasticity conditions in supply and demand. However, the consequence of BMC's monopsony is that the transmission of shocks to price and supply changes, and the allocation of their costs and benefits, relies on price-making behavior (see Fig. 1) that dictates that supply and demand shocks are passed imperfectly and partially between actors. Including the dynamics of cattle production allows the long term consequences of sales of young stock on the feedlot and processing industry to be represented in a more sophisticated manner than that employing static supply and demand.

4.2. Dynamic results

Fig. 4 reports producer cattle numbers during the model simulation period. These interact not only with the market, but also with the physical environment as a determinant of livestock carrying capacity based on rainfall (adapting the modeling concept used in Helldén (2008)). The interaction between total cattle population and carrying capacity introduces dynamic changes to cattle mortality and fertility which then underlies cyclical long term patterns in cattle stocks. It should be noted that the cattle population is generally higher for runs 3 (business as usual and FMD control) and 4 (market liberalization and FMD control) than for runs 1 (business as usual) and 2 (market liberalization) from mid-2018 onwards because there are fewer market interruptions in runs 3 and 4. This in turn increases producer profitability and thus the motivation to increase cattle numbers. Runs 1 and 2 exhibit high cattle numbers in late 2016 due to reduced offtake during an FMD outbreak. Following this initial period, producer stocks decline due to responses to reduced profits, and because high stock levels are associated with lower productivity.

Figs. 5 and 6 highlight the price movements in the adult cattle price paid by BMC, and in the weaner price, respectively, for the various runs. The policy change allowing export of weaners (runs 2 and 4) introduces competition between domestic value chain actors (i.e. BMC and traditional and modern domestic butchery and retail) and actors exporting to South Africa. Exporting weaners to South Africa leads to an

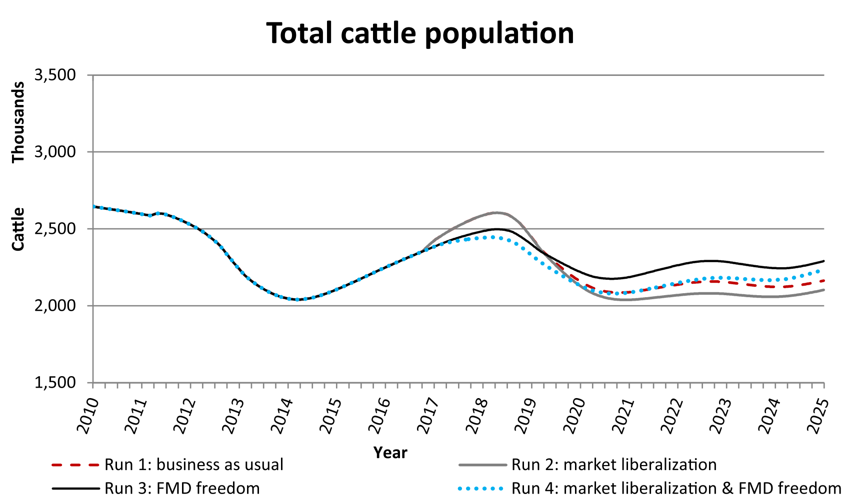

Fig. 4. Total cattle population in Botswana (simulation results).

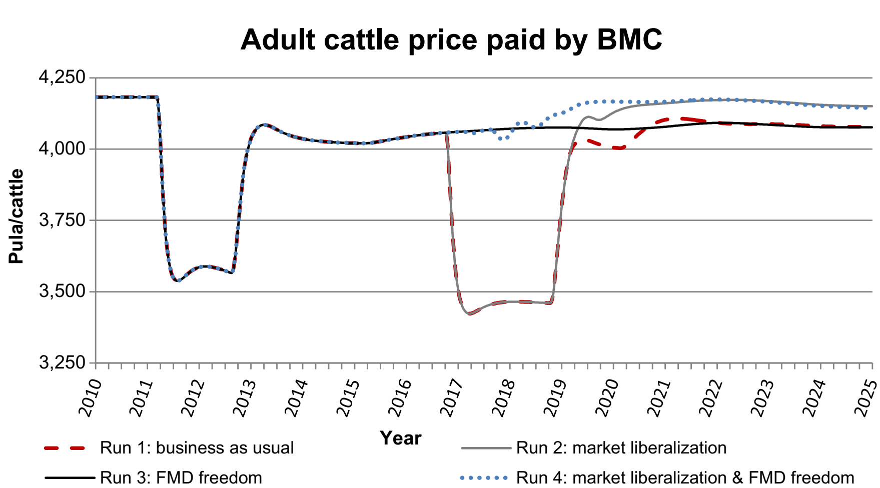

Fig. 5. Adult cattle price (BMC price) (simulation results).

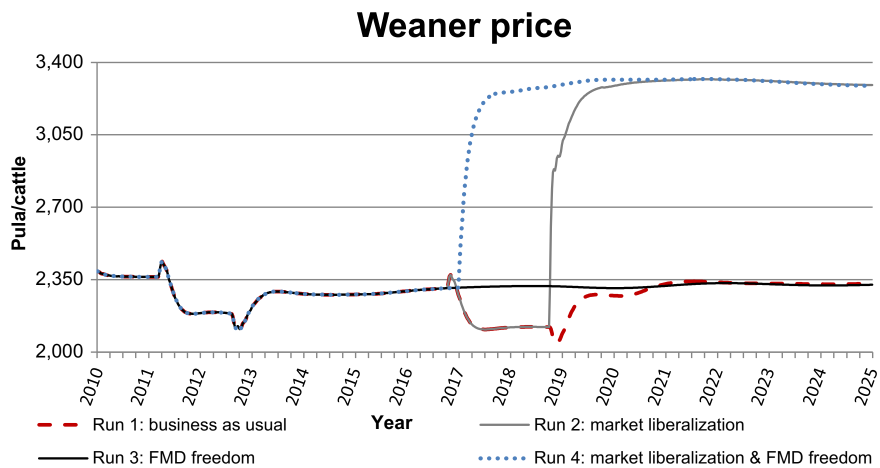

Fig. 6. weaner price (simulation results).

increase in the live weaner prices, which reduces BMC's market share. This forces BMC to pay higher prices to ensure a stable supply of weaners to BMC feedlots to serve export markets for finished cattle.

As noted above, all runs feature an FMD outbreak in early 2011, reflecting the actual event. In runs 1(business as usual) and 2 (market liberalization) the model is randomly shocked by an FMD outbreak in week 351 (early 2017). Note that in run 2, weaner exports to South Africa commence in week 364 (also early 2017). The FMD outbreak results in a reduction in total demand for animals due trade cessation, and this includes a ban on weaner exports. This can be interpreted (from Fig. 1) as a leftward shift in the demand curve for weaners. The dynamics of this adjustment include under- and overshooting due to the accumulation and depletion of inventory (animal numbers) as prices endogenously adjust.

Lost access to EEA markets leads to increased volume in the domestic market, which has the effect of lowering domestic prices. On the one hand, reduced prices lower the incentives for farmers to sell cattle, causing supplies of animals to fall; on the other, they stimulate domestic demand. There are time lags for this information to flow to producers and other value chain actors, and delays in the flows of cattle to the market as sales, production and breeding decisions are made and implemented. In runs 1 and 2, price reacts vigorously to disease-related shocks, with sharp declines arising in the short term that gradually dissipate over time. When the trade interruption due to an FMD outbreak ends (after two years), total demand heads back to the levels prevailing before the FMD outbreak. However, the demand curve overshoots the equilibrium in the short term as chain actors build their inventory, and then gradually moves back towards the demand curve shown in Fig. 1.

In run 3 (business as usual and FMD control), unlike in runs 1 (business as usual), 2 (market liberalization) and 4 (market liberalization and FMD control), price changes are minor as we impose no shocks to the supply or demand sides of the model at each point in the value chain. Prices of adult cattle paid to producers in run 4 change shortly after the ban on export of live weaners to South Africa is removed. This is because allowing live weaner exports affects the supply of adult cattle to BMC and other domestic market channels in the future. Nevertheless, the price of weaners (Fig. 6) in run 4 increases over time (from beginning of 2017) due to a rightward shift in the demand curve for weaners. Hence more weaners are traded under this scenario than the others. Rising weaner prices lead to a reduction in trading activities between producers and feedlots (the current main weaner purchaser in the domestic market), which lowers BMC's market share of the weaners sold, after a short time lag corresponding to information flows and decision making.

Similarly, the market shares of modern domestic chain actors (modern butchers and retailers), are reduced, albeit proportionately less than is the case for BMC and feedlots (see Tables 2 and 3 on relative changes to profitability). This is because the modern domestic market competes with export value chain actors for quality cattle. Traditional butchers and retailers generally purchase older cattle not desired for export, and producers can still supply these cattle to the domestic market without interruption from weaner exports to South Africa in the short term. However, in the long term, the supply of adult export quality cattle to BMC is restricted as a dynamic effect of weaners having been sold on export markets. Figs. 7–11 show that each chain actor's profit over time is clearly influenced by the price changes brought about in these scenarios.

Initially, all chain actors are profitable except BMC (note that not all BMC costs are accounted for as we do not have access to information about BMC's other non-cattle costs, such as overheads, and because BMC has frequently been subsidized by government to cover operating losses). However, during FMD outbreaks all chain actor profits are shown to decline: producer profits are negative, while BMC profits continue to decline for the duration of any export prohibition. The sharp changes in chain actor profitability in the early periods (due to lost access to the export market) and later periods (due to regain access to export market) of each simulated FMD outbreak is due to a dissipation of inventories and build up as the new export demand is served. A surprising result of the model is that producer profits over time were expected to increase when an FMD outbreak did not occur. However, model results show that although the FMD-free assumption (runs 3 – business as usual and FMD control – and 4 – market liberalization and FMD control) increases producer profits, it also increases the future investments of producers by increasing their herd size, which increases operational costs to the extent that they offset gains accrued over periods of uninterrupted export trade (see years 2022–2025 in Fig. 7).

Generally, other chain actor profits over time improve under FMD-free runs. Although the FMD-free scenario shows good financial results for all chain actors, allowing live weaner exports (runs 2 – market liberalization – and 4 – market liberalization and FMD control) increases producer profits over time but reduce profits for BMC and, to a lesser extent, modern retailers and butchers over time. This is because these actors lose market share of export quality cattle sold, and higher prices are paid for weaners. Feedlot profits during FMD outbreaks decline sharply because BMC does not use feedlot services at such times. Similarly, under the policy of allowing live weaner exports to South Africa, the market share of feedlots declines, leading to lower profits. Limited changes occur in the profits of traditional butchers under the policy of allowing live weaner exports to South Africa from 2017 onward because traditional butchers, unlike modern butchers and

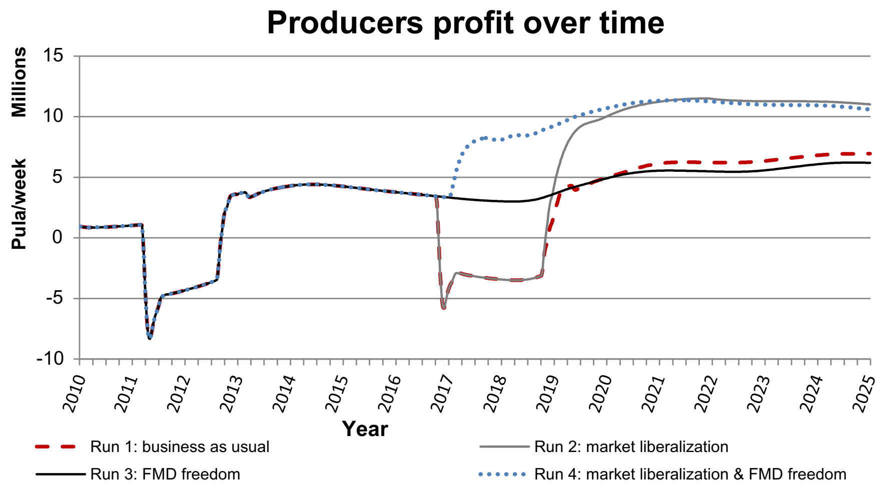

Fig. 7. Producers profit over time (simulation results).

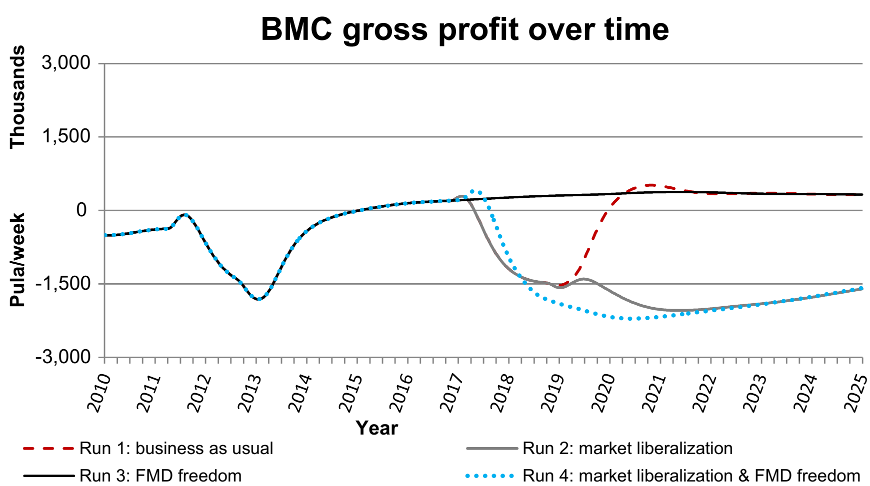

Fig. 8. BMC gross profit over time (simulation results).

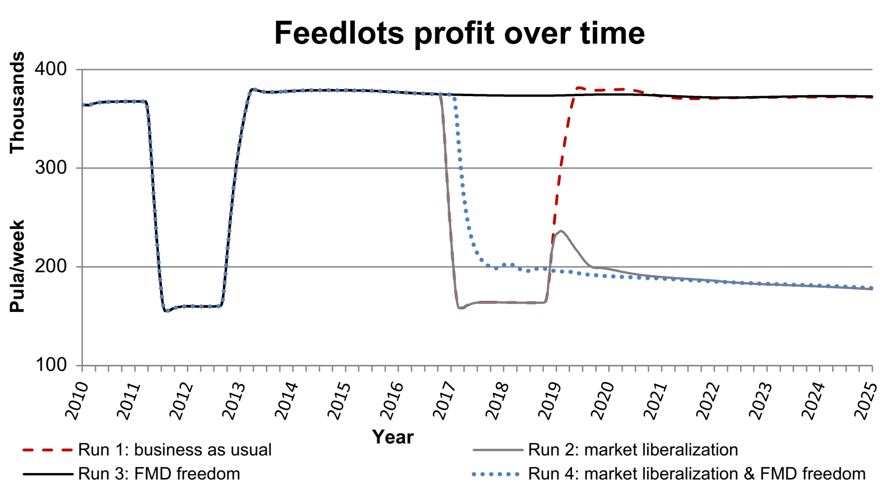

Fig. 9. Feedlots profit over time (simulation results).

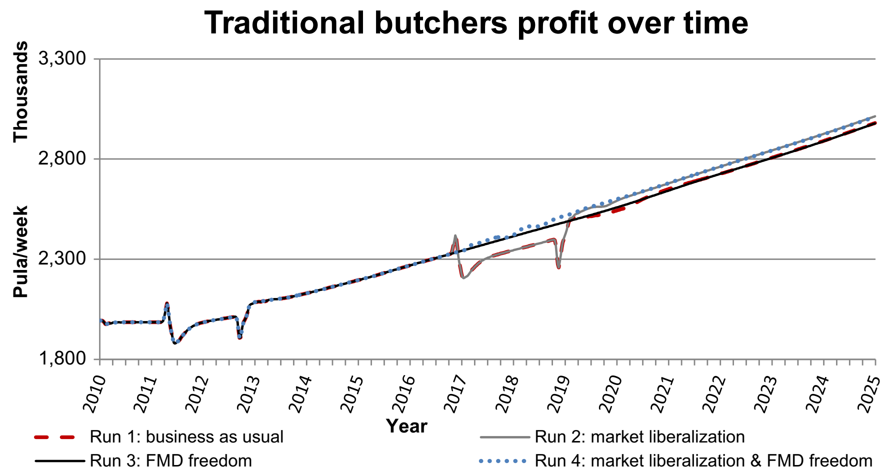

Fig. 10. Traditional urban and rural butchers profit over time (simulation results).

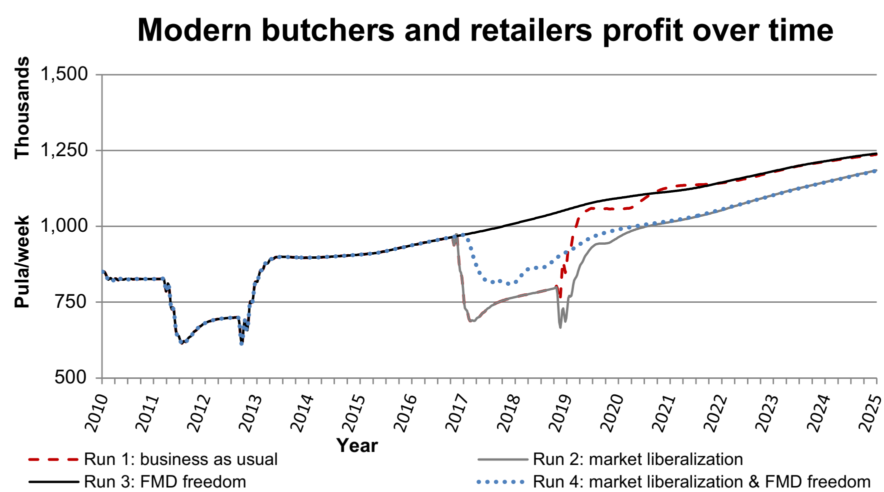

Fig. 11. Modern butchers and retails profit over time (simulation results).

retailers, do not purchase export quality cattle. Therefore, traditional butchers do not lose any market share when export of live weaners is allowed.

4.3. Discussion

A further consideration of whole chain effects and tradeoffs concerns initial investment to access markets: the case examined in this study targets weaner exports to South Africa which require few investments. However, accessing high value European product markets is investment-intensive, as has been experienced in Botswana regarding disease control and traceability. Given chain actors performance results under partial market liberalization, it is then likely that the gains of producers from full market liberalization would be offset by the investment required. The current model does however project profit accumulations which indicate the scope for financing capital investment, but the adequacy of such investment capacity requires further research.

Regardless of the trade-offs inherent in reducing market power, there are grounds for advocating to policy makers that the monopsony power of BMC be reduced. Van Engelen et al. (2013) claim that BMC carcass processing costs are above, while labor productivity is below, international norms. As BMC's profits are ostensibly distributed to producers by way of higher cattle prices, then in principle any increase in cost efficiency can offset some degree of monopsony-related economic inefficiency. Sensitivity analysis shows that beef value chain actors, particularly BMC and producers, are sensitive to BMC production cost per cattle. Any improvement in BMC's efficiency, e.g. reducing production costs, has a marked effect on BMC and producers and, to a lesser extent, on other value chain actors' profit. Similarly, sensitivity analysis also shows that changes in the beef price in export markets have a marked effect on value chain actors – particularly producers and BMC. Sensitivity analysis show that producer cumulative profits could vary by ± 100% and ± 80% from that in runs 1(business as usual) and 2 (market liberalization) (see Table 2), respectively.

This suggests that any benefits gained by policy interventions could be reduced by lower prices in export markets. A similar result is shown in Fig. A.10.–B (in Support document 2) in that increasing BMC efficiency could change BMC's cumulative profit from a negative figure (see Table 2 – run 1) to a positive one, which in turn positively affects the cumulative profits of producers and, to a lesser extent, other value chain actors. Sensitivity analysis results emphasize the need for multi-faceted policy change which improves both market access and BMC efficiency – policy interventions to increase the agility of the beef value chain in Botswana in respect of price variability in export markets and reduce BMC's subsidy bill to the government. More details about the sensitivity analysis of results shown in Table 2 are available in Support document 2.

An important lesson drawn from the model is that policy makers need to consider the trade-offs between gains and losses among chain actors. This is reinforced where implementation costs are high. Reducing the frequency of FMD outbreaks will come at a substantial cost. Moreover, the nationwide vaccination program is associated with awkward incentives as Botswana's FMD endemic area (Maun, in the country's north) has a small (200,000 heads) cattle population and does not supply export cattle. Government action is then needed to vaccinate in Maun in order to secure export market access for cattle from the rest of the country. Our reduced FMD frequency policy interventions (runs 3 – business as usual and FMD control – and 4 – market liberalization and FMD control) include the direct and indirect costs of two rounds of vaccination per year. According to van Engelen et al. (2013), the costs to conduct large scale vaccination of 200,000 heads exceeds 49 million pula (i.e. 245 BWP/head).

5. Conclusions

To our knowledge, this is the first attempt to empirically model the dynamics of Botswana's cattle production and marketing system so as to examine alternative policy and management scenarios on the basis of costs and benefits throughout the multi-actor value chain. Our model results highlight the important distributional impacts throughout the value chain associated with market liberalization and disease control in the beef sector of Botswana. Moreover, tradeoffs are apparent between such strategic approaches and these provide insights into future investment priorities.

The monopsony status of Botswana's parastatal BMC is discussed here in light of the tradeoffs between policy approaches revealed by the SD model. In particular, the mechanism by which liberalization and/or FMD control deliver benefits to value chain actors is seen to be complex. The model's results have provided some generalized answers to policy questions surrounding market power. More importantly, however, the model's SD specification has enabled considerable insight into the longer term effects of price changes in terms of stock behavior and accumulation of profits.

A notable result is that market liberalization that reduces the monopsony power of BMC has a positive impact on producer market access in domestic and export market channels, but lowers the market share of feedlot and BMC. In a similar vein, strategies that combine FMD control and market liberalization generate benefits for producers but damage the performance of feedlots and BMC. As might be anticipated, better FMD control on its own has been shown to particularly benefit feedlots, BMC, and producers. However, investment in FMD control is costly, with the market access benefits likely to be offset by significant fixed and recurrent costs for disease surveillance, vaccination, and maintenance of FMD zones. This suggests that although partial market liberalization has potential benefits, other accompanying actions such as minimizing losses of BMC and feedlots need also to be considered.

This paper contributes to the policy debate on industry management for export markets in several ways. First, it links the success of disease control (for which the investment justification has been questioned by past research on Botswana) to the generation of benefits from industry policy. Second, it projects the benefits from diversifying export markets to include live cattle exports, and indicates that in Botswana's case such a policy would not prevent the industry from producing sufficient cattle to serve sustainably the existing export and domestic markets. Third, key contributions of both trade management and disease control to welfare in the form of whole chain benefits are identified, which in Botswana's case relates to the future role of BMC.

The model presented here can be improved in terms of its precision about the costs and returns in the beef sector, particularly regarding the cost implications of capacity utilization in slaughter and distribution. In addition, a broader range of markets and disease threats could be examined, as well as the explicit roles of volatility and uncertainty. This would allow an extension to the existing treatment of risk in the conceptual model presented here. Further research should focus on complementary micro-economic analysis of the production system (large, medium, and smallholder cattle producers) disaggregation at producer level, and the model components at each node (butchers, feedlots, and BMC) of the value chain. Further research should also target regional disaggregation based on climatic zones to better represent the environmental part of the model. In this research, we deliberately treated Botswana's beef sector as one entity because FMD outbreaks have similar effects on different geographic regions and production systems in Botswana. However, further research should examine a more disaggregated and geographically dispersed set of value chain actors with the associated differential impacts and incentives.

We acknowledge that our model greatly simplifies the institutional aspects of the beef sector in Botswana. In our model, the differences between traditional and commercial sectors mainly concern pasture land ownership (i.e., the commercial sector operates on private fenced pasture land while the traditional sector operates on communal pasture land) and responsiveness to price and profit signals (i.e., commercial producers are more responsive to changes in prices and have higher offtake rates). Our model does not incorporate the livelihood effects that influence the development of each sector in Botswana. Addressing such issues in future research is particularly important as the vast majority of cattle producers in Botswana are smallholder producers operating on communal lands that are disadvantaged by a lack of scale and constraints such as an inefficient traceability system, quality control and management system issues, and which is unable to meet high export market standards, limiting their commercial potential. We defer strategies to unpack the different livelihoods oriented strategies faced by traditional farmers, versus the more market oriented ones by commercial farms to future research.

Further research is also called for to conduct ex-ante assessment to measure the effect of market liberalization policies such as: (1) removing direct government subsidies (subsidized inputs such as veterinary services, extension services, cattle traceability system) to producers, (2) passing on direct FMD costs (vaccination and vaccine delivery logistics costs) to producers, and (3) passing on BMC's losses to producers as lower cattle purchase prices. An intuitive response to such policy questions entails increased producer costs and reduced sales revenues and profits due to lower cattle prices. However, BMC's market power and surplus distribution as higher purchase cattle prices (i.e. any profit BMC makes is passed on to producers as higher cattle purchase prices), currently obscure the impacts of freer market policies on the performance of individual value chain actors and whole chain, on cattle prices, and on the financial sustainability of beef production.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.agsy.2017.05.007.

Acknowledgements

This study was conducted in association with the Competitive Smallholder Livestock in Botswana project, funded by the Australian Centre for International Agricultural Research (Project ID LPS/2010/010) and implemented by the International Livestock Research Institute (ILRI) and the Botswana Ministry of Agriculture's Department of Agricultural Research. 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. We would also like to thank the University of New England, Armidale for providing International Stipend and Tuition Fee scholarship to fund the first author's Ph.D. studies, from which this article is an outcome. We would also like to thank Dr. Sirak Bahta from ILRI for his support and assistant during the field work in Botswana.

References

d'Allonnes, T.R., 2006. Economic Impact of BMC Price Increases. U.S. Agency for International Development, Gaborone, Botswana Retrieved from. http://pdf.usaid.gov/pdf_docs/Pnadt825.pdf.

Arquitt, S.H., Honggangb, X., Johnstonea, R., 2005. A system dynamics analysis of boom

and bust in the shrimp aquaculture industry. Syst. Dyn. Rev. 305–324.
Bahta, S., 2013. A Survey of Smallholder Livestock Production in Central District in Botswana. International Livestock Research Institute, Gaborone.
Bahta, S., Malope, P., 2014. Measurement of competitiveness in smallholder livestock systems and emerging policy advocacy: an application to Botswana. Food Policy 49, 408–417.
Bhattacharya, S., Azzam, A.M., Mark, D., 2009. Ethanol and meat: a multi-market analysis. In: Selected Paper Prepared for Presentation at the Agricultural & Applied Economics Association's 2009 AAEA & ACCI Joint Annual Meeting, Milwaukee, WI.
Botswana Export Development and Investment Authority (BEDIA), 2010. Economic contribution of beef industry. Accessed. 1 Oct 2010. http://www.bedia.co.bw/print_page.php?id_mnu=55&lang.
Botswana Institute for Development Policy Analysis (BIDPA), 2006. Consultancy on the Viability and Long Term Development Strategy for the Livestock (Beef) Sub-sector in Botswana. Botswana Institute for Development Institute Analysis, Gaborone.
Botswana Press Agency (BOPA), 2011. Act Change Causes Bill Deferment. Botswana Daily News. Accssesible at, Ghanzi. http://www.olddailynews.gov.bw/cgi-bin/news.cgi?d=20110408.
Botswana Press Agency (BOPA), 2013. Parliament Approval Can end BMC Monopoly. Botswana Daily News. Accssesible at, GHANZI. http://www.dailynews.gov.bw/news-details.php?nid=7059.
Boy, R.L., 2013. Cattle traceability-a threat to sustainable supply of beef to EU: a Botswana meat commission. Eur. J. Logist. Purch. Supply Chain Manag. 1 (1), 1–9.
Central Statistics Office (CSO), 2010. 2008 Annual Agricultural Survey Report. Government Printers, Gaborone.
Cloutier, L., Sonka, S., 1999. A System Dynamics Model of Information Feedback and Activity Coordination in an Agricultural Value Chain. Presented paper at the sixteenth international conference of the system dynamics society. Quebec City, Qc.
Cooksey, B., 2011. Marketing reform: the rise and fall of agricultural liberalisation in Tanzania. Dev. Policy Rev. S57–S81.
van Engelen, A., Malope, P., Keyser, J., Neven, D., 2013. Botswana agri-Food Value Chain Project Beef Value Chain Study. Ministry of Agriculture - Botswana and the Food and Agriculture Organization of the United Nation, Gaborone.
Favretto, N., Stringer, L., Dougill, A., Perkins, J., Atlhopheng, J., Reed, M., Thomas, A., Mulale, K., 2014. Time-series Analysis of Policies and Market Prices for Provisioning Ecosystem Services in Botswana's Kalahari Rangelands. Report for the Economics of Land Degradation Initiative Leeds, UK.
Fisher, K.D., Norvell, J., Sonka, S., Nelson, M.J., 2000. Understanding technology adoption through system dynamics modeling: implications for agribusiness management. Int. Food Agri. Manage. Rev. 281–296.
Ford, A., 2010. Modeling the Environment, second ed. Island Press.
Forrester, J.W., Senge, P.M., 1980. Tests for building confidence in system dynamics models. In: Legasto, A.A., Foreester, J.W., Lyneis, J.M. (Eds.), System Dynamics, (Amsterdam: North-Holland).
Gardner, B.L., 1975. The farm-retail price spread in a competitive food industry. Am. J. Agric. Econ. 57 (3), 399–409.
Hamza, K., Rich, K.M., Wheat, I.D., 2014a. A system dynamics approach to sea lice control in Norway. Aquac. Econ. Manag. 344–368.
Hamza, K., Rich, K.M., Baker, A.D., Hendrickx, S., 2014b. Commercializing smallholder value chains for goats in Mozambique: a system dynamics approach. In: Proceedings in Food System Dynamics. 2014. pp. 117–134.
Helldén, U., 2008. A coupled human-environment model for desertification simulation and impact studies. Glob. Planet. Chang. 158–168.
Institute for Crop Research in Semi-Arid Tropics (ICRISAT) and International Livestock Research Institute (ILRI), 2005. Crop-livestock Systems Development in Southern Africa: Priorities for Future Research. Botswana country report.
Jefferis, K., 2007. Price Responsiveness of Cattle Supply in Botswana. U.S. Agency for International Development/Southern Africa, Gaborone.
Jones, A., Sevilleb, D., Meadows, D., 2002. Resource sustainability in commodity systems: the sawmill industry in the Northern Forest. Syst. Dyn. Rev. 171–204.
Kaitibie, S., Omore, A., Rich, K., Kristjanson, P., 2010. Kenyan dairy policy change: influence pathways and economic impacts. World Dev. 38 (10), 1494–1505.
Mahabile, M., Lyne, M., Panin, A., 2005. An Empirical Analysis of Factors Affecting the Productivity of Livestock in Southern Botswana. (Agrekon).
Mapitse, N., 2008. Transboundary Animal Disease and Market Access: Future Options for the Beef Industry in Southern Africa. Working Paper 3 Institute of Development Studies, Brighton.
McRoberts, K.C., Nicholson, C.F., Blake, R.W., Tucker, T.W., Padilla, G.D., 2013. Group Model Building to Assess Rural Dairy Cooperative Feasibility in South-Central Mexico. (International Food and Agribusiness Management Review).
Minot, N., Goletti, F., 1998. Export liberalization and household welfare: the case of rice in Vietnam. Am. J. Agric. Econ. 80 (4), 738–749.
Mowat, A.C., Collins, R.J., Spencer, M.M., 1997. A persimmon industry systems dynamics model for research and development management. In: Subhadrabandu, S. (Ed.), Proceedings of the 1st International Persimmon Symposium. 1st International Persimmon Symposium, pp. 51–58 Chang Mai City, Thailand. 17–19 July, 1996.
Moxnes, E., 2000. Not only the tragedy of the commons: misperceptions of feedback and policies forsustainable development. Syst. Dyn. Rev. 325–348.
Moxnes, E., 2004. Misperceptions of basic dynamics: the case of renewable resource management. Syst. Dyn. Rev. 139–162.
Naziri, D., Rich, K.M., Bennett, B., 2015. Would a commodity-based trade approach improve market access for Africa: a case study of the potential of beef exports from communal areas of Namibia. Dev. Policy Rev. 33 (2), 195–219.
Ransom, E., 2011. Botswana's beef global commodity chain: explaining the resistance to change. J. Rural. Stud. 431–439.
Rich, K.M., 2008. An interregional system dynamics model of animal disease control: applications to foot and mouth disease in the Southern Cone of South America. Syst. Dyn. Rev. 67–96.
Rich, K.M., Winter-Nelson, A., 2007. An integrated epidemiological-economic analysis of foot and mouth disease: applications to the southern cone of South America. Am. J. Agric. Econ. 89 (3), 682–697.
Rich, K.M., Perry, B., Kaitibie, S., 2009. Commodity-based Trade and Market Access for Developing Country Livestock Products: The Case of Beef Exports From Ethiopia. International Food and Agribusiness Management Review pp. 1–22.
Rich, K.M., Ross, R.B., Baker, D.A., Negassa, A., 2011. Quantifying value chain analysis in the context of livestock systems in developing countries. Food Policy 214–222.
Saysel, A.B., Barlas, Y., Yenigün, O., 2002. Environmental sustainability in an agricultural development project: a system dynamics approach. J. Environ. Manag. 247–260.
Scoones, I., Wolmer, W., 2008. Transboundary Animal Disease and Market Access: Future Options for the Beef Industry in Southern Africa Working Paper 1. Institute of Development Studies, Brighton. www.steps-centre.org/ourresearch/vetscience.html.
Statistics Botswana, 2011. Botswana Statistical Year Book 2010. Statistics Botswana, Gaborone.
Statistics Botswana, 2013. 2011 Annual Agriculture Survey Report. Statistics Botswana, Gaborone.
Statistics Botswana, 2014. 2012 Annual Agriculture Survey Report. Statistics Botswana, Gaborone.
Sterman, J., 2000. Business Dynamics: Systems Thinking and Modeling for a Complex World. Irwin/McGraw.
Stevens, C., Kennan, J., 2005. Botswana Beef Exports and Trade Policy. Institute of Development Studies University of Sussex, Brighton, UK.
The Technical Centre for Agricultural and Rural Cooperation, 2012. Agritrade Informed Analysis, Expert Opinion: Beef Sector. Wageningen, Technical Centre for Agricultural and Rural Cooperation.
World Bank, 2006. Study of the Viability and Long Term Development Strategy for the Livestock (Beef) Sub-sector in Botswana. Government of Botswana and The world Bank, Gaborone.