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Debunking the myth that a legal trade will solve the rhino horn crisis: A system dynamics model for market demand

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ABSTRACT

There is considerable debate in the literature over whether or not to legalise the trade in rhino horns. Here a system dynamics model is developed that considers five components: rhino abundance, rhino demand, a price model, an income model and a supply model. The study indicates the importance of shifting from a conventional (sectoral) conservation model to a more non-conventional (sustainable) approach that models the interactions between the different components. While the results under the no trade scenario are similar for both the equilibrium and disequilibrium model, under the trade scenario results were sometimes quite disparate. This study finds that sometimes second best solutions from an economic perspective may be optimal if conservation interests are to be achieved.

1. Introduction

There is much debate in the conservation literature over whether or not to legalise the trade in rhino horns. Biggs et al. (2013) write that a legal trade can only work if, among other things, "the demand does not escalate to dangerous levels as the stigma associated with the illegality of the product is removed." A number of authors (e.g. Collins, Fraser, & Snowball, 2013; Prins & Okita-Ouma, 2013) emphasise uncertainties over responses of market demand to a legal trade. If demand is positively sloping, by an Anthropogenic Allee Effect (AAE), then species extinction could actually be exacerbated by demand reduction strategies (Hall, Milner-Gulland, & Chourchamp, 2008). The AAE effect implies that the perceived rarity of a wildlife product could actually increase demand and therefore extinction risk (Courchamp et al., 2006). On the other hand, Biggs et al. (2013) argue demand is downward sloping (but inelastic). They argue, therefore, that demand reduction strategies would actually reduce the supply of rhino horns to the market. Those that advocate for the liberalisation of the rhino horn trade argue that allowing the sale of rhino horns will generate additional income for rhino farmers that will aid in the conservation of the species (e.g. Hanks, 2015). Alternatives that have been proposed to solve the 'rhino horn trade dilemma' include dehorning (Milner-Gulland, 1999) and consumer behaviour modification (Litchfield, 2013). As these issues are debated, poaching continues to increase, with the possibility that South African rhinos could be extinct in the next 20 years if current trends continue (Di Minin et al., 2015).

It is therefore important to develop a model to estimate the response of consumers to changes in demand, prices and income. Rhino horn price and income elasticities were estimated by Millner-Gulland (1993) using multivariate linear regression. Her model showed that the price coefficient was insignificant while the income elasticity was 1.06, indicating that rhino horns were luxury goods. However, market demand have increase dramatically in the past 20 years. We therefore need to ascertain whether or not these conditions still hold. Furthermore, estimation of market dynamics requires an understanding of how different market components (preferences, income and price) interact with each other. We therefore need to develop a model to consider the market dynamics associated with the rhino horn trade in order to estimate several crucial elasticities (price, income and consumption). However, instead of using the standard regression techniques to estimate elasticities, we develop a systems model that replicates the known behaviour of the system. Once the elasticities are known, we use the model to answer "what if" type questions on the behaviour of the system. In particular, we want to know the effect of legalising the trade in rhino horn on all key participants (rhino populations, rhino horn consumers and game reserve "suppliers"). In addition to the trade/no trade policy that forms the central thesis of this article, the model is also capable of modelling a number of other mitigation

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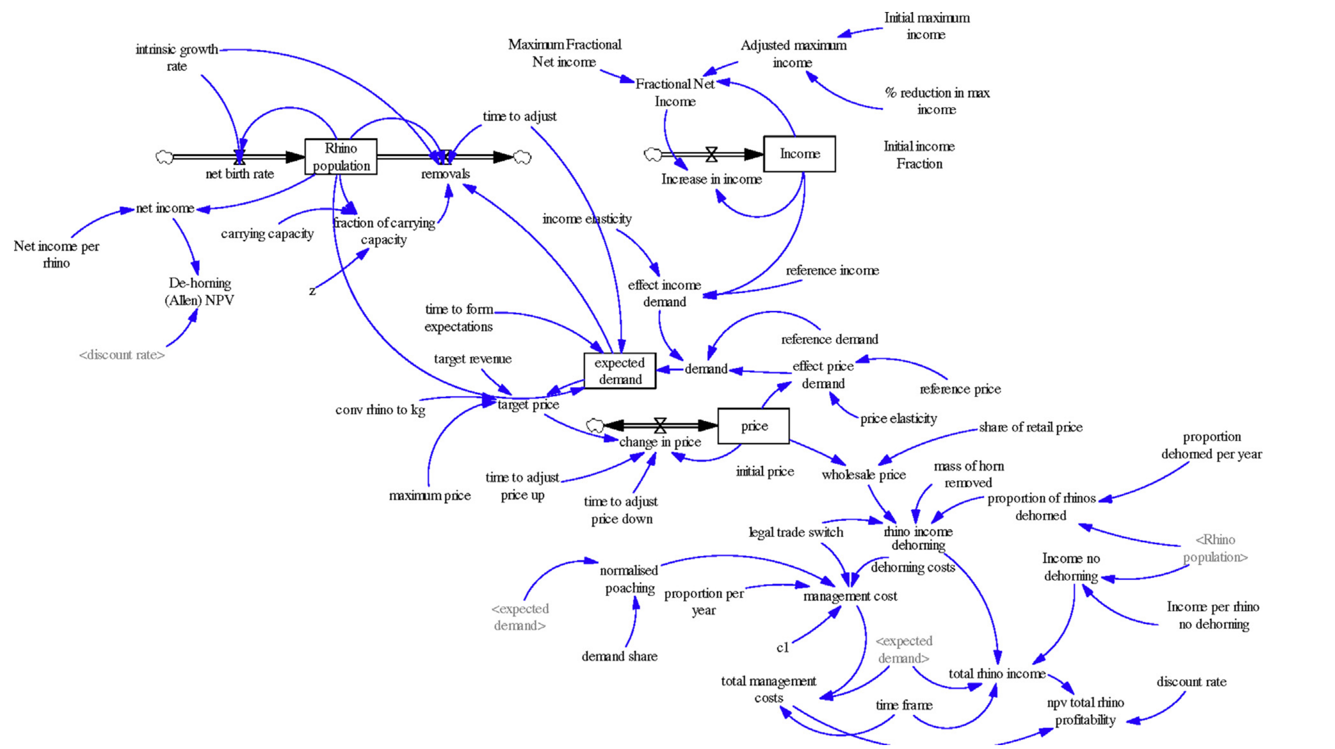

Fig. 1. Stock flow diagram of the market model.
The figure indicates the interactions between the different components of the model, namely a population model, market demand (price and income), and the profitability of rhinos for game farmers.

type policies, including consumer behaviour modification, as well as the effectiveness of a de-horning strategy.

A number of studies have utilised system dynamics models for wildlife populations. Chen, Chang, and Chen (2014) develop a model that simulates the effect of air pollution on habitat, which in turn affects the migratory behaviour of birds. Beall and Zeoli (2008) model the dynamics of Greater sage grouse populations in Western North America. Land management decisions are the main driver of population declines. Semeniuk, Haider, Cooper, & Rothley (2010) examine the effect of tourism on stingray populations. An interesting feature of the model is the use of a logistic growth formulation to model a density dependent tourism growth function. As far as mammals are concerned, Faust, Jackson, Ford, Earnhardt, and Thompson (2004) develop a stochastic, two sex, four stage model for grizzly bears in zoos, as well as the Yellowstone National Park. On the African continent, Weller et al. (2014) model African penguin populations subject to a number of pressures, including oil spills and competition for food from the fishing industry. An age structured model characterises the penguin population dynamics. This selection of studies indicates that system dynamics modelling is relatively common for modelling wildlife populations. However, applications to the rhino horn trade, apart from this study, are non-existent.

There are very few studies that have adopted an empirical approach to assess whether or not a legal trade in rhino horn is viable (but see Di Minin et al., 2015 as a notable exception). The rhino horn trade is a complex system with many participants, from the dynamics of rhino populations themselves, to producers (game farms) and the final consumer. A modelling approach that is capable of modelling complex systems is therefore required, hence the choice of system dynamics modelling. This study is the first known study to develop an integrated model that considers the interactions between the major participants of the rhino horn trade (populations, producers, consumers) in an interactive manner. The systems model distinguishes between two elements. Firstly, an equilibrium model is developed which follows largely a neoclassical framework. And secondly, a disequilibrium model is then developed to consider the dynamics of the trade. It is extremely rare for a systems model to contain both equilibrium (neoclassical) and disequilibrium (heterodox) elements (Crookes and De Wit, 2014). The model therefore makes a contribution to the systems literature as well.

The article is structured as follows. First, the systems model for the different components is developed. Section 3 deals with the parametrisation of the model, distinguishing between exogenous and endogenous parameters. The results are presented in Section 4, and the results are discussed in Section 5.

2. The model

There are five components of the market model (Fig. 1). These are: (1) a population model determining the dynamics of rhino abundance; (2) a income model determining the response of rhino horn demand to changes in income; (3) a price model, evaluating the effect of price changes on demand; (4) a demand function that combines the income and price models, and (5) a supply model, consider the effect on game farm profitability of either legalised trade or no trade. We use the term ‘game farm’ in the broadest sense to include private sector and public sector management of rhinos. We will now consider each of these components in turn.

2.1. Population model

The model utilises the population model of Milner-Gulland and Leader-Williams (1992), which is in effect a density dependent logistic model.

$$f(x) = rx\left(1 - \left[\frac{x}{k}\right]^{z}\right) - h$$