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African Rhino Conservation and the Interacting Influences of Property, Prices, and Policy

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ABSTRACT

Conserving terrestrial megafauna presents distinct challenges to policymakers. Despite decades of evolving regulatory measures, wild rhinoceros populations remain threatened by illegal killing to acquire rhino horn, a valuable commodity in East Asian markets. In Africa, rhino conservation performance has varied with geography and over time. This research draws on institutional economic theories to seek plausible explanations for such variable conservation outcomes. Such theories suggest that institutional variables such as property rights profoundly influence human behaviour, leading to hypotheses that we test using comparative institutional analytic methods. Our inquiry affirms that blanket trade restrictions do not account for local conservation success and that other institutional factors appear more relevant. We find that positive overall conservation outcomes correlate with greater institutional diversity within countries, notably those that enable non-state actors to play a meaningful role in rhino management. Our research further suggests that strengthening institutions through decentralization is a sensible conservation strategy for rhinos. However, a specific case study of the economics of white rhino ownership in South Africa reveals that this approach is not considered a panacea for conservation as it raises concerns over potential domestication. We conclude with recommendations for policy—notably, to avoid recentralization—and further research.

1. Introduction

Conserving the earth's biological diversity is a pressing global concern and challenge for policymakers (IPBES, 2019; Helm and Hepburn, 2012; Dasgupta, 2021). Charismatic megafauna such as rhinoceros species (hereafter rhinos) serve as 'umbrellas' for this cause (Ripple et al., 2015, 2017). However, despite their charisma and role as flagships for conservation fundraising over a period spanning decades, wild rhinos remain under severe threat, worldwide (Western, 1987; Veríssimo et al., 2011; Ferreira et al., 2022). A mix of factors, including excessive hunting and deliberate eradication and loss of suitable habitat for agricultural land clearing, accounts for the historical attrition of wild rhino populations, but since the 1970s the dominant driver of rhino loss in Africa has been illegal killing (poaching) to supply market demand for rhino horn (Martin and Martin, 1983; Emslie, 2020a, 2020b). This vexing (and essentially economically driven) conservation challenge provides the key focus and motivation for this research.

Rhino horn is an unusual commodity. Prized by humans for many centuries for both its ornamental and reputed healing properties, its observed wholesale market price by weight has risen substantially since the mid 1970s, in the face of concerted formal international efforts to curtail its trade and use (Leader-Williams, 1992; Vigne and Martin, 2018). Persistent pockets of consumer demand have continued to drive illegal trade and sustained conditions under which all surviving wild rhino populations require at least some measure of monitoring and physical security to deter poachers (Di Minin et al., 2022; Barichievy et al., 2017). This imposes unavoidable and often substantial financial costs on the actors responsible for conserving them (Collins et al., 2016; 't Sas-Rolfes et al., 2022). Whereas other wild megafauna such as elephants and big cats are similarly i) physically threatening to humans, ii) threatened with extinction, and iii) subject to illegal commercial exploitation for body parts, both the potential monetary gain from poaching a rhino and the average financial cost of protecting one currently appear to be the greatest for any large terrestrial mammal species.

Against this background, rhino conservation success has varied substantially over time and space, as well as between rhino species and subspecies (Amin et al., 2006; Chanyandura et al., 2021). Applying

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appropriate comparative analytical methods to identify the causes of such variation in past conservation performance should provide useful lessons for future policy. Viewed within a social-ecological systems (SES) framework (McGinnis and Ostrom, 2014), relevant causal factors may include inherent biophysical characteristics that vary between different rhino species and their habitats, but certainly also include variables that influence the human actions that ultimately determine conservation outcomes. We propose that, in the case of rhino conservation, the latter can be usefully analysed through the lens of institutional economics (see Sills and Jones, 2018).

The relevance of institutional arrangements (i.e., systems of rules), and especially property-rights regimes, to achieving effective renewable natural resource management has long been recognized in the conventional economics literature, following seminal work on fisheries (Gordon, 1954; Scott, 1955) and the emergence of exclusive hunting control (Demsetz, 1967). Whereas these analyses indicated that competitive open access regimes were more likely to result in overexploitation than those with private property rights, later work suggested that under certain conditions (i.e., slow species reproductive growth and high discount rates), private-property profit maximisation may be similarly problematic (Clark, 1973). Subsequent literature has developed more nuanced conceptual analyses of property-rights regimes (Schlager and Ostrom, 1992; Sikor et al., 2017) and further highlights that managing terrestrial wildlife with commercial harvest value entails more complex concerns than open access marine resources, calling for analytical models that incorporate the impact of habitat conversion in addition to direct overexploitation—and the allocation of resources required to mitigate both (Swanson, 1994; Barbier and Schulz, 1997). A key finding of this later work is that terrestrial wildlife habitat converts to other forms of human use through a 'disinvestment' process when it is economically uncompetitive (Skonhoft, 1999). This implies that conservationists should aim to identify and promote institutional arrangements that elevate the perceived economic value of such intact natural ecosystems and their component species to relevant decision-makers, official and unofficial (see Dasgupta, 2021).

However, regarding terrestrial megafauna with potential harvest value, opinions differ over effective institutional arrangements for conservation. The conventional (and internationally influential) 'North American Model' essentially eschews private property rights and prohibits wildlife commerce, instead relying on state wildlife ownership underpinned by the public trust doctrine (Peterson and Nelson, 2017; Lueck and Miceli, 2007). Its foundational principles of 'wilderness' protection and strict regulation of harvest appear to have been heavily influenced by the near loss of the American bison and extinction of the passenger pigeon during the nineteenth century—and remain strongly evident in contemporary policy (Tober, 1981; Mahoney et al., 2015). In contrast, from the 1950s onwards several southern African countries embraced decentralization and market institutions in wildlife conservation, enabling both the devolution of property rights to non-state actors and managed commercial exploitation (Child et al., 2012), building on principles articulated in the literature on common property governance (see Ostrom, 1990; Mahajan et al., 2021).

These substantially different policy approaches are linked to well-documented debates over the so-called 'sustainable use' of wildlife (Allen and Edwards, 1995), with supporters emphasizing incentive-driven conservation (Hutton and Leader-Williams, 2003) and sceptics raising concerns relating to governance effectiveness and the welfare of individual animals (Hoyt, 1994). They are further linked to broader philosophical debates as to whether biodiversity conservation is best pursued through anthropocentric approaches that emphasize instrumental values to humans versus approaches that emphasize intrinsic values (of ecosystems, species, and individual organisms), which are claimed to exist independent of human interests (McShane, 2007; Justus et al., 2009; Vucetich et al., 2015). Such long-standing debates, which persist in contemporary policy deliberations, have potentially profound implications for the future evolution of conservation governance, given that contrasting positions point toward fundamentally different conceptions of legal property rights (e.g., wild animals as objects of human rights versus wild animals as subjects of their own rights—see Epstein, 2004, and Bradshaw, 2018).

Focusing on specific megafauna, scholars have investigated institutional and economic issues concerning the American bison (Lueck, 2002; Taylor, 2011; Hill, 2014) and elephants, for which a rich and diverse literature exists, ranging from more conventional economic analyses (e.g., Barbier et al., 1990; Kremer and Morcom, 2000; Van Kooten, 2008; Do et al., 2020) to more overtly institutional (e.g., Kreuter and Simmons, 1995; McPherson and Nieswiadomy, 2000; Brennan and Kalsi, 2015). Within the broader literature on rhino conservation (see Chanyandura et al., 2021) economists have focused on anti-poaching measures and trade policy (e.g., Brown and Layton, 2001; Collins et al., 2016), reflecting the actual focus of rhino conservation effort (Leader-Williams, 2003). However, consistent with broader species conservation research (Ando and Langpap, 2018), there has been limited empirical analysis of the effectiveness of rhino conservation laws. There has also been limited focus on the functional role of market institutions (but see 't Sas-Rolfes, 1995, 2017, and Child, 2012), despite recognition of the growing significance of private landowners as rhino conservation actors (Rubino and Pienaar, 2017; Emslie et al., 2019; Chapman and White, 2020b; Ferreira et al., 2022; Clements et al., 2023).

We provide a novel contribution to the literature by systematically analysing a substantial body of historical evidence on evolving institutional arrangements in relation to rhino conservation performance in Africa over six decades. We explicitly examine the interplay between policy, property rights, market prices, and rhino conservation outcomes, thereby adding to the literature on evaluation of biodiversity policy instruments (see Miteva et al., 2012). We proceed by outlining some relevant history, following which Section 3 explains our theoretical framework. Section 4 describes our methodological approach, providing details of data sources used and the qualitative methods we use to infer relevant causal relationships. Section 5 presents the results of our analysis and Section 6 concludes by noting some caveats, policy implications, and possible avenues for further research.

2. Historical Background

The pre-historically diverse rhinoceros family (*Rhinocerotidae*) comprises five extant species, three of which occur in Asia, and two in Africa (Liu et al., 2021). All five species, once widely distributed, endured centuries of hunting for meat and other products (notably horn), as well as habitat loss, in the face of expanding human populations. In some instances, rhino populations were deliberately eliminated simply to create space for agricultural development. Two of the Asian species (the Sumatran and Javan) have declined to the point of near extinction, with less than one hundred individuals of each surviving in the wild, in Indonesia. The third Asian species (the greater one-horned rhino, numbering ~4014 in early 2022 in India and Nepal) and two African species have fared better, albeit in relatively few countries with meaningful success. At the end of 2021, wild African populations were estimated at 15,942 white rhinos in ~11 range states, and 6195 black rhinos in ~12 range states (Ferreira et al., 2022).

Although the fate of wild rhino populations has mostly been one of continued decline over recent centuries, there have been a few notable instances of recovery since the start of the twentieth century. The nineteenth century was characterized by European colonial control of most rhino range, in which extensive hunting took place subject to various regulations of questionable effectiveness (Adams, 2004; MacKenzie, 1997). The most effective means to control hunting was the eventual creation of designated protected areas within which hunting was essentially prohibited. In 1933, colonial government delegates to the London Conference on African Wildlife agreed that state protected areas would constitute the primary vehicle for wildlife preservation (Jepson and Whittaker, 2002) and these enabled at least two clear instances of rhino recovery during the twentieth century. The greater one-horned rhino population in India recovered from <20 individuals in 1908 (in Kaziranga National Park) to ~2300 regionally in 2009 (Zschokke et al., 2011) and the southern white rhino subspecies in South Africa recovered from <50 individuals in Hluhluwe-iMfolosi National Park (HiP) at the start of the twentieth century to become the world's most abundant variety, with >20,000 descendants worldwide, in 2010 (Pernetta, 2014).

Whereas wildlife protection in the first half of the twentieth century was undertaken in a relatively uncoordinated manner by designated state agencies with some support from elite international networks, the mid-twentieth century saw the establishment of the International Union for the Conservation of Nature (IUCN) as a coordinated world federation of state and non-state actors (Jepson and Whittaker, 2002). However, at around the same time, rhino conservation strategies started to diverge. Whereas all Asian rhinos remained under conventional state protection and management, various innovations emerged in Africa. These were largely initiated by the Natal Parks Board (NPB), a South African parastatal (i.e., partly autonomous) provincial agency established in 1947 and tasked with managing Natal's protected areas, including HiP (Hughes, 2001). As a parastatal, the NPB was empowered to manage and retain its own finances and engage in commercial activities to support its conservation mission.

The NPB's initiatives started with a strategy to re-establish founder populations of white rhinos outside of HiP in other areas of their former range. Enabled by advances in sedation and transport technology, from 1961 to 1972 a total of 1109 live white rhinos were translocated to other protected areas within South Africa and as exports to seven former range states and various captive facilities elsewhere in the world (Player, 2013). In 1969 the Natal government eased provincial laws to enable recreational ('trophy') hunting of excess males and then started supplying them to private landowners for a nominal fee using a wait-list allocation system. With relatively insecure ownership of live free-ranging wild animals and substantially higher trophy fees on offer, private landowners were incentivized to sell hunts immediately rather than breed rhinos ('t Sas-Rolfes, 1990). However, this changed after the NPB switched to live auctions as an allocation mechanism from 1986, further supported by new national legislation (the 1991 Game Theft Act) that recognized intentional private ownership of wild animals contained by fences ('t Sas-Rolfes et al., 2022; Taylor et al., 2020), following which a vibrant domestic market in live rhinos emerged.

While South Africa rebuilt its rhino populations from the 1960s to early 1990s, most other African range states experienced dramatic declines in theirs, driven by a surge of poaching for rhino horn to supply burgeoning demand in Yemen and East Asia (Leader-Williams, 1992). This prompted the listing, by early 1977, of all rhino species on Appendix I of the newly established Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES), which amounted to an effective ban on commercial rhino trade between the member countries (numbering ~31 at the time). The CITES listing was met by immediate dramatic increases in recorded wholesale import prices of horn in (non-member) consumer countries and poaching continued unabated in most of Africa until the early 1990s, despite further attempts at trade-restrictive measures in 1981 and 1987 ('t Sas-Rolfes, 2000). By 1993 the number of CITES signatories had risen to 120 and the USA applied diplomatic pressure on the four most significant consumer countries to bring about domestic trade restrictions. The latter measures were followed by a substantial reduction in poaching and thus appear to have enabled the subsequent recovery of populations in several range states, notably Kenya, Namibia, and Zimbabwe (Emslie et al., 2007), being countries that also adopted various innovative policy changes to allow some devolution of rhino management.

Rhino numbers continued to grow in South Africa, and in 1994 the CITES Parties agreed to down-list that country's white rhino population to Appendix II to enable commercial international trade in live animals and easier export of hunting trophies; however, this explicitly excluded commercial rhino horn trade, which remained internationally prohibited (while remaining legal within South Africa). In 2004, the CITES Parties approved proposals from both South Africa and Namibia to enable the legal hunting and trophy export of a small annual quota of black rhinos (Leader-Williams et al., 2005). From the mid-1990s until 2010, rhino populations of both species thrived in both countries, with sales of live animals and trophy hunts providing a substantial source of income to both private actors and government conservation agencies, further enabling the expansion of both rhino range and state protected areas ('t Sas-Rolfes et al., 2022).

Whereas continental African rhino poaching levels remained low from 1996 to 2001, from 2002 they started to increase and from 2003 a phenomenon of legal 'pseudo-hunting' began, whereby foreign nationals visiting South Africa masqueraded as *bone fide* trophy hunters to exploit the legal loophole for exporting rhino horns as hunting trophies ('t Sas-Rolfes, 2017). This, accompanied by rapidly growing live rhino exports to China, indicated a resurgent interest in rhino horn as a commodity in East Asia (Hall-Martin et al., 2009; Milliken and Shaw, 2012; Gao et al., 2016). In 2007, South Africa promulgated new legislation aimed at protecting threatened species, including both rhino species, the so-called 'ToPS' regulations. ToPS mandated specific permit applications for a comprehensive range of rhino management activities, thereby imposing substantial administrative restrictions on private rhino owners. In 2008, rhino poaching increased sharply in both Zimbabwe and South Africa, prompting the latter country to impose a moratorium on the domestic trade of rhino horn, effective from February 2009. However, poaching in South Africa continued to increase dramatically for the next few years, reaching a peak in 2015. Other range states were also affected during this time and rhino horn crimes even extended to European zoos and museum thefts.

A range of concerted international regulatory, enforcement, and campaign efforts over the last decade has been followed by a decline in observed illegal rhino horn market prices and poaching numbers since 2016. However, this has come at a considerable financial cost, poaching pressure persists, rhino range has been significantly reduced, and the world's largest rhino population within South Africa's Kruger National Park has declined significantly (from ~10,500 white and ~650 black in late 2010 to ~2607 white and ~202 black by 2020). Private landholders have adopted diverse strategies in response to the poaching crisis (Clements et al., 2020), but volumes of live rhino auction sales and recorded prices have declined substantially, adversely affecting the finances of both public and private owners; rhino conservation has become increasingly dependent on state subsidies and charitable donors. The COVID-19 pandemic has placed further substantial economic pressure on African conservation in general (Lindsey et al., 2020) and the future for rhinos appeared to remain perilous in late 2022 (Ferreira et al., 2022).

3. Theoretical Framework

We employ an institutional economic approach, situated in a complex-adaptive SES context (Ostrom, 2007). Agreeing that economics matters for endangered species protection (Shogren et al., 1999) and recognizing the limitations of conventional neoclassical approaches (Colander et al., 2004; Hodgson, 2007; Smith and Wilson, 2019), we draw on insights from institutional theory and broader social science research to provide a set of conceptual tools for analysis. In this section (and subsequent subsections) we outline our basic approach, with further elaboration in S2.

We define institutions as 'systems of established and embedded social rules that structure social interactions' (Hodgson, 2006: 18). Institutions, which may be static or dynamic (i.e., changing in response to evolving social norms – see Platteau, 2000), both shape and are shaped by human behaviour (Vatn, 2006). They vary in formality, from relatively informal customs to formal written laws enforced by the state (North, 1991; Lauth, 2015), and in 'strength', which may be assessed in two dimensions: i) extent of compliance, and ii) durability (Levitsky and Murillo, 2009).

Our analysis of rhino conservation focuses on the role of market institutions, which we define as the rules that govern recurrent voluntary exchanges of assets between actors. We define an asset as anything that is valuable or useful to an actor. We consider three key components of market institutions: property, prices, and policy. Both property and price systems are well-established informal institutions that have become increasingly formalised in recent history, with the state reducing transactions costs by defining property rights and enforcing contracts (McMillan, 2016). This formalisation process has entailed the co-evolution of markets and political institutions (Greif, 2005), with clear ongoing tensions between the two in response to varying moral sentiments (Abercrombie, 2020).

3.1. Property

The concept of property describes a relationship between individuals with respect to an asset (Fabbri et al., 2021). Property entails a social agreement over rights, benefits, and duties (Hodgson, 2009) and property rights may be loosely defined as the rules governing ownership in a society (Harris et al., 2020) with the implication that a property 'right' constitutes a socially recognized claim in respect of an asset. We distinguish between the core legal intuition of having property in a thing – '*in rem*' – and secondary elements of ownership such as secure tenure and beneficial use, which tend to be the focus of economic scholarship (Arruñada, 2012). These variable elements determine the strength of property ownership as an institution (Alchian and Demsetz, 1973) and may be assessed by four variable dimensions, namely: i) clarity of allocation, ii) security from trespass (or unauthorised use), iii) alienability (i.e., capacity to transfer to another party), and iv) credibility of persistence (Harris et al., 2020).

We recognize the vital role of an external enforcer in determining the strength of ownership by influencing these four variable dimensions and propose that 'strong ownership' implies an enforceable *in rem* claim with relatively unfettered secondary beneficial rights, and that weakness emerges to the extent that these are compromised. However, the potential for strong ownership is also influenced by the nature of the asset in question, as determined by the two key variable attributes of i) excludability and ii) rivalry or 'subtractability' of use (Ostrom, 2010). These attributes, which may vary over time with technological advances and human intervention, are frequently used to define four broadly different types of goods/resources (private, toll, common pool, and public) as represented in Fig. 1a.

Distinct from the four attribute-based asset typologies are four types of property regimes (aka systems or models), namely private, common, and state property, and 'non-property' (Bromley, 1989; Lueck and Miceli, 2007; Fig. 1b). Non-property, as formalised by the legal concept of *res nullius*, equates to an open access regime, and is most likely to result in the overexploitation of resources that yield private benefits. The standard policy prescription to prevent such overexploitation is to establish private, common, or state property regimes, depending on the type of asset and context (see Hanna and Musinghe, 1995). Typically, private property is prescribed for private goods. However, property regimes of environmental assets are typically complex mixtures of the basic models, and such composite assets are furthermore often divisible into stock and flow components, calling for a nuanced approach (Lueck and Miceli, 2007; Fennell, 2011). Accordingly, scholars of commons governance have developed sophisticated frameworks of property regimes, divisible into various categories of rights, including rights to manage resources and rights to define and allocate such management rights, i.e., 'authoritative rights' (Schlager and Ostrom, 1992; Sikor et al., 2017).

Property rights relevant to rhino conservation include those over their habitat (i.e., land rights), the animals themselves, and any harvested body parts. Viable rhino populations that play a functional ecological and evolutionary role in ecosystems provide collective benefits to society and therefore exhibit public good attributes, even at a global level. However, individuals or small groups of live rhinos have attributes of toll goods (for tourist viewing) or private goods (for hunting and harvest of body parts). Of interest for policy is the relative value of these different benefits and how to design property institutions for socially optimal effect (as defined through political processes).

3.2. Prices

Prices, expressed in monetary terms, are a critical component of market institutions, transmitting information about relative scarcity to diverse actors and creating economic incentives to guide their action (Hayek, 1945). Market prices, determined through competitive processes between buyers and sellers, are 'crude but often effective indicators of error or success' (Hodgson, 2015: 145). However, market prices may diverge from reflecting the true preferences of actors in the presence of weak property rights or asymmetries of information and market power (i.e., monopolies); these factors can cause mismatches between private and social costs and benefits. Accordingly, market prices may not reflect public values, economic or otherwise.

Economists have developed a total economic value (TEV) framework to assess the full spectrum of economic values of natural resources and wildlife (Swanson and Barbier, 1992), distinguishing between use

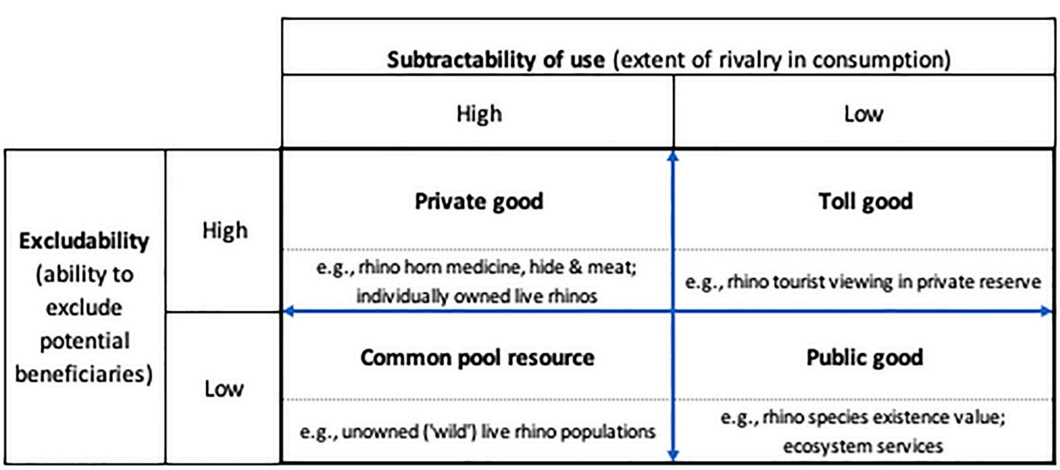

Fig. 1a. Four types of goods.
Adapted from Ostrom (2010: 645).

Regime type	Basic description	Rights	Duties
Private property	Exclusive ownership by an individual	Individuals can undertake socially acceptable uses; society can prevent socially unacceptable uses	Individuals to refrain from socially unacceptable uses; society to respect ownership and refrain from preventing socially acceptable uses
Common property	Exclusive ownership and management by a group	Assigned group members can exclude non-members; individual members have specified use privileges	Non-members must abide by exclusion; members have specified responsibilities in terms of management and use
State property	Ownership by government departments and agencies	Assigned government agencies can determine access and use rules	Society must abide by the access and use rules determined by government agencies
Non-property (open access)	Unrestricted access and use (absence of ownership)	Benefit streams are available to all	None

Fig. 1b. Property regimes.
Adapted from Bromley (1989: 872).

values, which may be direct, indirect, or future ('option value') and non-use values, which include human claims to value the mere existence of wildlife (Krutilla, 1967; Freeman, 1993). Empirical efforts to assess non-use values for rhinos suggest that these are considerable and in partial conflict with certain use values such as trophy hunting (Swanson et al., 2002). Critics of conventional economic valuation argue that TEV fails to consider other types of value that may be intrinsic (non-anthropocentric) rather than instrumental, cannot be expressed in monetary terms, and are therefore incommensurable (Aldred, 2006; O'Neill, 2017; Spash and Hache, 2021). Non-use and non-anthropocentric value sentiments represent a challenge to the credibility of market prices as a measure of the social value of rhinos, especially of their public good attributes. Nonetheless, actual market prices matter because of their ultimate influence on social outcomes (including conservation).

3.3. Policy

As with biodiversity in general, rhino conservation represents a social dilemma in the context of a complex social-ecological system—and a consequent challenge for collective action, calling for the thoughtful design of effective policy instruments and delegation of authoritative rights (see Ostrom, 1990, 2007). The economic literature on biodiversity policy evaluation recognises at least three policy instruments: protected areas, decentralization of resource management, and payments for ecosystem services (Miteva et al., 2012; Sills and Jones, 2018). In the case of rhino conservation, trade measures also constitute prominent instruments that interact with decentralization policies (but the use of payments for ecosystems services remains nascent—see Jeffries et al., 2019; Barichievy et al., 2021).

Decentralization may take one (or a combination) of two distinct forms. The first form, focused on economic efficiency, draws on insights from the literature on the problem of social cost, property rights, and transactions costs (Coase, 1960; Williamson, 1998; Demsetz, 2011; Anderson and Libecap, 2014) and promotes the establishment of robust market institutions (i.e., strong, devolved property rights and competitive contracting and trading environments that enable spontaneous price emergence through entrepreneurship). The second, more focused on equity, draws on insights from the literature on democratic natural resource governance (Agrawal and Ribot, 1999; Ribot, 2004, 2007; Larson and Soto, 2008) and promotes devolved management authority. The two forms of decentralization may work synergistically or antagonistically, depending on distributions of property rights, benefits, and costs, which are typically influenced through political processes.

The literature suggests that protected areas 'assign property rights to states or other public actors' (Sills and Jones, 2018). However, this interpretation ignores the growing complexity of protected area categories, which includes a rapidly expanding selection of privately and indigenously protected areas and hybrid institutional arrangements (Stolton et al., 2014; Borrini-Feyerabend and Hill, 2015). Whereas in historical times area-based state protection aimed to strengthen property rights over open-access resources, in contemporary contexts genuine open access to rhinos and their habitat is practically non-existent; therefore, proclaiming new state protected areas implies an approach somewhat opposite to decentralization. Furthermore, state structures themselves can benefit from the application of decentralization principles, such as through the conversion of government departments to independent parastatal agencies. We therefore posit a concept of centralization—being the inverse of decentralization—as a more relevant analytical policy variable for contemporary rhino conservation than protected areas.

(De)centralization policies can affect both property rights, with longer-term consequences, and market prices, with shorter-term consequences (see Williamson, 2000). Policymakers aiming to achieve socially optimal results (such as effective rhino conservation), should assign rights and responsibilities to actors at appropriate (i.e., matching) levels of collectiveness and physical scale. We propose that what is most appropriate will be largely determined by the nature of the specific environmental asset in question, i.e., its unique mix of private and public good attributes. Conceptually, examining the spread of potential economic values through the TEV framework can provide a sense of this mix (see Tisdell, 2004).

This leads us to two propositions for rhino conservation. The first is that decentralization policies will tend to optimize the more private attributes of rhinos, whereas a measure of centralization might attend to the more public attributes. Accordingly, rhino trophies and other exclusive use products are best provided privately by individual actors, whereas the maintenance of a (genetically robust) minimum viable population of wild rhinos implies a role for collective action, with rhino viewing tourism falling somewhere in between. The second proposition is that, given the varied and mixed attributes of rhinos, an institutionally diverse mix of appropriately focused centralization and decentralization polices will tend toward optimizing the full range of social values and thereby provide successful rhino conservation. These two propositions provide the basis of our policy analysis.

4. Methods and Data

Evaluating the effectiveness of individual policy instruments for rhino conservation is challenging, partly because of the uneven and simultaneous employment of multiple, sometimes conflicting instruments, and partly because opinions on what defines conservation success differ among scientists. To gain a deeper understanding of the plausible impact of policy interventions on rhino conservation success, we draw on principles of case study research (Gerring, 2016) to examine selected nested cases across a sixty-year period, from 1960 to 2020. The literature provides historical information on significant policy changes during this period, and we examine these in relation to sets of data we have assembled from a range of available sources. Following the theoretical framework outlined above, we classify significant policy interventions as constituting either centralization or decentralization. We treat trade-restrictive measures as a form of centralization and trade-enabling measures as a form of decentralization.

Species conservation success may be loosely defined by a composite of inter-related attributes, which may be impacted by the intensity of human management interventions that can undermine 'wildness' (Redford et al., 2011; Child et al., 2019). Successful rhino conservation is therefore not assessed in terms of rhino numbers alone but also the extent to which viable (genetically healthy) rhino populations continue to play a functional ecological role in natural landscapes, subject to ongoing evolutionary processes. These principles guide the policies and actions of government agencies and NGOs that support African rhino conservation. However, given the continued attrition of rhino populations due to poaching and habitat fragmentation—and a desire for quick recovery—contemporary African rhino conservation policies also typically aim to optimize population growth rates through specific management interventions (see 't Sas-Rolfes et al., 2022), and basic population data provide a useful first approximation of conservation success. For our purposes we therefore focus on recorded population trends (i.e., annual rhino numbers) at country levels to assess basic performance, before considering other factors such as the retention of adequate population sizes ($n > 100$) under suitably wild conditions (following Emslie and Brooks, 1999).

The information on international and national policy changes and available country-level rhino population trends and poaching data enables us to evaluate four questions through a combination of natural experiments (Dunning, 2012) and process tracing (Bennett and Checkel, 2014; Beach and Pedersen, 2019)—see S2 for further elaboration on the use of these methods for comparative institutional analysis. Additional price data time series enable us to consider the fourth question in more detail by highlighting market intermediation effects. The four questions can be formulated as the following testable hypotheses:

1. Biophysical rhino species traits are the principal determinant of conservation success.
2. Centralization through trade restrictions results in conservation success.
3. Institutional diversity within range states is positively related to conservation success.
4. Decentralization through stronger (devolved) property rights and market pricing supports conservation success.

4.1. Data

Data on rhino populations are collated by the IUCN Species Survival Commission's African Rhino Specialist Group. Whereas isolated local records of rhino numbers have existed since the late nineteenth century (e.g., southern white rhinos in South Africa), the first attempt at an Africa-wide population estimate took place in 1980 (Western and Vigne, 1985; Hillman Smith, 1981) and there have been regular continental surveys since then, enabling the creation of a comprehensive rhino numbers database amenable to country-specific trend analysis from ~1973 onwards. Population estimates vary in quality; prior to 1970 continental estimates were more speculative; the subsequent two decades were more accurate and precise, and from 1992 onwards considered most reliable, until the end of 2017, following which some data for South Africa remained incomplete. Comprehensive records of African rhino poaching incidents by range state exist from 2006 (Knight, 2020).

Although there is no official systematic collection of all relevant price data for live animals, hunting trophies, or rhino horn, indicative data (of varying quality) can be assembled from a wide range of sources. Live price data have been assembled from various sources (mostly South African public auction records), using the mean value from the largest available sample for each year. Data on trophy fees were recently collated by 't Sas-Rolfes et al. (2022).

Data on rhino horn prices have been collected erratically since at least the mid nineteenth century (see, for example, Ellis, 1994; Martin, 1979). Following the 1977 CITES trade ban, a few consumer countries continued to record import values until the early 1980s (see Leader-Williams, 1992) but the progressive implementation of law enforcement has gradually driven almost all persisting market activity underground, thwarting any attempts at reliable standardized monitoring of price trends. S3 contains further information on data sources. All prices have been converted to US dollars, using annual nominal rates of exchange, and adjusted to 2021 values using the same deflators as 't Sas-Rolfes et al. (2022).

5. Analysis and Results

We start our analysis by considering whether rhino conservation success may be largely attributed to species characteristics, given that white and black rhinos have distinct biological and behavioural traits that may affect their value to humans and potential extinction risk. White rhinos are more gregarious and docile grazers and typically more easily accessible to viewing tourists (and poachers) in open habitats, whereas black rhinos are more solitary and aggressive browsers and less easily seen by casual viewing tourists as they typically spend daylight hours in denser thickets. White rhinos also yield larger horns (with an average mass of ~5.9 kg per animal versus ~2.7 kg for a black rhino—see Pienaar et al., 1991) and are far more easily managed as free-ranging livestock, whereas black rhinos' temperament render them effectively unsuitable for this.

The species effect can be assessed from a simple natural experiment. Whereas the fate of the two African species has varied since 1973, as illustrated in Fig. 2, the fate of the two geographically separated but near-identical white rhino subspecies has varied even more dramatically. In 1960, northern white rhino numbers stood at ~2360 across 4–5 countries (Emslie, 2020a; Emslie and Brooks, 1999) and southern white numbers were around half that (~1250) in only one location (see Linklater and Shrader, 2017). By 2010 northern white rhinos were functionally extinct in the wild and southern white rhino numbers stood at ~20,160 across 9 range states, providing the world's greatest rhino recovery success story. Even if optimal white and black rhino

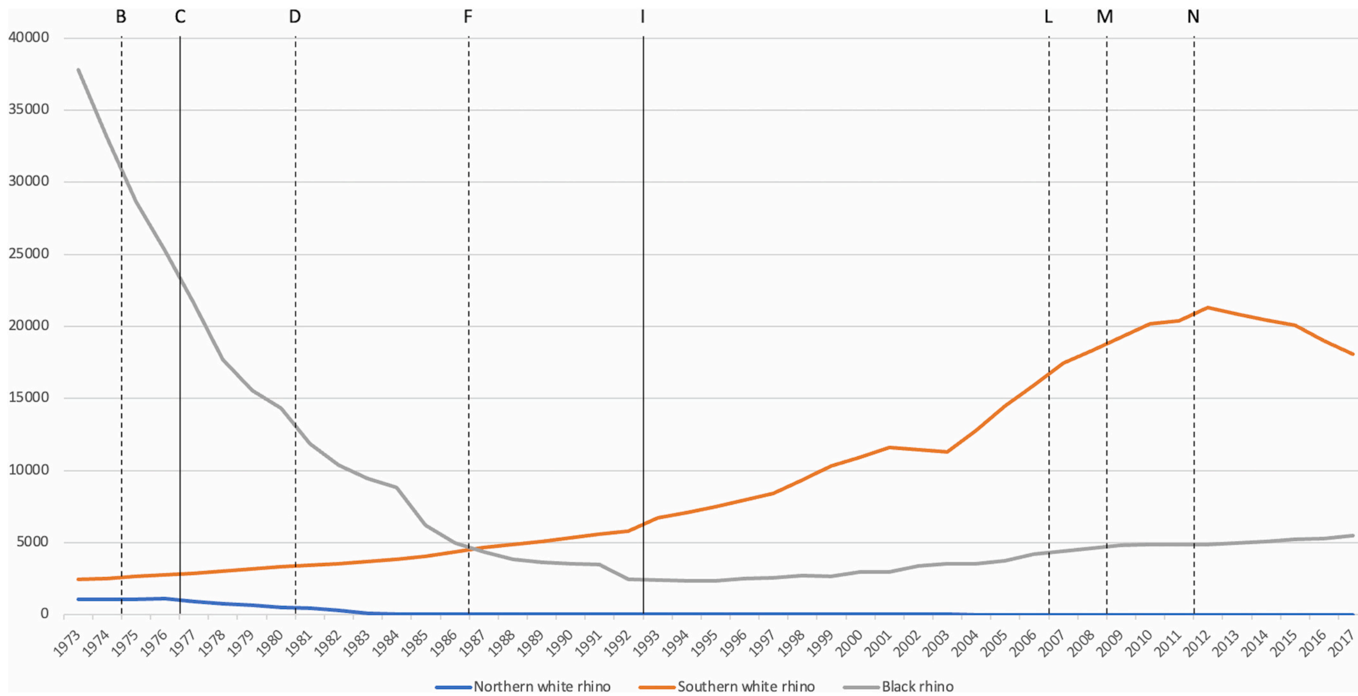

Fig. 2. Rhino numbers and trade restrictions.

Table 1
Significant regulatory interventions.

	Year	Intervention/measure		Jurisdiction(s)		Species affected		Description
		Type	*Name*	*International*	*National*	*White*	*Black*	
A	1969	Regulation	Natal legislative reform		SA (Natal only)	x		Easing of provincial legislation to enable legal hunting on private land
B	1975	Trade	CITES listings	All CITES signatories		x		CITES App I listing all rhinos except black
C	**1977**	**Trade**	**CITES uplisting black rhino**	**All CITES signatories**		**x**	**x**	**CITES App I listing black rhino**
D	1981	Trade	CITES Res Conf 3.11	All nations		x	x	Calls on non-CITES parties to participate; moratorium on government stocks
E	1986	Trade	Auctions - white rhino		SA	x		First live white rhino auctions from state
F	1987	Trade	CITES Res Conf 6.10	All nations		x	x	Prohibit domestic trade; destroy stockpiles (non-binding)
G	1990	Trade	Auction - black rhino		SA		x	First live black rhino auctions from state
H	**1991**	**Ownership**	**Game Theft Act**		**SA**	**x**	**x**	**Statutory recognition of private wildlife ownership in South Africa**
I	**1993**	**Trade**	**US Diplomatic pressure (Pelly Amendment)**	**Rhino horn consumer countries**		**x**	**x**	**Domestic trade restrictions in consumer markets**
J	1994	Trade	CITES down-listing	All CITES signatories	SA	x	x	CITES App II listing for SA white rhino; hunting trophies and live sales
K	2004	Trade	CITES trophy export quotas	All CITES signatories	SA, Namibia		x	Establishment of annual quotas for black rhino hunts in South Africa and Namibia
L	2007	Regulation	ToPS regulations		SA	x	x	Tighter permitting regulations affecting management and trade of both species
M	2009	Trade	SA domestic moratorium		SA	x	x	Domestic rhino horn trade moratorium for CITES compliance
N	2012	Regulation	TH norms and standards		SA	x	x	Tighter regulation of trophy hunting to deter potential horn trade

Note: Shaded areas constitute centralization interventions, unshaded areas constitute decentralization. Interventions of major significance in **bold**.

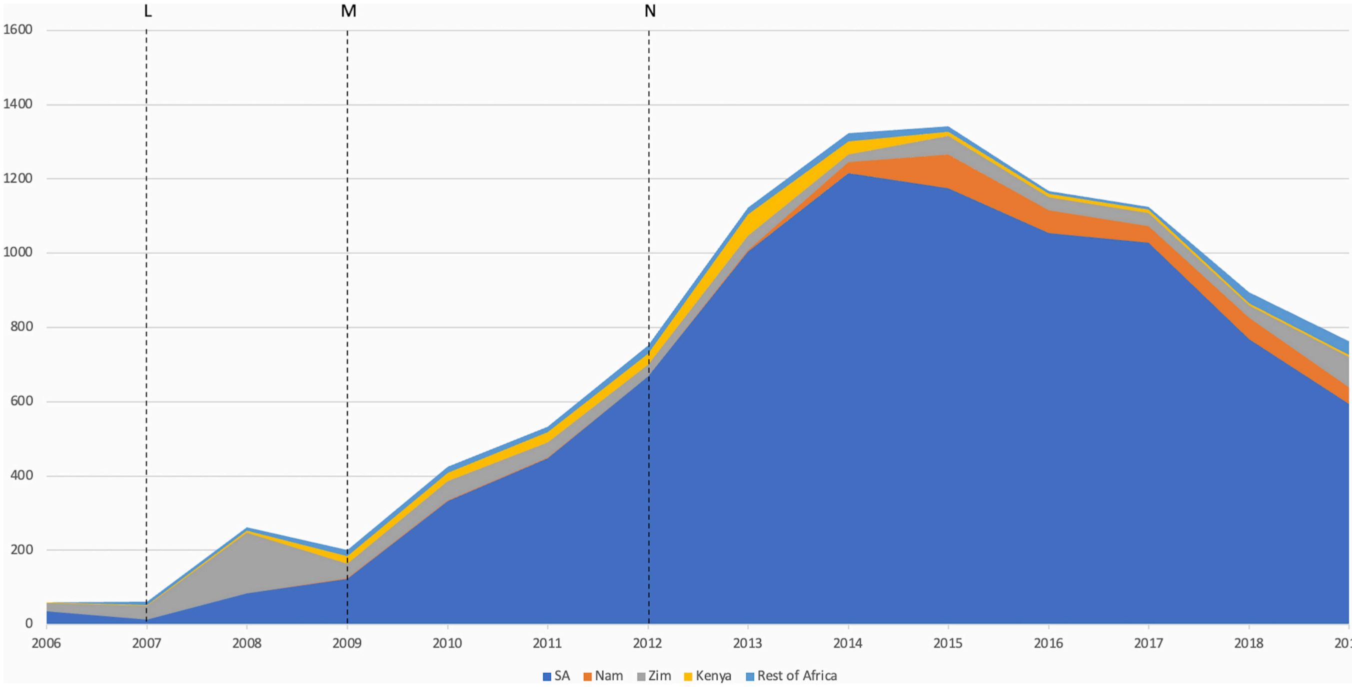

Fig. 3. Rhino poaching numbers by country.

management strategies may vary, we can reject the hypothesis that species characteristics alone are the principal determinant of conservation success. We therefore turn to examine institutional variation as a causal factor.

Next, we consider the extent to which attempted centralization by way of trade restrictions may account for conservation success, by examining the response of recorded rhino numbers and subjecting this hypothesis to a process tracing hoop test (Collier, 2011; S2), for which a positive post-intervention response is at least necessary for affirming causal inference. Returning to Fig. 2, we observe the effects of eight instances of tightened restrictions (indicated by vertical black lines, and drawn from Table 1), two of which we consider as most significant (indicated by the solid lines), namely the listing of all rhino species on CITES Appendix I by early 1977 and the banning of domestic rhino horn trade in key consumer markets in 1993. The latter event constitutes the only observable positive change of fortune for a species, as the decline in black rhino populations was reversed following this event. However, none of the other seven instances appeared to be followed by a significant positive change for black rhinos (or for northern white rhinos).

Southern white rhino numbers increased throughout the early period but started to decline as poaching levels increased rapidly following the imposition of the latter three sets of restrictions in South Africa from 2007 to 2012 (see Fig. 3). These trade-restrictive measures also resulted in no discernible effect on the three Asian species, numbers of which followed relatively uninterrupted trends throughout this period (i.e., one up, one down, one stable); furthermore, two African and at least one Asian rhino subspecies have become extinct in the wild since 1993 (Di Minin et al., 2022) and trade restrictions alone have therefore also clearly failed to conserve diversity within the rhinoceros family.

Other than the reversal of black rhino decline following domestic trade bans in key rhino horn consumer markets in 1993 (e.g., China), the evidence that trade restrictions account for rhino conservation success is weak and we therefore examine more specific institutional variation within range states as a potential stronger explanatory factor, for which

Table 2
Rhino conservation success by country category.

Category 1			Category 3		
South Africa	**W, B***	17,761	Angola	(b)	–
Namibia	**B, W***	2,832	Cameroon	(b)	–
Kenya	**B, W***	1,258	CAR	(b, w)	–
Zimbabwe	**B, W***	887	Chad	(b, w)	##
			DRC	(w)	##
Category 2			Ethiopia	(b)	–
Botswana	**W***, B*	502	Mozambique	W* B*	30
Malawi	B*	28	Rwanda	B*	19
eSwatini	W*, B*	87	Somalia	(b)	–
Tanzania	**B***	160	(South) Sudan	(b, w)	–
Zambia	B*, W*	62	Uganda	W* (b)	22

Notes
Each listed country followed by species present and total number of rhinos at end 2017.
Extant rhino species indicated by W for white and B for black, with more abundant species first.
Populations of >100 indicated in bold.
Populations supplemented by imports indicated by an *.
Extinct populations of either species indicated by small letters in parentheses.
Small numbers of black (Chad) and southern white (DRC) rhinos were introduced in 2018.

we can draw on another natural experiment. A continental survey in 1979–1980 identified 20 African rhino range states (Hillman Smith, 1981). We divide these into three categories (Table 2).

The four Category 1 countries retained wild populations of their indigenous rhino species of >100 individuals throughout the subsequent period, although all also imported (relatively small) additional numbers. The five Category 2 countries saw official numbers of each species drop below 50 by 1995 but were able to recover them somewhat with assistance from imported reintroduced animals. The eleven Category 3 countries saw their indigenous populations poached to extinction (this includes all the former northern white rhino range states); three of those countries subsequently benefited from small reintroductions by 2017 (and a further two in 2018).

We find significant institutional differences between the three country categories. All Category 3 extinctions took place in a context of centralized state protection (and no institutional diversity). All Category 2 recoveries have involved parastatal or non-state actors as management partners (e.g., allowing NGOs to play key roles in managing specific local populations). Following the lead of South Africa, the Category 1 countries have all variously embraced significant decentralization reforms and consequent institutional diversity that includes a substantial role for non-state actors, including private landowners. The exact nature and timing of this emergent institutional diversity varies between the four countries. South Africa has the highest diversity with a wide array of models, ranging from state agency ownership and management to full private ownership of land and rhinos. The private sector plays a substantial and growing role relative to the state (Ferreira and Dziba, 2021). Namibia allows private ownership of white rhinos and although the state retains ownership of black rhinos, it has created a custodianship programme whereby communities and private landowners may benefit from the presence of the species on their land through income from wildlife tourism and limited permitted hunts. In both South Africa and Namibia, the regulated sale of hunting experiences (with legal hunting trophy exports) is employed as a deliberate conservation strategy for both rhino species (see 't Sas-Rolfes et al., 2022, for further detail).

Kenya maintains a commercial hunting ban that was implemented in 1977 but allows custodianship of rhinos on private land. All rhinos on state land are managed by Kenya Wildlife Services (KWS), a parastatal that is empowered to retain and reinvest income from wildlife tourism (Wanyonyi, 2012). KWS was formed in 1989, the year in which Kenya's rhino numbers reached their lowest point before starting to recover. Zimbabwe's institutional arrangements also enable the custodianship of both species on private conservancies and these privately protected populations accounted for >90% of numbers in 2018 (Zimbabwe Parks and Wildlife, 2019), up from ~38% in 1994. Fig. 4 illustrates the performance of the four Category 1 countries for both rhino species relative to the rest of Africa, from 1973.

Whereas the (southern) white rhino recovery represents the most notable achievement during the study period, the preceding analysis suggests that factors other than species characteristics are more critical in determining rhino conservation success, which appears to be correlated with institutional diversity, including a substantial measure of decentralization, most prominently in South Africa. Conversely, we lack robust evidence that trade-restrictive centralization measures have had positive effects. However, since the first five trade-restrictive instances (between 1975 and 1993) were international in scope, there is no counterfactual that enables us to infer whether the growing rhino populations in South Africa during that time would still have thrived without the imposition of these restrictions. Nonetheless, the fact that by 1993 South Africa accounted for ~78.5% of African rhino populations (~94.4% of the white and 33.8% of the black) suggests that its domestic institutions deserve closer scrutiny.

We therefore turn to focus on South Africa and observe that following the provincial legislative reform affecting white rhinos in 1969 (i.e., initial easing of hunting restrictions), nationally relevant decentralization (trade-enabling) measures were implemented for white rhinos in 1986, 1991, and 1994, and for black rhinos in 1990, 1991, and 2004 (ref. Table 1). For both species, the most significant reform was the promulgation of the 1991 Game Theft Act, which established a basis for strong private property rights over live wild animals, in both cases also preceded by the introduction of state to private live rhino auctions and later followed by CITES measures to facilitate the export of rhino hunting trophies.

Fig. 5 reflects reported numbers of each species from 1970 to 2017/18 (white rhino in light grey, primary Y-axis; black rhino in dark blue, secondary Y axis at scale = 0.1), as well as total numbers poached (in red, scaled with primary Y-axis), indicating the points at which the decentralization measures were implemented (in green) as well as centralization measures (in black, with solid lines indicating more significant events and dashed lines indicating less significant ones). Measures relevant to only one species are indicated with an arrowhead. We highlight four distinct periods along this timeline, separated by vertical yellow lines.

During the first period (Period 1, 1970–1985) white rhinos were provided by the state to private landowners at low cost and many of those were legally hunted for commercial gain. Black rhinos occurred on

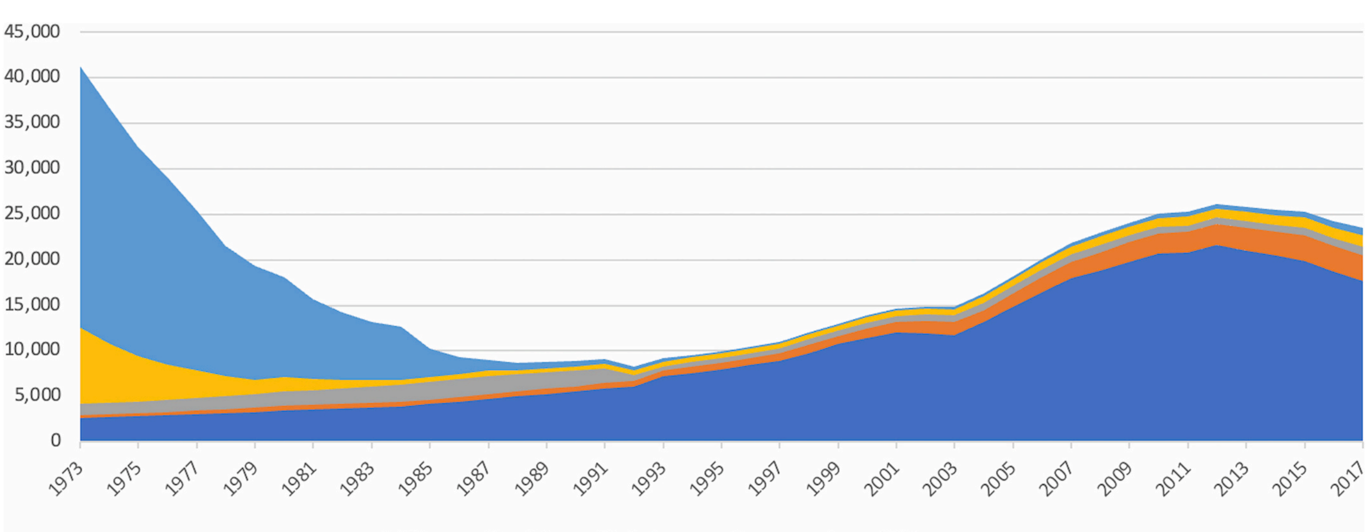

Fig. 4. African rhino numbers by country.

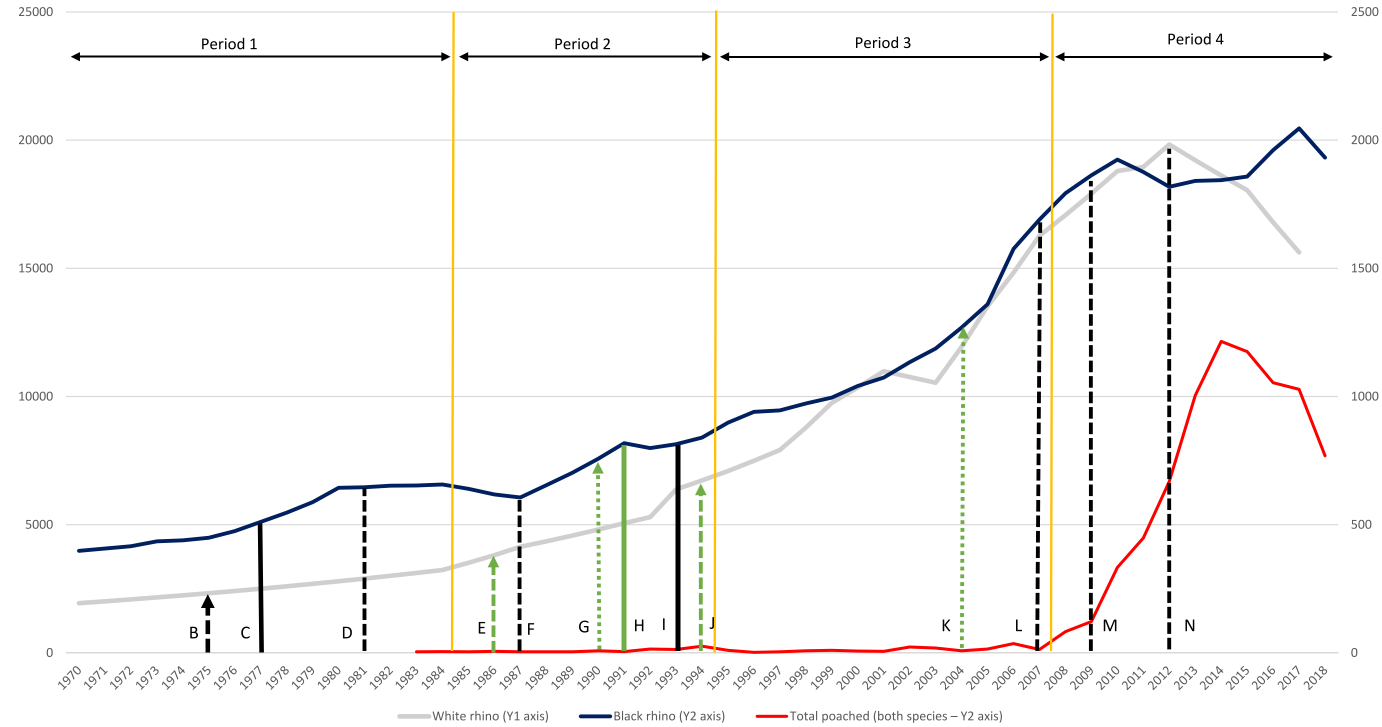

Fig. 5. Black and white rhino numbers in South Africa.

state land only and South Africa was essentially unaffected by rhino poaching. Period 2 (1986–1994) was characterized by various decentralizing domestic legal reforms during a period of greater political instability and uncertainty leading up to South Africa's transition to democracy (in 1994). Rhino poaching increased slightly during this time, prior to the imposition of domestic market restrictions in key Asian consumer countries (in 1993).

Period 3 (1995–2007) was characterized by growth and spread of rhino populations on private land, following the earlier decentralization reforms and the implementation of a black rhino range expansion programme from 2003. Poaching was limited, but from 2003 some legal white rhino hunts were used to channel horn to illegal Asian consumer markets, indicating rising demand and prices. Black rhino trophy exports were approved in 2004 and legal black rhino hunts commenced in 2005, followed by a spurt of accelerated growth in black rhino numbers. Period 4 (2008–2018) was characterized by the imposition of increasing legal restrictions (on trade-related activity) and the surge in rhino poaching, which had clear negative impacts on their numbers.

The variable slopes of the two curves indicate that that overall population growth performance for both species increased each Period from Periods 1 through 3, but then deteriorated markedly in Period 4. Periods 2 and 3 stand out as the most successful for both species, suggesting that the role of decentralization policies deserves closer scrutiny.

To provide further insight on the possible mechanisms and effects of (de)centralization policies, we examine market price data for white rhino trophy fees and live sales over the period 1982–2018. Fig. 6a illustrates the 3-year moving average of actual US$ prices of each; Fig. 6b illustrates the proportional difference between trophy and live prices (expressed as a percentage premium: red dotted line) and a poaching index (rhinos poached as percentage of total x100: red dashed line) in relation to white rhino numbers (dark grey line; secondary Y axis). Although excluded from the Figure due to deficient data, we note that wholesale African rhino horn prices were thought to be increasing dramatically by the start of Period 4, with a peak in 2013 at an estimated US$65,000/kg in East Asia, following which they declined gradually to between roughly 29–43% of that price (i.e., US$19,000–28,000) at the end of 2017 (Hall-Martin et al., 2009; Vigne and Martin, 2018).

Fig. 6 thus illustrates the relationship between legal market prices of rhinos and population performance, which we interpret as follows. In Period 1, state-subsidized live prices in an environment of insecure property rights enabled a substantial trophy price premium and failed to encourage private investment in white rhino breeding. In Period 2 the subsidy was removed with the introduction of live auctions (E), following which both live and trophy prices rose rapidly to reflect the growing market demand and changing attitude toward private breeding, further enhanced by the Game Theft Act (H). However, with a growing threat of poaching and political uncertainty, these trends reversed somewhat during the early 1990s in the lead up to democratic elections, with a downward adjustment in prices and slight increase in the trophy premium; however, growth in numbers was not adversely affected by this and still exceeded Period 1 significantly. In Period 3, following a peaceful political transition, live prices rose gradually and converged toward stabilized trophy fees, reducing the trophy premium, as white rhino numbers rose steadily. However, in Period 4 the combined resurgent threats of poaching and imposition of more restrictive trade policies (L–N) was accompanied by diverging prices, with trophy fees rising markedly and live prices starting to fall, while population growth slowed down and then started to decline. By the end of this Period, the trophy premium had surpassed the pre-election (1993) level, and the population was on a downward trajectory.

The data visualisations in Figs. 5 and 6 enable a hoop test of the hypothesis that decentralization through stronger property rights and market pricing causes conservation success. For both species, rhino numbers and population growth rates increased following all decentralization interventions and these trends were only reversed following the implementation of counteracting recentralization interventions. Closer analysis of white rhino price data suggests that decentralization interventions support relative increases in the market value of live animals, which act as an intermediary causal influence of conservation success. It further suggests that factors such as political stability and illegal market prices of rhino horn are also relevant, but this does not negate the decentralization hypothesis from passing the hoop test. Assessed in terms of rhino numbers at country level, rhino conservation has appeared to benefit more from decentralization policies and less

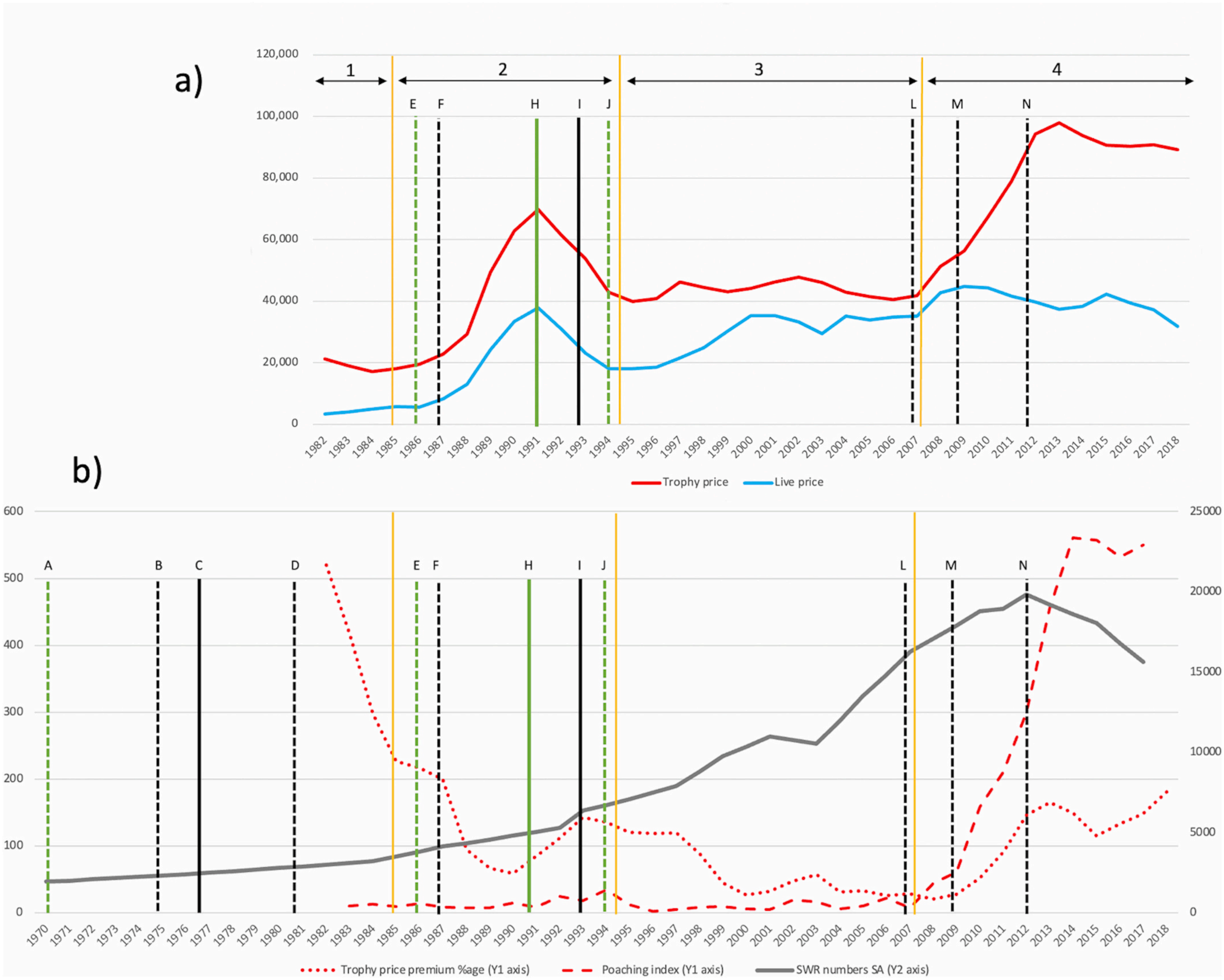

Fig. 6. White rhino trophy and live prices (a); numbers and trophy premium (b).

from centralization policies, which, with only one exception, fail the hoop test and may even be detrimental.

6. Discussion

Our analysis affirms that species characteristics alone do not determine rhino conservation success, that trade restrictions alone do not account for success, that countries with greater institutional diversity demonstrate greater success, and that decentralization policies that devolve authority, strengthen property rights, and boost the market values of live animals appear to perform significantly better than (re) centralization policies. These findings are consistent with our theoretical framework, which suggests that because African rhinos have both public and private good attributes, a diverse set of institutional arrangements (involving both public and private actors) is most likely to be optimal. Given the relatively high economic values of private rhino goods such as trophies (as indicated by market prices), a significant role for non-state actors is appropriate if such goods are to be legitimately provided. Furthermore, the efficient legal provision of such private goods supports higher market values for live animals linked to additional income streams that can fund range maintenance (and expansion) and essential management costs such as security.

Our findings align with those of related broader research. Property rights institutions have a first order effect on long-run economic growth, investment, and financial development, with legal uncertainty and threats of expropriation acting regressively (Acemoglu and Johnson, 2005; Weiss, 2019). Strong formal *in rem* ownership rights are furthermore found to promote individual private land conservation initiatives through varied psychological pathways across a range of extrinsic and intrinsic (non-monetary) motivations (Gooden and Grenyer, 2019; Gooden, 2019) and these results are mirrored by surveys of private rhino owners and custodians (Rubino and Pienaar, 2018; Clements et al., 2020). Performance of state, corporate, communal, and other collective ownership regimes is influenced by internal organizational incentives, determined in turn by agency factors and residual claims, and affected by group size and homogeneity (Fama and Jensen, 1983; Cole and Ostrom, 2012). Heterogeneous management systems (arising partly from institutional diversity) are found to provide net benefits to biodiversity conservation through socio-economic and ecological functional diversity, which supports social-ecological resilience (Child et al., 2013; Walker et al., 2004).

These findings also align with those of a substantial body of recent empirical research focused on rhino conservation. For example, Hübschle (2016) found that (re)centralization policies lacked social legitimacy among critical actors, including public officials, and were thus undermined. Surveys of Asian consumers reveal significant persistent residual demand for rhino horn despite almost three decades of prohibition and supporting measures (e.g., Hanley et al., 2018; Dang Vu and Nielsen, 2018; Cheung et al., 2021). Systematic literature reviews reveal that the evidence that trade restrictions deliver long-term conservation success for terrestrial megafauna is both limited and weak (UNEP, 2019; 't Sas-Rolfes and Hiller, 2021). Centralization policies underpinned by use of militarized force in and around state protected areas have been found to entrench inequality, alienate disadvantaged rural communities, and stimulate resistance, including poaching (Hübschle and Shearing, 2018; Lunstrum and Givá, 2020; Duffy et al., 2019). Conversely, decentralization policies have enabled the employment of managed legal hunting and trophy trade to achieve biological and socio-economic goals that enhance rhino conservation ('t Sas-Rolfes et al., 2022). Multiple surveys of private land- and rhino owners in South Africa have found that most (>80%) strongly support decentralization policies, including the legalisation of rhino horn trade, which they consider necessary to offset growing security costs (e.g., Hall-Martin et al., 2009; Rubino and Pienaar, 2018; Chapman and White, 2020a; Clements et al., 2020).

Our findings are subject to certain caveats. Whereas hoop tests suggest that decentralization measures outperform centralization measures as causal factors of success, at least one targeted centralization-supportive measure appears to have made a temporary positive contribution to rhino conservation—i.e., the 1993 domestic trade bans in rhino horn consumer countries. Relatedly, other factors are also clearly influential, notably the state of socio-economic development and governance (including political stability) of a particular country (see Underwood et al., 2013; Amano et al., 2018; Kuiper et al., 2023), and the variable price and quantity components of rhino horn consumer demand, which influence poaching incentives. For our natural experiment analysis of the 20 range states, we expect some correlation between the conservation performance of the more successful countries that embraced institutional diversity (including devolution) and proxy indicators of their socio-economic development and governance. Similarly, our specific analysis of South Africa suggests some correlation between periods of greater political stability and improved performance. That analysis also indicates a disruptive effect of significantly rising wholesale rhino horn prices, which is challenging to separate from the impact of (re)centralization policies, although there is clear evidence that rising prices pre-date the onset of the poaching surge by at least four years (Hall-Martin et al., 2009; Gao et al., 2016).

As a further caveat, species differences do appear at least partly relevant to conservation success. The biophysical differences between white and black rhinos shape distinct potential approaches to achieving optimal conservation outcomes. White rhinos are better suited to both a wider range of tourism operations and more intensive management and husbandry practices, enabling the establishment of secure semi-wild breeding operations, as currently practiced by several private actors ('t Sas-Rolfes and Fitzgerald, 2013). Such operations have grown substantially over the last decade, with the largest poised to play a potential critical role as a source for restocking extensive areas (Emslie et al., 2019). However, the existence of these operations, most of which routinely dehorn their animals as an added security measure, raises concerns over their potential to become driven by purely commercial considerations, especially if harvested horn is sold for profit. This could incentivise practices such as selective breeding for enhanced horn growth and shift the trajectory of genetic evolution away from what might be considered as natural for the species toward 'domestication'. Unlike black rhinos, white rhinos are therefore susceptible to another route to extinction in the wild, i.e., via a loss of wildness.

A recent policy deliberation in South Africa revealed stark differences in opinion as to how the recent trend toward intensive white rhino management should be addressed (DFFE, 2020), with a majority view calling for a policy shift away from domestication but failing to consider potential impacts on property rights that would amount to further, potentially counterproductive, centralization. Whereas the creation of stronger (private) property rights over wild animals is typically associated with a transition from natural selection to economic selection (Lueck and Torrens, 2020), such 'domestication' may not be inevitable for a species if strong property rights to individual animals in wild conditions can be established at sufficiently low net transactions costs, which could be achieved through a combination of appropriate technology and 'smart' regulation (Gunningham and Sinclair, 2017). Notwithstanding such possibilities, many resist the notion of humans owning wild animals on ideological grounds, linked to their ethical disapproval of physical animal commodification and concerns for the welfare of individual animals that are subject to any form of harvest (see 't Sas-Rolfes and Gooden, 2023). The latter could be addressed through pragmatic compromise solutions that can potentially deliver welfare outcomes that are superior to the status quo of high poaching incidence and substantial associated animal suffering (Derkley et al., 2019).

Intractable ideological objections to decentralization measures such as private wildlife ownership and legal commercial harvesting are influenced by the internationally dominant framing inherent in the contemporary North American Model of wildlife conservation. However, there has been a notable exception to the application of the model within the USA itself. Following its near extinction, the American bison was reclassified as an agricultural animal in some jurisdictions and therefore not subject to the stringent conditions imposed on other wild species. Bison recovery in the USA over the last century has thus taken place in the context of widespread private ownership, market harvesting, and trade in harvested bison products such as meat (Sanderson et al., 2008). Whereas some ecologists question the conservation value of the bison recovery (Freese et al., 2007) a minimum viable population of wild bison remains secure and there are recent private initiatives to expand wild populations and their range (Lueck, 2018). This raises the question as to whether a similarly commercially valuable large herbivore such as a white rhino should be subject to more stringent restrictions in a developing country context, given evidence from South Africa that small, mostly private reserves have substantially outperformed the large publicly protected Kruger National Park in controlling poaching (Ferreira and Dziba, 2021).

Our research results yield one clear policy implication: any reversals of previously successful decentralization measures should be exercised with great caution, with due attention to the possible perverse effects of weakening property rights and undermining the market asset values of live wild animals and their range. Whereas the state may be regarded as having a social-ecological obligation to maintain genetically robust minimum viable populations of wild rhino species, their efforts may be boosted through effective partnerships with non-state actors, enabled by smart regulation grounded in decentralization principles. Such non-state actors could include local community structures, following varied nascent examples of community-based rhino conservation initiatives in Namibia, Kenya, South Africa, and Zimbabwe.

Our results also point to potentially fruitful areas of further research. The first concerns further examination of the consequences of cross-scalar institutional mismatch, highlighted by the tensions between CITES and its North American Model logics and the successful decentralization measures implemented in Southern African countries. Second, the links between relevant biophysical and institutional notions of 'wildness' and elucidation of tractable and policy-relevant definitions deserve further attention. Finally, there is considerable scope for further fine-grained comparative analysis of conservation institutions in relation to their performance, also using other methodological approaches such as multivariate models and statistical methods. In the case of rhino conservation, a useful next step would be to further examine the critical role of non-state actors in rhino conservation, with a view to forging more nuanced constructive institutional links across sectors and scales.

CRediT authorship contribution statement

Michael 't Sas-Rolfes: Conceptualization, Data curation, Formal

analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Visualization, Writing – original draft, Writing – review & editing. **Richard Emslie:** Data curation, Formal analysis, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolecon.2024.108123.

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