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How illegal wildlife trade adheres to and defies conventional market behavior

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Illegal wildlife markets comprise a complex global economy generating criminal profits while harming biodiversity and livelihoods. The negative externalities from biodiversity loss, ecosystem destabilization, and zoonotic disease risk may be orders of magnitude larger than the multibillion dollar annual total market value. Despite decades of international policy attention, fundamental economic characteristics of these markets remain poorly understood. We suggest distinguishing three categories of illegally traded wildlife products based on product durability and intended use: luxury durable goods, nondurable products processed to be food or medicine, and live or perishable exotic pets and plants. Through case studies of elephant ivory, pangolin scales, and succulent plants, we characterize market organization, pricing structures, supply network architecture, and regulatory vulnerabilities across product types. Our analysis suggests illegal wildlife markets exhibit economic characteristics distinguishing them from other illegal markets, including biological production constraints creating absolute supply limits, opportunistic supply networks exploiting existing legal trade infrastructure, and extreme markup structures leaving harvesters with a fraction of final retail value. We conclude by proposing the concept of Accelerating Demand for Novel or eXclusive Assets, or AD NOXA, which describes how scarcity may paradoxically increase rather than decrease the appeal of consuming certain wildlife markets. This paradox creates feedback loops that may drive species toward extinction, despite—or because of—protective regulations and fundamentally limits the effectiveness of supply-side interventions. Policy responses may be more effective when they integrate supply-side enforcement with demand reduction strategies tailored to the distinct characteristics of illegal wildlife markets.

illegal wildlife trade | elephants | illicit markets | wildlife trafficking | pangolins

Significance

Illegal wildlife markets threaten biodiversity conservation, ecosystem stability, and local livelihoods, and their dynamics sometimes challenge conventional economic assumptions underlying typical policy responses. Conventional supply-side strategies assume rising scarcity increases prices, thereby reducing demand and allowing populations to recover. For some high-value wildlife products, the opposite can occur: scarcity signals exclusivity, potentially making endangered species Veblen goods for which rarity accelerates rather than dampens demand. This could create feedback loops driving species toward extinction rather than economic equilibrium. Unlike manufactured contraband, wildlife faces absolute biological production limits that cannot be technologically overcome, meaning supply restrictions and trade bans that typify policy responses may be insufficient or counterproductive for some products with inelastic demand.

At least since the third century BCE, when the Edicts of Ashoka prohibited the killing of animals with aesthetic value on the Indian subcontinent, wildlife has been trapped, harvested, and sold in contravention of laws (1). Today, wildlife is traded illegally and legally as food, trophies, medicine, pets, medical research subjects, luxury goods, cultural symbols, and more. Like other illegal markets, many nodes in illegal wildlife supply chains are clandestine (2, 3), so information on market prices and transaction volume is sparse and imprecise. Illegal wildlife markets (IWM)—the social and economic structures that facilitate prohibited trade—comprise hundreds of thousands of unique goods, though the bulk of the value of trade lies in a much smaller subset (4). The value of IWM in aggregate is unknown. Widely cited—and widely critiqued (5)—global estimates from more than a decade ago ranged between US$5 to 20 billion (6, 7). A more recent and rigorous study estimated the value of illegal wildlife entering the United States (US) at US$3.2 to 4.3 billion annually (8). While the United States is a major importer of legal wildlife (9), and illegal wildlife as well, the latter estimates of US domestic value suggest the former estimates understate the monetary value of global IWM. The negative externalities IWM generate may be orders of magnitude larger than the value of the markets themselves, depending on how people value biodiversity loss (10, 11). The detrimental impacts of IWM on biodiversity conservation, ecosystem stability, and wildlife-dependent livelihoods (12–14) tend to be most acute in the communities from which these resources are extracted (10). Despite international conventions and multilateral environmental agreements, most notably the 1972 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), weak enforcement, shifting compliance obligations, corruption, and global supply chain complexity allow IWMs to thrive (3, 4, 12, 15, 16).

Legal wildlife markets can produce benefits when they are effectively regulated and sustainable. They are associated with technological innovation, small business development, cultural preservation (17), education and awareness, global collaboration,

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population recovery among endangered species (18), and ecosystem services support (19). However, not all legal markets are well regulated. Poorly managed legal markets, along with illegal markets, can lead to overexploitation of species that accelerates biodiversity loss (20–22), increases enforcement costs, and diffuses negative externalities including ecosystem destabilization, extinction risk, food safety risks, erosion of state authority (21, 23, 24). IWMs can threaten public health and safety through violent conflict and the spread of zoonotic diseases (5, 11, 25, 26).

Around the world, civilizations have approached human–animal relationships through distinct legal and moral frameworks. Unlike Ashoka, the Roman jurist Gaius's *res nullius* doctrine established wildlife was not protected under Roman property rights, even on common lands. This doctrine underpinned laws across nations influenced by the Roman legal tradition for centuries. It also set up conditions for overexploitation of wild game and rejection of indigenous property rights claims during colonialization, from bison and beavers in North America to elephants and antelope in Africa (27). By the early 20th century, the consequences of unregulated wildlife exploitation had begun to generate society-wide concern. Early conservation efforts, such as the 1900 London Convention and colonial game laws in Africa laid the groundwork for contemporary governance, despite being motivated by fears of depleting game for elite's access to sport hunting rather than ecological balance or community justice (28, 29). In the post–World War II era, a convergence of ecological science advancement, environmental activism, and newly independent states spurred international conservation norms (30), culminating in CITES, which established international trade regulations for listed species across 184 member countries. Trade violating these rules is generally considered illegal under members' implementing laws, creating the regulatory foundation against which IWMs operate.

CITES shifted earlier regulatory approaches marked by sovereign interests toward coordinated global governance. However, IWMs still present regulatory problems in communities where products are sourced, which are typically spatiotemporally distant from consumption markets. Hardin argued (31, 32) that because individuals and companies are self-interested, they tend to overexploit and deplete common goods like wildlife—rivalrous or limited natural resources for which property rights are difficult to establish or enforce—resulting in long-term harm. Harms from IWMs manifest in myriad ways. In communities living around places where protected species are illegally extracted, salient harms from overexploitation include diminished food security, public health risks, and cultural and traditional resource loss. These harms are difficult to monetize but their impacts may be large (33).

Materials and Methods

In this article, we describe the contemporary dynamics of IWM through the lens of economic reasoning, demonstrating where market functions adhere to or defy conventional market behavior. Our review excludes timber and fisheries, which each merit separate treatment (34). We describe IWMs using a categorization system for understanding supply and demand across both products and their markets. We use the categorization system to review the economic fundamentals of IWMs in terms of market scale, price, and demand elasticity; supply network structure; and regulatory and enforcement capacity. Each section begins with general principles, establishing the foundations relevant to that aspect of market behavior. Our discussion is illustrated through three IWM products: elephant ivory, pangolin scales, and succulent plants (hereinafter succulents). These products have been studied in prior work and demonstrate variability across key market characteristics. While they do not encompass all species for which IWMs exist, they represent economically significant products across each of the three categories and offer sufficient data to illustrate the economic dynamics we examine. These case studies serve to broaden understanding of IWM and differences therein. Thousands of IWM exist. They cannot be reduced to basic elements without critical loss of information, and the vast majority of IWMs have not been studied in detail.

Disclosure of Delegation to Generative AI. According to the GAIDeT taxonomy (2025), the following tasks were delegated to GAI tools under full human supervision: Proofreading and editing. The lead author (Midgette) used Anthropic Claude Opus 4.6 to assist with manuscript editing to improve concision and grammar.

A Simple Categorization of Products in Illegal Wildlife Markets. IWMs operate under discrete physical market constraints. Biological reproduction rates and habitat availability inherently limit production capacity. Unlike markets for illegal drugs, which have increasingly been replaced by synthetic alternatives (35, 36) or other manufactured contraband, IWM's ecological limits prevent indefinite scaling of supply. Demand for some IWM products appears to be highly inelastic among the consumers who remain despite international efforts to curb supply and demand. The limited available evidence on market dynamics suggests demand among remaining consumers may sometimes be perniciously based on their scarcity, organic quality, and wild-caught provenance, thereby limiting opportunities for synthetic or otherwise sustainable substitutes. This Veblen good dynamic–when utility increases as a function of higher prices associated with exclusivity–affects market participation and can cause supply control efforts to have perverse effects.

Of the estimated 8 to 20 million species on the planet (37), the CITES Secretariat regulates approximately 40,000 under three Appendices arranged by the degree of restrictions on trade. Much of the literature, including this paper, focuses on the approximately 1,100 species in CITES Appendix I as of November 2025, which are threatened with extinction and for which transnational commercial trade is prohibited. Approximately one-quarter of Appendix I species are plants, whereas nearly 90 percent of Appendix II listings are plant species. Appendix II includes species that are not currently at risk of extinction but are subject to trade controls to prevent unsustainable exploitation. Legal trade in CITES-regulated Appendix II and III products generates an estimated US$2 billion annually (4). The value of Appendix I species trade is unknown, but likely also on the same order of magnitude. Although the illegal trade of Appendix II and III species and derivative products may be substantial, the extent of those markets remains very difficult to quantify since they are frequently laundered into legal markets. CITES Appendix III covers approximately 300 species that are unilaterally protected by one or more countries seeking international cooperation in trade monitoring.

There is tremendous biological diversity among the species listed in CITES Appendix I, and these species can be grouped in various ways. CITES-listed species groupings are guided by taxonomy (e.g., mammals, reptiles, arachnids) geography (e.g., Indonesian, Canadian, Oceania), or by the physical nature of the commodity driving demand (e.g., live, processed). CITES uses these groupings because its mission and legal mandate are ecological and conservation based. Here, we introduce a categorization focusing not on conservation but on economic market characteristics. This allows for parsimonious exploration of system dynamics and mechanisms. It is based on intended use and durability and includes three groups (Table 1). The first group comprises species traded as *luxury durable goods*, such as sculptures and ornaments. Luxury durable goods tend to be illiquid but high-value, often functioning as status symbols, or serving as investment-like goods (38). The second group comprises species traded as nonliving *nondurable products*. These products are often intended to be used as food or medicine, are typically derived from body parts or plant matter, and are traded in bulk. Nondurable products are often characterized by high volume and relatively low margins at the source level and substantial markups along the supply chain (e.g., pangolin scales, sea cucumbers, lion fat) (39). The third group is *perishable products*–either trafficked alive (e.g., exotic pets, ornamental plants) or dead but risk decaying (e.g., bushmeat). Perishable products may command high prices due to handling dangers to workers, mortality risk to the trafficked species themselves, and the exotic appeal of the product in its destination (40). This market-based categorization helps distinguish IWMs by economic characteristics that bear on market resilience and opportunities for disruption, such as turnover rate and storage costs, offering a foundation for analyzing variation in supply chain structure, risk exposure, and actor specialization. This categorization helps advance thinking beyond the biological units and ecologically based metrics (e.g., country of origin) associated with CITES, as well as typologies describing the transactional process of trade.

Table 1. Market-based categorization of illegally traded wildlife products

Category	Description	Examples
Luxury durable goods	High-value, long-lasting items often used for status, decoration, or collection	Ivory carvings, python-skin handbags, leather boots, taxidermy mounts, coral furniture, trophy heads
Nondurable products processed to be food or medicine	Items consumed or applied; typically derived from body parts or plant matter	Pangolin scales, bear bile, rhino horn powder, medicinal roots
Live or perishable exotic pets and plants	Organisms trafficked alive for the pet trade, ornamental use, or cultivation	Parrots, turtles, orchids, bushmeat, succulents

Focusing on the relationship between product durability and market structure helps reveal systematic differences across our categories. Industrial organization research demonstrates that storability creates strategic options unavailable to sellers of perishables. Sellers of durable or storable goods can warehouse inventory during periods of low prices or high enforcement pressure and release stock when conditions improve–a form of temporal arbitrage that requires capital, favors well-resourced incumbents, and supports tacit coordination among a small number of patient sellers (41, 42). Storage infrastructure and working capital requirements create barriers to entry, while inventory holdings serve as credible commitment devices in oligopolistic competition (43). By contrast, perishable goods markets tend toward competition precisely because sellers cannot withhold supply: each market period is effectively terminal, eliminating the intertemporal linkages through the threat of loss (41, 43, 44). Even when holding an unsold perishable good, sellers have declining opportunity costs as expiration approaches, making it individually optimal to cut prices over time (45). These dynamics help explain differences in IWMs, for example why ivory trafficking–where tusks can be stockpiled for years–concentrates among a small number of actors, while the succulent trade, constrained by plant mortality during storage and transport, remains atomized and competitive despite involving far fewer geographic source regions. The Coase Conjecture (46) provides a potentially relevant theoretical perspective: using ivory prices as an example, syndicate sellers of durable goods like ivory face competition from their own prior sales, potentially eroding market power over time. Illicit inventory destruction programs (i.e., "ivory crushes") and ongoing enforcement create uncertainty that may counteract this dynamic, allowing these sellers to maintain pricing power.

We do not attempt to estimate what proportion of global IWM falls into each category, as this would require comprehensive trade data that do not exist. However, the three categories appear to encompass the major high-value IWM products that drive policy attention: luxury durables (e.g., ivory, rhino horn, exotic bird feathers, tiger bone), nondurables (e.g., pangolin scales, bear bile, box turtle jelly), and perishables (e.g., live parrots, reptiles, ornamental plants, bushmeat). Products that resist easy categorization, such as the aptly named diabolical ironclad beetle, which is durable but usually traded alive, likely represent a small fraction of total trade value.

Characterizing Illegal Wildlife Markets Using Value and Price

Estimating IWMs' size inherits all the challenges common to any illegal market; notably, market participants hide their activities. Furthermore, there are many different submarkets. A reliable estimate of the aggregate size, and thus value, of global IWMs does not currently exist. The number of different markets renders a census impractical. Some IWMs are larger in geographic scope than others (e.g., elephant ivory is traded globally; saiga antelope horn trade is primarily constrained to East Asia). Aggregate market value may be concentrated among a few markets and products, including the three we focus on in this paper. Several efforts to estimate the size of market value start with the documented valuation of *legal* wildlife trade and then presume illegal trade is some fraction thereof. Among Appendix II species, estimates of the proportion of illegal trade within legal wildlife trade vary by species and geography, including: 10 to 25% of the total trade in reptile skins, tropical birds, and exotic pets (6) and 10 to 50% of total species from biodiversity hotspots (47). Up to 80% of wildlife labeled as being captive bred may be sourced illegally from wild populations (24). One of the only systematic and reliable recording mechanisms for collating and releasing wildlife import data across all taxa involved in trade is US Law Enforcement Management Information System (LEMIS). LEMIS is focused only on US trade. The United Nations Office on Drugs and Crime reviewed LEMIS' wildlife trade in the United States between 2000 and 2022 and reported 29,445 species were traded over 2.85 billion recorded transactions. LEMIS has some limitations, but it continues to represent the best available dataset with which to gauge the magnitude of legal wildlife trade. One point estimate of the illegal wildlife entering the United States in 2013 was US$4.3 billion, with an uncertainty range of $1.3 to 9.6 billion (8). Market value may be increasing over time; the volume of US-based seizures grew from 12,751 in 2013 to 20,762 in 2017 (6), though it is difficult to differentiate market growth from potential shifts in the intensity or effectiveness of law enforcement (48). Beyond LEMIS, estimates of IWM size that focus exclusively on a single country are less generalizable. The CITES Secretariat publishes the volume of international legal commerce reported by nations in regulated products annually, but comparable illegal activity is poorly reported. No programs exist to collect data on all 40,000+ regulated species; some estimates are available for certain high-profile species, including those selected as case studies for this paper.

Durable Illegal Wildlife Markets: The Case of Elephant Ivory

Among wildlife traded in IWMs, elephants are perhaps the most well-studied. Ivory from an elephant tusk is a durable good; ivory is a hard and dense material that is highly resistant to scratches and wear. It is long-lasting and able to be carved into intricate crafts including knife handles, jewelry, and piano keys. Elephants are large, charismatic, and are culturally and environmentally important, which helps justify their scientific study. African elephants, including savannah and forest species, are one of the few animals to be globally censused. Others include the vaquita, emperor penguin, and blue whale (49). African elephants have experienced population declines over the past five decades, as the population of forest species fell by 90% and savanna species fell by 70% (50). CITES developed two programs to standardize data on killings in over 30 elephant range countries, which provides essential biological data for conservation.

Drawing on published scientific literature and other data, the UN (2020, p.115) suggested that before global supply chain disruptions caused by COVID-19 "the annual, overall gross illicit income generated by (African elephant) ivory was estimated to be US$400 (310 to 570) million," with significant consumption markets in China, Southeast Asia, and parts of Africa. That may appear to be a low number relative to some other nonwildlife

illegal markets, but breaking the estimate into constituent parts provides important context. The UN estimate, based off the two elephant-specific CITES programs, reflect that prior to 2020 10,000 elephants were illegally killed annually, yielding about 100 tons of ivory, net of seizures. Ivory price data remain sparse, out of date, and are complicated by great price inflation as ivory moves down the supply chain, but the poachers do not earn hundreds of millions of dollars. The Global Initiative Against Transnational Organized Crime documented the price paid to *poachers* in Kenya for ivory to be approximately US$15 per kg of ivory in 1999, increasing to a peak near US$190/kg in 2014, then declining to about US$52/kg in 2018 (51); they estimated wholesale ivory prices in China were US$2,572/kg in 2014, US$1,000/kg in 2017, and US$1,500/kg in 2020.

Ivory price fluctuations may be an artifact of sparse and noisy data describing a low transaction volume market; they are not necessarily due to secular shifts in consumer demand. Substitute materials replaced ivory for practical uses decades ago (e.g., piano keys, billiard balls). Ivory remains a niche market. We do not observe strong evidence that price fluctuations trend with poaching activity, which most sources estimate is stable at low volume. While regional Southern African conservation efforts have led to stable or increasing elephant populations, those gains have been offset by poaching in other regions like Central and Eastern Africa. In 2017, the People's Republic of China shifted policy and shuttered domestic factories that refined and manufactured ivory products. This may have coincided with shrinking demand. Or, consumers who were not deterred by closures readily accepted prices reflecting larger risk premiums. Today, retail prices for ivory are presumably higher than wholesale. If one multiplied 100 t by US$4,500/kg, an arbitrary but reasonable 200% mark-up from wholesale, then the total market value in consuming countries could be on the order of US$450 million per year. That is certainly enough to drive business interests, but in the context of global illegal markets, it is not very large.

Nondurable Illegal Wildlife Markets: The Case of Pangolin Scales

Until recently, the illegal trade in pangolin scales was much less discussed than illegal trade in ivory. Today it could well be a larger generator of criminal income (52). Pangolin scales cannot be reused beyond their modal purpose, which is usually to be ground into medicinal powder or paste or boiled into tonics. The value of these nondurable goods lies in their immediate consumption (e.g., for itch relief, lactation, or traditional beliefs). Although the scales can be stored, they will dry out over time, which can impact perceptions of quality and thus wholesale prices. Pangolins typically give birth to one offspring per year, limiting the capacity of populations to recover from overexploitation (24). Estimating the average number of scales per animal is challenging because the volume of scales harvested varies with animal size, which ranges between 2 to 33 kg in total body weight depending on species and maturity. Common wisdom is that scales make up approximately 20% of an adult pangolin's mass.

All eight species of pangolin were uplisted onto CITES Appendix I in 2017. Markets for harvesting and transshipping pangolin scales are geographically diverse, but most large volume shipments are destined for China, Southeast Asia, and diaspora communities. Estimates prior to 2020 suggested 2.7 million pangolins were trafficked annually into the region (53). Recent estimates suggest significant postpandemic market contraction (54). Using the estimates of prepandemic trade of 2.7 million animals/year, 1 kg per animal, and retail prices in the hundreds of dollars per kg produce annual market value estimates for pangolin scales at over US$1 billion. China continues to allow a domestic market for pangolin scales sourced from verified government stockpiles, but has reduced the official market quota from 26.6 MT in 2015 (55) to 1 MT in 2025. The country likely remains where demand is concentrated today.

Overexploitation helped drive supply shifts from Asia to Africa after the four Asian pangolin populations shrank toward extinction levels. Regardless of geography or species, poachers receive a very small percentage of the wholesale price for scales in the final market countries. They receive an even smaller share of retail prices. Prices increase significantly as the scales move along the supply chain. The best available, but now dated, sources estimate are that 1 kg of scales that might yield a poacher in Nigeria between US$5-10. The same volume would command US$450 to 650 in illegal markets in Vietnam and China, and US$1,400 in China's regulated market (56). Wholesale markets in Africa charge less than those in Asia. These estimates are based on reporting from researchers and journalists from various points along the supply chain, including work by key stakeholders in peer-reviewed (57) and unvetted (56) venues.

Perishable Illegal Wildlife Markets: The Case of Succulents

Succulents are highly sought after for their aesthetic and practical horticultural applications, their unique appearance, and charisma. They have a reputation for hardiness but are still perishable. The roots and stems are highly susceptible to rot, and plants often die in captivity due to stress, exposure to pathogens, and inadequate substrate watering. They cannot be stockpiled indefinitely and have a short shelf life without proper care. Succulents are now among the most sought-after IWM products; demand has surged, particularly for rarer species. Plants are often concealed for transit in shoe and toy boxes, animal feed bags, and sometimes within toys or ornaments, and are shipped around the world through the postal service or private courier services.

In selected countries with data (e.g., Czech Republic, Germany, Spain, Netherlands, United Kingdom, United States, South Africa) there is a positive relationship between rarity and price. Succulents at greater risk of extinction on the International Union for Conservation of Nature's (IUCN) Red List are more expensive, as are products that are CITES Appendix-listed. Assuming US$1 equates to 20 ZAR, the price of IUCN Red Listed succulent species illegally traded from South Africa increased in these countries from US$1.25–2.5 to US$7–12 between data published in 1998 and 2023 (58). The price increases come alongside massive growth in the market. Recently, the volume of seized succulents in South Africa increased dramatically, from 58,779 plants in 2019 to 1,129,870 in 2023 (58). Interviews with individuals arrested for trafficking succulents indicate that most (79 percent) attributed their involvement to socioeconomic circumstances. Succulents have very specific ecological habitat requirements, and poachers have been caught with publicly available research articles, printouts of webpage articles, and databases detailing the location of species (58) to help in their search for rarer and more valuable plants.

Comparing and Contrasting Case Studies of Illegal Wildlife Markets

We analyze three IWM case studies that differ in product type, geographic scope, and market structure. Comparing across cases provides both replication and contrasting logic, revealing common

patterns and critical differences that species- or product-specific analyses would miss. Using the categorization introduced above, we interrogate each market in terms of supply elasticity, markups, network structure, and enforcement vulnerability to identify the enabling conditions most amenable to policy intervention.

Illegal Wildlife Market Supply Chains. IWM supply chains involve actors with specialized roles at each stage: harvesters who extract wildlife at the source, intermediaries who bundle and transport products, and retailers who serve end consumers. These supply chains typically traverse national borders because the species rarely inhabit the same regions as the consumers who want them. They also almost always piggyback on other, often legal, supply chains. This may be a practical necessity given modest dollar value of most illegal wildlife products relative to the complexity of transporting them independently, particularly those that are alive or perishable. It is also possible that the lack of rigorous enforcement along trafficking routes may make the covert tandem structure the least costly trafficking option.

Four supply chain characteristics from industrial organization research help describe IWM structure: producer concentration, vertical integration, horizontal integration, and influence of spatial proximity of sources and destinations on each. These characteristics vary systematically across IWM product types. In competitive markets like python skins for fashion or succulents, numerous actors vie for market share by streamlining logistics—automating advertising on lightly supervised e-commerce platforms, utilizing digital payments, enabling automatic language translation, and uploading photographs and videos to reach broader customer bases (59). In contrast, markets where wildlife is scarce, difficult to access, or requires specialized skills to harvest tend toward oligopoly or monopoly. Elephants, for example, require coordinated effort to locate, kill, and transport harvested ivory, favoring centralized control. Pangolins, by contrast, can be captured opportunistically by individuals with minimal equipment, enabling more distributed sourcing even as downstream consolidation occurs.

Once a trafficking network has cultivated corrupt officials or developed reliable concealment and documentation protocols, the marginal cost of adding new product lines can drop substantially. This helps explain why IWM supply chains frequently converge with transit networks for other legal and illegal markets. Concentration and integration also occur at the retail level: social media and e-commerce platforms often sell a diverse range of products, from wild-collected orchids to songbirds to small cats and frogs (60, 61). The same infrastructure, wholesalers, retailers, and corrupt officials can serve multiple IWM products simultaneously. Laundering through the legal channels is also common: illegal python skins are often mixed with legal shipments or moved using fraudulent CITES permits (62, 63).

IWMs occasionally converge with drugs and human trafficking networks (64, 65). The risk of convergence is more pronounced in conflict zones, where weak governance enables violent extremist groups to occupy protected lands such as national parks and use them as bases for poaching alongside arms trafficking and other illicit activities (66). Conflict-monitoring sources document trafficking spikes in war-affected regions which frequently overlap with biodiversity hotspots and protected areas (see, e.g., (67)).

When products are sufficiently valuable per unit weight and concentrated in exploitable locations, dedicated supply chains can emerge. Luxury handbag designer Nancy Teresa Gonzalez de Barberi pled guilty in 2024 to smuggling charges for repeatedly importing python-skin handbags by recruiting friends, relatives, and employees to carry them in passenger luggage (68). Dedicated networks also exist for exotic pets and flora. Between 2000 and 2010, over 54,000 birds were exported from the Solomon Islands under "captive-bred" permits; investigations revealed these were wild-caught birds sold through Singapore and Malaysia for re-export to Taiwan (69). Similarly, one-tenth of 441 succulent collectors interviewed by survey admitted to knowingly violating CITES regulations by transporting plants without required documentation (39).

Product perishability shapes network architecture in predictable ways. Durable goods like ivory carvings and nondurable but stable products like pangolin scales can be warehoused—some for months or years. Warehousing enables temporal arbitrage by stockpiling during enforcement lulls and releasing inventory when interdiction forces prices up. Durability also permits geographic arbitrage, with sourcing concentrated in lowest-risk regions regardless of distance to retail markets. Perishable products face different constraints. Some species of live animals suffer mortality rates as high as 60 percent during transport (70), creating powerful incentives for rapid, direct routing. Shipping costs for live animals can consume a large share of retail value, whereas shipping costs for durable goods may be negligible relative to price. Still, efficiency does not fully explain market dynamics. Traditional medicine markets sometimes require specific geographic provenance, limiting substitutability even when alternatives are more conveniently available (71, 72).

Some high-level patterns emerge despite the diversity of IWM supply networks. The transport stage tends to involve more differentiated and often professionalized labor than either harvesting or retail. Some actors purchase bush planes to move high-value products like rhino horn, though the transit stage is generally not capital-intensive—most trafficking exploits commercial shipping and passenger flights rather than using dedicated infrastructure. Transit captures a larger share of total revenues than harvesting yet still employs easily replaceable workers. An intermediary with modified luggage for concealing python skins or clothing with hidden pockets for songbirds can be easily replaced if caught. Many participants are part-time and opportunistic laborers, joining networks once or twice based on social ties rather than professional commitment (6, 73). At the retail end, many sellers in destination markets, such as traditional medicine shops, online pet vendors, and luxury boutiques, sell both legal and illegal products and are not IWM-specific (15). A salesperson may sell legal and illegal products from the same store; customers may purchase both from the same vendor legal and illegal products from the same vendor. In some cases, nominally legal entities like zoos, rescue centers, or rehabilitation facilities provide documentation cover for illegal shipments, blurring the line between legitimate and criminal operations.

Ivory Trafficking as an Oligopolistic Supply Network. Ivory supply networks exhibit oligopolistic characteristics at both the geographic and organizational levels, as do other scarce, durable, and valuable IWM goods (e.g., hawksbill turtle scute, snow leopard hide). Market entry is restricted, and a small number of trafficking syndicates control the movement of product from source to consumer markets. Forensic DNA analysis of 28 large ivory seizures (≥0.5 t) between 1996 and 2014 revealed that 85 to 93 percent of savanna elephant ivory originated from a single hotspot, the Selous-Niassa ecosystem in southeastern Tanzania and northern Mozambique. A similar proportion of forest elephant ivory was traced to the TRIDOM (Tri-National Dja-Odzala-Minkébé protected ecosystem spanning Cameroon, Central African Republic, Gabon, and Republic of Congo) (74), a potential range area that spans 37 nations. This extreme geographic

concentration has facilitated correspondingly concentrated criminal control. Subsequent research directly identified the actors by matching DNA from separated tusk pairs across different shipments—finding both tusks from the same elephant in separate seizures—researchers linked shipments to common trafficking networks. Analysis of 4,320 tusks from 49 seizures totaling 111 t (2002–2019) identified over 600 familial matches across separate shipments, demonstrating that as few as three major criminal cartels are responsible for smuggling most of the elephant ivory out of Africa (74, 75). These networks operated from Mombasa (Kenya), Entebbe (Uganda), and Lomé (Togo), with considerable connectivity between ports.

Long-run ivory supply is highly inelastic. African elephants have a 22-mo gestation period, and females only begin to reproduce at around age ten (22). Populations cannot recover quickly from poaching. The high value of ivory incentivizes poachers to target animals of any size or age (20–22), accelerating local population declines. Durable goods like ivory can also be stockpiled, buffering networks against intermittent interdiction efforts. Poaching hotspots have spatially shifted over time as populations are depleted and enforcement pressures change; forensic evidence has identified past hotspots in Democratic Republic of the Congo and Tanzania, though the geography of poaching continues to evolve. Ivory also enters the market through leakage from national stockpiles, confiscations, and elephants killed in human-wildlife conflicts.

The concentration of both elephant populations and trafficking infrastructure suggests that targeted enforcement could disrupt supply chains. When the conservation organization African Parks assumed management of Zakouma National Park in Chad in October 2010, deploying armed rangers and establishing rapid-response units, poaching inside the park was reported to drop to near zero by 2011; the elephant population began recovering from a 90 percent decline (76). However, the continental market impact of such localized interventions remains unmeasured; Chad's elephants represent a small fraction of Africa's total population, and critics have noted elephant displacement rather than elimination of poaching pressure (77).

Pangolin Scale Trafficking as Monopsonic Supply Networks. A relatively small number of pangolin scale transit actors and exporters exercise market power over many local hunters, poachers, or sellers of pangolin meat who possess scales as a waste byproduct. These markets function as a monopsony, where a small number of buyers exert pricing power over a diffuse pool of suppliers who have minimal bargaining leverage (64, 78). Although enforcement risks are overwhelmingly concentrated at the poacher level, poachers are price takers and almost never control meaningful product flows or pricing. Purchasing is coordinated through trusted middlemen networks, which suppresses competition and strengthens supply chain resiliency. Some pangolin scale buyers maintain broad hunter networks they can tap into when circumstances change—for example, if a road is impassable as a transshipment route, if noncorrupt police are working at a border checkpoint, or if cellular service is not working and word-of-mouth becomes the only way to coordinate transactions.

Most pangolin scales are trafficked from West and Central Africa to geographically concentrated demand centers in China and Vietnam (79), which creates logistical advantages for trafficking networks without necessarily reducing retail competition. Hunters and the local communities within which they live often lack bargaining power when middlemen offer low prices for scales; hunters may not negotiate aggressively when they live in regions with weak governance, systemic unemployment, or are from indigenous groups. Many poachers derive income from selling pangolin meat for local consumption as well as scales that initially were a waste byproduct but now supply an international market. Poachers may have more power over meat prices than they do over scale prices and usually earn more from meat than scales. Thus, changes in scale prices may have surprisingly little effect on motivations to poach pangolins. The relative durability of scales compared to perishability of meat has also led to strategic scale stockpiling to evade intensive, periodic enforcement efforts (56). Pangolin poaching ranges from hours of purposeful hunting to opportunistic capture during other activities, such as working in gardens or walking between locations for daily life. In such opportunistic circumstances, almost any positive price is sufficient to motivate capture of the animal.

Succulent Trafficking as an Atomized Supply Network. The succulent trade appears more atomized than either the elephant ivory oligopoly or pangolin scale monopsony. High-value succulent species originate from many parts of the world, and demand exists where species are considered exotic. In the sense that there are many buyers and sellers, illegal succulent markets are more competitive than the other case study markets, but geographic concentration of particularly valuable species provides a degree of market power among relatively few suppliers for those species in particular (39). Plant characteristics make supply fundamentally inelastic. Some species of succulents do not flower until they are between 2 y (*Lithops spp*.) and 10 y *(Aloe ferox)* old (80). However, the relative expense of succulent trafficking likely creates an offset. Transportation with temperature and humidity control leads to comingling of succulents with other perishable agricultural products during shipment and storage to keep plants healthy for retail sale, so small shifts in prices or input costs may lead to rapid exit among suppliers. Otherwise, poachers target species that are easier to transport, such as dwarf succulents which fit into small containers and are in demand as unique growth forms whose maximum height is 5 cm.

The demand side of these networks remains strong. Qualitative interviews with a small sample of succulent dealers revealed many plants are "not for beginners" and that price was determined by size and quality of the plant, as well as supply and demand, rather than where the plant originated (81). Like animals with slow gestation cycles, in some markets, there is a preference for large succulents, including specimens that are more than 100 y old.

A 2022 IUCN Red List assessment (82) determined 97% of 111 South African *Conophytum* were categorized as threatened and 45% were critically endangered; poaching for the international ornamental market was listed as the primary driver of population declines. Similarly, US demand for ornamental succulents and cacti has led to increased regulation. All Mexican cacti and their seeds are now listed on CITES Appendix II. To date, demand has mostly been rooted in ornamental plants. Research is limited, but there appears to be little trade in succulents with hallucinogenic properties in the dark web (83). Growing interest in psychedelic drugs may change this soon.

Regulatory and Enforcement Capacity for Illegal Wildlife Markets

The CITES Framework and Its Limitations. CITES provides the primary international framework for regulating wildlife trade, but it was intentionally designed with significant constraints on its authority. The CITES Secretariat has limited direct enforcement power (84): staff do not patrol source locations, cannot arrest or detain traffickers, and do not operate detention facilities.

Some scholars argue this weakness is intentional; CITES was deliberately designed to avoid coercive mechanisms, consistent with many multilateral environmental agreements. Between 2020 and 2022, the CITES annual budget was $14 to 20 million (85), with the majority of that allocated to scientific services and area-focused conservation programs rather than enforcement (86). Its strongest regulatory tools—temporary trade suspensions or loss of voting rights within CITES—rely entirely on member countries for implementation and rarely carry sufficient incentive for compliance. This institutional design has consequences. CITES is routinely tasked with combating illegal trade beyond its actual capacity. Policy outcomes are heavily shaped by interest group influence (87), with decisions like elevating species from Appendix II to Appendix I often reflecting the priorities of well-funded NGOs, the scientific community, and consumer-country lobbies rather than source countries (88, 89). Because no organization can marshal attention for 40,000 regulated species, enforcement becomes selective, gravitating toward charismatic megafauna and politically viable interventions.

Characteristics of Illegal Wildlife Market Enforcement. On-the-ground enforcement against IWMs exhibits three distinctive characteristics. First, NGOs, conservation organizations, scientists, and philanthropic donors play an unusually prominent role, effectively waging a "war to save biodiversity" (90) that supplements—and sometimes substitutes for—state enforcement capacity. NGOs matter far more for IWM enforcement than they do for enforcement against other illegal markets such as drug trafficking, money laundering, or even firearms.

Second, the probability of punishment is vanishingly low despite potentially severe penalties—far from the "swift and certain" principle that, for other illicit markets, is seen as ideal for deterrence (91). A recent case illustrates the disconnect: a 30-y-old Harvard cancer researcher illegally obtained frog embryos for her research while visiting a French laboratory during her vacation. Caught entering the United States with smuggled wildlife, she now faces up to 20 y in prison, fines up to $250,000, and her visa was revoked (92, 93). The severity is striking, but such outcomes are exceptionally rare. Most IWM participants face minimal risk of serious sanctions.

Third, a spatial mismatch exists between those demanding enforcement and those subject to it. Conservation funding and enforcement priorities originating in the Global North often focus on species harvested in source countries far from where those decisions are made. The demand for enforcement often originates with people who do not live where the crimes occurring or where the externalities are most acutely and immediately felt, producing what scholars term "contested illegality" (94, 95): local communities may not recognize the legitimacy of prohibitions imposed by distant actors with different values and priorities.

These dynamics compound weak enforcement capacity and inconsistent perceptions of CITES' legitimacy across member states. Each signatory must pass domestic legislation aligning with CITES listings, but mismatches between national legislation and CITES commitments are common. Compliance is further undermined by legal loopholes, lenient penalties, and the nature of the victims themselves—wild flora and fauna cannot advocate for their own protection.

Ivory Markets and Longstanding Regulations and Enforcement. Ivory is among the most regulated wildlife markets on the planet. CITES banned the transnational commercial ivory trade for Asian elephants in 1975 and African elephants in 1989, with exceptions for pre-Convention ivory and ivory illegally obtained before the ban came into force. Japan, a signatory to CITES, has maintained a domestic ivory market in large part to support *hanko* and antique carvings (96). Despite this long-standing worldwide commercial ban, consumer countries continue to see illegal ivory sales through black markets and online platforms (97, 98). There is varied domestic enforcement; countries must implement CITES through their own sovereign laws and enforcement of those laws varies. Dissonance between domestic laws and international conventions creates loopholes that IWM actors can exploit. Similar phenomena occur in African, Central American, and South American succulent markets. Particularly charismatic megafauna like elephants have been assigned flagship status and receive disproportionate attention (99); an elephant tusk features in the CITES logo. Substantial efforts have been made to elevate the regulatory attention of other species that are not warm and fuzzy but are significantly impacted by illegal trade (e.g., vultures, frogs). One result of this species-centric approach is that supply-side interventions have dominated regulatory and enforcement interventions over demand-side efforts (100).

Enforcement of ivory market regulations involves more than legal bans. On-the-ground enforcement activities continue, though enforcement by a state or even a region may be undermined by inaction among neighbors because of large elephant ranges (50). Enforcement efforts are hampered by practical challenges, particularly the fact that customs tracking systems do not use harmonized system codes of tariff nomenclature which is an internationally recognized system of names and numbers used to classify traded products, resulting in imprecise monitoring, impairing traceability and prosecution efforts.

Pangolin Scales and Highly Vulnerable Regulations and Enforcement. Because of inconsistent application and enforcement of trade restrictions, pangolin scales continue to appear in markets under the guise of legal or mislabeled products (7, 24). In China, the sale of officially authorized preexisting pangolin scales has been grandfathered in to remain available for traditional medicine; incentives for retailers or consumers to differentiate truly permissible stock scales from new illegally supplied scales are small. This ongoing trade legitimizes demand and enables exploitation by illegal network actors and weakens the effectiveness of the regulation.

The market for pangolin scales—and meat—typifies the regulatory dissonance that can occur in efforts to combat IWMs. Although CITES prohibits trade of most pangolin species across member states, national-level variation and inconsistencies create logjams for control (101). Since 2017, all international commercial trade in pangolins and their parts has been banned, yet China and Vietnam continue to allow domestic use under national laws (102). The role of nonrange states is clear in uplisting pangolins to Appendix I at the 2016 Conference of Parties in South Africa. Globally known conservation organizations including WildAid, TRAFFIC, Wildlife Conservation Society, World Wildlife Fund, and IUCN Pangolin Specialist Group helped frame pangolins as the "world's most trafficked mammal." Vietnam and the Philippines sponsored, and Nigeria, Chad, Angola, and Senegal cosponsored, the listing (103). Despite being listed on Appendix I, pangolins remained formally listed in the Chinese Pharmacopoeia (i.e., Traditional Chinese Medicine Compendium) until 2020. This meant pangolin scales had legitimate domestic use in China until they were removed and even now, "stockpiled" scales are used. Some sources cite the COVID-19 pandemic as being the impetus for removing pangolins from the 2020 Pharmacopoeia, with CITES compliance as a distant secondary motivator (104, 105). The regulatory and enforcement attention on pangolin scale

trafficking has resulted in a range of innovative detection methods and tools for authorities such as using African giant pouched rats as detection sniffers (106). Further, regional cooperatives involving cross-border collaborations have formed with some high visibility operations (e.g., ASEAN Wildlife Enforcement Network).

Succulent Markets and Dissonant Regulations and Enforcement. Regulatory and enforcement efforts against illegal succulent markets are fragmented and their effectiveness remains uncertain. Unlike most trafficked wildlife, confiscated succulents can often be rescued and rehabilitated rather than destroyed. This has spurred novel regulatory approaches; contemporary enforcement increasingly includes relocating, replanting, and monitoring confiscated plants, and botanical gardens have developed protocols for receiving law enforcement consignments while maintaining chain-of-custody standards suitable for criminal prosecution (107). Global coalitions have formed to promote awareness of trade regulations, particularly for species destined for ornamental and medicinal markets.

Interagency task forces have also emerged to coordinate enforcement. Namibia's Protected Plants Task Team, established in 2023, brought together the Ministry of Environment, Forestry, and Tourism, the National Botanical Research Institute, Directory of Forestry, Intelligence Investigation Unit of the Directorate of Wildlife and National Parks, Namibian Police, and Namibia Revenue Agency—with technical support from the U.S. Forest Service International Program—to develop standard operating procedures for border and law enforcement and species identification (107). Such collaborations represent important institutional innovations for a class of species that historically received little enforcement attention.

Despite these developments, there is limited evidence thus far that criminalization has reduced plant poaching or improved conservation outcomes. New CITES listings and trade restrictions targeting specific succulent species may redirect pressure to unprotected taxa, which may have a taxonomic balloon effect analogous to displacement patterns observed in drug enforcement. This effect may be particularly acute for succulent trafficking, where collector demand often targets entire genera rather than individual species. Compounding the challenge, poachers often know more about population locations than scientists or the authorities responsible for conservation. Intergenerational knowledge is rarely included in the IUCN Red List assessment plans that are used to inform conservation management planning or trade guidelines (108), creating information asymmetries that favor poachers over authorities.

Discussion

Distinguishing durable, nondurable, and perishable goods facilitates comparing IWMs with one another and with other illegal markets, yielding insights that specifies-specific or geographic approaches might miss. Those comparisons, in turn, may inform decision-making and interventions that help deter illegal behavior and improve conservation outcomes for the environment and people. The categorization herein is meant to highlight key similarities and differences that determine the size, structure, and value of specific IWM as a complement to taxonomical and geographical schema. Taxonomy—the dominant organizational foundation used currently by the global conservation community—is intended to differentiate species, and geographic categorization focuses on one coarse dimension of trafficked wildlife. In this regard, we discuss three insights from our analysis that are related to demand elasticity in IWMs and the limits for supply control.

Price Elasticity of Demand for Illegal Wildlife Products and Potential Veblen Goods. Demand elasticity presumably varies across IWMs, but few markets, if any, have sufficient data to accurately measure consumers' or producers' responses to price. Relative stability in aggregate demand for pangolin scales since the market's explosion may be the result of growing human populations, digital access, and wealth in retail market countries offsetting demand reduction efforts. Further, while awareness campaigns and trade bans may influence some segments of the population, a small core of demand remains resistant to price changes and legal restrictions. There are considerations other than price that are known to influence consumer demand for illegally traded wildlife, some of which are directly related to the consumer (e.g., age, occupation, income), and others that operate at larger scales (e.g., religion, social class). In some instances, supply restrictions may lead to soaring prices, which paradoxically may be a dangerous outcome for endangered species (109). Products with inelastic demand are not ideal candidates for trade bans or other supply restrictions (110), and if demand has a Veblen-like positive relationship with price, supply controls, and interdiction may perversely prop up these small luxury markets. Cross-price elasticity is also important to consider vis-à-vis consumer demand for substitutes or complements (e.g., elephant, mammoth, walrus, synthetic). A paucity of research to examine the determinants of demand leaves many unanswered questions about demand and IWM. However, one systematic analysis determined that demand for ivory and rhino horn is highly inelastic, emphasizing that supply restrictions alone can drive up prices and create incentives for illegal harvest (109). Choice experiments focused on rhino horn consumers in Vietnam determined that among study participants, price played less of a role than legality, prestige, and origin in fueling demand (111). And in response to regulations protecting one vulnerable species, market actors have repeatedly adapted by targeting another. As discussed above, pangolin scale supply generally shifted from Asia to Africa when the former became depleted, and the latter became easier to obtain. Similarly, as tiger populations fell, African lion bone became a market substitute for tiger bones in traditional medicine, and once lion populations began to decline, South American jaguars were targeted (112).

Complicated Sustainable Substitutes for Products in Illegal Wildlife Markets. The idea of substitutes in IWM remains an opportunity for innovation, such as farming or captive breeding wildlife to remove pressure on wild populations (e.g., alligators) or creating synthetic alternatives (e.g., plastics to replace ivory piano keys, lab-grown rhino horn). Empirical evidence shows that shrinking elephant populations were associated with an increase in ivory prices. The relationship was predicted by basic economic principles; absent viable substitutes, price increased as supply decreased, *ceteris paribus*. Ivory price declines during the more recent period of small but relatively stable populations are tied to general shifts in consumer preferences away from ivory products. For example, current piano key materials are more durable than elephant ivory, have less color variation, do not turn yellow as they age, and maintain consistent tactile properties just as well as organic ivory. Synthetic ivory piano keys are now ubiquitous and are generally considered to be superior to ivory keys. Based on a simple search, there is no evidence of an ivory premium for high-end vintage pianos today.

For any given IWM product, there almost always exists a substitute. For some illegally traded species, substitutes can be sustainable. For example, pythons have high reproductive output in the wild and even in captivity; some species can lay 100 eggs at a time with short incubation periods and have high survival rates.

Farming pythons for their skins might be economically viable, but pangolins are uniquely difficult to breed in captivity, and many types of rare, prized succulents grow so slowly that farming could be a multigenerational endeavor. Still, because some substitutes exist for python skins used in fashion (e.g., reticulated python, Burmese python, tiger python) (113), it is possible that demand for specific species could be elastic. Policies or other initiatives to shift toward species that can be farmed sustainably and cost-effectively, or toward synthetic substitutes, may be the best path forward for conservation. There are numerous examples of organic pharmaceuticals being replaced in the market by synthetic alternatives, including opioids for opiates in both licit pain management and illegal drug supply.

When farmed or synthesized products are logistically infeasible, the existence of a legal and sustainable substitute depends on the nature of demand, and the peer-reviewed or gray literature is sparse in this regard for most illegal wildlife products. In the case of pangolin scales, one study examining Traditional Chinese Medicine practitioners found a general awareness of medicinal substitutes for some, but not all, conditions treated with pangolin scales. Further, the study found a general lack of perceived equal efficacy between pangolin scales and substitutes (71). There is no scientific literature to support Western medicinal use of pangolin scales, which suggests the adoption path of substitutes cannot simply be informed by dissemination of clinical study results on alternative treatments.

Exploring the Limits of Supply Control Strategies for Illegal Wildlife Markets. Supply control strategies for IWMs are appealing because enforcement actions are immediately visible to stakeholders, and they are carried out locally so can quickly adapt to the local environment. Interventions such as intelligence-led policing, antipoaching patrols, and animal monitoring technology like arboreal thermal cameras can complement existing noneconomic supply control strategies such as protected area management. We observe the limits of supply control for multiple reasons, including weak or apathetic governance in both source and destination communities for IWM products. We cannot reasonably expect effective management without some degree of governance. Toward that end, Ostrom (114, 115) and subsequent environmental policy-oriented researchers (116, 117) have developed theories of resource management that rely on communal governance under conditions when states' capacity to regulate and enforce is weak. As Biggs and colleagues (118) argued, the policy process may be protective to a fault because they create additional layers of compliance obligations for authorities that are already underfunded and sometimes undertrained. Community-based approaches that facilitate local benefits of wildlife can theoretically strengthen capacity for monitoring and enforcement and foster local stewardship, but local people increasingly suffer from conservation fatigue and lack of promised benefits materializing.

In many IWMs, the price received by harvesters or poachers represents only a small fraction of the final retail price paid by end consumers. The significant markups along the supply chain, driven by transportation, concealment, corruption, laundering, and the profits of middlemen, suggest that producers could be paid many times their current compensation without necessarily pushing retail prices up enough to deter final consumers. This severely challenges efforts to persuade producers to transition into other lines of work. Even if economic development or other interventions created jobs that pay triple what poachers now make, the illegal market could quadruple poachers' wages without pushing up retail prices anywhere near proportionally. This was what appears to have occurred in crop substitution schemes to combat poppy production in Afghanistan (119, 120). Likewise, major increases in enforcement directed against poachers could drastically increase reservation wages but might translate into small increases in retail price and thus small reductions in consumption.

The disconnect between consumer-targeted interventions and supply-side responses has potentially important implications for policy. Moderately effective demand-reduction strategies may have little to no effect on poaching and illegal harvesting. The high markup structure is likely driven in part by an information advantage held by intermediate actors over poachers. And if poachers are neither aware of moderate changes in demand nor are they very sensitive to the value their product commands, the effect on wildlife could be very small. While speculative, this suggests that intervening at intermediary nodes—where value and volume are concentrated—may be more efficient than focusing on demand or local harvesting practices.

Synthesizing our findings across the case studies (Table 2), we observe increased demand for a particular quality of a protected species can reduce a species' population size. That could in some cases increase its appeal as a signal of exclusivity, driving still greater demand, which could in turn push species toward extinction rather than simply higher prices clearing the market. This hypothesized feedback loop, accelerating demand for novel or exclusive assets (AD NOXA), is an economic dynamic that may distinguish some IWM from other legal or illegal markets.

Empirical patterns across our case studies seem consistent with the AD NOXA proposition. Pangolin trafficking and the price of scales appears to have grown rapidly, if temporarily, after species were added to Appendix I. For succulents, IUCN Red List status correlates positively with market prices: critically endangered species command prices 3 to 5 times higher than less threatened types (58). The most provocative illegal market response to regulatory action involved Ivory. In 2008, despite the standing international trade prohibition, CITES authorized a one-time sale of stockpiled ivory from four African countries to China and Japan, reasoning that the action would satisfy residual demand, depress prices, and allay further poaching (121). Data from 2008–2014 show that ivory prices and seizures spiked and elephant populations declined sharply (51). The market grew in response to an action meant to satiate it. These patterns are correlational rather than causal, but they suggest that the AD NOXA dynamic merits consideration in policy design. Additional empirical research could help interrogate this claim and its potential relevance to policy design.

Conclusion

Comparing and contrasting IWMs with other illegal markets can raise a suite of new questions for policymaking. Do IWMs conceptually align with these other markets sufficiently to be included in, for example, an updated United Nations Protocol Against Transnational Organized Crime, as some stakeholders are calling for? Including IWMs in discussions about illegal markets pushes against the knowledge horizon, perhaps encouraging more holistic thinking about complementary criminal activities and enforcement against diversified criminal enterprises. In many instances, globalization has facilitated the convergence of IWMs with money laundering and drug trafficking by expanding trade routes and spurring economic integration. This perspective reinforces some arguments for including IWMs in policy design alongside drugs, guns, humans, and cybercrime. Convergence has resulted in increased demand for wildlife products and created complex networks that exploit gaps in international regulations and enforcement (122, 123).

Table 2. Market features of three illegally traded wildlife products

Market feature	Ivory (Luxury durable)	Pangolin scales (Nondurable)	Succulents (Perishable)
Supply elasticity	Highly inelastic. Low reproductive rates (22-mo gestation; sexual maturity at ~10 y) constrain supply. Scarcity increases consumption appeal.	Highly inelastic. Low reproductive rates (one offspring per year) prevent population recovery under continued harvest pressure. Scarcity increases consumption appeal.	Rarity-dependent. Slow maturation (2 to 10 y to flowering for some species) constrains supply response. Scarcity increases consumption appeal, particularly for large or old specimens.
Price markups, harvest to retail	Extreme. Poachers receive ~$52/kg (2018 estimate). Retail prices reach ~$4,500/kg in destination markets.	Extreme. Poachers receive $5 to 10/kg. Retail prices reach $450 to 1,400/kg in destination markets.	Substantial. Harvesters receive minimal compensation. Retail prices increase sharply with IUCN Red List and CITES Appendix status.
Network structure	Oligopolistic. Entry restricted to a small number of trafficking syndicates. Durability enables stockpiling and temporal arbitrage.	Monopsonistic at source; fragmented at retail. Distributed sourcing due to ease of capture and transport. Scales can be stockpiled despite consumable end use.	Atomized and competitive. Networks exploit e-commerce, digital payments, and courier services. Perishability necessitates rapid, direct routing.
Enforcement vulnerability	Vast cross-border ranges and lack of harmonized customs codes hinder traceability. Long-standing bans undermined by persistent black markets.	High vulnerability to laundering into legal traditional medicine supply chains. Market scale demands enforcement capacity exceeding available resources.	Trafficking via postal and courier services enables concealment. Regulatory dissonance between domestic laws and CITES commitments complicates prosecution.

IWMs share several structural features with other illegal markets, particularly drug trafficking: production concentrated in countries distant from primary consumption markets, substantial price escalation along supply chains (poacher-to-retail markups in IWM are comparable to coca farmer-to-retail markups in cocaine). Both also rely on weak enforcement and corruption to facilitate transit. Indeed, illicit drug markets provide evidence that total expenditures can increase in response to enforcement when demand is sufficiently inelastic (124). However, IWMs differ fundamentally in their supply constraints. While coca cultivation could triple in a decade, from 121,000 ha in 2013 to 377,000 in 2023, wildlife populations face absolute biological limits that enforcement success may paradoxically worsen by enhancing exclusivity appeal.

Globalization has brought heightened risks to biodiversity and global health along with new enforcement challenges. The illegal movement of wildlife across borders facilitates the spread of zoonotic diseases, as demonstrated by avian influenza outbreaks (125) and the 2003 Mpox outbreak in the United States (126), and the contested but socially disruptive claims that pangolin trafficking may have contributed to the emergence of COVID-19 underscore how data deficiencies in illegal markets compound both epidemiological and policy risks (125). Additionally, globalization exacerbates regulatory misalignments between nations, making it difficult to curb illegal wildlife trade effectively (127). Emerging markets for wildlife products, driven by global economic shifts, further complicate enforcement and conservation strategies, highlighting the need for more cohesive global governance approaches (87, 128). Many studies collectively stress the importance of aligning conservation, public health, and security policies to mitigate the global impacts of IWMs.

A central policy question for IWMs becomes how to achieve a market equilibrium that minimizes social costs and sustains species. Even when prices balance supply and demand in any given period, underlying constraints on biological capital may mean that rate of harvesting exceeds the species' biological replenishment rate and threatens extinction for many species that struggle to reproduce in captivity, such as pangolins. Research on IWMs reveals an apparent disconnect between the claimed trillions in social costs and the modest investment in research, regulation, and enforcement, suggesting either misaligned priorities or skepticism about underlying valuations. If willingness-to-pay studies truly indicate trillion-dollar social costs, we should aim to invest substantially more in understanding market-specific mechanisms and policy analysis.

These findings suggest several policy principles. First, for products exhibiting AD NOXA dynamics, supply-side enforcement alone may be insufficient; demand reduction campaigns targeting the status associations of consumption may prove more effective. Second, as discussed above, the extreme markup structures in IWMs suggest that enforcement resources might yield greater returns when concentrated at intermediary chokepoints rather than diffused across numerous low-level harvesters. Third, where demand is driven by function rather than status, facilitating substitution may offer more durable solutions than prohibition alone. However, unlike manufactured contraband such as cocaine, where production can scale to absorb enforcement pressure, wildlife faces biological replenishment limits that make even modest sustained harvest pressure potentially irreversible. This asymmetry makes prevention more critical than interdiction and underscores the need for interventions calibrated to each market's specific supply constraints and demand characteristics.

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