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The complex interactions of markets for endangered species products

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Abstract

Economic models of trade in endangered species products often do not incorporate four focal arguments in the policy debate over trade bans: (1) law-abiding consumers may operate in another market, separate from illegal consumers, that trade would bring online; (2) legal trade reduces stigma, which affects demand of law-abiding consumers; (3) laundering may bring illegal goods to legal markets when trade is allowed; (4) legal sales may affect illegal supply costs. This paper analyzes systematically which aspects of these complicated markets, separately or in combination, are important for determining whether limited legalized trade in otherwise illegal goods can be helpful for achieving policy goals like reducing poaching.

JEL classification: K42; Q21; D11

Keywords: Endangered species; Black markets; CITES; Poaching; Stigma

1. Introduction

The question of whether to sell confiscated endangered species products regularly generates debate at meetings of the 160-member Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Sales of ivory in particular have been hotly contested. International trade in ivory has been banned since 1989, marking the end of a decade when poachers in Africa killed as many as 100,000 elephants annually and the continent's population was halved. Since then, conservation activities in certain southern African nations have allowed elephant populations to recover. Seeking funds to aid these activities, these countries have asked for special authorization to sell stockpiled ivory. The first exception permitted Botswana, Namibia and Zimbabwe to sell Japan about 110,000 pounds from their existing legal stocks of raw

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ivory in 1999, raising $5 million for elephant conservation activities. In November 2002, at the 12th Conference of the Parties (CoP12), CITES again conditionally accepted proposals from Botswana, Namibia and South Africa, allowing one-off sales of ivory [6]. The proposals involve the tusks of elephants that have died from natural causes or as a result of government animal control programs, and funds must be used for conservation and local community development. However, the agreement comes with considerable controversy. Support was not unanimous, and similar proposals by Zambia and Zimbabwe failed because of concerns that those governments could not effectively protect their pachyderm herds or monitor the ivory sales. Furthermore, accounts of the effects on poaching of even limited legalized trade have reported mixed evidence. According to the Environmental Investigation Agency (EIA), a nongovernmental group based in the United Kingdom, elephant poaching increased with the 1999 sales [17]. According to the United Nations Environment Programme and the TRAFFIC network, the legal sales did not elicit an apparent poaching response [9,15]. According to simple economic theory, however, poaching should have decreased.

Traditional economic theory says that selling confiscated goods should unambiguously lower prices by satisfying consumer demand. These lower prices mean the gains from poaching must be smaller, leading to reductions in that activity. Prohibiting confiscated goods from being sold, on the other hand, increases scarcity and drives up prices. In some cases, enforcement can then actually increase poaching, as poachers raise their total catch to ensure enough of the unconfiscated share gets through to the market and the higher prices [3]. A key assumption is that illegally produced goods and legally sold confiscated goods are interchangeable, perfect substitutes in a single market. In reality, though, separate legal and illegal markets can exist, and arbitrage between them may not be perfect. In other words, while consumers in the illegal market may care only about price, as in the traditional model, law-abiding consumers also care about the source of the product.

Anecdotal evidence of the experience with these products suggests that the legal and illegal markets are intertwined in complex manners. For example, many consumers of ivory may prefer their purchase to have been obtained legally and without harm to the species. Thus, not only will law-abiding consumers refuse to purchase from the black market, but their preferences may further depend on aggregate consumption of legal and illegal stocks, not just their own consumption of the good. Consequently, a higher proportion of legal trade can raise their willingness to pay, while more poaching or more illegal trade can lower it. Legalizing trade may then raise overall demand. Meanwhile, more legal trade can lower the odds of being caught in an illegal exchange, affecting prices and incentives in the illegal market. Finally, the legal supply may be intrinsically tied to the illegal supply, as in the case of selling confiscated products obtained from poaching. These kinds of interactions seem to be at the root of concerns voiced by animal preservationist groups that legal trade will remove the stigma of owning ivory, stimulate demand, facilitate smuggling, and increase poaching.[1] Indeed, accounting for these complex interactions, one finds that loosening restrictions on legal supply or tightening enforcement for illegal transactions could have ambiguous or unexpected effects. Thus, it is important to understand the nature of the markets for the illegal product to determine the best policy response.

[1] Hastie et al. [10].

We conceptualize the demand externalities as "stigma" and "outrage". Stigma derives from the perception that the product was obtained through illegal or inhumane means; the impact of stigma on utility then depends on how much the consumer cares about that perception in order to enjoy the product. This kind of stigma is likely to be more important for display goods, like ivory or diamonds, than consumed goods, like medicinal uses of rhino horn.[2] Stigma depends on the relative sizes of the illegal and legal markets; outrage, on the other hand, depends on the absolute size of the illegal activity. Outrage has some roots in altruism or existence value, since personal enjoyment of the good is reduced by the scope of the harmful behavior, regardless of whether one's own purchase was obtained in a lawful or cruelty-free manner.

We also allow for supply-side interactions in the form of cost externalities. For example, the relative size and scope of the legal market could affect smuggling costs. Both demand and supply sides can then interact through arbitrage. Arbitrage occurs when law-ignoring consumers cross into the legal market to buy goods, or when launderers make illegally supplied goods available in the legal market.

Most previous studies assume that a single market exists, in effect imposing perfect arbitrage. Some exceptions deal with individual aspects of these complexities but ignore the interactions that may occur when they are considered together. Heltberg [11] recognizes that international consumer demand may shift in a switch from free trade to a trade ban regime, but he does not model separate types of markets with limited legal trade. Barbier and Swanson [2] examine the major sources of demand for ivory and consider the effect of limited legal sales, but they do not formalize the market interactions. They focus primarily on raising ivory values for elephant conservation efforts and funds for enforcement, rather than on depressing the return to poaching. Bulte and van Kooten [5] consider separate domestic and international markets for ivory, the former not being subject to the trade ban and the latter displaying perfectly elastic demand. However, their model does not capture the complexities of stigma externalities or nonconsumptive use values. Another long economics literature exists on competition among imperfect substitutes. Again, consumers are assumed to participate in both markets and to care only about product prices, while production of each product proceeds independently (except in imperfect competition).

Although there is a dearth of data on black market sales, studies of the Japanese ivory market, the designated consumer of legal African ivory sales, offer indications that market separation and stigma may be at play. According to Menon and Kumar [14], in the two decades prior to the international ivory ban, domestic prices remained relatively constant at 18,000–20,000 yen per kg for large tusks. Shortly after the ban, prices rose quickly, peaking at 180,000 yen and then gradually falling to a fixed price of 60,000 yen ($450) per kg. This pattern would be consistent with an initial restriction of legal supply and then growing stigma as legal stocks dwindled relative to illegal supplies. Meanwhile, the surveyed price for smuggled ivory is considerably lower at 20,000–25,000 yen per kg, which is consistent with separated markets. They indicate that original supplier costs might be 6000–8000 yen, with the difference attributed to markups by exporters and transporters (smugglers). Separate price data for Japanese ivory imports from Botswana, Namibia

[2] While stigma has not been empirically documented in this area, consumer attitudes toward ivory and the trade ban are frequently mentioned as important factors in policy debates. Stigma effects have been formally documented in other areas of economics, including out-of-wedlock child bearing [16].

and Zimbabwe[3] document that the prices rose from 14,941 yen/kg in 1983 to 37,216 in 1989, as populations dwindled and the ban loomed. They also reveal that prices for the 1999 transactions averaged 10,904 yen per kg, considerably lower than the pre-ban prices, which could reflect stigma effects.[4]

Although reliable data on the linkages between legal and illegal markets are difficult to obtain, perceptions of their importance are widespread among CITES stakeholders. Many conservation groups and Asian countries with elephant populations remain adamantly opposed to any form of legalized trade in ivory, due in large part to concerns about market interactions. For example, observing increased seizures after the first one-off sales, the umbrella organization Species Survival Network worries, "Further legalised ivory trade is likely to confuse consumers even more and to encourage them to believe that all international ivory trade is now legal."[5] Although such a reduction in stigma seems extreme, the trade ban and public education campaigns are indeed widely credited with reducing demand for ivory, not just supply, indicating that some reversal in consumer preferences is also possible.[6] The Indian delegation to CoP12 expressed particular concerns over supply linkages, that "legally acquired ivory is being used for providing a cover to the illegal stocks of ivory."[7]

The purpose of this paper is to think through systematically which aspects of these complicated markets are important for determining whether limited trade in illegal goods is helpful for achieving policy goals like reducing poaching. Four main characteristics peculiar to these markets are considered, both separately and together:

1. Law-abiding consumers may operate in another market, separate from illegal consumers, that certified trade would introduce.
2. Stigma may affect demand of law-abiding consumers, and legal trade reduces stigma.
3. Laundering may bring illegal goods to legal markets when trade is allowed.
4. Legal sales may affect illegal supply costs.

We develop a theoretical economic model taking dual markets, demand externalities, and endogenous production costs into consideration. We explore how different opportunities for arbitrage and different market interactions affect the scope of illegal behavior and the effectiveness of confiscation and resale policies. Section 2 presents the analytical model of dual markets with stigma goods. Section 3 analyzes the case in which only illegal consumers can arbitrage. Section 4 subsequently adds laundering and supply-side externalities. Also included is an appendix that uses simple functional forms to solve the model numerically; it explores the effects of the different market assumptions on how confiscation rates affect poaching, consumption and welfare. Although the model used in this paper is static, it serves as a useful

[3] Monthly Trade Statistics, Japan Ministry of Finance, cited in [12].

[4] Of course, drawing strong inferences from price data is tricky, since prices are affected by origin (Africa or Asia) and by tusk size, and averages have varied over time. Furthermore, the legal market for ivory is dominated by five major dealers that dominate both of the industry associations that determine the amount offered at annual auction, so prices may be distorted by market power.

[5] "African Elephant," SSN Fact Sheet. Washington, DC: Species Survival Network, 2002, p. 3.

[6] See, e.g., [1].

[7] "Statement of the Delegation of India Regarding Proposals for the Reopening of International Trade in Ivory from the African Elephant (Loxodonta Africana)," CoP12 Inf. 41, p. 3.

foundation for analyzing renewable resource problems as well. A dynamic component of a resource stock response could be added to consider long-run effects.[8]

The results indicate that serving the separate demand of law-abiding consumers is not in itself a problem for poaching, but stigma has important implications for policy prescriptions. When limited trade is allowed, unconfiscated poached materials remain illegal to sell; thus, in the dual markets model, black markets continue to operate. Since illegal consumers will change their behavior only if prices in the legal market fall below black market prices, legal trade either depresses prices (and thereby poaching incentives) on the black market or has no impact at all. The key effect of stigma is not to change this result, but to imply that selling all available certified products may not minimize the international price when stigma impacts are strong. Stigma can also render the effects of increasing confiscation rates ambiguous, even with the full resale policy that had ensured lower returns to poaching in the traditional model. The other main result is that for any legal trade to be problematic to poaching, legal demand must be tied to illegal supply, either through arbitrage opportunities like laundering or through externalties with respect to poaching costs. Laundering opportunities bring illegal goods fraudulently to legal markets and can bid up illegal prices if legal demand is higher. The presence of stigma in this case also creates countervailing effects for changes in legal sales and smuggling enforcement policies; however, confiscation and resale of laundered goods is more clearly indicated. Thus, understanding the nature of both demand by law-abiding consumers and also the feedback effects on supply costs for endangered species products is essential for gauging the impacts of limited legal trade and of anti-poaching efforts.

2. Dual markets model

We assume that two types of markets exist for endangered species products, which for the sake of brevity and example we will refer to as ivory. Consumers are separated into two types: law-abiding consumers (denoted by subscript L), who will only purchase certified products (denoted by superscript c), and noncompliant consumers (denoted by subscript N), who do not care about the products' origin and are willing to buy uncertified products (denoted by superscript u). Suppliers are represented by poachers in the illegal market and a government or enforcement agency in the certified goods market. We will first assume that certified products can be distinguished from uncertified and then later introduce laundering as a means to bring uncertified goods to supply the legal market.

Let us define the following variables:

$Q_{\mathrm{L}}^{\mathrm{c}}$ consumption of certified products by law-abiding consumers
$Q_{\mathrm{N}}^{\mathrm{c}}$ consumption of certified products by noncompliant consumers
Q^{u} consumption of uncertified products by noncompliant consumers
Q_{N} total consumption by noncompliant consumers
S^{c} total availability of certified products
S^{u} Total availability of uncertified products

[8] For example, interacting markets with stigma could change the optimal strategy found by Kremer and Morcom [13] regarding enforcement and sales for open-access resources producing storable goods.

K total amount of goods produced through poaching (killing)
H total amount of goods produced through harvesting
ϕ share of poached goods that remain unconfiscated
σ stigma rate

The intent of the static model is to develop intuition about the demand interactions. For simplicity, the presumed policy variable of concern will be the amount of the illegal activity (poaching), as in Bergstrom. A fuller welfare analysis would have to incorporate the utility of different consumer types, enforcement costs, rents from legal sales, and—especially for the case of ivory—it would have to recognize that the variables of interest are actually dynamic. Effectively, this model takes the elephant stock as exogenous. In a dynamic model, equilibrium poaching from the static model would feed back into the elephant stock, determining both harvesting and poaching supply costs in the next period. Equilibrium enforcement might also be endogenous, in that revenues from certified sales of ivory are generally earmarked toward conservation and enforcement efforts. However, the price effects of focus here are useful indicators for a subsequent dynamic model. If we consider the current stock of elephants to be the result of a long-run dynamic equilibrium under a trade ban, the predicted changes in the illegal price will indicate whether more or less pressure will be put on the resource stock. The main differences are that the stock feedbacks on poaching, harvesting and policies in a dynamic equilibrium will also affect stigma; consequently, it would be interesting in subsequent work to investigate how demand interactions affect the path dynamics and the stability of the resource equilibrium.

2.1. Supply

2.1.1. Illegal supply

Illegal supply, S^{u}, equals the quantity of animals poached and not consfiscated: $S^{u} = \phi K$. The cost of poaching, $C(K)$, is assumed to be increasing and convex in the catch. Poachers maximize profits with respect to the quantity of animals caught, given the price on illegal markets, the cost of poaching, and the rate of expropriation:

$$P^{u}\phi K - C(K),$$

leading to

$$K > 0, C'(K) = \phi P^{u},$$

$$K = 0, C'(0) > \phi P^{u} \tag{1}$$

Thus, if half of poached goods are confiscated, the poacher requires twice the price to catch a given amount (as opposed to producing a given amount).

2.1.2. Legal supply

Legal supply, S^{c}, is composed of legal harvesting and of materials confiscated from poachers. Legal harvesting, H, can be from animals that died of natural causes or from active farming.[9]

[9] An interesting extension would link this resource management problem in a dynamic model of supply to the existing demand model.

Confiscated goods are a linear function of total poaching and of enforcement effort $(1-\phi)$, where ϕ is the fraction of poached goods that escape enforcement. The confiscation rate is exogenous to the market actors, set by the government. The government collects confiscated and harvested products and can choose how much of this stock to sell. The constraint on legal supply is then

$$S^{c} \leqslant H + (1-\phi)K.$$

The chosen amount is auctioned (or otherwise efficiently allocated), and in equilibrium, total consumption of certified products must equal the supply:

$$Q_{N}^{c} + Q_{L}^{c} = S^{c}. \tag{2}$$

Thus, legal supply is assumed to be perfectly inelastic, and production costs are irrelevant at this point; effectively, the government is assumed to conduct enforcement and choose auction quantities for reasons other than profit maximization. Later we may endogenize legal supply by considering the planner's decision, such as to minimize poaching or to maximize welfare.

2.2. Demand

2.2.1. Law-abiding consumers

Law-abiding consumers will only buy from legal suppliers. Their utility from consumption is affected not only by quantity, but also by the stigma that may be attached to their consumption. Stigma derives from the perception that the product was obtained through illegal or inhumane means. We assume that the consumer knows her type and knows that the product was obtained in a legal transaction; however, others are uncertain about her type and the source of the ivory, knowing only the odds of the product being purchased legally. Thus, we assume that this negative perception is an increasing funtion of σ, the fraction of the total market that is illegal.[10] The impact of stigma on utility then depends on how much the consumer cares about that perception in order to enjoy the product. We also allow the level of poaching activity to affect demand, as "outrage" at the associated horrors may decrease utility; alternatively, consumers may enjoy their product more if the population stock, net of poaching, is higher.[11] The distinction is that stigma depends on the relative sizes of the illegal and legal markets, while outrage depends on the absolute size of the illegal activity. Outrage has some roots in altruism or existence value, since

[10] We assume this ratio is known to consumers, at least in a rational expectations sense. However, in reality, this information may be uncertain, and some posit that greater uncertainty may be a source of the reduction in stigma. In a Species Survival Network press release dated July 2, 2002, Dr. Teresa Telecky, director of The Humane Society of the United States' Wildlife Trade Program, argued "Reopening trade in ivory will also confuse consumers as to the legality of ivory and lead to increased demand for ivory." For our purposes, though, the effects of stigma are subsumed in the demand function, which could incorporate uncertainty. Formally, we need only that demand responds in some decreasing fashion to the actual ratio of illegal sales. This treatment of stigma can also allow for interpretations other than perception by others, since disutility may be related to the probability the ivory was obtained by cruel methods, when the consumer is uncertain about the reliability of certification in the presence of laundering.

[11] While stigma is likely to be a function of the flow of poached products compared to legal ones, outrage is arguably more likely to be a function of the stock of elephants and the precariousness of its health. In this static model, poaching is a proxy for stock impacts; in a dynamic model, we recognize the relationship between poaching and herd size is more complicated (as equilibrium poaching will tend to decline with the stock size).

personal enjoyment of the good is reduced by the scope of the harmful behavior, regardless of whether one's own purchase was obtained in a lawful or cruelty-free manner.

Formally, let us represent the utility of the legal consumer as the function $V(Q_L^c, \sigma, K)$. Marginal utility from own consumption is positive and diminishing: $V_1 \geqslant 0$; $V_{11} < 0$. Due to stigma effects, utility is decreasing in σ: $V_2 < 0$; $V_{12} < 0$.[12] The strength of stigma effects can depend on whether the good is used publicly or consumed privately, but we assume in all cases that if no legal market exists, law-abiding consumers will not buy anything at any price: $V_1(0, 1, K) \leqslant 0$. Finally, the third term reflects the effects of "outrage," which causes utility to decrease with total poaching: $V_3 < 0$; $V_{13} < 0$.

Law-abiding consumers maximize their utility less the costs of consumption:

$$V(Q_L^c, \sigma, K) - P^c Q_L^c,$$

leading to the result that if their consumption of certified goods is positive, their marginal utility equals the price:

$$Q_L^c > 0, \quad V_1(Q_L^c, \sigma, K) = P^c. \tag{3}$$

Stigma is an increasing function of illegal supply and a decreasing function of legal supply; we will assume it is a direct ratio of the former to the total market:

$$\sigma = \frac{S^u}{S^c + S^u}.$$

With no illegal market, $\sigma = 0$. Under a trade ban, $\sigma = 1$. Let $\gamma = H/K$. In an equilibrium with no sales of confiscated goods, with only harvested goods being certified, $\sigma = \phi/(\phi + \gamma)$. If all confiscated goods are sold as well, $\sigma = \phi/(1 + \gamma)$. Without harvesting and with only confiscated goods to sell, $\sigma = \phi$.

The effect of stigma is to shift legal demand. Given any level of stigma, one can consider demand by law-abiding consumers to be downward sloping in a typical form. However, a fall in stigma shifts that demand upward ($-V_{12} > 0$). Thus, given any level of poaching and illegal supply, the effect of a change in certified sales causes both an upward shift in demand and a downward movement along the demand curve as consumption increases. The net effect on willingness to pay depends on the relative strength of the stigma effect.

Fig. 1 depicts demand as a function of total certified sales, given a certain level of poaching and illegal supply; thus, outrage is also held constant. At a given level of certified sales, S_1^c, stigma is fixed and marginal utility is declining in consumption. At a greater level of certified sales, S_2^c, stigma is lower so larger quantities are demanded at any price. On the effective demand curve, certified sales also equal the quantity consumed. Note that changes in the level of poaching would shift the entire effective legal demand curve. An increase in poaching would increase outrage and reduce demand at every price level and every level of stigma. If increased poaching also increases illegal supply, each level of certified sales is associated with greater stigma, and thus lower willingness to pay as well.

The impact of stigma on utility depends on how much the consumer cares about that perception in order to enjoy the product, which may vary according to the type and use of the good. For

[12] On the other hand, for goods like guns, marginal utility may be increasing in the fraction of the sales going to illegal consumers.

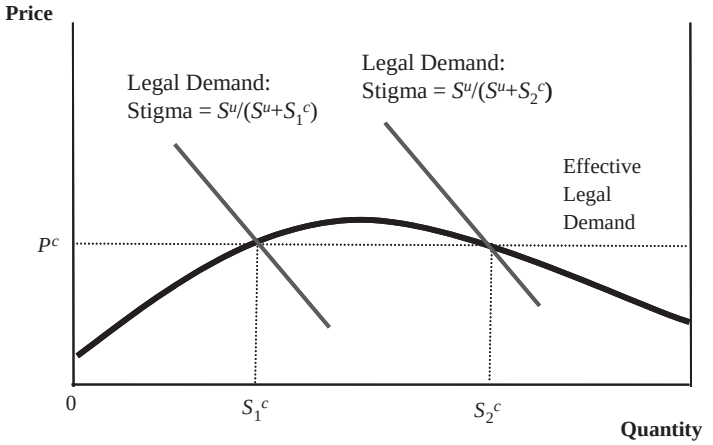

Fig. 1. Legal demand and stigma.

example, stigma effects are likely to be more important for display goods, like ivory or diamonds in jewellery, than for consumed goods, like medicinal uses of rhino horn or industrial uses of diamonds.[13] Thus, in different cases, the effective legal demand curve facing the policymaker may be downward sloping, upward sloping, or nonmonotonic. Since we consider the case of ivory sales as our main example, we will assume that the effective demand curve is concave, as depicted. The initially upward slope of demand is implied by the concern of wildlife preservation groups that legal sales will increase demand, indicating a perception that stigma effects will dominate at the outset. However, as certified sales increase and achieve a large market share, satiation is likely to become relatively more important, implying that demand will ultimately slope downward.

2.2.2. Noncompliant consumers

Noncompliant or "illegal" consumers are assumed to be impervious to stigma or outrage. Their utility arises solely from their total ivory consumption $U(Q_N)$. They may purchase Q_N^c from legal markets and Q^u through illegal channels (the subscript can be ignored because they are the only consumers active in the market). They maximize their consumption utility less purchasing costs from each market:

$$U(Q_N^c + Q^u) - P^c Q_N^c - P^u Q^u.$$

The resulting first-order conditions lead to three possible outcomes:

$$Q_N^c > 0, \;\; Q^u = 0, \;\; U'(Q_N^c) = P^c < P^u, \tag{4}$$

$$Q_N^c = 0, \;\; Q^u > 0, \;\; U'(Q^u) = P^u < P^c, \tag{5}$$

$$Q_N^c > 0, \quad Q^u > 0, \quad U'(Q_N^c + Q^u) = P^c = P^u. \tag{6}$$

[13] Andrew [1] notes that public education was more effective for reducing demand for ivory, speculating that consumer preferences for luxury goods may be more malleable than those for products whose uses are rooted in cultural traditions.

Since noncompliant consumers are indifferent to the source of the product—whether it was obtained legally or illegally—and therefore will buy whichever product is cheaper. If the price on illegal markets is higher, they will purchase in legal markets. If the price in legal markets is higher, they will resort to illegal markets. If demand is not satisfied fully by one market or another, then arbitrage implies equal prices for certified ivory and for contraband. Under what circumstances can each of these market equilibria occur and what do they imply for the effectiveness of trade bans for protecting endangered species?

3. Legal sales without laundering

Some supporters of the trade ban for ivory and other endangered species products argue, in part, that by reducing the stigma of ivory consumption, legal sales of seizures spur more demand. Whether this translates into more illegal behavior, however, depends critically on the type and availability of arbitrage opportunities between the legal and illegal markets. We will show that if the following conditions hold:

- demand-side arbitrage opportunities are unidirectional (illegal consumers will shop in both markets but law-abiding consumers will not);
- illegal suppliers cannot arbitrage between markets (they can sell only to noncompliant consumers); and
- illegal supply costs are unaffected by legal sales;

then

1. a trade ban maximizes poaching;
2. selling all harvested and confiscated goods may not minimize poaching; and
3. increasing enforcement may have ambiguous effects on poaching in all cases, even with full resale of confiscated goods.

To demonstrate these three results, we present the trade ban scenario as a benchmark and then evaluate the three types of market equilibria that can arise under trade. While the first result is reminiscent of the Bergstrom model, the second and third results are different, revealing the influence of stigma effects; thus, the scenario of focus is when illegal consumers arbitrage. Furthermore, we see with separate markets a situation in which legal sales do not affect the illegal market at all, a result absent in single-market models.

An important assumption in this initial analysis is that certified products can be distinguished from uncertified ones at the point of sale. In the next section, we will introduce laundering as a means to bring uncertified goods to supply the legal market. In this case, the first result will no longer necessarily hold.

3.1. Trade ban

In this case, no legal market exists. Consumption and supply of certified products are zero, and noncompliant demand is satisfied by illegal supply. In the notation, $Q_{\mathrm{L}}^{\mathrm{c}} + Q_{\mathrm{N}}^{\mathrm{c}} = S^{\mathrm{c}} = 0$ and

$Q^u = S^u = \phi K$. In this equilibrium,

$$U'(\phi K) = C'(K)/\phi. \tag{7}$$

Let K_{ban} be the level of poaching activity that solves this equation. Fig. 2 depicts the market equilibrium when only the illegal market is active. K_{ban} is determined where the marginal cost of poaching, including the tax of confiscation, equals the price per successfully sold unit. Actual illegal supply, ϕK_{ban}, is the portion of the goods poached at that price that remain after confiscation. This illustration uses a confiscation rate of about 1/2.

As in the Bergstrom model, without resale of confiscated goods, greater enforcement may actually increase total poaching if the price increase outpaces the additional confiscation. Totally differentiating (7) and solving, we get the change in equilibrium poaching due to a small increase in the confiscation rate (a decrease in the escape rate):

$$-\frac{dK_{ban}}{d\phi} = \frac{-U' - \phi K_{ban} U''}{C'' - \phi^2 U''}.$$

The denominator is clearly positive, but the numerator is of ambiguous sign. Rewriting, we see that the result depends on whether the elasticity of demand in the illegal market ($\eta^u = -(U'/U'')/Q^u$) is greater than or less than one:

$$-\frac{dK_{ban}}{d\phi} = \frac{(1-\eta^u)P^u Q^u}{\phi(\eta^u Q^u C'' + \phi P^u)}. \tag{8}$$

Thus, if demand is inelastic, greater enforcement increases poaching, since the price increase more than compensates for the additional confiscation. If demand is elastic, greater enforcement reduces poaching.

Fig. 3 portrays a change from a confiscation rate of 1/2 to 2/3, which shifts the supply curve from the inelastic portion of the demand curve. As a result, while illegal consumption falls to $\phi' K'_{ban}$, total poaching increases to K'_{ban}.

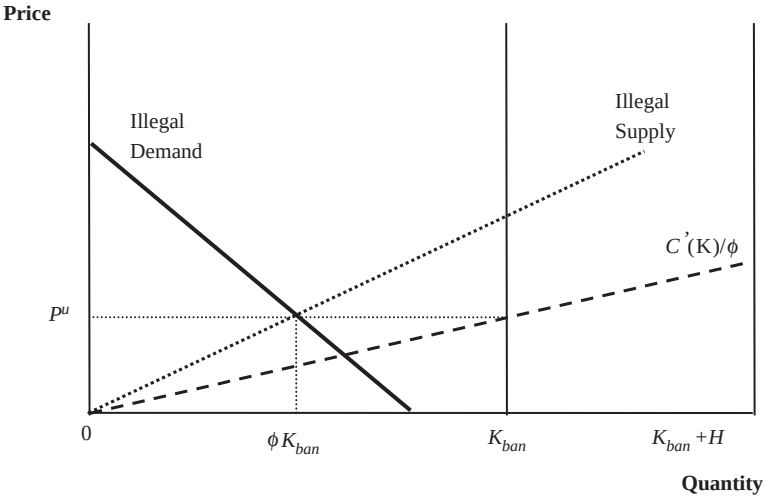

Fig. 2. Trade ban.

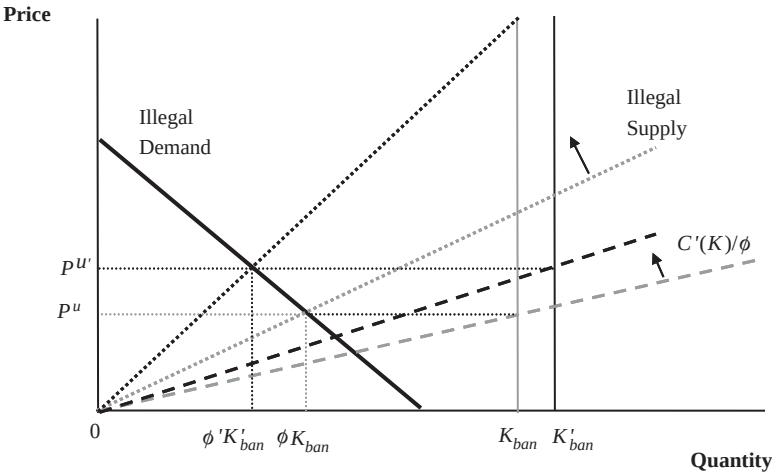

Fig. 3. Change in enforcement.

Note that if this market were the only one (as in the Bergstrom model), a policy of reselling confiscated goods would drive the price down to where poaching supply intersects demand: $P^{\mathrm{u}}_{\mathrm{resell}} = C'(K)/\phi = U'(K)$. In this case, an increase in enforcement would unambiguously decrease poaching:

$$-\frac{dK_{\mathrm{resell}}}{d\phi} = \frac{-U'}{C'' - \phi U''} < 0.$$

This result will no longer hold with certainty when we introduce separate markets and stigma effects.

3.2. Single legal market

In an equilibrium where only the legal market is active, we have $Q^{\mathrm{c}}_{\mathrm{L}} + Q^{\mathrm{c}}_{\mathrm{N}} = S^{\mathrm{c}}$ and $Q^{\mathrm{u}} = 0$. If no one buys poached materials, then $K = 0$; no poaching then implies no confiscation and $S^{\mathrm{c}} \leqslant H$. In other words, legal harvesting must fully satisfy both markets. A trade ban in this situation, then, necessarily increases poaching.

From the first-order conditions for consumers (3) and (4), in this equilibrium we have

$$V_1(Q^{\mathrm{c}}_{\mathrm{L}}, 0, 0) = U'(S^{\mathrm{c}} - Q^{\mathrm{c}}_{\mathrm{L}}) = P^{\mathrm{c}} \tag{9}$$

and from (1),

$$P^{\mathrm{c}} < C'(0)/\phi. \tag{10}$$

This situation can occur if expropriation is very high or complete ($\phi = 0$), or if legal harvests are large enough such that residual demand is very low—that is, below the threshold for poaching: $C'(0)/\phi$. The value of H relative to demand is obviously important here, as it determines whether

sufficient returns to poaching exist. For the remainder of the paper, we assume that H is not large enough to drive out illegal trade: $U'(H - Q_L^c) > C'(0)/\phi$.[14]

3.3. Separate legal and illegal markets

In an equilibrium where both markets are active but separate, we have $Q_L^c = S^c \leqslant H + (1-\phi)K$, $Q_N^c = 0$, and $Q^u = S^u = \phi K$. From the first-order conditions for consumers and producers (Eqs. (3), (5), and (1)), we see that prices must be higher in the legal market:

$$V_1(S^c, \phi/(\phi + S^c/K), K) > U'(\phi K), \tag{11}$$

and the illegal market price after confiscation must equal marginal poaching costs:

$$U'(\phi K) = C'(K)/\phi. \tag{12}$$

Since this latter condition is identical to that under a trade ban, the equilibrium amount of poaching is also equal to trade ban level K_{ban}. Any policy that raises prices in the legal market would have no effect on poaching, as the illegal market is satisfied by current poaching levels and higher prices in the legal market would not affect demand by noncompliant consumers. Poaching will be affected only by changes in the amounts legally auctioned if the result is to lower prices in the certified market below those in the illegal markets. At that point, illegal consumers will arbitrage and the markets will be pushed into the next category of perfect arbitrage. The net effect will be to reduce poaching by lowering the return.

The direction of impact on prices in the legal market of a change in certified sales depends on the relative strength of the stigma effect. Given any quantity of legal sales, which determine stigma, marginal utility is always declining. However, each level of sales corresponds to a different level of stigma, which shifts the marginal utility curve. The legal demand curves pictured are the result of the equilibrium combinations of price and quantities, given the corresponding stigma. The question is whether the direct effects of more legal consumption on the marginal utility of the law-abiding consumer are dominated by indirect utility (shifting) effects of stigma: $V_{11} >?< -V_{12} d\sigma/dS^c$. That determines whether the effective legal demand curve is downward or upward sloping.

In either case, starting from a point where the markets are separate, a trade ban does nothing to illegal markets and thereby does not affect poaching. A change in legal sales will affect welfare through consumption, but it will not affect poaching unless a regime switch occurs. And in that case, it can only reduce poaching.

Although trade policy in this model can affect illegal behavior only indirectly through equilibrium effects with the legal market, enforcement policy affects the illegal market directly. The equilibrium supply effects of enforcement then also affect legal demand. Holding S^c fixed,

[14] We also note that in a dynamic model the stock of elephants would affect both H and poaching costs. Brown and Layton [4] note that sales from an initial stockpile can drive out poaching in the short term. However, in the long run, sustainable harvesting must both be sufficient to satisfy demand and also not correspond to a herd size so plentiful that poaching is easy enough to be worthwhile. Although the government may want to harvest optimally, poachers follow the laws of the commons and do not consider their effect on herd dynamics. Thus, in thinking ahead toward a model of optimal harvesting, we need to recognize Eqs. (9) and (10) as constraints, in addition to the biological response functions. These interesting additional complications will be saved for later exploration.

increasing enforcement effort tends to raise prices in both markets: the marginal costs of illegal supply rise, as does the willingness to pay by law-abiding consumers, because of a fall in stigma. Unless the contraction in the illegal market causes prices to rise even higher than in the legal market, the effect of increased enforcement will be identical to that in the trade ban case.

If we sell all harvested and confiscated goods ($S^c = (1-\phi)K + H$), an increase in enforcement may depress the legal price, due to increased consumption, but the effects on poaching remain the same as with a trade ban. As long as the markets remain separate, the impact on poaching supply depends strictly on the elasticity of demand in the illegal market. Meanwhile, a fall in poaching raises consumer surplus and marginal utility in the legal market. However, should the illegal market prices rise to the level of the legal market, the regime will switch to one of arbitrage.

3.4. Perfect arbitrage

Thus far, a trade ban either increases poaching or has no effect. Therefore, the only situation in which trade restrictions might help protect species is if noncompliant consumers arbitrage between certified and uncertified product markets. Under perfect arbitrage, $Q_L^c + Q_N^c = S^c$, and $Q^u = S^u = \phi K$. Combining the first-order conditions for consumers and producers (Eqs. (3), (6), and (1)), we know that the marginal utilities of legal consumption are equalized:

$$V_1(Q_L^c, \phi K/(\phi K + S^c), K) = U'(S^c - Q_L^c + \phi K); \tag{13}$$

and the marginal utility of illegal consumption equals the marginal cost, after confiscation:

$$U'(S^c - Q_L^c + \phi K) = C'(K)/\phi. \tag{14}$$

Let us call the resulting equilibrium level of poaching (given S^c and ϕ) K_{arb}.

We know that $K_{arb} < K_{ban}$, since $U'(\phi K_{ban})$ represents an upper bound on the price in the illegal market. If law-abiding consumers demand more than is legally available at that price, the price of certified goods would be driven up and the two markets would remain separate. However, if law-abiding consumers do not soak up the entire legal supply at that price, prices would have to fall, as would the return to poaching. In other words, since the arbitrage can occur only in one direction,

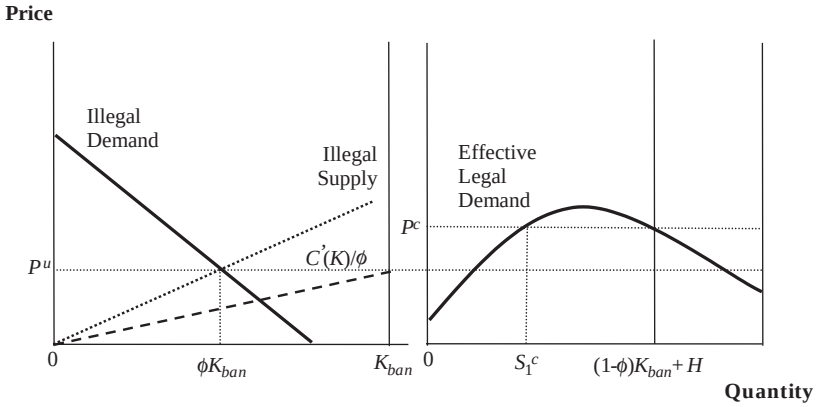

Fig. 4. Separate markets.

it can only drive down the prices in the illegal market compared with no trade, not raise them. Therefore, under no conditions can a full ban on trade reduce the level of poaching in this model.

3.4.1. Sales policy

Still, with stigma effects, the relationship between poaching and legal sales may not be monotonic. The level of legal sales that would minimize poaching is that which minimizes prices and maximizes Q^c_N. The policy prescription then depends on the shape of effective legal demand.

Consider two equilibrium prices. First, let "all" denote the price when all harvested and confiscated goods are sold:

$$P^c_{all} = V_1\left(Q^c_{L,all}, \frac{\phi}{1+H/K_{all}}, K_{all}\right) = U'(K_{all}+H-Q^c_{L,all}) = C'(K_{all})/\phi. \quad (15)$$

If effective demand were strictly downward sloping, then this would be the lowest achievable price.

Next, let "none" denote the lowest equilibrium price when no certified products are sold *to law-abiding consumers*:

$$P^c_{none} = V_1\left(0, \frac{\phi}{\phi + S^c_{none}/K_{none}}, K_{none}\right) = U'(\phi K_{none} + S^c_{none}) = C'(K_{none})/\phi. \quad (16)$$

In other words, some certified sales occur, but they satisfy illegal consumers that cross over, serving to drive down the price in the legal market until stigma is just low enough that legal consumers consider buying. If effective legal demand increased monotonically, P^c_{none} would represent the lowest achievable price, since any additional sales shift legal demand and raise prices.

Thus, for our example of concave effective legal demand, the price is minimized at $\min\{P^c_{all}, P^c_{none}\}$. Fig. 4 reveals the two ways to drive down the legal price below the trade ban. First, one could sell a lot of certified products and saturate the market, but this would require a large source of harvested goods. Second, one could dramatically cut back certified sales to an amount that raises stigma, driving down legal consumers' willingness to pay, while satisfying more illegal consumer demand and lowering prices.

The intuition for the latter case is that, when stigma effects are initially strong, for very small S^c the illegal consumers have a higher marginal willingness to pay. Rather than dropping to the legal demand level, the price for certified goods follows along the illegal demand curve, as those consumers arbitrage. The difficulties of portraying a dual-market equilibrium become evident here. The effective legal demand curve incorporates stigma effects from additional certified sales. However, as equilibrium prices fall, K contracts, which shifts the legal demand curve upward through changing stigma and outrage effects.[15]

In Fig. 5, the gray lines portray the trade ban equilibrium. If certified sales are above the level S^c_{switch}, the markets remain separate. Below this level, because of the greater stigma, law-abiding

[15] Poaching changes in this case have an attenuating effect on the impact of additional sales—stigma and outrage effects will raise willingness to pay if poaching decreases, and lower it if poaching increases. However, in equilibrium, the shift cannot completely crowd out the initial price change, else there would be no change in poaching to generate the shift in the first place. Therefore, to understand the direction of the effect on poaching, it is sufficient to consider the partial effects of a small change in sales, holding all else constant.

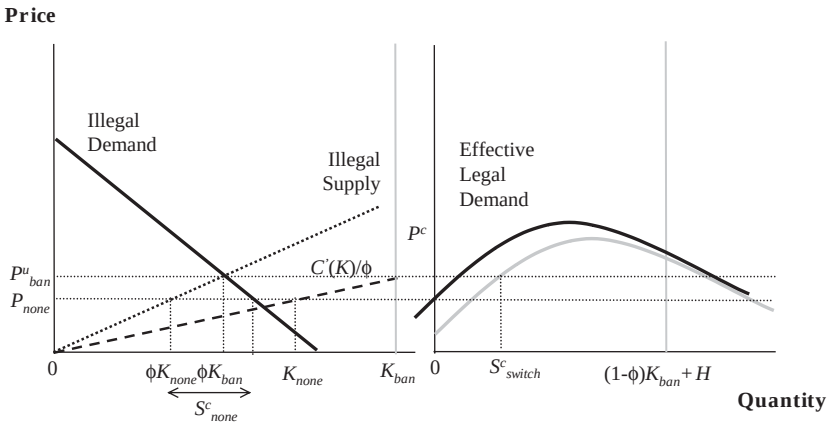

Fig. 5. Perfect arbitrage with declining stigma effects.

consumers' willingness to pay lies below the trade ban price. If the certified price falls, illegal consumers will buy some of the certified products, driving down the illegal price. The corresponding reduction in poaching shifts up legal demand; at any level of legal consumption, both outrage and stigma will be lower. The black legal demand curve depicts the equilibrium at which the arbitrage price is lowest. If any more than S^c_{none} of certified ivory is made available, law-abiding consumers will bid up the price. If any less is sold, illegal consumers will bid up the price.

Following the other end of the demand curve, we see that the same price could be achieved with a large amount of certified sales. However, for the harvesting supply shown in the picture, this level of sales would not be feasible.

An important point is that these cases—in which something less than full resale can minimize poaching—exist only because of stigma effects and only when they are strong enough to make effective demand increasing over some range.[16] Without them, full resale always minimizes prices. In all cases, then, some level of certified sales occurs and is preferred to a trade ban.

3.4.2. *Confiscation policy*

Note that while greater enforcement raises the poaching and supply curves, it also shifts up legal demand, which causes the kink in the effective demand curve to shift upward as well. If certified sales are held constant, tighter enforcement may or may not dampen poaching, as seen with the trade ban case. An increase in enforcement not only reduces illegal supply but also shifts up legal demand through lower stigma; both effects unambiguously reduce illegal consumption and raise prices. As in the single illegal market case, depending on the elasticity of the (effective) demand (including stigma effects), this price increase can more than offset the cost increases.

Outrage also has an attenuating effect on the impact of additional enforcement—it will raise willingness to pay only if enforcement actually decreases poaching. As before, additional enforcement contracts illegal supply, which raises prices in the illegal market and, by arbitrage, in

[16] Interior minima are possible with nonmonotonic demand curves that are convex over some range. This would mean the relative effects of stigma become stronger as it falls, at least over some range. At the minimum price, some certified goods would be consumed by law-abiders, but not all available certified products would be sold.

the legal market. In this case, holding S^c fixed, the reduction in illegal supply reduces stigma, which raises willingness to pay by lawful consumers. As before, it also lowers the return to poaching. Then the question is whether the higher prices in the illegal market outweigh the additional costs of bringing uncertified products to market. Whether selling these additionally confiscated goods mitigates the price effects of reducing illegal supply depends on the previously analyzed demand parameters.

Without a stigma effect, the perfect arbitrage case would mimic that of the conventional single market (as in the Bergstrom model): increasing enforcement unambiguously reduces poaching, since reselling the additional confiscations keeps demand low while costs rise. With stigma, however, the effects of greater enforcement may now also be ambiguous even when all confiscated goods are resold. In a policy of full resale, as in (15), stigma is proportional to the share of poached products that escape confiscation: $\sigma_{\text{all}} = \phi/(1 + H/K)$. Now, raising enforcement reduces stigma and shifts up demand, making the net impact on price (and poaching) dependent on the strength of the stigma effect, as well as the regular demand elasticities of legal and illegal consumers.

Appendix A presents a simple simulation model to explore how changes in the confiscation rate affect consumption and poaching, as well as consumer surplus, with a policy of full resale. It compares a trade ban with resale policies for separate and combined markets with and without stigma. Confiscation can have a nonmonotonic effect on poaching with either a trade ban or a perfect arbitrage scenario with stigma effects.

4. Legal sales and supply linkages

In the preceding cases, with only stigma effects, we saw that a trade ban could never reduce poaching compared with a regime with sales of confiscated and harvested products, although selling all available certified products might not be optimal. However, these results may change if we relax the assumptions that arbitrage is unidirectional or that illegal costs are unaffected by legal market behavior. By allowing legal consumption to affect the supply of endangered species products, or vice versa, trade policy can have ambiguous effects.

This reverse link between the markets can arise in different ways. First, the very existence of a certification process makes counterfeiting possible. Thus, laundering can bring poached goods to the certified market. Second, thicker legal markets may affect the costs of illegal supply, possibly by making enforcement more difficult or smuggling easier. We see that the former mechanism implies that legal sales can increase poaching if prices are higher in legal markets. The latter mechanism, however, can have ambiguous effects, depending on the precise form of the linkage of supply to legal demand.

It is useful to make a distinction between smuggling and laundering. Smuggling is part of the process of supplying illegal consumers with poached goods. Laundering takes some of those illegal supplies and passes them off as certified products. Ongoing seizures of shipments of poached ivory reveal that smuggling remains a real problem. However, the important question for certified sales policy is the scope for laundering, since that is the mechanism for legal sales to raise illegal prices. Both of the major CITES monitoring systems for ivory, Monitoring of Illegal Killing of Elephants (MIKE) and Elephant Trade Information System (ETIS), focus on illegal

supply. ETIS has begun recording international seizures of ivory, but subsidiary information on the legal trade in elephant products is still under development. This analysis indicates that improved monitoring of legal markets should be a priority; according to EIA, Japan has one of the most strictly regulated ivory markets, yet illegal stocks regularly enter.[17]

4.1. Laundering

Suppose we have intermediaries who are willing to buy black-market goods and launder them for fraudulent sale in legal markets. We then must allow for another type of enforcement, $(1-\phi^{\mathrm{f}})$, the rate of confiscation of laundered products. We assume that the more laundering is performed, Q^{f}, the greater the costs of doing so, $F(Q^{\mathrm{f}})$, where $F'(Q^{\mathrm{f}})>0,\ F''(Q^{\mathrm{f}})\geqslant 0$ for $Q^{\mathrm{f}}>0$. (Thus we assume for now that laundering costs are unaffected by the size of the legal market.) Launderers maximize their net profits, defined as

$$(P^{\mathrm{c}}-P^{\mathrm{u}})Q^{\mathrm{f}}\phi^{\mathrm{f}}-F(Q^{\mathrm{f}}).$$

The first-order condition for laundering to occur is

$$P^{\mathrm{c}}-P^{\mathrm{u}}=\frac{F'(Q^{\mathrm{f}})}{\phi^{\mathrm{f}}}. \tag{17}$$

Thus, if no price differential exists and the illegal consumers are doing the arbitrage, no laundering will occur, because excess supply in the legal market is satisfying demand in the illegal market. On the other hand, when the market equilibrium involves separation, laundering offers a vehicle to use illegal supplies to satisfy excess demand among legal consumers. Laundering cannot occur under a trade ban, nor is it worthwhile when both types of consumers operate within a single legal market. Therefore, we will focus on circumstances where this form of arbitrage is active.

Since the relevant case requires $P^{\mathrm{c}}>P^{\mathrm{u}}$, we know that $Q^{\mathrm{c}}_{\mathrm{N}}=0$. Therefore, the market-clearing conditions are

$$Q^{\mathrm{c}}_{\mathrm{L}}=S^{\mathrm{c}}+\phi^{\mathrm{f}}Q^{f}\leqslant H+(1-\phi)K+Q^{\mathrm{f}},$$

$$Q^{\mathrm{u}}=\phi K-Q^{\mathrm{f}}\geqslant 0,$$

where $0<S^{\mathrm{c}}\leqslant H+(1-\phi)K+(1-\phi^{\mathrm{f}})Q^{\mathrm{f}}$. We maintain the assumption that stigma is represented by the odds of the product being supplied illegally, the ratio of total illegal supply to total consumption: $\sigma=\phi K/(S^{\mathrm{c}}+\phi K-(1-\phi^{\mathrm{f}})Q^{\mathrm{f}})$. Note that in an equilibrium with full resale, stigma is unaffected by laundering, since laundering (and its enforcement) merely diverts illegal supplies from one market to the other: $\sigma_{\mathrm{resell}}=\phi K/(H+K)$.

From the first-order conditions for consumers and producers, we have

$$Q^{\mathrm{f}}>0,\ V_1(S^{\mathrm{c}}+\phi^{\mathrm{f}}Q^{\mathrm{f}},\sigma,K)=\frac{C'(K)}{\phi}+\frac{F'(K)}{\phi^{\mathrm{f}}} \tag{18}$$

[17] Hastie et al. [10].

and

$$Q^{u} > 0, U'(\phi K - Q^{f}) = P^{u} = C'(K)/\phi, \tag{19}$$

$$Q^{u} = 0, U'(0) < C'(K)/\phi. \tag{20}$$

Two types of solutions result when this arbitrage is present. One is a separating equilibrium where illegal consumers buy at lower black-market prices, and part of the legal market is fed by fraudulently certified products. We call this "imperfect arbitrage" since a cost is incurred bringing illegally obtained goods to legal markets. Both markets are active, and the price in one affects that in the other, although they remain separate. In this equilibrium, we get the same condition as in Eq. (21), as well as (19).

The other solution occurs when demand in the market for certified products is so strong that illegal consumers are crowded out completely, leaving a single "legal" market. In the previous case of a fully legal market, illegal consumers could find cheaper access to goods in legal markets. In this case, a single market occurs because values are so much higher in the market for certified goods that launderers resell everything. If the illegal market is crowded out, then $Q^{f} = \phi K$. In equilibrium,

$$V_1(S^{c} + \phi^{f}\phi K, \phi K/(S^{c} + \phi^{f}\phi K), K) = \frac{C'(K)}{\phi} + \frac{F'(\phi K)}{\phi^{f}}. \tag{21}$$

Furthermore, it must be that $V_1 - F'(\phi K)/\phi^{f} > U'(0)$.

4.1.1. Sales policy

The primary result is that if the market parameters are such that laundering occurs, a trade ban will reduce poaching. These conditions imply that, in the absense of laundering, marginal utility in legal markets must be greater than in illegal ones ($V_1(S^{c}, \phi/(\phi + S^{c}/K_{ban}), K_{ban}) > U'(K_{ban})$). If the price difference would be enough to justify laundering, then the subsequent diversion of the illegal supply drives up prices in the illegal market and thereby the incentive to poach. The second result is that selling more certified products does not necessarily further increase poaching, as it depends on the relative effects of consumption versus stigma. If stigma dominates, prices rise, as do poaching and laundering. If satiation dominates, prices fall, as do illegal activities.

4.1.2. Confiscation policy

The combination of laundering and stigma has interesting effects on the effectiveness of confiscation policy. Consider the case of the single "legal" market, which removes any incidence on illegal consumers since they have been driven out of the market. In this case, we are in a version of the Bergstrom world, but with stigma effects. Since enforcement against poaching both raises poaching costs and lowers stigma, the direction of impact on poaching could be ambiguous, whether or not confiscated goods are automatically resold, as it was in the perfect arbitrage equilibrium (without laundering). On the other hand, enforcement against laundering with full resale does not directly affect stigma; it changes the share of sales that are laundered but not the share of sales that are originally certified. Thus, increased confiscation of laundered goods has the

effects predicted by the traditional model: returns to poaching are driven down when confiscated goods are resold, while the effect is ambiguous if they are not.

To see these results mathematically, consider an equilibrium in which all confiscated products are sold (and no harvesting is available):

$$V_1(K,\phi,K)=\frac{C'(K)}{\phi}+\frac{F'(\phi K)}{\phi^{\mathrm{f}}}. \tag{22}$$

Totally differentiating, we get the change in poaching as the confiscation rate increases:

$$-\frac{dK}{d\phi}=\frac{-C'/\phi^2+KF''/\phi^{\mathrm{f}}-V_{12}}{C'/\phi+KF''\phi/\phi^{\mathrm{f}}-V_{11}-V_{13}}.$$

Although the denominator is positive, the numerator is of ambiguous sign, since enforcement raises poaching costs but lowers laundering and its costs and lowers stigma. A similar (but more complicated) result can be obtained holding certified sales fixed. One would expect this case to be more likely to yield a counterproductive effect, since certified prices are likely to rise more in the absence of reselling additional confiscations.

Greater enforcement of laundering, on the other hand, would raise costs and unambiguously decrease poaching if everything confiscated is resold:

$$-\frac{dK}{d\phi^{\mathrm{f}}}=\frac{-F'/(\phi^{\mathrm{f}})^2}{C''/\phi+\phi F''/\phi^{\mathrm{f}}-V_{11}-V_{13}}<0.$$

This result is similar to that of the Bergstrom model with resale. Given K, a change in enforcement of laundering merely reduces the share of sales that are laundered, leaving stigma and consumption unaffected. In equilibrium, then, less laundering means less poaching. The price incidence depends on the consumption and stigma effects.

However, if the fraudulent goods that are confiscated are not resold, the impact of greater enforcement against laundering could have an ambiguous impact on poaching. Totally differentiating (21), we get

$$-\frac{dK}{d\phi^{\mathrm{f}}}=\frac{-F'/(\phi^{\mathrm{f}})^2-\phi KV_{11}}{C''/\phi+\phi F''/\phi^{\mathrm{f}}-\phi\phi^{\mathrm{f}}V_{11}-\sigma(1-\sigma)V_{12}/K-V_{13}},$$

for which the numerator is of ambiguous sign. The intuition is similar to that in the trade ban case without resale, where the price elasticity of demand is a key factor in determining whether the price effects outweigh the cost effects.

Appendix A presents simulation scenarios for the effect of confiscation policy on poaching when laundering is present.

4.2. Supply externalities

A concern with allowing legal trade is that it may cause illegal costs to fall, possibly by making enforcement less effective, given any level of effort. However, if such connections exist, they do not necessarily lend support to the trade ban argument. In fact, it is important exactly what form the externality takes. Do thicker legal markets make enforcement less effective? Do they make

poaching cheaper? Do they lower marginal costs of laundering? Or do they lower the confiscation rate for laundering? The discussion will reveal that

- an externality of legal trade that reduces enforcement effectiveness can have ambiguous effects on poaching; and
- an externality that lowers direct poaching costs may affect the optimal scope of legal trade, but it does not necessarily follow that a trade ban minimizes poaching.

If expanding the legal market makes enforcement more difficult, the effect will be similar to lowering the confiscation rate, which has already been shown to have ambiguous effects on overall poaching in several cases. The intuition is that lowering the confiscation rate lowers the illegal supply curve disproportionately compared with the poaching supply curve, since not only do average returns per kill rise, but also fewer kills need to be made to supply the same amount of goods to the market. Since the illegal supply curve falls more with the lower confiscation rate, the equilibrium price will be lower, given an equivalent shift in the poaching supply curve. Thus, the price may fall enough to mitigate the impact of the cost reduction on poaching. This result for the trade ban case was given in Eq. (8).

If, on the other hand, the externality affects pre-confiscation poaching costs, then legal trade is more likely to increase the profit to poaching. The reason is that lowering poaching costs lowers both the illegal supply and the poaching supply curves proportionately. The number of kills to supply a given amount to market remains the same, so if the price falls and consumption increases, it must be that poaching increases as well.[18]

With laundering, similar differences exists between lower laundering costs or less confiscation. If all confiscations are resold, decreased enforcement or lower costs will increase poaching. If certified sales are fixed, a decrease in laundering confiscations could have ambiguous effects. Lower laundering costs would still increase poaching.

However, the presence of cost externalities does not necessarily imply that a trade ban minimizes poaching. The action that creates the cost-lowering effect (more legal sales) also tends to lower prices. If stigma effects from the legal sales are strong, then part of the incidence of increased laundering will be to push up stigma and mitigate any price increase.

Thus, the question of whether to sell additional certified goods is whether the price-lowering effect outweighs the externality effect. With stigma, it was whether satiation outweighed the shift in demand. Here, the question is whether any negative net impact on the price is outweighed by the shift in supply.

5. Conclusion

Traditional, single market models for endangered species products suggest that sales of confiscated and legally harvested goods help reduce incentives for poaching. The analytical model in this paper shows that incorporating more complex interactions between markets for endangered species products can lead to results that contradict those earlier models. However,

[18] Consider the trade ban case where $U'(\phi K) = aC'(K)/\phi$, with a being a cost-shift parameter. A negative cost shock necessarily increases poaching: $-\frac{dK_{\text{ban}}}{da} = \frac{C'}{aC'' - \phi^2 U''} > 0$.

Table 1

Regime	Equilibrium	Effect of sales on poaching	Effect of more enforcement
Trade ban	Single illegal market	N.A.	Ambiguous
All harvesting	Single legal market	No poaching	N.A.
Legal price higher			
No laundering	Separate markets	Same as trade ban	Same as trade ban
Laundering	Imperfect arbitrage or single "legal" market	More poaching than with ban, but effect of additional sales ambiguous	Ambiguous, though confiscation and resale will lower return to poaching
Legal price lower	Perfect arbitrage	Less poaching than with ban, but effect of additional sales ambiguous	Ambiguous

not all the interactions that concern trade ban proponents imply that limited sales of certified products will encourage poaching. Table 1 summarizes the results.

In the absense of laundering, poaching is still greatest under a trade ban. However, unlike the traditional model, selling all confiscated and harvested goods may not minimize poaching; given some level of certified sales, additional legal sales may have an ambiguous effect on poaching if stigma effects are important. In the traditional model, a full resale policy for confiscated goods ensures that tighter enforcement reduces poaching. However, with separate legal and illegal markets, resale does not always help satisfy illegal demand. If all resale goes to law-abiding consumers, changes in enforcement have the same potentially ambiguous effects as under the full trade ban. If illegal consumers arbitrage between markets under a resale policy, increased enforcement may still have ambiguous effects, now if the stigma effects are strong enough to raise prices in the legal market.

On the other hand, if laundering will always be present, the least poaching occurs under a trade ban. This result requires not only that fraud be possible, but also that the lowest attainable price in the legal market (given legal supplies) remain above the trade ban price in the illegal market.

When the policy goal is simply to minimize poaching, the intuition behind the "To ban, or not to ban?" question depends on the characteristics of the markets. If demand from law-abiding consumers is relatively big and laundering can and would occur, an enforceable ban on trade would minimize poaching. However, if laundering can be eliminated, allowing certified sales would do no worse than a ban with respect to poaching, while welfare would be higher. If the bulk of demand comes from noncompliant consumers and laundering would generally not occur, then allowing sales of certified goods would tend to lower prices and lower the return to poaching.

Stigma can play an important role, but it does not imply that some certified sales are necessarily counterproductive for poaching policy. Stigma figures into the ban question because it affects the relative size of legal demand. A trade ban is more likely to be needed when stigma effects (as modeled here) are weak and lawful demand is strong. If stigma is initially strong and little affected by small amounts of certified sales, a limited resale policy can help drive down prices in

the illegal market. However, full resale may not minimize poaching; changes in stigma can be important for determining the optimal amount of trade.

Similarly, supply externalities may affect the extent of legalized trade that is desirable, but their presence does not necessarily make a trade ban preferable. If legalized sales make enforcement more difficult, the effect on poaching can be ambiguous, just like the effect of changes in the confiscation rate. If certified sales make poaching itself easier, that effect must be weighed against the price-decreasing effect, perhaps leading to fewer sales rather than no sales at the optimum. If laundering would occur and certified sales would make it cheaper, that would indeed reinforce the case for a trade ban. Alternatively, limited auctions could be combined with a tax on certified sales to eliminate the producer price discrepancy and laundering incentive between legal and illegal supplies.[19]

Appropriate trade and enforcement policy for endangered species products (or dual market products more generally) thus requires a reasonable sense of the different demand and supply parameters. For example, if lawful demand for rhino horn is low and most consumers are indifferent to certification, the trade ban is likely to be ineffectual in reducing demand, and selling confiscated products would bring down prices, primarily by increasing supply to illegal consumers. If ivory, on the other hand, is in large demand by law-abiding consumers with a strong sense of stigma, sales of some but perhaps not all the available stock may help reduce the return to poaching.

An essential research need is to understand these demand variables better according to the products in questions. Unfortunately, such an endeavor can be tricky, given the inherent lack of good data for black-market sales. Improved monitoring of legal markets should also be a priority to determine the extent to which laundering might allow poached goods to masquerade as certified ones, as that is a central mechanism for legal sales to have detrimental effects.

In addition to empirical investigations, a dynamic model could add more richness to the analysis of the supply side as well. For these kinds of species applications, harvest and poaching variables should be endogenous to the resource stock. Although adding a biological response function will influence equilibrium levels of poaching and prices, the underlying market fundamentals studied here will remain. Recognizing that products like ivory are durable and storable is also likely to be important for price dynamics.

Of course, the policy goal may not simply focus on poaching. Restricting trade has several consequences, including forgone enjoyment of the products (consumer surplus), enforcement costs, revenues available for wildlife management, and changing producer costs, not to mention community impacts of changes in the species population. If the goal is to maximize welfare, determining optimal policy involves more complex issues, not the least of which is defining welfare. For example, should one care about the utility of illegal consumers? Or illegal producers? How does stigma affect the evaluation of the utility of law-abiding consumers? An additional question raised by stigma is whether and how sensitivity to stigma should be manipulated. For products with malleable demand, publicity campaigns—such as "Just say no"[20] or "I'd rather go

[19] A literature in environmental economics exists on interactions between legal and illegal options for waste disposal and tax structures to cope with it [7,8].

[20] Nancy Reagan's campaign against drug use.

naked than wear fur''[21]—could be important policy tools. By reducing law-abiding consumer demand, one could make sales policy more effective at driving down the return to poaching.

Finally, the complications created by separate markets for stigma-related or regulated goods are not restricted to ivory and other endangered species products (like rhino horn, tiger bones, and turtle shells). For example, the current model could be applied directly to the case of ''blood'' diamonds from war-torn areas, which involves both stigma and laundering. Final demand is from lawful consumers and is large enough to make a ban an unlikely policy, although differentiating that demand through certification is possible. However, to the extent that some will pay a premium for certified non-blood diamonds, openings for fraud will translate some of this differential into higher prices for all diamonds, including those from war-torn areas. If consumers realize that laundering occurs, stigma may influence market prices.

The model could also be adapted to analyze many other products with grey, black, or otherwise segregated markets: GMO-free, cruelty-free or organic products; certified, sustainably harvested timber; drugs; and guns. Several of the other examples share the complex interactions of dual markets, but the demand externalities or the supply interdependence may be quite different.[22] Judging from the results in this model, understanding these kinds of real interactions will be critical to evaluating the effects of banning or restricting sales of many kinds of products that are societally problematic.

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Appendix A. Simulating the stigma model

Since poaching activity is typically the variable of most interest to policymakers, we would like to understand how equilibrium poaching reacts to policy changes. To solve for equilibrium poaching activity, we must specify functional forms for demand and supply. To explore further the effects of dual markets and stigma on the impact of enforcement, consider the following simple example using linear supply and demand curves.

Let illegal (inverse) demand be linear of the following form: $P_N = y - Q_N$. Law-abiding consumers have linear demand in the absence of a ban, but $Q_L = 0$ under a ban. Their demand is assumed to be either identical to that of noncompliant consumers or adjusted by a stigma factor. Let marginal poaching costs also be linear: $C'(K) = cK$, leading to the (inverse) poaching supply curve $P_S = cK/\phi$.

[21] People for the Ethical Treatment of Animals' campaign against fur.

[22] For example, for endangered species products, the legal supply is tied in part to the illegal supply, as in the case of selling products confiscated from poachers. However, in the case of guns, the illegal supply might instead be a function of the legal supply, if some guns that are initially sold legally subsequently get stolen, resold or otherwise diverted into the unregulated market. The stigma of gun ownership may also be reversed; legal consumers may get more utility from gun ownership the larger the illegal market is, as a response to more criminals' owning guns.

Now we solve for equilibrium poaching in four cases. No trade ban in a scenario means that the remaining illegal supply (ϕK) is not restricted to illegal consumption.

Trade 1: An equilibrium with just illegal consumers and all confiscations resold.

Trade 2: An equilibrium with both markets and all confiscations resold, but where legal consumers are identical to illegal ones. In other words, there is no trade ban and no stigma effect, but antipoaching policy remains. Note that this case represents a single market (as in traditional models); allowing for separated legal and illegal markets would lead to equilibrium poaching of $\min\{K_{\text{ban}}, K_2\}$.

Ban: A trade ban equilibrium.

Trade σ: A no-ban, perfect arbitrage equilibrium with stigma and all confiscations resold. This case again represents a single market. Allowing for separated legal and illegal markets, the resulting equilibrium would be $\max\{\min\{K_\sigma, K_{\text{ban}}\}, K_1\}$.

The following table summarizes the functional form assumptions and equilibrium values for the different scenarios.

Scenario	*Ban*	*Legal demand*	*Price Eq.* (P_S)	*Supply Eq.*	*Poaching*
Trade 1	No	NA	P_N	$Q_N = K$	$K_1 = \frac{y\phi}{c+\phi}$
Trade 2	No	$P_N = y - Q_L$	$P_N = P_L$	$Q_N + Q_L = K$	$K_2 = \frac{2y\phi}{2c+\phi}$
Ban	Yes	NA	P_N	$Q_N = \phi K$	$K_{\text{ban}} = \frac{y\phi}{c+\phi^2}$
Trade σ[23]	No	$P_L = b(1-\phi)y - Q_L$	P_N and/or P_L	$Q_N + Q_L = K$	$K_\sigma = \frac{(1+b(1-\phi))y\phi}{2c+\phi}$

A.1. Enforcement policy and poaching

Fig. 6 depicts an example where $y = 10$, $b = 2$ and $c = 0.5$ (or half the slope of the demand curves). With the trade ban, we see that for smaller confiscation rates, increasing enforcement actually increases equilibrium poaching. Not until confiscation becomes more complete is poaching actually reduced.[24] Without stigma effects, a resale policy implies that increases in enforcement always lead to less poaching, as is evident in both trade cases 1 and 2.

The horizontal line shows that a ban alone (without enforcement) is more effective than a full-trade policy, up to fairly high levels of confiscation, since it immediately eliminates the law-abiding half of the market. A combination of ban and legal resale would follow the minimum of the ban and full trade poaching. The smaller is the law-abiding portion of the market (of which Trade 1 is the limit), the sooner can an enforcement policy with resale reduce poaching.

Stigma produces interesting effects. As modeled here, stigma is so high for low levels of confiscation, lawful consumers are outbid by illegal consumers for the resold goods. Thus, initially, the arbitrage path follows Trade 1 until a positive equilibrium quantity generated in the legal market (around $(1-\phi) = 0.2$ in this example). But only for higher confiscation rates is more enforcement effective at reducing poaching, and at that point, the effect of falling stigma makes it harder to reduce poaching.

[23] This scenario has corner solutions. $P_S = P_N = P_L$, for $Q_L > 0$ and $Q_N > 0$; and $P_S = P_N$ for $Q_L = 0$, and $P_S = P_L$ for $Q_N = 0$. The equation for K_σ represents the interior solution.

[24] In this case, until $\phi = c$, or c/m for other linear demand functions with slope m.

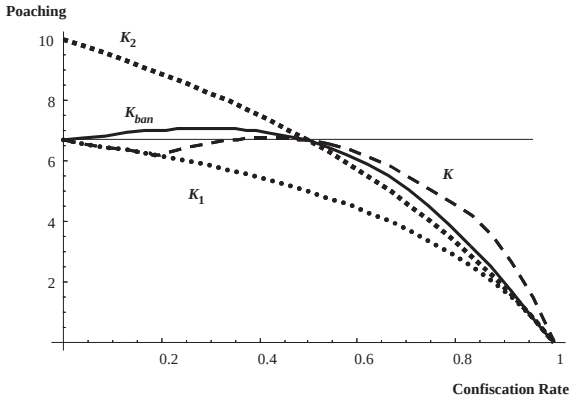

Fig. 6. Poaching and enforcement.

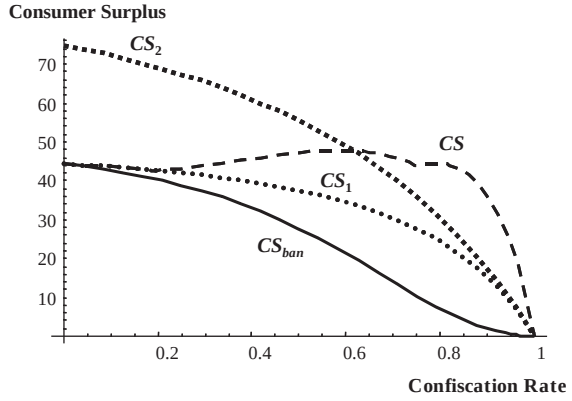

Fig. 7. Consumer welfare and enforcement.

A.2. Welfare

Poaching, however, may not be the only variable policymakers are concerned with. Restricting trade also has other implications, including forgone enjoyment of the products (consumer surplus), enforcement costs, and changing producer costs (although we may tend to sympathize less with the last). As an illustration, Fig. 7 displays the combined consumer surplus of the previous example.

A trade ban is always worst for consumers, and more so at higher confiscation rates, when it performs worse at reducing poaching compared with trade scenarios. Welfare is always higher and poaching lower when confiscated goods are resold on illegal markets (the traditional single market example). When stigma is irrelevant, welfare steadily declines with enforcement, reflecting the consumption decline. However, when stigma is a factor, welfare can rise with enforcement (although so may equilibrium poaching). The kinks in that curve reflect switching from and to corner solutions. First, stigma is so high that all goods are bought by illegal consumers; then, perfect arbitrage occurs; finally, stigma falls so low that legal consumers drive the illegal ones out

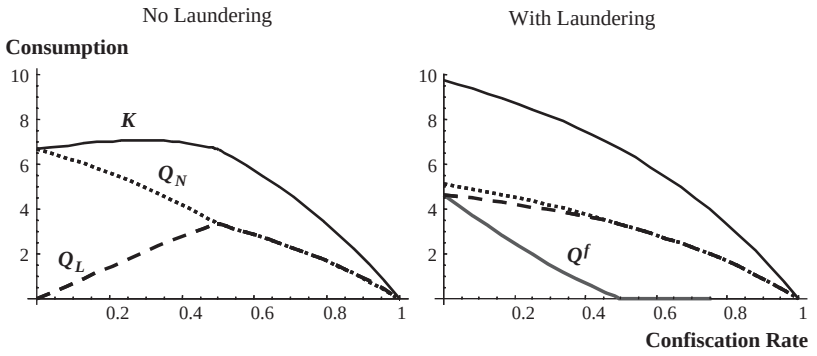

Fig. 8. Enforcement and laundering without stigma.

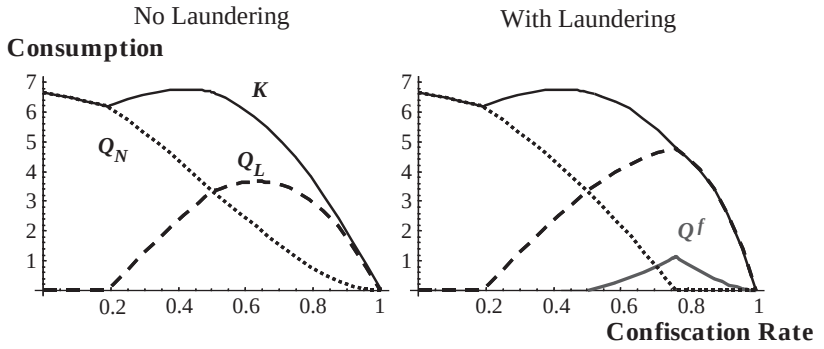

Fig. 9. Enforcement and laundering with Stigma.

of the market. The consumer welfare-maximizing confiscation rate is positive but less than 1 when stigma is important (here roughly 65%).

A.3. Laundering

Adding laundering results in equilibria much like the no-ban scenarios Trade 2 and Trade σ. Both consumer types have almost full access to the overall market, although the costs to legal consumers are slightly higher because of laundering costs. Figs. 8 and 9 illustrate the effects of laundering and enforcement on consumption and poaching, for the cases without and with stigma, respectively. The presence of laundering, in the absence of stigma, ensures that poaching returns are strictly declining with the confiscation rate. With or without laundering, however, a trade ban alone may be more effective than confiscation until the rate is relatively high.

With our form of declining stigma, laundering becomes less significant for enforcement policy, as the price differential appears only when stigma is relatively low, which occurs only when enforcement rates are relatively high.

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