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.

Keywords: Endangered species, black markets, CITES, poaching, stigma

JEL: K42, Q21, D11

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1 Introduction

The question of whether to sell confiscated endangered species products such as ivory generated a great deal of debate at the 11th Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in April, 2000. An experiment authorized by CITES allowed three southern African countries to sell some of their stockpiles of captured ivory in 1999. Accounts of the effects on poaching of this limited legalized trade have reported mixed evidence. According to the Environmental Investigation Agency, a non-governmental group based in the United Kingdom, elephant poaching has increased since the sales. According to the United Nations, it has not. According to simple economic theory, however, it 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 (Bergstrom 1990). 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.

As a result of these complex interactions, 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. Interactions can occur on both the demand and supply sides of dual markets, and the type and extent of these interactions vary for different products.

On one side are demand externalities, which we refer to 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 more important for display goods, like ivory or diamonds, than consumed goods, like medicinal uses of rhino horn. While stigma depends on the relative size of the illegal market to the legal one, 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.

On the supply side, interactions can arise 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 also 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. These latter costs may also be affected by legal market activity, besides just enforcement.

Most previous studies assume 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. Barbier and Swanson (1990) and Heltberg (2001) both recognize that international consumer demand may shift in a switch from free trade to a trade ban regime, but they do not model separate types of markets with limited legal trade. Bulte and van Kooten (1999) 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 non-consumptive use values. Another long literature exists on competition between 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).

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 bring online.

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 impact 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 of one-way demand-side arbitrage. Section 4 subsequently adds laundering and supply-side externalities. Section 5 uses simple functional forms to solve the model numerically and explore the effects of the different market assumptions on how confiscation rates impact poaching, consumption and welfare. Although the model used in this paper is static, it serves as a useful foundation for analyzing renewable resource problems as well. A dynamic component of a resource stock response could be added to consider long-run effects.

The results indicate that separate demand by law-abiding consumers is not a problem in itself for poaching. 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 only change their behavior if prices in the legal market fall below black market prices, legal trade can only serve to depress prices (and thereby poaching incentives) on the black market or do nothing. Stigma effects do not change this result, except that selling all available certified products may not minimize the international price. For trade to be problematic to poaching, legal demand must be tied to legal supply, either through arbitrage opportunities like laundering or through externalties with respect to poaching costs. Laundering opportunities to bring illegal goods fraudulently to legal markets can bid up illegal prices if legal demand is higher.

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 assume, at least for now, that certified products can be distinguished from uncertified ones. Later, we will introduce laundering as a means to bring uncertified goods to supply the legal market.

Let us define the following variables:

Q_L^c	Consumption of certified products by law-abiding consumers
Q_N^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
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

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

$$\begin{aligned} K &> 0, C'(K) = \phi P^u; \\ K &= 0, C'(0) > \phi P^u \end{aligned} \tag{1}$$

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 consfiscated from poachers. Legal harvesting, H, can be from animals that died of natural causes or from active farming (which we may add later in a dynamic 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

$$S^c \leq H + (1-\phi)K.$$

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

$$Q_N^c + Q_L^c = S^c.$$

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 worry about stigma that may be attached to their consumption. They may also care about the health of the species population. 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: $V_1 \geq 0$; $V_{11} < 0$. Since stigma derives from the perception that the product was obtained through illegal or inhumane means;[1] we

[1] We assume that the consumer knows her type, and knows if the product was obtained legally; however, others do not know her type, only the odds of the product being purchased legally. The impact of stigma on utility then depends on how much the consumer cares about that perception in order to enjoy the product.

will assume this negative perception is an increasing funtion of σ, the fraction of the total market that is illegal. Thus, for endangered species products and like goods, utility is decreasing in σ: $V_2 < 0$; $V_{12} < 0$. (On the other hand, for goods like guns, marginal utility may be increasing in the fraction of the sales going to illegal consumers.) The strength of stigma effects can depend on whether the good is used publically 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: $V_1(0, 1, K) \leq 0$. Finally, consumers may enjoy their product more if the population stock, net of poaching, is higher; alternatively, poaching activity and the associated horrors may increase stigma effects. We will call this third term "outrage" and assume utility is decreasing 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 they are consuming certified goods is positive, their marginal utility of consumption equals the price:

$$Q_L^c > 0,\ V_1(Q_L^c, \sigma, K) = P^c. \tag{2}$$

2.2.2 Stigma

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:

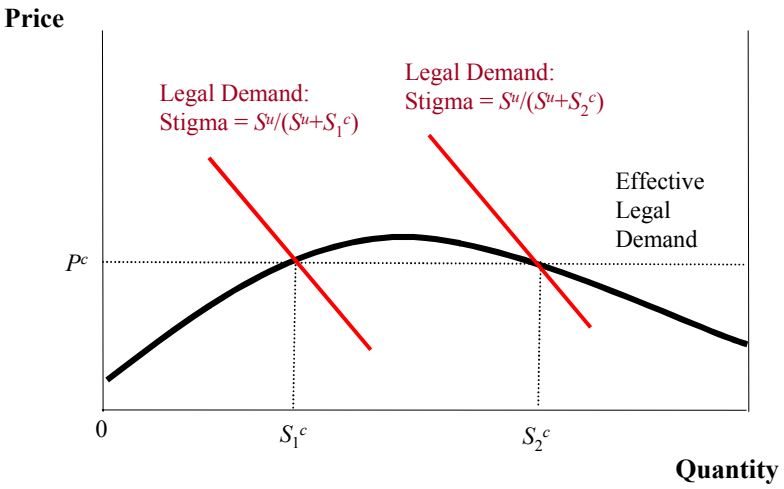
$$\sigma = \frac{S^u}{S^c + S^u}$$

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, $\sigma = \phi$.

We assume for now that the stigma variable does not affect supply; i.e., the costs of bringing illegal goods to market are unaffected by the availability of certified products. The total legal supply only affects the stigma of consuming endangered species products. This assumption allows us to consider the implications of demand-side market interactions.

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. Effectively, then, the legal demand curve facing the policy maker may be either downward sloping, upward sloping, or nonmonotonic. The following figure illustrates the case where stigma effects initially dominate but decline as sales increase and satiation becomes more important.

Figure 1: Legal Demand and Stigma



2.2.3 Noncompliant Consumers

Noncompliant or "illegal" consumers are assumed to be impervious to stigma or outrage. Their utility arises solely from their total ivory consumption: $U(Q_N)$, and they are indifferent to the source of that consumption. They may purchase Q_N^c from legal markets and Q^u through illegal channels (the subscript can be ignored since 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:

$$Q_N^c > 0, \quad Q^u = 0, \quad U'(Q_N^c) = P^c < P^u \tag{3}$$

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

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

Noncompliant consumers are indifferent as to the source of the product, whether 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 One-Way Arbitrage

Some supporters of the trade ban for ivory and other endangered species products argue, in part, that allowing legal sales of seizures, by reducing the stigma of ivory consumption, and thus 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:

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

then

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

To demonstrate these results, we now return to the three possible types of market equilibria with trade and compare them to the trade ban scenario.

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, $Q_L^c + Q_N^c = S^c = 0$ and $Q^u = S^u = \phi K$. In this equilibrium,

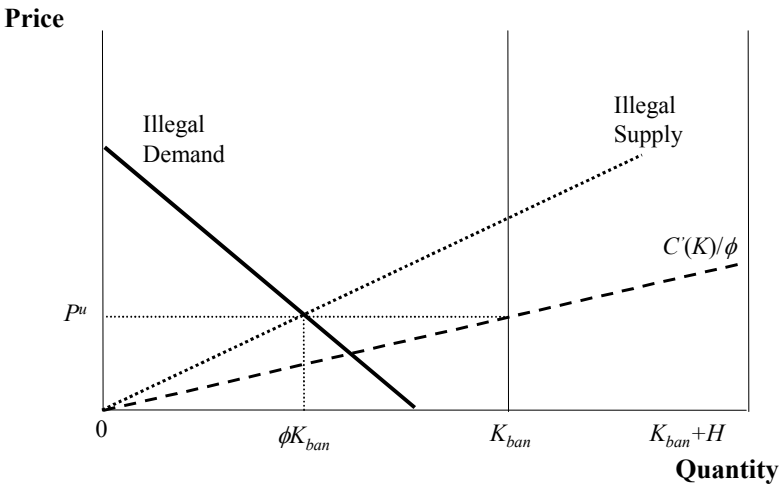
$$U'(\phi K) = C'(K)/\phi. \tag{6}$$

Let K_{ban} be the level of poaching activity that solves this equation. Figure 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 (6) and solving, we get the change in equilibrium poaching due to a small increase in the confiscation rate (a decrease in the escape rate):

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

Figure 2: Trade Ban



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:

$$-\frac{dK_{ban}}{d\phi} = \frac{(1-\eta^u)P^uQ^u}{\phi(\eta^uQ^uC'' + \phi P^u)}. \tag{7}$$

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.

Figure 3: Change in Enforcement

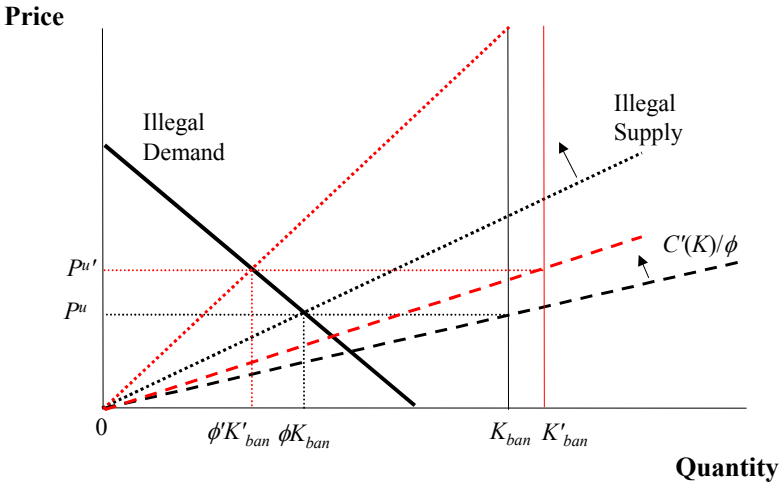


Figure 3 portrays a change from a confiscation rate of 1/2 to 2/3, which shifts the supply curve from the inelastic portion of the demand curve. As a result, while illegal consumption falls to $\phi' K'_{ban}$, total poaching increases to K'_{ban}.

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: $P^u_{resell} = C'(K)/\phi = U'(K)$. In this case, an increase in enforcement would unambiguously decrease poaching:

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

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 $Q^c_L + Q^c_N = S^c$ and $Q^u = 0$. If no one buys poached materials, then $K = 0$; no poaching then implies no confiscation and $S^c = H$. In other words, legal harvesting must fully satisfy both markets. From the first-order conditions for consumers (2) and (3), in this equilibrium we have

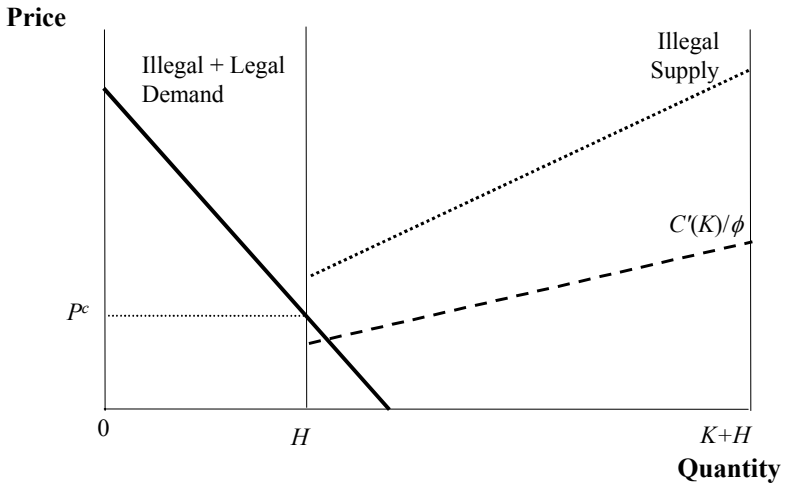
$$V_1(Q^c_L, 0, 0) = U'(H - Q^c_L) = P^c \tag{8}$$

and from (1),

$$P^c < C'(0)/\phi \tag{9}$$

This situation can occur if expropriation is very high or complete ($\phi = 0$), or if residual demand after legal harvests are sold is very low, that is, below the threshold for poaching: $C'(0)/\phi$. Figure 4 depicts this case. Decreasing S^c necessarily raises prices: it lowers the marginal utility from direct consumption and does not affect stigma, as long as all products are still legal. In terms of the picture, decreasing sales from H would shift the kink in the supply curve left. Raising prices then does risk causing poaching to begin if the production threshold is reached. A trade ban in this situation then necessarily increases poaching.

Figure 4: Single Legal Market



Increasing enforcement has no effect, since no poaching is taking place. Decreasing enforcement, all

else equal, could induce poaching if the after-confiscation return is raised above the threshold.

The value of H relative to demand is obviously important here, as it determines whether sufficient returns to poaching exist. In a dynamic model, the stock of elephants will affect both H and poaching costs. Brown and Layton (2001) 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 the herd dynamics. Thus, in thinking ahead toward a model of optimal harvesting, we need to recongnize equations (8) and (9) as constraints, in addition to the biological response functions. These interesting additional complications will be saved for later exploration.

3.3 Separate Legal and Illegal Markets

In an equilibrium where both market are active but separate, we have $Q_L^c = S^c \leq H + (1-\phi)K$, $Q_N^c = 0$, and $Q^u = S^u = \phi K$. From the first-order conditions for consumers and producers (equations (2), (4), and (1)), we see that prices must be higher in the legal market:

$$V_1(S^c, \phi/(\phi + S^c/K), K) > U'(\phi K), \tag{10}$$

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

$$U'(\phi K) = C'(K)/\phi. \tag{11}$$

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 only be impacted 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 determines 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.

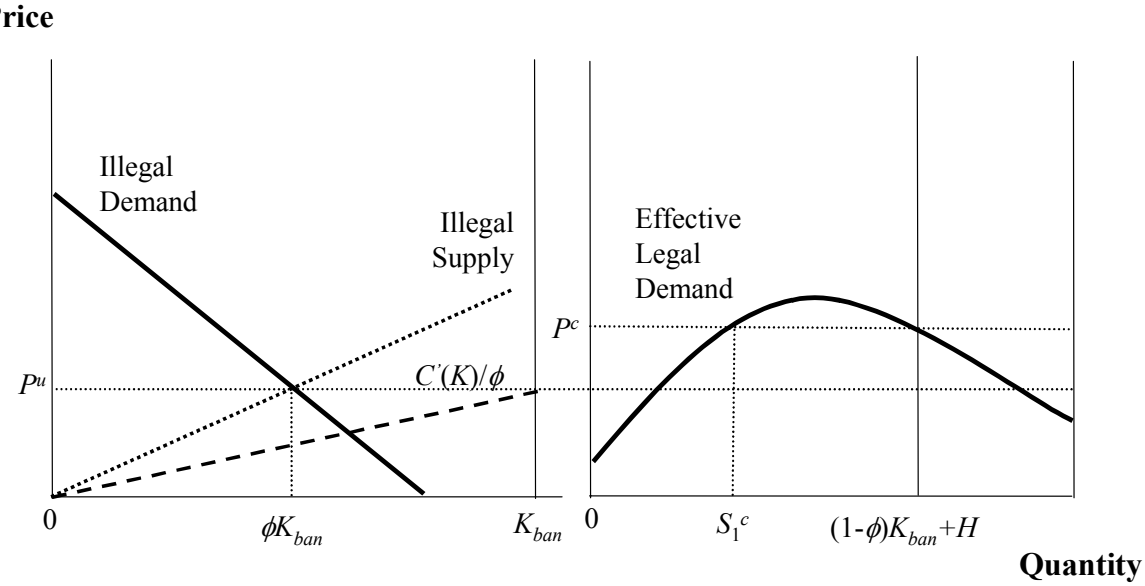
In either case, starting from a point where the markets are separate, a trade ban does nothing to illegal markets, and thereby does nothing for poaching. A change in legal sales will affect welfare through consumption, but it will do nothing to poaching unless a regime switch occurs. And in that case, it can only

reduce poaching.

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

Figure 5: Separate Markets



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 (equations (2), (5), and (1)), we know that the marginal

utilities of legal consumption are equalized:

$$V_1(Q_L^c, \phi K/(\phi K + S^c), K) = U'(S^c - Q_L^c + \phi K); \tag{12}$$

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

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

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 would 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 would 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 only occur in one direction, it can only drive down the prices in the illegal market compared to no trade, not raise them. Therefore, under no conditions can a full ban on trade improve 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_N^c.

Given any K, totally differentiating (12), we get

$$\frac{dQ_L^c}{dS^c} = \frac{U'' + V_{12}\frac{\phi K}{(\phi K + S^c)^2}}{V_{11} + U''} > 0 \tag{14}$$

Increasing legal sales unambiguously raises legal consumption as it reduces stigma and the supply shift lowers prices. The impact on illegal consumption will depend on the direction of price change in the legal market.

Let us write $P^c = V_1(S^c - Q_N^c, \phi K/(\phi K + S^c), K)$. Holding Q_N^c and K constant,

$$\frac{\partial P^c}{\partial S^c} = V_{11} - V_{12}\frac{\sigma}{\phi K + S^c} > 0? \tag{15}$$

The sign depends on whether the stigma effect at that point is greater or less than the direct effect on marginal utiltity; that is, if the movement along the demand curve dominates the shifting up.

In equilibrium, part of the incidence of this change will be borne by illegal consumers and part through changes in poaching. If P^c goes down, illegal consumers will shift away from uncertified goods toward certified ones, stemming some of the price fall; meanwhile the return to poaching will fall. 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.

The policy prescription then depends on the shape of effective legal demand.

Strictly Declining Demand If effective legal demand declines monotonically with legal consumption, then maximizing sales minimizes the price. Selling all harvested and confiscated goods then minimizes poaching, given any level of enforcement. Let us define this price as

$$P^c_{all} = V_1(Q^c_{L,all}, \frac{\phi}{1 + H/K_{all}}, K_{all}) = U'(K_{all} + H - Q^c_{L,all}) = C'(K_{all})/\phi. \tag{16}$$

Strictly Increasing Demand If effective legal demand increases monotonically with legal consumption, then the price is minimized when no certified products are sold *to law-abiding consumers*. This distinction is important: some certified sales must occur, else we would not be in a perfect arbitrage equilibrium. As will soon be illustrated, these sales serve to drive down the price in the legal market until stigma is low enough to get legal consumers to consider buying. Let us define this price as

$$P^c_{none} = V_1(0, \frac{\phi}{\phi + S^c/K_{none}}, K_{none}) = U'(\phi K_{none} + S^c) = C'(K_{none})/\phi. \tag{17}$$

Nonmonotonic, Concave Demand If effective legal demand is strictly concave, then the price is minimized at $\min\{P^c_{all}, P^c_{none}\}$. Let us illustrate this result.

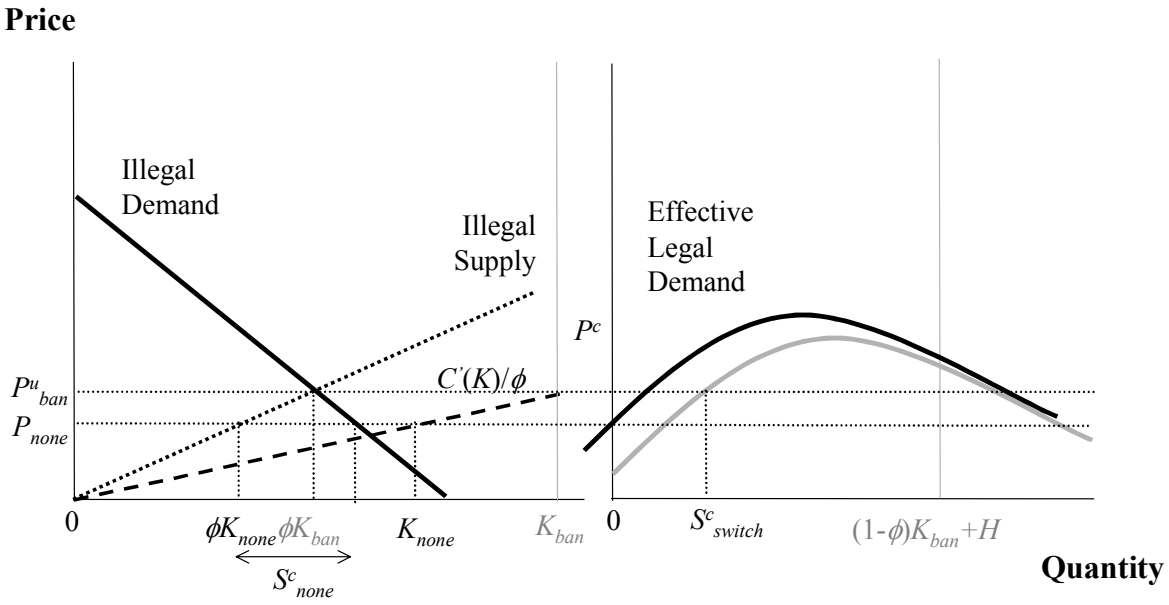
From Figure 5, we saw that when legal demand is nonmonotonic, the legal price may be driven down below the trade-ban price in two ways. First, one could sell a lot of certified products and saturate the market, but this may require a large source of harvested goods. Second, one could dramatically cut 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 down 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.

In Figure 6, the gray lines portray the trade-ban equilibrium. If certified sales rise above the level S^c_{switch}, the markets remain separate. Below this level, due to greater stigma, the willingness to pay by law-abiding consumers 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, as 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

Figure 6: Perfect Arbitrage with Declining Stigma Effects



amount of certified sales. However, for the harvesting supply shown in the picture, this level of sales would not be feasible.

Nonmonotonic, Nonconcave Demand 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.

These last three cases, that something less than full resale might minimize poaching, exist only due to stigma effects. In all cases, however, 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 of these 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 only raise willingness to pay if enforcement actually decreases poaching. As before, additional enforcement contracts illegal supply, which raises prices in the illegal market and, by arbitrage, in the legal market. In this case,

holding S^c fixed, the reduction in illegal supply reduces stigma, which also 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.

Unlike the trade-ban case, the effects of greater enforcement may now also be ambiguous even when all confiscated goods are resold, due to the impact of stigma. Consider a policy of full resale, as in (16). Then stigma is proportional to the share of poached products that escape confiscation: $\sigma_{all} = \phi/(1 + H/K)$. Without a stigma effect, increasing enforcement unambiguously reduces poaching, since reselling the additional confiscations keeps demand low while costs rise (as in the Bergstrom model). However, raising enforcement now also 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.

Figure 7: Enforcement and Stigma Changes

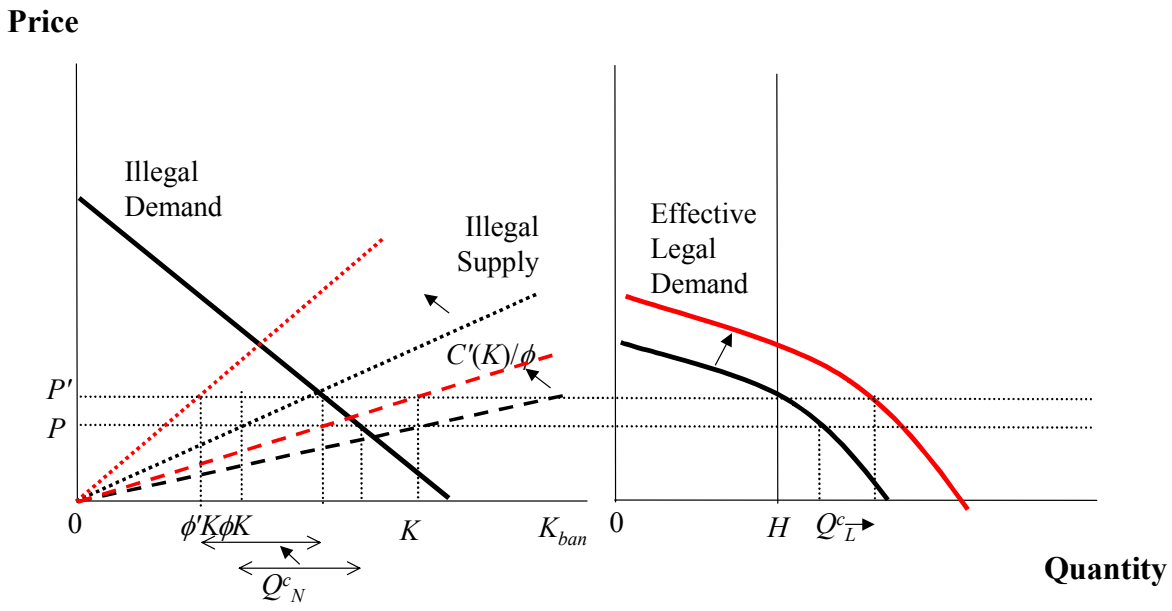


Figure 7 portrays an example where an increase in the confiscation rate (decrease in ϕ) generates an outward shift in demand from reduced stigma that happens to just outweigh the upward shift in poaching supply costs. Thus, the degree of the stigma effect plays an important role for enforcement decisions in a perfect-arbitrage equilibrium.

4 Two-Way Arbitrage

4.1 Laundering

In the preceding cases, with only stigma effects, we saw that a trade ban could never reduce poaching compared to 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 visa-versa, trade policy can have ambiguous effects.

This reverse link between the markets can arise in different ways. The very existence of a certification process makes counterfeiting possible. Thus, laundering can bring poached goods to the certified market.

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, $(1-\phi^f)$, the rate of confiscation of laundered products. We assume that the more laundering is performed, Q^f, the greater their costs of doing so, $F(Q^f)$, where $F'(Q^f) > 0$, $F''(Q^f) \geq 0$ for $Q^f > 0$. (Thus we assume for now that laundering costs are unaffected by the size of the legal market.) Launderers maximize their net profits:

$$(P^c - P^u)Q^f\phi^f - F(Q^f)$$

The first-order condition for laundering to occur is

$$P^c - P^u = \frac{F'(Q^f)}{\phi^f} \tag{18}$$

Thus, if no price differential exists and the illegal consumers are doing the arbitrage, no laundering will occur. That is because excess supply in the legal market is satisfying demand in the illegal market. On the other hand, when the market equilibrium would involve 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 $P^c > P^u$, we know that $Q^c_N = 0$. Therefore, the market-clearing conditions are

$$\begin{aligned} Q^c_L &= S^c + \phi^f Q^f \leq H + (1-\phi)K + Q^f \\ Q^u &= \phi K - \phi^f Q^f \geq 0 \end{aligned}$$

where $0 < S^c \leq H + \theta K + \theta^f Q^f$. From the first-order conditions for consumers and producers, we have

$$Q^f > 0, V_1(S^c + \phi^f Q^f, \sigma, K) = \frac{C'(K)}{\phi} + \frac{F'(K)}{\phi^f} \tag{19}$$

and

$$Q^u > 0, U'(\phi K - \phi^f Q^f) = P^u = C'(K)/\phi \quad (20)$$

$$Q^u = 0, U'(0) < C'(K)/\phi \quad (21)$$

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. The other is when demand in the market for certified products is so strong, illegal consumers are crowded out completely, as intermediaries can get higher prices by laundering the goods.

We maintain the assumption that stigma is represented by the odds of the product being obtained illegally, which is unaffected by laundering: $\sigma = \phi K/(S^c + \phi K)$.

4.1.1 Imperfect Arbitrage

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 equation (22), as well as (20). The effect of greater sales or enforcement display the same direction as in the previous case, although the magnitude will differ, since some of the incidence is borne by changes in illegal demand.

Thus, if the market parameters are such that laundering occurs, a trade ban will reduce poaching. These conditions imply that marginal utility in legal markets is greater than in illegal ones ($V_1(S^c, \phi/(\phi + S^c/K_{ban}), K_{ban}) > U'(K_{ban})$), enough to justify laundering, which drives up prices in the illegal market and thereby the incentive to poach.

4.1.2 Single "Legal" Market

In the previous single legal market case, 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, launderers resell everything. If the illegal market is crowded out, then $Q^f = \phi K$. In equilibrium,

$$V_1(S^c + \phi^f \phi K, \phi K/(S^c + \phi K), K) = \frac{C'(K)}{\phi} + \frac{F'(\phi K)}{\phi^f} \quad (22)$$

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

Selling more certified products then has an impact on the level of poaching depending on the relative effects of consumption versus stigma. If stigma dominates, prices rise, as does poaching and laundering. If satiation dominates, prices fall, as do illegal activities. By definition, a trade ban would reduce poaching, since $C'(K)/\phi > U'(0) > U'(\phi K_{ban})$.

An equilibrium where all confiscated products are sold (and no harvesting is available) is characterized by

$$V_1(K, \phi, K) = \frac{C'(K)}{\phi} + \frac{F'(\phi K)}{\phi^f} \quad (23)$$

Figure 8: Single "Legal" Market

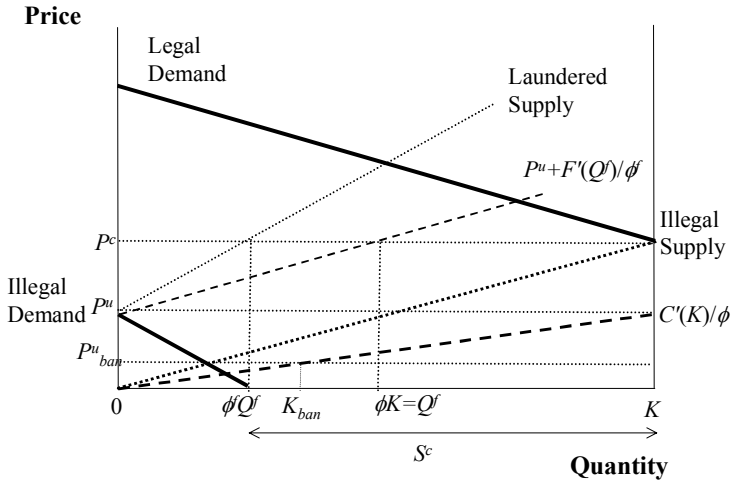


Figure 8 depicts what such an equilibrium would look like when all confiscated products are sold. The certified price is that at which legal demand equals total supply K. That supply is determined by the price in the illegal market. Furthermore, at the corresponding price differential, the entire poached supply remaining after confiscation is laundered, of which $\phi^f Q^f$ gets through while the remainder is resold. Laundering has driven the illegal market price above the intercept of the illegal demand curve.

4.1.3 Confiscation Policy

The effect of increased enforcement against poaching in a market with laundering would be to raise poaching costs and lower stigma. Theoretically, the direction of impact on poaching could be ambiguous, as it was in the perfect arbitrage equilibrium (without laundering). In this case, with complete laundering leading to a single "legal" market, illegal consumers do not change their consumption as prices change. Since we need not concern ourselves with the incidence on illegal consumers, the results can be shown more easily mathematically. Consider the full-resale equilibrium with no harvesting and complete laundering, as in (23). Totally differentiating, we get the change in poaching as the confiscation rate increases:

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

While the denominator is positive, the numerator is of ambiguous sign, as enforcement raises poaching costs but lowers laundering and its costs and lowers stigma.[2]

Greater enforcement of laundering, on the other hand, would raise those costs and unambiguously de-

[2]A similar but messier result is achieved 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. Totally differentiating 22:

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

crease poaching if everything confiscated is resold:

$$-\frac{dK}{d\phi^f} = \frac{-F'/(\phi^f)^2}{C''/\phi + F''/\phi^f - V_{11} - V_{12} - V_{13}} < 0.$$

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 affects.

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 (22), we get

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

The intuition is similar to that in the trade-ban case without resale, where the price elasticity of demand is a key factor.

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

1. make enforcement less effective?
2. make poaching cheaper?
3. lower marginal costs of laundering?
4. lower the confiscation rate for laundering?

The discussion will reveal that

- An externality that reduces enforcement effectiveness can have ambiguous effects on poaching;
- An externality that lowers direct poaching costs may affect the optimal scope of trade, but 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 to the poaching supply curve, since not only do average returns per kill rise, but 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 equation (7).

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 lower poaching costs lower both the illegal supply and the poaching supply curves proportionately; the ratio remains the same since the number of kills to supply a given amount to market remains the same. 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:

$$-\frac{dK_{ban}}{da} = \frac{C'}{aC'' - \phi^2 U''} > 0. \tag{24}$$

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 Enforcement Policy and Poaching

Since poaching activity is typically the key variable of interest to policy makers, 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. That demand is assumed to be either identical to 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 $P_S = cK/\phi$.

Now we solve for equilibrium poaching in four different 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 anti-poaching

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 $\min\{K_{ban}, K_2\}$.

Ban: A trade ban equilibrium.

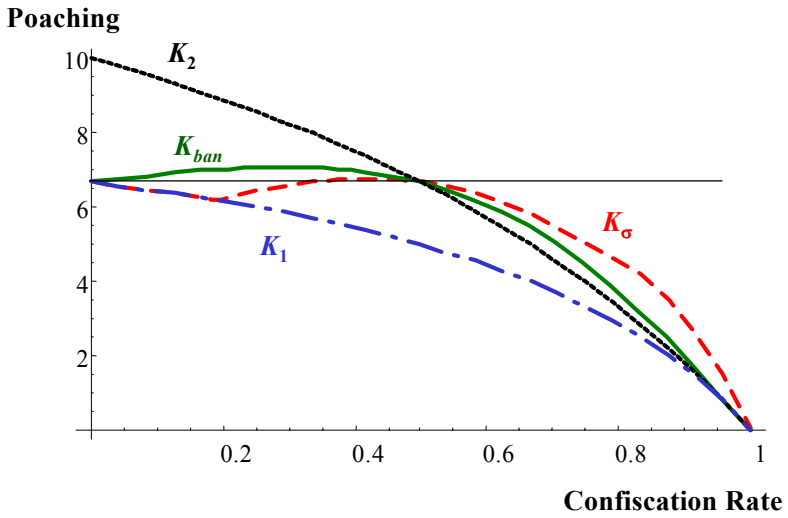
Trade σ: A no-ban, perfect arbitrage equilibrium with stigma and all confiscations resold. This case again represents a single market. Allowing for separated legal and illegal markets, the resulting equilibrium would be $\max\{\min\{K_\sigma, K_{ban}\}, K_1\}$.

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	$Q_N = \phi K$	$K_{ban} = \frac{y\phi}{c+\phi^2}$
Trade σ[3]	No	$P_L = b(1-\phi)y - Q_L$	P_N and/or P_L	$Q_N + Q_L = K$	$K_\sigma = \frac{(1+b(1-\phi))y\phi}{2c+\phi}$

Figure 9 depicts an example where $y = 10$, $b = 2$ and $c = .5$ (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.[4] 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.

Figure 9: Poaching and Enforcement



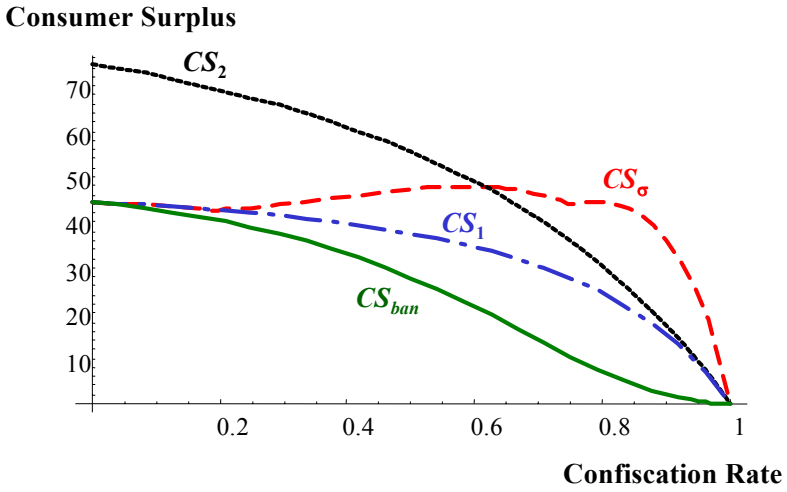
[3]This scenario has corner solutions. $P_S = P_N = P_L$, for $Q_L > 0$ and $Q_N > 0$; and $P_S = P_N$ for $Q_L = 0$, and $P_S = P_L$ for $Q_N = 0$. The equation for K_σ represents the interior solution.

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

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 Trade1 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 Trade1 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.

Figure 10: Consumer Welfare and Enforcement



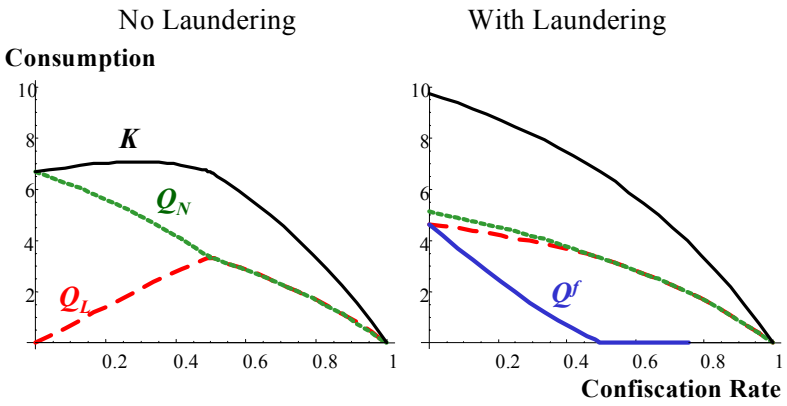
Poaching, however, may not be the only variable policy makers are concerned with. Restricting trade also has other implications, including foregone enjoyment of the products (consumer surplus), enforcement costs, and changing producer costs (although we may tend to sympathize less with the latter). As an illustration, Figure 10 displays the combined consumer surplus of the previous example.

A trade ban is always worst for consumers, and moreso at higher confiscation rates when it performs worse at reducing poaching compared to 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 all goods are bought by illegal consumers; then, perfect arbitrage occurs; finally, stigma falls so low that legal consumers drive the illegal ones out of the market. The consumer welfare-maximizing confiscation rate is positive but less than 1 when stigma is important (here roughly 65%).

Adding laundering results in an equilibria much like the no-ban scenarios Trade 2 and Trade σ. Both

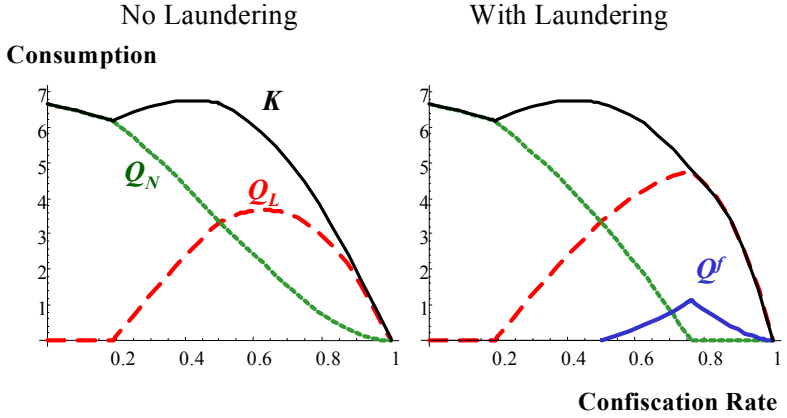
consumer types have almost full access to the overall market, although the costs to legal consumers are slightly higher due to laundering costs. Figures 11 and 12 illustrate the effects of laundering and enforcement on consumption and poaching, for the cases without and with stigma, repectively.

Figure 11: Enforcement and Laundering without Stigma



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.

Figure 12: Enforcement, Laundering and Stigma



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

6 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, not all the interactions that concern trade-ban proponents imply that limited sales of certified products encourage poaching.

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 markets, resale does not satisfy illegal demand, making the effect of greater confiscation ambiguous, depending on the elasticity of demand. If illegal consumers arbitrage between markets under a resale policy, increased enforcement may again have ambiguous effects, now depending on the extent of the stigma effects.

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 is comprised of non-law-abiding consumers, and laundering would generally not occur, then allowing sales of certified goods would tend to lower prices and 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 affects the relative size of legal demand, and thus impacts on the ban question. 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 is 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 less 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.

The policy goal may not simply focus on poaching, however. If the goal is to maximize welfare, determining optimal policy is even more complex. Restricting trade has a welfare cost, although a complicated one to evaluate if stigma is strong. Another question raised by stigma effects is whether they can be manip-

ulated. For products with malleable demand, publicity campaigns—such as "Just say no"[5] or "I'd rather go naked than wear fur"[6]—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.

Appropriate trade and enforcement policy for endangered species products (or dual-market products more generally) thus requires a reasonable sense of these different demand and supply parameters. For example, if lawful demand for rhino horn is low and the bulk of consumers are indifferent to certification, the trade ban is likely to be ineffectual in reducing demand, while 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, tempered with a strong sense of stigma, some sales may help reduce the return to poaching, but perhaps not all the available stock.

An essential research need is to understand better these demand variables according to the products in questions. Unfortunately, such an endeavor can be tricky, given the inherent lack of good data for black-market sales.

For species applications, a dynamic model that endogenizes the harvest and poaching variables according to the resource stock can add more richness to the analysis of the supply side as well. Although adding a biological response function will influence equilibrium levels of poaching and prices, the underlying market fundamentals studied here will remain.

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). The model could be adapted to analyze many other products, including

- "blood" diamonds, as with the current discussion of marking diamonds certified not to have come from war-torn areas;
- GMO-free, cruelty-free or organic products;
- certified, sustainably harvested timber;
- drugs;
- guns.

For diamonds, the application of the current model is quite direct, involving the case with 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 with certification is possible. However, to the extent that some will pay premia 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 laundering occurs, stigma may influence market prices.

Several of the other examples share the complex interactions of dual markets, but the demand externalities or the supply interdependence may be quite different. For example, for endangered species products,

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

[6]People for the Ethical Treatment of Animals anti-fur campaign.

the legal supply is tied in part to the illegal supply, as in the case of selling confiscated products of poaching. However, in the case of guns, the illegal supply might instead be a function of the legal supply, as some guns that are initially sold legally subsequently get stolen, re-sold 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. 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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