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The potential for a backward-bending supply curve of non-timber forest products: An empirical case study of wild American ginseng production

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ABSTRACT

Renewable natural resources that have biological constraints on reproduction and are open-access may be subjected to intense harvest activity that limits regeneration, potentially leading to a backward-bending long-run supply curve. Empirical evidence of such supply abnormalities has been found for some open-access fish species but not yet for non-timber forest products (NTFPs). We describe the theory of the backward-bending long-run supply and how such a supply relationship could produce multiple market equilibria, affecting regulatory outcomes. An empirical example is provided to test the theory in the case of wild American ginseng (*Panax quinquefolius*), which has been subjected to habitat loss and harvest pressure since the 18th Century and now has its exports regulated. We find evidence that quantities supplied are negatively related to price in the long run, indicating that harvest pressure is restricting wild ginseng harvestable stocks. Also, we find that a federal regulation banning exports of roots from plants under five years old, in effect since 1999, coincided with a reduction of supply. This result could be due to the slow natural rate of population recovery.

1. Introduction

Renewable natural resources provide numerous products in the economy, including food, fiber, energy, and medicine. In certain cases, legal and customary rights as well as specific characteristics of the resource and its environment can create situations where access is difficult to limit and harvests are difficult to monitor and control – making them "*de facto* open-access" resources (Bulte and Engel, 2006). Status as an open-access resource has vast implications for production, markets, trade, and regulation of these resources, which in turn can influence the availability and sustainability of the resources themselves. A classic example is marine fisheries (Gordon, 1954), which are difficult to regulate and monitor because of their vast size and international nature, and hunting and trapping of certain wildlife species can also fit this paradigm.

Non-timber forest product (NTFP) markets and trade are often informal and not fully understood (Alexander et al., 2002). Since the 1970s, the harvest of certain NTFPs has been regulated in the United States, with wild American ginseng (*Panax quinquefolius*) being the foremost example (US FWS, 2017). Design of regulatory policies depends crucially on sociological and ecological research to understand harvesters and harvest impacts. However, Gordon (1954) recognized that the question of commercial exploitation (and over-exploitation) of natural resources includes an economic component. Market price, which is determined simultaneously with production and consumption, undoubtedly influences and is influenced by harvests. The position of the supply function in price-quantity space is itself determined by economic and biological factors including stocks, reproductive rates, cost of productive inputs, and policies that may constrain activities or make them more costly, while the position of the demand function is determined by numerous social, macroeconomic, and policy factors.

The present study offers insights into how supply and demand curves for NTFPs that are rivalrous, open-access, and under intense harvest pressure, could be shaped and describes how external factors, including regulations, may impact supply and demand. The objective was to develop a theoretical framework for understanding certain aspects of NTFP markets, trade, and regulation under certain conditions. We argue that, in cases where it is difficult to limit access of outsiders to products, a backward-bending supply curve is theoretically plausible at high levels of harvest intensity, particularly for NTFPs where the entire plant is harvested. We discuss the implications of this curvature on harvest and trade, well-being of harvesters, and regulation. Finally, we use data on wild American ginseng harvest and sale for export to look for evidence of the backward-bending supply and discuss implications.

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2. Theory of supply and regulation of wild-harvested non-timber forest products

2.1. Demand and supply

The Laws of Demand and Supply state that for most products, aggregate quantity demanded, the sum of individual consumption decisions, is negatively related to price, and aggregate quantity supplied is positively related to price. Supply of a wild-harvested product is affected by a combination of social and biological factors, which vary for different types of NTFPs. For many NTFPs, production inputs are dominated by individual producers' labor, which is dedicated to the search for and extraction of the product from the forest (Chamberlain et al., 2017). Each laborer has a reservation price, below which no labor is provided, which could be affected by factors such as employment status of the individual. In the aggregate, holding factors like unemployment rate constant, higher product prices would attract more labor.

The "short run" in economic modeling is defined as a time period in which some production inputs are fixed; in the "long run" none are fixed. Given constant NTFP stocks, in the short run higher prices lead to increased labor input and hence increased production. However, if harvest increases lead to stock decreases, then a negatively sloped, or "backward-bending" supply relationship with price could emerge in the long run. While short-run supply is typically expressed as a function of variable factor inputs and quasi-fixed stocks (inventories), long-run supply relaxes the fixed stock assumption, potentially leading to inverse price-quantity supply relationships.

2.2. Backward-bending long-run supply curves in natural resource literature

Forestry literature has presented models of backward-bending long-run aggregate supply curves for timber in certain situations (Binkley, 1993). The situation can occur where there is neither intensification of investment (such as planting trees, site preparation, etc.) nor conversion of land to timber production from other uses (Yin and Newman, 1997).

Evidence from fisheries highlights the pivotal role that a fixed production base, lack of clear ownership rights, and biology play in making a backward-bending long-run aggregate supply relationship possible. In the short-run, increasing fishing efforts will always increase catch – there is no backward-bending short-run supply. However, in the long run, intense fishing efforts at the aggregate level result in a decrease in catch (Bell, 1972; Clark, 2005; Copes, 1970; Nøstbakken and Bjørndal, 2003; Thuy and Flaaten, 2013; Turvey, 1964). Above a certain effort level, fish populations are depleted such that they cannot reproduce enough to meet the maximum sustainable yield (MSY) (Clark, 2005, p. 13). This "biological over-fishing" would occur in cases where the market price is relatively high, and the effort costs relatively low (Flaaten, 2011, p. 36). Maximum profits (maximum economic yield, MEY) are achieved at effort levels below that of MSY (Flaaten, 2011, p. 32; Gordon, 1954).

Copes (1970) identified two necessary conditions for a backward-bending supply curve: biological limitations on reproduction and inability to restrict access of others to harvest. Even if a resource meets these conditions, they alone are not sufficient to imply that the resource is on the backward-bending portion of the curve. Since zero harvest effort implies zero harvests, the long-run supply curve must be upward-sloping at low harvest levels before it can then bend backward at higher harvest intensities. Thus, high harvest intensity is necessary before backward-bending supply becomes an empirical reality.

With a backward-bending long-run supply, supply and demand may define multiple price-quantity equilibria. Fig. 1 shows hypothetical demand and backward-bending long-run supply curves. There are two equilibrium points in this hypothetical scenario: q_a and q_b. However, q_b is unstable. That is, if an initial price falls on the curve below q_b, it will be driven in equilibrium towards q_a, if above q_b, it would create a situation in which price and quantity are driven away from the unstable equilibrium q_b towards higher price and zero quantity produced in the long-run—i.e., extinction (Clark, 2005, pp. 133–135). Such price-quantity conditions can be initiated by a shift in the supply curve caused by natural reproductive variability, natural disasters, or policy changes (Holden and McDonald-Madden, 2017), or a shift in the demand curve caused by macroeconomic, social, or other factors.

2.3. Common-pool resources

Copes' (1970) two conditions for a backward-bending long-run supply, restated, are essentially the definition of a "common-pool resource": limits to reproduction suggest the resource is rivalrous,[1] i.e., an individual's use of the resource reduces another's potential use; and inability to restrict access suggests that the resource is open-access[2] (Ostrom and Ostrom, 1977).

Many forest plants and fungi grow and mature slowly. Harvesting an NTFP means that someone else cannot also harvest it, so it meets the first condition of rivalry. In a legal sense, however, forest plants do not technically meet the second condition of open access. The land in the United States is owned by discrete landowners who legally own the plants on their land and control access rights. However, forests are large, and some wild NTFPs are remote and scattered over a large area, with precise locations that are not well known or that shift over time, and/or can be extracted over long periods during the year, so access is extremely difficult to monitor and control (Bulte and Engel, 2006; Everett, 2001; Love and Jones, 2001). Private lands have a large number of absentee landowners (Petrzelka et al., 2013). Even for public lands and for private lands with landowners residing nearby, land area and number of access points may be too large to effectively monitor. Furthermore, many of the NTFPs themselves are small, lightweight, and easily concealed (Everett, 2001). These factors create a "*de facto* open-access" condition for many NTFPs (Bulte and Engel, 2006). This concept is further validated by the well-known fact that many NTFP harvesters are extremely secretive about harvest methods and locations (Love and Jones, 2001; Vaughan et al., 2013); that is, there would seem to be little need to be so secretive if the resource were well monitored and controlled.

Ostrom and Ostrom (1977) recognized that there are degrees of rivalry and open access, and some NTFPs fall more into the common-pool category than others. For example, harvesting which kills the entire plant, such as harvesting the roots of ginseng or goldenseal, is more rivalrous than only removing fruits or fruiting bodies, such as with mushrooms or berries; or simply collecting dead portions of a tree, such as pine straw. Similarly, some NTFPs are more easily monitored and controlled and therefore easier to exclude outsiders. For example, a wild huckleberry patch may be geographically compact and have a relatively short harvest season.

2.4. Regulation and conservation

Since common-pool resources may have supply and demand curves that define multiple equilibria, and situations where populations are driven to extinction or simply over-harvested are possible, regulation is justified to reach a management regime closer to what is economically optimal, defined by the maximum economic yield (MEY) (Turvey, 1964). The reversal of the usual slope of the supply curve produces regulatory results that may seem counter-intuitive if the explicit economic model is not fully considered. For this reason, it is useful to consider qualitative theoretical descriptions of the potential impacts

[1] Several synonymous terms may be used: "alternative use", "subtractible", "consumptive", etc.

[2] The term "non-excludable" is a synonym.