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Property rights enforcement and no-till adoption in crop-livestock systems

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ABSTRACT

In developing country agriculture property rights over crop residue left on privately farmed land are often poorly enforced, resulting in common grazing. The introduction of no-till agriculture, a technology that presents an alternative use for residue, may sufficiently increase its value so that farmers enforce property rights over this resource. Enforcement of property rights diminishes the amount of common residue available for grazing, and consequently makes the adoption of no-till by other farmers more costly. Using a model of property rights enforcement and technology adoption in a mixed crop-livestock system calibrated with data from Morocco, I demonstrate how one farmer's no-till adoption can prevent other farmers from adopting and present some welfare implications of technology induced property rights enforcement.

1. Introduction

Mixed crop-livestock farming systems are highly prevalent worldwide, particularly in developing countries.[1] These systems contain nearly 70% of the world's ruminant population and account for close to 50% of the world's cereals, 75% of the world's milk, and 60% of the world's meat (Herrero et al., 2010; Steinfeld et al., 2006). Because agricultural byproduct trade is costly, crop-livestock farmers leverage complementarities of production by using manure as fertilizer, manure or crop residue as fuel, crop residue as bedding or building material, and most commonly, crop residue as livestock feed.

Crop residue can be divided into straw, which can be transported and marketed, and stubble, which remains on the field and is rarely, if ever, traded. In many instances, farmers cannot or do not exert property rights over their crop stubble, which creates a system of mixed property rights where farmers privately farm their land, but stubble becomes a common property resource for grazing. In some cases, crop stubble is a tightly managed resource held by a distinct group of individuals (Godoy, 1991; Hoffmann, 2004; Powell et al., 2004; Smith, 2000; Wade, 1987). In other cases crop stubble is an unmanaged common resource over which access can be denied, but intensity of use is unregulated (Ekboir, 2002; Lesorogol, 2010). Bromley (1991) and Feeny et al. (1990) help elucidate the differences between the terms "common property" and "open access". In this paper I refer to crop stubble as common property; use is limited to farmers in a given community, but intensity of use is unregulated.

Although crop stubble has value as livestock feed, the benefit of private grazing may be less than the cost of enforcement, particularly when stubble is abundant. If the resource is scarce its value is high and the benefits of enforcing property rights may exceed the costs. Enforcement may also become beneficial upon the introduction of an agricultural technology that offers a new and more valuable use for the resource. If some farmers enforce property rights in order to adopt this technology, the pool of common stubble decreases, which would make adoption by subsequent farmers more costly.

This paper proceeds as follows. In Section 2 I provide some background on no-till agriculture (NT), the shadow price of crop stubble, and the relationship between property rights enforcement and technology adoption. In Section 3 I present a multi-household model of cereal-livestock farmers who interact in a mixed property rights regime where farming is done privately and crop stubble is commonly grazed after harvest. I demonstrate how households that do not initially enforce property rights for grazing may do so upon the introduction of a new technology that increases the value of the common resource, and how their property rights enforcement increases the cost of NT adoption for subsequent farmers.

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[1] A common definition of a crop-livestock system is one in which more than 10% of dry matter fed to livestock comes from crop byproducts and at least 10% of the total value of production comes from non-livestock farming activities (FAO, 1996).

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In Section 4 I calibrate the model using household and agronomic data from the Middle Atlas region of Morocco and present simulation results. In Section 5 I discuss some extensions to the model, and in Section 6 I conclude.

2. Shadow prices, technology adoption, and property rights enforcement

In his seminal paper on property rights, Demsetz (1967) states that, "Changes in knowledge result in changes in production functions, market values, and aspirations. New techniques, new ways of doing the same things, and doing new things all invoke harmful and beneficial effects to which society has not been accustomed. It is my thesis…that the emergence of new property rights takes place in response to the desires of interacting persons for adjustment to new benefit-cost possibilities" (p. 350). NT could be such technique; by presenting a new use for crop stubble, NT changes the benefit-cost calculus crop-livestock farmers face as they decide whether or not to enforce property rights over this resource.

In most cases crop stubble is a nonmarket good and has no market price.[2] However, stubble does have a shadow (or implicit) price that can be affected by the introduction of a new technology such as NT. NT is generally thought to produce yields at least as great as those achieved through conventional tillage methods (CT), but with increased sustainability over time; less sensitivity to rainfall variation; and lower requirements for labor, fuel, and seeds (Ekboir, 2002; Erenstein, 2003; Lal, 2007; Mrabet, 2008; Pieri et al., 2002). In addition to improving farmer revenue, NT offers global environmental benefits: lower emissions from agricultural machinery and farmland that acts as a carbon sink. As climate change becomes a more important issue worldwide, the mitigating benefits of NT are gaining more attention among policymakers (see World Bank 2010).

NT requires that the farmer maintain a layer of permanent vegetative matter composed of crop stubble from previous years. Farmers therefore face a tradeoff between using residue for livestock production, for which it has one shadow price, or as input for crop production, for which it has a different shadow price. If the shadow price of stubble as feed is lower than the cost of enforcement, and the shadow price of stubble as an input for NT is higher than the cost of enforcement, the introduction of NT will result in property rights enforcement over a resource previously used in common.

Enforcement of property rights by any one farmer reduces the total amount of stubble available for common grazing; each farmer's enforcement increases all other farmers' shadow prices for stubble as feed. Interdependence of property rights enforcement and technology decisions can therefore arise across farmers. De Meza and Gould (1992) elaborate on the concept of interdependence of property rights enforcement using a theoretical model of multiple landowners engaging in common grazing of private land because of prohibitively high enforcement costs. When a less labor-intensive technology – wheat farming – is introduced, some landowners enforce property rights in order to cultivate land previously used as common pasture.[3] Because landowners interact in a labor market, each one that adopts wheat cultivation causes the price of labor for all to drop, which increases the benefit of private grazing compared to wheat cultivation or leaving the land as common pasture. A cascade of privatization ensues, and in the end all the land is either used for private grazing or wheat cultivation; no land is left for common grazing.

Interdependence of technology adoption becomes a greater concern when households are heterogeneous. Agricultural extension is resource constrained, so there are many reasons why agents might disseminate new technologies first to larger, wealthier, more educated, and better connected farmers with the hope that these technologies will spill over to smaller and more isolated farmers (Anderson and Feder, 2004). Farmers with relatively large amounts of land stand to benefit more from experimentation, and empirically have been shown to be first adopters (Besley and Case, 1994; Feder, 1980). The literature on social learning in agriculture indicates that technology adoption by one farmer encourages subsequent adoption (Bandiera and Rasul, 2006; Foster and Rosenzweig, 1995; Maertens, 2013; Magnan et al., 2013; McNiven and Gilligan, 2012; Munshi, 2004). However, there could be a negative effect of early adoption for a technology that increases property rights enforcement and changes relative (shadow) prices. In a common or mixed property rights regime, the uptake of technologies that require adopters to enforce property rights over resources previously held in common could make adoption by other farmers costlier.

3. Multi-household cereal-livestock farming model

I use a constrained optimization problem to demonstrate the formation of a farmer's individual shadow price of crop stubble. The model begins with N cereal-livestock farmers. Farmer i has landholdings of area L^i and a herd of size H^i, which are both exogenous. Exogenous herd size may be a plausible assumption in the short term, but farmers can adjust their herd size over time for various reasons. However, the degree to which small farmers can adjust their herds is limited by indivisibilities and returns to scale in herding, and farmers may not be willing to draw down their herds to experiment with a new technology. It is reasonable to think farmers would treat their herd size as fixed when contemplating a new technology, and for simplicity I maintain the assumption of exogenous and constant herd size. In Section 5 I address the possible implications of allowing for endogenous herd size in the model.

Farmer i maintains his herd by feeding it a combination of crop stubble, B^i, and a bundle of complimentary market feed (straw, hay, bran, maize, beet pulp, etc.) of total value M^i. I define livestock production (or maintenance) as a function of stubble and market feed, $g(B^i, M^i)$, which is continuous, increasing, and concave in both arguments. Complimentary feed is either produced on-farm or acquired at market at an exogenous price. I ignore transaction costs for market feed so that a farmer who uses feed produced on-farm incurs an opportunity cost equal to the market price. I will address how transport costs and other market imperfections could impact the model in Section 5.

The farmers in the model use all of their land to grow wheat. Before the introduction of NT, farmers have two possible uses for land covered in stubble during the non-growing season: allow common stubble grazing, or enforce property rights at a private cost and graze stubble exclusively. When NT is introduced, farmers have a third option, which is to enforce property rights and leave stubble on the field as an input to NT. In the model, Q^i_{EX} indicates the amount of land farmer i dedicates to private grazing and Q^i_{NT} indicates the amount he allocates to NT. Stubble is produced proportionately with cereal so that the total quantity of stubble available on farmer i's land is $\gamma \cdot L^i$, which can be normalized to L^i. Each farmer's herd grazes a quantity of common stubble proportionate to the size of his herd relative to the aggregate herd. On privately

[2] Lesorogol (2010) reports instances of farmers attempting to sell grazing rights to stubble that were met with strong opposition from other farmers. In the study area I found rare instances of farmers selling, or trying to sell, stubble grazing rights in Morocco. These attempts were also at times met with fervent resistance from other community members.

[3] In their model De Meza and Gould (1992) do not allow for the possibility of land being privately cultivated during the growing season and commonly grazed afterward.