Estimating the implicit value of crop stubble as a barrier to technology adoption in Morocco

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Abstract

For mixed cereal-livestock farmers, cereal production provides both food and feed that can be consumed or sold at market. Cereal production also generates crop stubble, which can be used as livestock feed but is rarely traded or sold, and therefore has no market price. Some agricultural technologies require farmers to forgo using crop stubble as feed, and cultivation of high value crops entails sacrificing stubble production. In this paper we a structural econometric model to household data from Morocco to estimate the implicit value of this resource. We use a sample splitting technique to investigate differences in the value of this resource and find that it is significantly higher for smaller farmers, who therefore face an even larger barrier to technology adoption.

1. Introduction

Cereal production is widespread throughout Morocco, accounting for about 70 percent of agricultural land (FAO, 2009). It is especially prevalent in rainfed areas, which compose nearly 90 percent of Morocco's agricultural land (Arab Organization for Agricultural

Development, 2008). Most small cereal farmers in Morocco are also livestock producers so they benefit from complementarities of production. In addition to grain for sale or consumption, cereal cultivation also produces residues in the form of straw (residue taken off the ground and usually baled) and stubble (residue left on the ground). These are valuable inputs towards livestock production. In Morocco, up to 40 percent of the average ruminant's diet (in terms of biomass) is composed of cereal residues depending on the region (Guessous as cited in Mrabet, 2008), but this percent can be higher for individual herds. The dominance of crop residue in livestock diets is not unique to Morocco; In India, crop residue is estimated to compose 40-60 percent of livestock diet (Rao and Hall, 2003), in Ethiopia 40-50 percent (Keftasa, 1988), and in Sudan 13 percent (Nordblom and Shomo, 1993). In arid and semi-arid cereal growing regions of Morocco crop stubble is typically the sole source of small ruminant (the dominant form of livestock) feed in the summer and fall months following the harvest, so intra-seasonal substitutability between residues and other feed sources may, in fact, be low (Tarzhouti et al., 2006).

The importance of crop stubble to small farmers has implications for long-term economic development. Crop residues are a byproduct of conventional cereal production. If a farmer adopts no till cereal production to replace conventional cereal production, or if he[1] adopts high value crop production and abandons cereal production altogether, then he must forgo using that crop stubble as animal feed. If the value of crop stubble as animal feed is not considered, the cost of adopting cash crops or no-till will be underestimated.

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[1] I use masculine pronouns throughout the paper as heads of farming households are nearly exclusively male in Morocco.

Consequently, farmers may be more hesitant to adopt than development practitioners and policymakers would believe.

No-till agriculture[2] is another technology farmers can adopt to increase their income can help farmers reduce the cost of cereal production and increase and stabilize yields. Specifically, no-till agriculture allows farmers to forgo plowing by seeding directly through the stubble of previous years' crops, which the farmer is required to leave on the field. Because the farmer does not plow and the field remains covered in stubble, no-till lowers fuel costs (and emissions), prevents erosion, and increases soil moisture and soil organic carbon, making the soil act as a carbon sink (Erenstein, 2003; World Bank, 2010). Despite the perceived benefits, adoption rates worldwide have been low, particularly among small farmers in developing countries (Ekboir, 2002; Pieri et al., 2002; Knowler and Bradshaw, 2007). This is true in Morocco, even though field trials conducted by the Institut National de Recherche Agricolce in Morocco have been largely successful from an agronomic point of view (Mrabet, 2002; Mrabet, 2008). An often cited-but never quantified- reason for low adoption rates is that mixed cereal-livestock farmers face a tradeoff between using crop stubble as animal feed or as an input for no-till agriculture (Antle and Diagana, 2003; Ekboir, 2002; Lal, 2007; Pieri et al., 2002).

Cereals are generally considered to be low-value and high-risk compared to cash crops. Conversion from cereal production to cash crops is thought to have the potential to allow small farmers escape poverty (World Bank, 2008). Currently several major projects are underway in Morocco to help small farmers convert from cereal production to cash

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[2]Also called conservation agriculture, zero-till, minimum-till reduced-till, and conservation-till. Throughout this paper I will use the term "no-till".

crops. In 2007 the Millennium Challenge Corporation signed a contract with the

government of Morocco to improve and expand fruit-tree production, with expansion

aimed at land currently in cereals.[3] In a separate effort, the government of Morocco aims to

convert 3 million hectares of marginal cereal land to cash crop production to help alleviate

rural poverty.   In addition to generating more income for small farmers, perennial cash

crops can help reduce greenhouse gas emissions through carbon sequestration (World

Bank, 2010). However, cash crops generally do not provide stubble that can be used as

animal fodder, so the gap between profits from high value crops and cereals might not be

as great as perceived when the implicit costs of crop stubble are considered.

Measuring the value of crop residue is complicated. Valuing straw, the residue

taken off the field, is fairly straightforward when markets exist, although the value of straw

can differ between farmers when transaction costs affect market participation. Stubble, the

residue left on the field, is much harder to value since it is not traded.[4]   Furthermore, since

stubble markets do not exist, the non-market value of stubble will differ from farmer to

farmer.   If smaller and poorer farmers are more limited in access to marketable animal

feed, they could have a higher value for crop stubble, and therefore face a greater barrier to

no-till or high value crop adoption than larger farmers.

In this paper we develop and implement a technique to value crop stubble using a

unique set of panel data from the Middle Atlas region of Morocco.   Applying the data to a

highly generalizable production function for livestock, we solve the farmers' cost-

minimization problem for maintaining their herd. From the first order conditions of the

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[3] See http://www.mcc.gov/mcc/countries/morocco/ma-projects/index.shtml.
[4] In rare instances in the study region, stubble grazing rights are traded but prices vary widely as markets are not well established.

cost minimization problem we derive an econometrically estimable system of equations. The implicit value of crop stubble and other non-traded livestock feed can be derived from the reduced form parameter estimates. We find that the value of crop stubble is large and significant, and is much higher than the value of other non-marketable feed sources.

Because the value of crop stubble can vary across farmers, we apply a simple sample splitting technique that tests for differences in crop stubble values and other parameters along key variables (i.e. landholdings). We find that smaller farmers in value crop stubble twice as much as larger farmers in terms of cultivated area, which suggests that the barrier of forgoing this resource in order to adopt high value crops or no-till technology is much higher for smaller farmers.

The findings of this study highlight that farmers in Morocco depend on crop stubble to supplement marketable feed sources. It is not simply a waste byproduct of crop production, but an important input to livestock production with a tangible implicit value. If farmers did not have this resource, they would need to increase net purchases of other feed. These complementarities are widely recognized, yet difficult to quantify. The findings of this study indicate that it is important for policy makers, researchers, and extension agents to figure the implicit cost of crop stubble into the farmer's balance sheet when attempting to disseminate no-till agriculture (for which stubble must be left on the ground), or high value crops (that do not produce stubble), and that this is especially true for smaller farmers.

2.   Model

Estimates of the prevalence of crop residue in livestock diets are typically calculated by projecting some estimated average quantity of kg of biomass generated per unit of land over total cultivated area (Nordblom and Shomo, 1993). The method assumes that all crop residues are used as feed. While this method might be appropriate for estimating the quantity of crop residues used as animal feed for the aggregate of a region, it does not lend itself well to calculating the value of crop stubble at the farm level. Existing estimates of the quantity of crop residue used as livestock feed do not differentiate straw from stubble, which is important because of possible nutritional differences between the two as well as property rights differences that govern how they are used.

During harvest, grain can be knocked off the stalk and fall to the ground amidst the crop stubble. Consequently, crop stubble can include grain whereas straw does not, making stubble more nutritive than straw (Personal communication with Abdelaziz Chergaoui, August 15, 2007). Although crop stubble may be more nutritive than straw, property rights over stubble are much more tenuous than property rights over straw. Straw is usually baled, making it transportable. It can be brought to a location where its owner can be sure that no one else will use it, or taken to market and sold at a well-established local price. A farmer who owns a plot of land cultivated in cereal does not, however, necessarily enjoy full property rights over his crop stubble due to a combination of high enforcement costs, traditions, and social norms (Ekboir, 2002; Pieri et. al, 2002; Wade, 1987). Consequently, some households produce more stubble than they consume, and others consumer more stubble than they produce.

Farmers in the study region use a combination of marketable and non-marketable feed sources to maintain their herd. Some marketable feeds- straw, hay, barley grain, and bran- can either be produced on site or acquired at market. Other marketable feeds- maize, dried beet pulp, and commercial concentrate- are nearly exclusively bought at market. We assume that farmers face zero transport costs for these inputs so that consuming (and consequently not selling) marketable feed produced on-farm farm is equivalent to buying the same feed from market. This assumption does not align with the reality of the study region, where transport costs can be substantial. Incorporating and estimating unobserved transport costs would require substantial changes to the model that would allow us to estimate transport costs. This is something we hope to explore elsewhere. Non-marketable feed sources- crop stubble and fallow and pasture- are grazed directly off the ground. A breakdown of the different feed sources used in the study region can be found in Table 1. For our model, we aggregate feed source to the level of the smallest boxes, i.e. straw, hay, high-grade feed, stubble, and pasture/fallow.

Our model begins as a cost-minimization problem, where a farmer minimizes the cost of maintaining a herd of size H using some combination of feed $\mathbf{z}$, where z_j is the quantity of feed source j. Feed sources $j = 1...m$ (straw, hay, and high-grade feed) are all marketable at market prices $\mathbf{w}$. Feed sources $j=m+1...M$ (stubble and pasture/fallow) are "free" in the sense that the farmer does not have to pay out of pocket for these inputs, but is quantity rationed by the availability of these feed sources, $\bar{\mathbf{z}}$.

$$\min_{\mathbf{z}} w \cdot z$$

$$\text{s.t.} f(\mathbf{z}) \geq H, z_j \leq \bar{z}_j \text{ for } j = m+1 \dots M$$

(1)

We assume that livestock production, $f(\mathbf{z})$, can be modeled with a highly flexible generalized linear production function (Diewart, 1971). This type of production function allows for both substitutability and complementarities between feed types. The farmer's constrained optimization problem is given in equation (2), where $\alpha_{jk} = \alpha_{kj}$.

$$L = \sum_{j=1}^{m} w_j \cdot z_j + \lambda \cdot \left(H - \sum_{j=1}^{M}\sum_{k=1}^{M} \alpha_{jk} \cdot z_j^{0.5} \cdot z_k^{0.5}\right) + \sum_{j=m+1}^{M} \rho_j \cdot (z_j - \bar{z}_j) \tag{2}$$

It should also be true that $\alpha_{jk} \geq 0$ for all j and k. We cannot impose this restriction on the model, but can test if it holds. We report and discuss the reduced form estimates in the appendix. In the main body of the paper we limit our discussion to the structural parameters. The parameter λ is the marginal cost associated with supporting an additional unit of livestock and ρ_j is the implicit value of input j for $j = m+1...M$ and. The implicit value for input j is zero for farmers who are not quantity constrained for this resource and positive for farmers who are quantity constrained. We cannot identify which households are constrained and unconstrained from the data, but we can test if groups of households are constrained by testing for positive implicit values.

The first order conditions to the optimization problem are:

$$w_j - \lambda \cdot \alpha_{jj} - \sum_{k\neq j}\lambda \cdot \alpha_{jk}\left(\frac{z_k}{z_j}\right)^{0.5} = 0 \text{ for } j = 1 \dots m \tag{3}$$

$$\rho_j - \lambda \cdot \alpha_{jj} - \sum_{k\neq j}\lambda \cdot \alpha_{jk}\left(\frac{z_k}{z_j}\right)^{0.5} = 0 \text{ for } j = m+1 \dots M \tag{4}$$

$$H - \sum_{j=1}^{M}\sum_{k=1}^{M} \alpha_{jk} \cdot z_j^{0.5} \cdot z_k^{0.5} = 0 \tag{5}$$

Because not all farmers used a nonzero quantity of all inputs, we multiply through first order conditions (3) and (4) 3**Error! Reference source not found.Error! Reference source not found.5Error! Reference source not found.**3333by $z_j^{0.5}$ and divide through by the Lagrangian

multiplierλ. The result is an estimable linear system of *M+1* equations with the cross equation restriction that $\alpha_{jk} = \alpha_{kj}$ for all j and k.

$$\varphi \cdot w_j \cdot z_j{}^{0.5} + \alpha_{jj} \cdot z_j{}^{0.5} + \sum_{k \neq j} \alpha_{jk} \cdot z_k{}^{0.5} = \varepsilon_j \text{ for } j = 1 \dots m \tag{6}$$

$$\theta_j \cdot z_j{}^{0.5} + \sum_{k \neq j} \alpha_{jk} \cdot z_k{}^{0.5} = \varepsilon_j \text{ for } j = m + 1 \dots M \tag{7}$$

$$\sum_{j=1}^{M} \sum_{k=1}^{M} \alpha_{jk} \cdot z_j{}^{0.5} \cdot z_k{}^{0.5} - H = \varepsilon_h \tag{8}$$

From the reduced form parameter estimates we can estimate the marginal cost of supporting an additional unit of livestock, λ, and the implicit value of non-marketable good j, ρ_j, as combinations of reduced form parameters.

$$\lambda = -\frac{1}{\varphi} \tag{9}$$

$$\rho_j = \frac{\theta_j - \alpha_{jj}}{\varphi} \tag{10}$$

3.   Data

Survey

The data we use in this study were collected during the summers of 2007 and 2008 in the Middle Atlas Region of Morocco by a team of researchers from the Institut National de la Recherche Agricole, Meknes and the University of California, Davis. Surveys were conducted in four rural districts, ranging from 300 meters above sea level to 1500 meters above sea level in altitude (the urban fringe, low plains, foothills, and mountains). Mixed cereal-livestock farming is the dominant form of livelihood in three lowest zones. Because farming operations are very different in the mountainous zones than the other four regions,[5] data from the mountainous zone is not used in this

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[5] In the mountainous zone households depend mostly on tree crops for incomes and grow cereal mostly for household consumption. Cereal cultivation is mostly entirely rainfed in the three lower zones, but irrigated on many

study. All summary statistics and estimation results given in this paper refer to the three lower zones only. The primary cereals grown in the region are soft (bread) wheat, hard (durum) wheat, and barley, which is used mostly for feed but also for food. Livestock predominantly consists of sheep, but also includes cows and goats. Many households also have several equines for traction and transport. Farmers generally feed all animals in their aggregate herds the same type of feed, especially in the case of small ruminants.

Within each zone, four to five villages were randomly selected and within each village around 20 households were randomly pre-selected from village rosters, with an average of nearly 13 households per village completing the survey. In the three zones pertinent to this paper, 223 households were surveyed in 2007 and 203 of the same households were resurveyed in 2008. Because stubble availability, pasture and fallow availability, feed prices, and herd size can change from year to year there is substantial variation in the composition and quantity of animal feed from year to year so we pool observations from both years. We limit the sample to households with both land and livestock, leaving 385 observations (196 from 2007 and 189 from 2008).

Respondents were asked a wide variety of questions on their households' economic activities, particularly cereal and livestock cultivation. The survey asked cereal production questions at the plot level, including how much straw was produced and what happened to the crop stubble after the harvest. The survey also included several questions about the farmers' ability to prevent others from grazing crop stubble on their land. Livestock questions included an animal inventory and a detailed accounting of quantities of different feed sources used, including a breakdown of what feed was bought at market and what feed was produced on site. Feed prices were gathered as part of a village survey. The most unique data gathered by this survey is on

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plots in the mountainous zones. In the lower three zones, small ruminant herds are dominated by sheep, where is in the mountains goats dominate. Common pasture grazing is far more prevalent in the mountain zones than in the lower zones.

grazing. Household heads were asked how many months their herds (by animal type) were taken to graze on the farmer's own crop stubble, other farmers' crop stubble, fallow fields, and common pasture.

3.2   Descriptive statistics

In the study sample, the average farm size[6] was 10.9 ha. The maximum reported farm size was 112 ha, but 99 percent of respondents reported a farm size of less than 60 ha and 95 percent reported less than 33 ha. In each year, an average of just over three-quarters of cultivated land was planted in cereals, including forage crops. Other crops cultivated include legumes and vegetables. Around 15 percent of land was left fallow. Households had, on average, 34.6 sheep, 2.8 cows or cattle, 5.4 goats, and 3.7 equines. To aggregate across livestock types we employed the tropical livestock unit (TLU), assigning a weight of 0.1 TLU for each goat or sheep, and 0.7 TLU for each cow or equine.[7] The sample mean for TLU was 6.6. With the exception of number of equines,[8] all descriptive statistics reported here did not differ significantly between years.[9] By most accounts, the majority of farmers in the sample are considered smallholders, although there is substantial heterogeneity in the sample in terms of farm size. We will make use of this heterogeneity to examine if the implicit value of stubble is higher for smaller farmers, who would appear to be more constrained for that resource. Descriptive statistics on farm size can be found in Table 2.

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[6] This includes land rented in and sharecropped, but does not include land rented out. Most land in the study area, however, is owned and cultivated by the same household.
[7] This is the common conversion rate employed by the FAO. See
http://www.fao.org/docrep/V1650T/v1650T0d.htm.
[8] The average number of equines went from 1.53 in 2007 to 1.86 in 2008, a small but statistically significant change.
[9] Unless otherwise noted, we use the 0.1 confidence level to denote significance.

Crop stubble use for livestock feed is ubiquitous in the study region. Nearly 95

percent of households with livestock use either crop stubble from their own fields (89

percent), stubble from other households' fields (50 percent), or both as feed. Because

farmers do not exclusively graze their own plots, and graze other farmers' plots, they do

not know the area of crop stubble they graze except for the rare occasions where a farmer

can prevent all others from grazing their herds on his land, and does not graze his herd on

other's land. Farmers do, however, know for approximately how long they grazed their

animals on crop stubble (both on their own land and others'). This is the measurement of

crop stubble use we captured in the survey.   On average, farmers grazed stubble for 71

days. For our estimation, the quantity of stubble used is livestock weighted days (LWD).

For instance, a farmer who grazes 2 cows and 6 sheep (2 TLU) on crop stubble for 60 days

consumes 120 livestock weighted days of stubble.   On average, farmers in our sample used

1,022 LWDs of stubble each year over the two survey years. We used an analogous

measure for the number of days spent grazing pasture and fallow land.[10]

Data from 2007 refers to the 2006-2007 agricultural year (August to August) and

data from 2008 refers to the 2007-2008 agricultural year. Most stubble grazing occurs in

the spring, right after the harvest. Because of the drought of 2007 and the resulting poor

harvest, farmers were able to graze their herds on crop stubble significantly longer in 2008

(1,224 LWDs) than in 2007 (836 LWDs).[11] For pasture/fallow land, low rainfall in 2007

also led to reduced biomass in pastures and fallow fields.   Consequently, farmers grazed an

average of 2,336 LWDs of pasture/fallow in 2008, compared to only 848 in 2007.   To

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[10] Reports from the survey team and the resulting data indicate that farmers do not easily distinguish pasture land
from fallow land. Instances of farmers claiming to use both resources are very rare (6 percent of respondents). We
therefore employ the total number of LWDs spent grazing pasture and fallow lands as a single variable.
[11]

compensate for having less stubble and pasture/fallow available in 2007, farmers used greater quantities, and slightly more variety, of marketable feed in 2007 than 2008. Straw was used by nearly all farmers in both years, but the quantity used was nearly twice as great in 2007. About nine percent of farmers who used hay in 2007 did not in 2008, presumable because of increased availability of non-marketable feed. The same is true for high-grade feeds. Average quantity of hay used was nearly three times as much in 2007 than 2008 and the quantity of high-grade feed used in 2007 was 75 percent more than in 2008. Table 3 contains descriptive statistics on feed use by year.

Although the main point of this paper is not exploring differences between years, these differences are quite informative about how farmers substitute between marketable and non-marketable feed sources. First of all, households did not appear to alter their herd size from year to year depending on the quantity of non-marketable feed available. Households clearly compensated for reduced availability of non-marketable feeds available in the drought year of 2007 by using more marketable feed. Furthermore, a significant amount of farmers used high quality marketable feeds (hay and high-grade feed) in 2007 that did not in 2008. This indicates that straw alone is not a substitute for stubble and pasture/fallow, and that the bundle of feed used to compensate for the lack of non-marketable feed available in 2007 included a variety of marketable feeds.

4.   Estimation and results

We estimated the system of equations described in equations (6)-(8)66666666 using three stage least squares. Since we are interested in estimating a cost of a rather abrupt technological change- the value of crop stubble as animal feed- we assume some variables

that are endogenous in the long run are exogenous in the short run. For instance, a farmer

can alter their herd size by buying or selling livestock to respond to price changes, but we

assume that in the short run herd size is exogenous. We also assume that the amount of

stubble and pasture/fallow land a farmer can use to be exogenous, although in the long run

a farmer could increase or decrease the amount of stubble and fallow he has access to by

changing his crop portfolio or cultivated area. We assume that prices for marketable crops

are exogenous to the farmer.

The quantity of marketable feed consumed, however, is clearly endogenous, even in

the short run. This leaves us with three endogenous variables for which we must

instrument. In addition to the excluded exogenous variables for the different equations of

the system, we also employ exogenous (in the short term) variables from outside the model

as instruments: farm size, area of cereal cultivated, household size, car and/or truck

ownership, distance to market, and age and education of household head.

Because the quantity of stubble available in 2007 was so much less than the

quantity of stubble available in 2008, we control for year fixed-effects in our regression.

We assume that the production function parameters are constant over time, but that

parameters that reflect constraints can vary by year. We therefore restructure equations

(6) and (7) as:

$$(\varphi + \omega) \cdot w_j \cdot z_j^{0.5} + \alpha_{jj} \cdot z_j^{0.5} + \sum_{k \neq j} \alpha_{jk} \cdot z_k^{0.5} = \varepsilon_j \text{ for } j = 1 \ldots m, \qquad (6')$$
$$\tau = 1 \text{ if year} = 2007$$

$$(\theta_j + \omega_j) \cdot z_j^{0.5} + \sum_{k \neq j} \alpha_{jk} \cdot z_k^{0.5} = \varepsilon_j \text{ for } j = m + 1 \ldots M, \qquad$$
$$\gamma_j = 1 \text{ if year} = 2007 \qquad (7')$$

From the reduced form estimates from equations (6'), (7'), and (8) we derive the structural coefficients in equations (9') and (10').[12]

$$\lambda^{2007} = -\frac{1}{(\varphi+\omega)}, \lambda^{2008} = -\frac{1}{\varphi} \qquad (9')$$

$$\rho_j^{2007} = \frac{\theta_j + \omega_j - \alpha_{jj}}{\varphi + \omega}, \rho_j^{2008} = \frac{\theta_j - \alpha_{jj}}{\varphi} \qquad (10')$$

We use a bias-corrected percentile bootstrap of 1,000 pseudosamples to construct confidence intervals (Efron and Gong, 1983). The structural coefficients are the marginal cost of supporting one more TLU, implicit value of one LWD of crop stubble grazing, and the implicit value of one LWD of pasture/fallow grazing. A positive implicit value for a non-marketable resource implies that the farmer is quantity constrained for this resource. A zero value implies that the farmer is not constrained, and that the farmer gains nothing more (net the cost of acquiring it) by using more.

The average implicit value of stubble is 17.8 Moroccan Dirham (DH)[13] per LWD across all farmers for 2007 and 11.6 DH for 2008. Pasture/fallow grazing has a lower, but still significant value of 6.9 LWD in 2007 and 3 DH per LWD in 2008. We estimate the marginal cost of supporting an additional TLU for one year as 6,974 DH in 2007 and 5093 in 2008. At first glance, this estimate seems high since the average selling price of a TLU in the study sample ranges from 7,800 DH (three female goats and one cow) to 12,800 DH (three male sheep and one bull). However, this marginal cost includes non-marketable inputs which that do not require the farmer to pay out of pocket. This is an important

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[13] At the time of the study 10 DH equaled approximately 1 USD.

distinction, and one we will return to later.   Regression estimates for the structural

coefficients can be found in Table 4.

Taking the implicit value of non-marketable feed sources, we compare the total

value of marketable and non-marketable feed used across years (Table 5). In 2007, when a

drought severely limited stubble and pasture/fallow grazing, half of feed by value came

from marketable feed. In 2008, just under one-third came from marketable feed.   The

value of stubble consumed was 40 percent of all feed value in 2007 and over 50 percent in

2008, and in both years was three times the value of pasture and fallow consumed. Clearly,

stubble is a valuable resource for farmers to sacrifice in order to adopt a new technology,

even if it should be beneficial in the long run.

Differences across farmers

Because crop stubble is not traded, its value is implicit and can vary between

farmers depending on the degree to which they are constrained to stubble and other inputs

to livestock production. Differences in the implicit value of crop stubble across farmers

could be one reason why it is more difficult to smaller farmers to adopt high value crops

that replace cereals, or adopt no-till cereal production, which precludes them from using

crop stubble as animal feed. The phenomenon of small farmers being slow to, or failing to,

adopt technologies that would appear beneficial is well documented and researched.

In this portion of this paper we demonstrate that the implicit value of crop stubble,

which acts a barrier to agricultural technology, is larger for smaller farmers than larger

farmers. Borrowing from Hansen's (2000) threshold estimation technique, we estimate

our model allowing some parameters to differ for smaller farmers in the sample, indicated

by a dummy variable D_s where $D_s = 1$ if farm size $< s$ and zero otherwise (Equations (6") and

(7"). We continue to allow these same parameters to vary by year, as in equations (6') and

(7') and hold the production function constant across all farmers and years.

$$(\varphi + \omega + \delta \cdot D_s) \cdot w_j \cdot z_j^{0.5} + \alpha_{jj} \cdot z_j^{0.5} + \sum_{k \neq j} \alpha_{jk} \cdot z_k^{0.5} = \varepsilon_j \text{ for } j = 1 \dots m \qquad (6")$$

$$(\theta_j + \omega_j + \delta_j \cdot D_s) \cdot z_j^{0.5} + \sum_{k \neq j} \alpha_{jk} \cdot z_k^{0.5} = \varepsilon_j \text{ for } j = m + 1 \dots M \qquad (7")$$

Instead of using an ad-hoc method to determine what constitutes a smaller farm, we

allow the data to decide. We estimate equations (6"), (7"), and (8) for all values of s found

in the data and compare the objective function of the 3SLS routine to see what value of s

best fits the data. There are 81 unique farm sizes in the sample. We find that the threshold

that minimizes the objective function is at 4 ha. In our sample, 27.5 percent of households

fall below this level (Figure 1).

Hansen (2000) devises a method to rigorously test for the confidence region of

threshold estimation in least squares based on a likelihood ratio test. Under the naïve

assumption that errors are homoskedastic and normal, the likelihood ratio for the

threshold estimator under least squares is:

$$LR(\tau) = n \cdot \frac{S(\tau) - S(\hat{\tau})}{S(\hat{\tau})} \qquad (11)$$

Where $S(\tau)$ is the sum of squared errors with some threshold τ, $S(\hat{\tau})$ is the sum of squared

errors at the estimated threshold $\hat{\tau}$ and n is the sample size. Using this likelihood ratio as a

convenient test statistic we cannot reject any hypothesis of a threshold between 2.5 ha and

6 ha. In order to split the sample as evenly as possible, we will continue our analysis

imposing a threshold of 6 ha, which 34 percent of farmers in the sample fall below.

The threshold estimation results indicate that there are large and significant

difference between the structural parameter estimates for smaller and larger farmers

(Table 6). The marginal cost of supporting an additional TLU is 50 percent higher for

smaller farmers, and the implicit value of stubble is nearly twice as much. These findings

are consistent across both years. There was no significant different in the implicit value of

stubble between the two groups.

Conclusions

Still reading? Thanks! Please let us know what you think,

References

Antle J. and B. Diagana (2003). "Creating incentives for the adoption of sustainable agricultural practices in developing countries: The role of soil carbon sequestration." *American Journal of Agricultural Economics,* 85(5): 1178-1184.

Arab Organization for Agricultural Development. Statistical Yearbook 2008.

Diewert, W. (1971). "An application of the Shephard duality theorem: a generalized Leontief production function." *The Journal of Political Economy* 79(3): 481-507.

Efron, B. and G. Gong (1983). "A leisurely look at the bootstrap, the jackknife, and cross-validation." *The American Statistician* 37(1): 36-48.

Ekboir, J. (2002). *CIMMYT 2000-2001 World wheat overview and outlook: developing no-till packages for small-scale farmers*. Centro International de Mejorimiento de Maiz y Trigo.

Erenstein, O. (2003). "Smallholder conservation farming in the tropics and sub-tropics: A guide to the development and dissemination of mulching with crop residues and cover crops." *Agriculture, Ecosystems and Environment* 100: 17-37.

Hansen, B. (2000). "Sample splitting and threshold estimation." *Econometrica*: 575-603.

Keftasa, D. (1988). Role of crop residues as livestock feed in Ethiopian Highlands. In B.H.

Dzowela (ed). African Forage Germplasm and Extensive Livestock Production Systems. Proceedings of a Workshop Held in Arusha, Tanzania, 27-30 April 1987. Pp. 430-439.

Knowler, D. and B. Bradshaw (2007). "Farmers' adoption of conservation agriculture: A review and synthesis of recent research." *Food Policy 32*: 25-48.

Lal, R. (2007). "Constraints to adopting no-till farming in developing countries." *Soil and Tillage Research* 94: 1-3.

Mrabet, R. (2002). "Wheat yield and water use efficiency under contrasting residue and tillage systems in a semiarid area of Morocco. *Experimental Agriculture 38*: 237-248.

Mrabet, R. (2008). *No-tillage systems for sustainable dryland agriculture in Morocco.* Manuscript. Institut National de la Recherche Agricole. Rabat.

Nordblom, T. and F. Shomo (1993). "Livestock and feed trends in West Asia and North Africa: past, present and future." *Cahiers Options Méditerranéennes* 1(5): 15-30.

Pieri, C., G. Evers, J. Landers, P. O'Connel, and E. Terry (2002). "No-till farming for sustainable rural development." Agricultural and Rural Development Working Paper. World Bank: Washington, DC.

Rao, P., and A. J. Hall (2003). "Importance of crop residues in crop–livestock systems in India and farmers' perceptions of fodder quality in coarse cereals." *Field Crops Research* 84, no. 1-2: 189-198.

Tarhzouti, O., B. Boulanouar, and M. Sibaoueih (2006). "L'élevage ovin en bour defavorable: Caracteristiques, atouts et contraints. " In Boulanouar, B. and R. Paquay (eds). *L'Elevage du Mouton et des Systèmes de Production au Maroc*. Institut National de la Recherche Agronomique: Rabat.

Wade, R. (1987). "The management of common property resources: finding a cooperative solution." *The World Bank Research Observer* 2(2): 219-234.

World Bank (2008*). World Development Report 2008: Agriculture for Development*. World Bank: Washington DC.

World Bank (2010). World Development Report 2010: *Development and Climate Change*. World Bank: Washington DC.

Tables and Figures

Marketed (price rationed)			Non-Marketed (quantity rationed)	
Straw (no grain) ·Wheat ·Barley ·Oat ·Maize*	Hay (grain) ·Barley ·Oat ·Alfalfa*	High-grade feed ·Bran ·Barley grain ·Maize ·Dried beet pulp ·Commercial concentrate	Stubble ·Wheat ·Barley ·Oat ·Maize*	Pasture /Fallow
*Extremely rare in the sample Note: Data aggregation is done at the level of the box.				

Table 1. Livestock Feed sources in the Middle Atlas Region of Morocco

Variable	Mean	Standard deviation
Land (Ha)	10.87	12.44
Sheep	34.57	76.76
Cows	3.73	2.79
Goats	5.43	27.09
Equines	1.70	1.61
TLU	7.80	10.39

Table 2: Farm size and livestock holdings

Feed source	Variable	2007	2008
Straw	Percent farmers using	96.11	97.88
	Bales (1 bale~15kg)	454.98	237.57**
		(448.92)	(231.90)
Hay	Percent farmers using	58.33	48.68*
	Bales (1 bale~15kg)	215.51	81.46**
		(440.06)	(225.78)
High-grade feed	Percent farmers using	90.00	82.0**
	100 kg	28.49	16.13**
		(74.96)	(25.91)
Stubble	Percent farmers using	95.44	94.77

	Livestock weighted days		836.92	1,224.10
			(1,114.19)	(2,031.4)
Pasture/	Percent farmers using		34.44	62.96**
fallow	Livestock weighted days		847.85	2,335.73**
			(2,089.07)	(4,729.34)

Standard deviations in parenthesis. A * denotes the difference between years is significant at the 0.1 level and ** denotes at the 0.05 level.

Table 3: Feed source use by year

Parameter	Estimate	95 percent confidence interval		Small sample bias‡
		Lower	Upper	
Marginal cost 2007 (λ^{2007})	6,974.03	5,488.00	8,888.00	-161.37
Marginal cost 2008 (λ^{2008})	5,093.47	4,148.36	5,723.59	-543.38
Stubble value 2007 ($\rho_{stubble}^{2007}$)	17.78	12.67	24.53	-0.30
Stubble value 2008 ($\rho_{stubble}^{2008}$)	11.62	8.00	14.47	-1.13
Pasture/fallow value ($\rho_{past/fal}^{2007}$)	6.92	5.22	11.46	0.64
Pasture/fallow value ($\rho_{past/fal}^{2008}$)	2.96	1.66	3.70	-0.72

Confidence intervals are derived using bias-corrected percentile bootstrapping with 1,000 pseudosamples.

‡Small sample bias calculated as the difference between the estimate using the original data and the mean estimate using the pseudosamples (Efron and Gong, 1993).

Table 4: Regression estimates of structural parameters

	2007	2008	Difference
Value of marketable feed	24,892	11,844	18,486
	(2,515.5)	(1,175.0)	(14,41.7)**
Value of stubble	19,603.3	20,596.4	-933.1
	(1,958.7)	(2,574.3)	(3,220.0)
Value of pasture/fallow	5,740.2	6,913.8	-1,174.5
	(1,020.6)	(1,018.3)	(1,442.2)
Total non-marketable	25,343	27,510	-2,166
	(2826)	(3449.6)	(4,444.8)

Total	50,235.8	39,354.2	10,881.6	
	(4441.2)	(4266.1)	(6,164.8)*	
Total per TLU	8,151.6	5,132.9	3,018.7	
	(434.5)	(254.6)	(508.2)**	

Standard deviations in parenthesis. A * denotes the difference between years is significant at the 0.1 level and ** denotes at the 0.05 level.
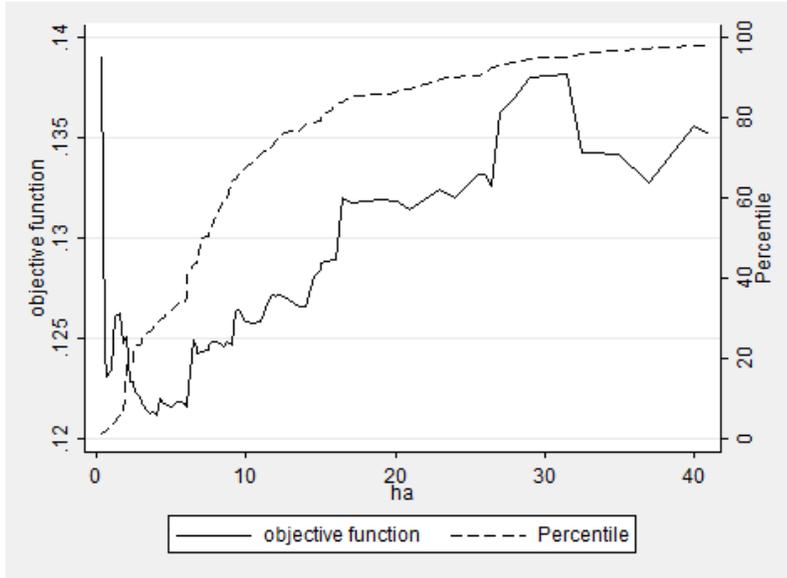
Table 5. Value of different feeds used across years

Figure 1: Threshold search over different farm sizes

Parameter	Farm size	Estimate	95 percent confidence interval		Small sample bias‡
			Lower	Upper	
Marginal cost 2007 (λ^{2007})	Small	10,273.54	8,263.77	17,674.46	610.66
	Large	6,219.12	5,218.34	7,943.40	-69.27
Marginal cost 2008 (λ^{2008})	Small	6,232.84	4,909.55	7,549.40	-406.94
	Large	4,476.57	3,713.45	4,934.25	-424.86
Stubble value 2007 ($\rho_{stubble}^{2007}$)	Small	35.24	24.94	82.32	4.03
	Large	16.14	12.42	23.25	0.27
Stubble value 2008 ($\rho_{stubble}^{2008}$)	Small	18.05	12.50	26.44	-0.21
	Large	9.21	6.06	11.53	-0.95
Pasture/fallow value ($\rho_{past/fal}^{2007}$)	Small	7.75	2.80	14.87	0.22
	Large	5.78	4.32	9.09	0.35
Pasture/fallow	Small	2.63	-1.26	4.53	-1.23

| value ($\rho^{2008}_{past/fal}$) | Large | 2.67 | 1.28 | 3.33 | -0.55 |

Confidence intervals are derived using bias-corrected percentile bootstrapping with 1,000 pseudosamples.

‡Small sample bias calculated as the difference between the estimate using the original data and the mean estimate using the pseudosamples (Efron and Gong, 1993).

Table 6: Threshold regression estimates of structural parameters