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ASSESSING FARMERS' WILLINGNESS TO SUPPLY BIOMASS AS ENERGY FEEDSTOCK: CEREAL STRAW IN APULIA (ITALY)

Giacomo Giannoccaro*[1,3], Bernardo C. De Gennaro[2], Emilio De Meo[2], Maurizio Prosperi[1,3]

[*1]Department SAFE, University of Foggia, Via Napoli 25, 71122 Foggia, Italy

[2]Department DiSAAT, University of Bari, Via Orabona 4, 70126 Bari, Italy
[3]STAR AgroEnergy group, University of Foggia, Via Gramsci 89/91, 71122 Foggia, Italy

* corresponding author: giacomo.giannoccaro@unifg.it

Abstract: Cereal straw currently has end-uses such as animal bedding and feeding, but there are no official statistics regarding the fraction of straw that is not used. Although cereal straw is an abundant source of biomass still largely unexploited for energy purposes, the feedstock market interplay with current straw uses (e.g. animal bedding and feeding) and on-farm practices (e.g. chopped and incorporated) is still unknown. This research used farmers' stated preferences to assess the supply curve (i.e. amount and price) of cereal straw for bio-energy purposes. In addition, we performed an econometric regression on the straw price demanded by farmers (Willingness to Accept). A sample of data gathered in 2014 from 203 cereal growers in Apulia region (southern Italy) was used, and the results show that more than half of respondents would sell their cereal straw on the feedstock market, and that the preferred sales method is in-swath. The price requested would be higher (15.15 EUR ha^{-1}) than that currently applied on the local straw market (12.00 EUR ha^{-1}). Explanatory factors refer to farmers who currently burn stubble on-field, farmers involved in Agro-Environmental Schemes or contract provision, farmers with off-farm employment and farms with larger areas dedicated to cereals.

Key Words List: bio-energy, farmers, feedstock market, Heckman model, willingness to accept.

JEL: C10; C52; Q42

1. Introduction

A key research area in the biomass and bioenergy literature consists of technological feasibility studies to assess the potential amount of biomass feedstock. However, there are no official statistics on quantities, prices or supply methods at the national or local level for second generation feedstock, such as straw. Consequently, assessment of biomass feedstock availability is seen as a precondition in bio-energy planning, and a number of studies have focused on the assessment of biomass feedstock, including cereal straw.

For instance, Ericsson and Nilsson (2006) estimated the potential biomass supply in Europe using a resource-focused approach. As an innovative approach, energy-crop yields were correlated with national wheat yields, and their results indicated the plentiful availability of resources. Chinnici et al. (2015) conducted a comprehensive analysis of biomass availability, among other agricultural residues, for energy use in Sicily (Italy). Their estimates of raw materials were based on statistics referring to 2013, and were obtained by applying a series of parameters obtained from a wider review of current literature and direct research.

De Wit and Faaij (2010) assessed biomass availability (i.e. bio-energy crops plus agricultural and forestry residues) together with handling, transport and storage costs. Using a Geographical Information System together with Multi-Criteria Analysis (GIS-MCA), Delivand et al. (2015) attempted to define the most cost-effective location of biomass energy plants in southern Italy, taking into account the local availability of straw and minimizing the total transportation distance. They assessed the operating costs of all activities involved in the annual supply system, including collection, baling, field hauling, loading, transportation from farm to facility center, stocking and storage. The unit cost of supply ranged from 21 to 23 EUR t^{-1} of wheat straw. As in many other studies (e.g. Edwards et al., 2005), no costs were allocated to straw as a raw material because agricultural residues were considered to be food production residues. Kingwell and Abadi (2014) have recently examined how temporal and spatial costs of cereal straw accumulation may affect the establishment of a bioenergy plant in Australia, highlighting the impacts of climate change. The cost structures of cereal straw accumulation are constructed on the basis of mathematical programming.

The studies mentioned have generally focused on the agronomic availability of straw as feedstock, considering only the supply costs for collecting and transporting the biomass from the field to the plant, while the competition with current straw uses (e.g. animal bedding and feeding) and on-farm practices (e.g. chopped and incorporated) has been totally ignored. It is always assumed that cereal straw is an abundant biomass source that is still largely unexploited (e.g. Delivand et al. (2015); alternatively when straw material is priced, the theoretical price-distance equation is used (e.g. Kingwell and Abadi, 2014).

From this point of view, at least two economic aspects have been neglected. Firstly, cereal straw currently has end-life uses as feed (grazing and hay) or bedding for livestock, and market information is available to some extent. There could be a pricing discrimination effect for producers who already operate on the local market, in addition to price-distance functions (Gallagher et al., 2005)[1]. Secondly, farmers who do not currently sell their biomass may keep it for agronomic uses (soil fertility and structure). These uses of biomass represent farmers' opportunity costs, and prices offered for biomass will need to cover at least these costs (Altman et al., 2015). In this respect, commercial farming practice is greatly influenced by policy incentives and directives, and soil health is a key element of the EU Common Agricultural Policy (CAP) (Glithero et al., 2013a).

While there has been much research to investigate technological feasibility, farmers' actual willingness to supply remains under-researched (Altman et al., 2015).

Contrary to the studies mentioned above, Glithero et al. (2013a) surveyed 249 farmers across England to estimate current straw use and its potential availability for second generation biofuels. The authors found that while the amount of straw would not be a limiting factor, the main barrier to bio-energy plant development would be the high price demanded by farmers for their straw, apart from the baling and transportation costs. As argued by Glithero et al. (2013b), a further barrier to the development of bioenergy sector is the need to stipulate contracts with farmers in order to secure feedstock supply. For instance, there is little information available about farmers' preferences in terms of contract duration.

In the context outlined, this research aims to assess the supply of wheat straw as energy feedstock. This paper considers farmers' stated preferences, with the aim of assessing the supply curve (i.e. amount and price) of cereal straw that farmers would be willing to sell on a feedstock market. We follow the approach applied by Glithero et al. (2013a) to assess current straw uses and its potential availability for an energy plant, attempting to move forward in the economics of cereal straw as feedstock. Contrary to other studies, the price that farmers demand for their straw (i.e. willingness to accept) is analyzed using an econometric regression. We had two

[1] Gallagher et al. (2005) examined corn pricing in the vicinity of ethanol plants in Iowa (USA) during spring 2003 and tested several price-distance models. Although price-distance functions describing spatial prices near plants all depended on local transportation costs, they found that the pricing system and the extent of local competition defined the level and spatial rate of change in prices.

objectives: to investigate the factors influencing farmers' willingness to accept (WTA) sale of their straw, and to identify the level of payment that would make farmers willing to sell the straw that is not currently traded.

Roughly speaking, our hypothesis is that the average price of feedstock supply will be higher than that observed on the established local straw market. In fact, the supply of straw depends on the extent of land under cereals and on farmers' willingness to sell. Since income from straw amounts to no more than about 10% of farmers' income from grain production, cereal land will not be affected in the short term by a change-induced increase in feedstock market demand; however, farmers' willingness to sell their straw will be influenced by price rises. Therefore, farmers currently involved in supplying the established straw market will demand the same or a higher price than present levels, while those who burn and incorporate straw will be the lesser willing to sell it, and the straw that is currently unsold will fetch the highest price.

A sample of 203 farmers in Apulia Region (south-eastern Italy) has been used to construct supply curves for the current straw market and for the hypothetical straw market for energy uses, while a two-step Heckman model has been applied in the econometric regression.

The remainder of the paper includes a description of the study area and survey. The methods used are reported in Section 3, and the main findings are presented in Section 4. This is followed by a discussion of policy implications based on farmers' willingness to accept.

2. Survey and sample description

The data source for this analysis was a survey of farmers in 24 municipalities in Foggia Province of Apulia Region, south-eastern Italy. The province of Foggia produces one-third of Italy's annual durum wheat output, on a total area of almost 200,000 ha. The list of farmers recorded in the official state census (ISTAT, 2010) was used as the basis for designing a stratified sample based on median values of farmland used to grow cereals within each municipality. We obtained a sample of 203 farms across 24 municipalities, and Table 1 compares the sample with the overall population.

The municipalities were selected throughout Foggia Province at a distance of up to 70 km from the site of a combustion power plant (25 MWe) using straw as its main fuel, which is being built in the municipality of Sant'Agata di Puglia. This implies that 130 Kt d.m., the equivalent of approximately 30% of the area's total annual cereal straw output, will be used to fuel the plant, meaning that an area of 110,000 ha around the plant will necessarily be used for straw production. According to the sustainability criteria of the Apulia Regional Government (LR 31/2008), the average distance of feedstock transportation should not exceed 70 km.

Table 1 - Comparison between study area and sample

	Case Study [a]		**Sample**	
No. of farms classified by median				
< 10 ha	5,813 (53%)		98 (48%)	
>= 10 ha	5,215 (47%)		105 (52%)	
Total	11,028		203	
Cereal area classified by median				
< 10 ha	31,294 (18%)		554.5 (18%)	
>= 10 ha	141,699 (82%)		2,559 (82%)	
Total	172,993		3,113.5	
Livestock	*Farms*	*Units*	*Farms*	*Units*
Cattle	360	14,410	12	562
Sheep and goats	524	47,148	7	680
Pigs	120	18,651	1	40
Poultry	296	1,965,108	1	150,000
Total	1,300	2,045,317	21	151,282

Source: adapted from ISTAT (2010); a <= 1.99 ha is excluded.

Summary statistics from the 2010 Agricultural Census (ISTAT, 2010) show that 20% of the total number of specialized cereal farms have less than 2 ha of cereal land, although these cover a very small proportion of the area's total cereal land (9%). On the contrary, 18% of farms have an area of over 20 ha, and these account for the largest proportion of cereal land (42%). There are also over 1,000 livestock farms, of which the majority raise sheep and goats; these account for 52% of livestock farms and raise over 47,000 animals. Cattle are also important in this area (14,410 units), and are reared on 360 farms.

The average age of sampled farmers is 55; 45% of respondents also have off-farm jobs, and 91% of farms rely on family labor. The average farm size is 22.91 ha, with an average on-farm cereal area of 15.33 ha. Straws yield (t ha^{-1}) ranges from 1 to 5 t ha^{-1}, with an average of 3.08 t ha^{-1}.

Overall, the sample is satisfactorily representative, considering the great variability within the study areas. Farms with less than 2 ha of cereal land were excluded because the largest proportion of cereal land is actually cultivated by larger farms; therefore the influence of smaller farms on the final assessment can be disregarded.

A questionnaire was designed to collect data from farmers on a range of topics, including farming practices, farm profiles, current straw uses, and socio-demographics, together with farmers' willingness to enter the energy market and their relative willingness to sell their straw on this market. The questionnaire includes information about farm households' planned behavior in the event of a biomass energy plant within 70 km.

A trained team administered the questionnaire in spring 2014. Farmers were also asked to indicate their level of commitment (percentage of biomass they would be willing to supply), participation (duration of supply contract) and supply method (i.e. sold in-swath or baled) in a hypothetical energy feedstock market.

The question on willingness to enter the feedstock market was set out as a binary choice (Yes *vs*. No), asking farmers if they expected to sell straw residues on the energy market. Respondents who indicated their willingness to participate in the proposed market were presented with a willingness to accept (WTA) question to establish the minimum price they would be prepared to accept (EUR ha^{-1} equiv. per annum) in order to switch from current straw use/practice to supplying the energy market. There may be some market information (formal or informal) for cereal straw that currently has end-uses such as animal bedding and feeding, but not for the straw that is not traded (e.g. chopped and incorporated). Consequently, some form of non-market evaluation is required. The contingent valuation (CV) methodology is a survey-based stated preference technique in which respondents are asked to express their preferences directly (Carson, 2000).

Three different straw delivery methods were proposed: sold in-swath, sold in bales left on the field, and sold baled and delivered to the energy plant. In-swath sale fetches the lowest price, bales left on the field fetch a higher price, and straw bales delivered to the energy plant fetch the highest price. Respondents were firstly allowed to choose their preferred supply method, and then to indicate the WTA price according to the method chosen. The elicitation format was a semi-open ended payment card. Farmers were asked to indicate the minimum price they were WTA in order to sell their straw. Bid intervals were based on the current informal market information supplied by local experts, and were consistent with the 2011-2013 average straw prices on the official Foggia Chamber of Commerce website. The average price in the case area was approximately 53 EUR per tonne. A pre-test pilot trial was carried out, and bids were framed on a per hectare equivalent basis, as farmers are more familiar with this measurement than with EUR per ton. Figure 1 shows an example of a payment card.

Figure 1 - Payment card

|_| sold in-swath (EUR ha^{-1}) 0...1…2…3…4…5…6…7…8…9…10…12…14…16…18…20…22
|_| baled and left on field (EUR ha^{-1}) 10…15…20…25…30…35…40…45…50…55…60
|_| baled and delivered (EUR ha^{-1}) 15…20…25…30…35…40…45…50…55…60…65…70…75…80

3. Methodology

3.1 Econometric modelling

Contingent valuation (CV) is a stated preference technique for monetary valuation of a non-market good, and involves eliciting responses from individuals in constructed, hypothetical markets. Contingent valuation is rooted in Lancaster's (1966) Value Theory and consistent with Thurstone's Random Utility Theory (1929). The economic theory underlying CV assumes that the stated price yields the highest utility for the respondent. Minimum willingness to accept (WTA) compensation is the appropriate measure in a situation where an agent is asked to give up a good voluntarily. This measure is the Hicksian consumer surplus measure and is often defined net of the price actually received (Carson, 2000).

In estimation of the valuation model, several observed variables are censored. The most relevant of these are the monetary values for WTA, which are only available for those willing to participate in straw trading. Obviously, there are no data for non-participating farmers. This produces a selection bias that violates the random selection process assumed in canonical regression models. In this situation, ordinary last square (OLS) generally produces biased and inconsistent estimates. Heckman (1979) proposed a model to account for the self-selection process within the sample itself, which is performed in two stages. Firstly, the selection equation is estimated using a probit model, i.e. the probability of selling straw on the market for energy, a function of X_i independent variables.

The canonical specification for this relationship is a probit regression of the form:

$$\mathrm{Prob}(D = 1|Z) = \Phi(Z\gamma), \quad (1)$$

where D indicates trader ($D = 1$ if the respondent is willing to trade and $D = 0$ otherwise), Z is a vector of explanatory variables, γ is a vector of unknown parameters, and Φ is the cumulative distribution function of the standard normal distribution.

Yields estimated according to the model give results that can be used to predict market participation for each individual. The residuals of the selection equation are used to construct a selection bias control factor, lambda (λ), which is equivalent to the inverse Mill Ratio.

In a second step, the principal (or substantial) equation is estimated by OLS, in our case WTA prices, including selection bias correction factor (λ) as an additional independent variable. Formally:

$$WTA_i = W_i^* \alpha + \alpha_\lambda \lambda_i + \mu_i \text{ , } (2)$$

where *W** is a vector of explanatory variables that are not observed if the respondent does not trade, α is the equation coefficient and μ is the unobserved determinant of willingness to accept.

If λ is significant, there is a selection bias, and its coefficient corrects the influence that the explanatory variables have on WTA: upwards (negative coefficient) or downwards (positive coefficient).

Statistical package STATA (IC.14) has been used to estimate the Heckman model. The data and command files are available in the Data in Brief (Giannoccaro, 2016).

A number of factors can affect a farmer's willingness to supply biomass. First of all, livestock farms may use their on-farm straw for bedding and feed. Therefore, the *Pre-dominant farm system* is introduced as an explicative variable in the selection equation (first step of econometric model). Secondly, current straw end-practices, such as soil incorporation, might be influenced by policy incentives (i.e. Agro-Environmental Schemes - AES), and compliance with these farming practices might prevent farmers from market participation.

With reference to farmers' WTA, the price heterogeneity is analyzed by OLS regression performed in the second step of the Heckman model. As argued in the introduction, price rises might encourage farmers to supply straw that is currently unused (i.e. incorporated or burnt). In the regression, a discrete variable is associated to current straw practice as reported in Table 2. The policy incentives (i.e. AES) might also increase a farmer's WTA, especially AES correlated to straw incorporation (e.g. soil fertility enhancement). Moreover, as largely reported in the economic literature (Beckmann and Czudaj, 2014), farmers can obtain a higher steady price with a supply contract. Assuming that a farmer's WTA is at least the same as that observed on the local market, we expect that farmers who have previously had production contracts will demand a higher WTA price. A discrete variable labeled *production contracts* is used with three categories: without contracts (*none*), with all on-farm grain and straw production under contract (*wholly*), or with a proportion of wheat and straw production under contract (*partly*). In addition, it has been claimed that off-farm employment may be related to farmers' attitudes towards new activities (Giannoccaro and Berbel, 2012). The rigidity of farmers' work schedules and the complexity of selling straw may have a significant bearing on their WTA (Altman et al., 2015), and this will reflect the opportunity cost of current straw use and its supply on the feedstock market. Therefore, a dummy variable (Yes *vs*. No) is introduced for off-farm employment. Finally, according to the pricing modality observed on the local market (Table 4), the cereal area (ha) is used as a covariate in the regression.

3.2 Supply assessment

We essentially followed the approach applied by Glithero et al., (2013b) who estimated straw uses and potential availability for second generation biofuels by surveying 249 farmers across England. We applied an inference procedure from the sample to the study area, matching the sample data at municipality level to the census data (ISTAT, 2010).

On-farm straw quantities were obtained by multiplying the three-year straw yields by cereal area, as given by the respondents. In addition, an adjustment factor was applied at the municipality level. This was calculated as the difference – plus or minus – between the relative extent of the cereal crop in each municipality (ISTAT, 2010) and the proportion of each municipality's cereal area in the sample (see Appendix). The straw quantity refers to technically collectable dry matter, meaning that losses during handling, baling and on-farm transportation were also taken into account, while a minimum amount of straw is returned to the soil to comply with Good Agricultural and Environmental Conditions (GAEC) (on average 1.48 t ha-1 of dry matter is collectable *per annum*; for procedure see Delivand et al., 2015).

The supply curve was estimated by taking the product of each farmer's response (WTA for selling - EUR ha^{-1} was converted to EUR t^{-1}) multiplied by their level of commitment (% of on-farm straw they are willing to sell) and collectable straw (t ha^{-1}). Average figures were calculated separately for each municipality, and then aggregated at any available price. The aggregated market curve was obtained by horizontally summing the amounts farmers are willing to sell at each price using a Windows Excel sheet. A comprehensive description of procedures and results of the feedstock assessment is provided in Giannoccaro *et al*. (2016).

4. Results and Discussion

4.1 Overview of survey findings

This section presents the main findings of the survey, summarized in Table 2.

Table 2 – Farm profile of willing and non-willing participants

	Sample	Non participants	Do not know/Other	Willing to partecipate
No.	203	63 (31%)	25 (12%)	115 (57%)
Farmer age (median)	55 years	57 years	58 years	54 years
Farm size (mean ha)	22.91	16.95	34.70	23.66
Cereal crops (mean ha)	15.33	12.17	19.41	16.22
Pre-dominant farm system				
Specialist in cereals	66.5%	71.4%	66.7%	64.4%
Mixed arable crops	22.7%	3.2%	20.8%	33%
Livestock rearing	10.8%	25.4%	12.5%	2.6%
Pre-dominant straw practice				
on-farm use for livestock	8.9%	22.2%	8%	1.7%
sale (in-swath or baled)	45.3%	47.6%	44%	44.3%
chopping & incorporation	20.7%	12.7%	8%	27.8%
on-field burnt	14.3%	12.7%	28%	12.2%
many of previous	10.8%	4.8%	12%	13.9%

No.= 203

Straw can have many alternative end-uses (Table 2, Sample column). According to the survey returns, almost half the farms (45%) are already active on the straw market. Of the 203 farms, 89 sell straw in-swath, while three farms bale and sell their straw. Livestock farms use most of the straw they produce for animal bedding and feed (9% out of 10% of sampled farms). Alternative end-practices include soil incorporation (21% of farms) and on-field burning (14% of farms). Finally, approximately 10% of farms use several of these practices, depending on the on-farm livestock demand, cropping schedule, straw yields and price, or weather conditions.

Under GAEC (i.e. cross-compliance of the CAP), straw incorporation into soils has been enforced with the aim of improving soil organic matter. Additionally, within the AES (Rural Development Plan Measure 214) farmers incorporating straw into the soil at the end of wheat production receive an additional payment of 100 EUR ha^{-1}. Although the survey did not include a direct question about this payment, respondents were asked if they were involved in at least one of the environmental contracts aimed at soil erosion and fertility enhancement. A total of 44 (22%) apply specific farming practices (e.g. green manure, straw incorporation) under an AES contract; for 16 of the farms receiving agro-environmental payments, the end-practice for straw is incorporation. For 14% of respondents, on-field burning is the most convenient practice; this controversial practice is officially justified in some circumstances involving pest, disease or fire risk.

When asked the main reason for soil incorporation, the majority of respondents gave soil fertility and fertilizer saving as the reasons, while timeliness was the commonest reason given for on-field burning (Table

3). A third common reason given by farmers for these two end-practices was the lack of economic convenience, meaning that their opportunity cost is higher than the current straw market prices. On the whole, the most frequent reason (20 observations) given was the timeliness of farming activities at the end of cereal cropping, while the same number (17 observations) gave saving on fertilizer and the lack of economic convenience as their reasons. English cereal producers also reported major timeliness benefits from end-practices such as incorporation (Glithero et al., 2013b).

Table 3- Reasons for current straw practices (respondents)

	chopped & incorporated	on-field burning	many	Total
Farming timeliness	6	10	4	20
Soil fertility improvement	9	3	5	17
No economic convenience	8	7	2	17
Saving on fertilizer	8	4	2	14
Harvesting contractual or technical constraints	7	3	-	10
Other	2	1	-	3
Total	40	28	13	81

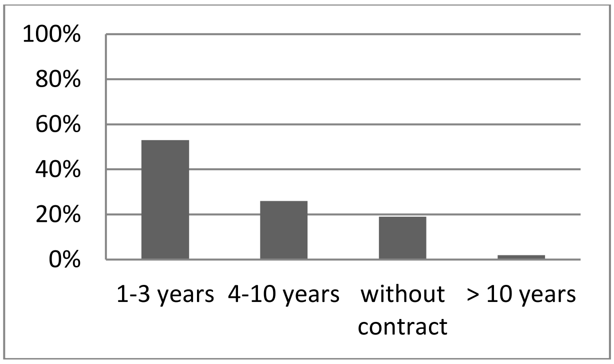
No.=81

Regarding their willingness to sell straw on a feedstock market, 57% of respondents agreed, 31% would not trade on this market, and 12% were undecided (Table 2). The stated preference method can lead to a high percentage of 'undecided' responses (Viaggi *et al*., 2011), and this figure is in line with other studies (e.g. Giannoccaro *et al*., 2015). Farmers' willingness to trade was heterogeneous, and livestock farms were much less willing than others. Essentially, livestock farms use on-farm straw for animal feed and bedding.

Almost all respondents who agreed with selling straw on the feedstock market would prefer to sell all their on-farm straw. Therefore, the largest proportion of farmers would be fully committed.

The preferred sale method was in-swath (133 respondents), while a very small number of respondents (5) would prefer to bale the straw and deliver it to the energy plant (2). Specifically, when straw is sold in-swath, the buyer takes the straw directly from the field, where it remains in rows (swaths) after the harvest. This implies that straw baling and transportation firms will be needed to supply energy plants.

Figure 3: Farmers' preferences regarding contract duration (% of respondents)



No.= 140

Half of those willing to sell would prefer a one to three-year contract to supply straw. Many farmers willing to sell their straw would prefer longer contracts, but 19% would refuse any contract at all. The most popular contract lengths reported in Glithero *et al*. (2013b) for English farmers were 3 years (23% of respondents), followed by 1 year (22%), while 20% preferred to sell without a contract.

Table 4 shows the sample statistics for in-swath straw prices. Only half the cereal growers receive cash payment for their straw (45 out of 98 farmers who currently sell straw in-swath), while the other half indirectly estimate the economic value of straw by deducting it from cereal harvesting costs. Grain and straw are harvested by specialized firms, who accept straw in part exchange for harvesting costs estimated at 70 EUR ha^{-1}. The pricing scheme is heterogeneous, with the on-farm cereal area as the determining factor. The average cultivated cereal area (10 ha) is significantly lower than the 22.41 ha of cereal land farmed by the farmers who trade straw for cash payments (F=13,893; p=0.000). 12 EUR ha^{-1} is the most frequent cash price for straw sold in-swath.

Table 4 – Summary statistics of WTA for the sample (straw sold in-swath)

Current market (EUR ha^{-1})	frequency	Feedstock market (EUR ha^{-1})	frequency
deducted	53	2	1
10	9	4	1
11	2	10	2
12	20	12	7
12.5	3	14	44
13	3	16	35
14	2	18	9
15	1	20	5
16	1	22	4
19	2	missing	7
20	1	Total	115
missing	1		
Total	98		

Farmers' willingness to accept (WTA) selling straw in-swath on the feedstock market ranges from 2 to 22 EUR ha^{-1} with an average of 15.15 EUR ha^{-1} (s.d. 2.87). In the class of respondents for which a market clearing price and WTA are observed (32 respondents), the straw price increased from 12.36 to 15.06 EUR ha^{-1}.

The CV approach to WTA has often been criticised as leading to higher prices (see Carson, 2000 for a review). Since the WTA question was set as an open-ended value, giving respondents ample freedom of choice, the first CV applications to assess WTA generally led to an overestimation. However, as Carson (2000) noted, the CV method has been improved. As in our case, using a payment card with a check list of values to elicit the WTA of respondents allows a more consistent assessment.

On the other hand, as underlined in Barnes *et al*. (2014), as for all surveys of future intent, the responses may have a built-in bias reflecting present agricultural conditions that may influence the responses. In other words, the WTA revealed should be taken as a reference value at the moment of analysis. The study's conditions actually refer to the economic situation in 2014 (i.e. market price, job opportunities, individual debt, turnover, etc.), and any change in these variables could influence the farmer's WTA values.

4.2 Results of econometric model

The econometric regression was performed on the WTA for straw sold in-swath, since this was the sale method most frequently chosen by respondents.

Table 5 shows the results of the econometric regression.

Table 5 – WTA regression analysis results

Variables	**Principal model**	Marginal effects	Mean value
Cereal area (ha)	.05**(.015)	.05	15.78 (ha)
Production contracts (none)			.70
wholly	2.93*(1.52)	2.71 [a]	.03
partly	-		.27
Agro Environmental Schemes (none)			.76
soil fertility	1.90**(.65)	1.90 [a]	.21
others	-		.03
Current straw practice (sold in-swath)			.44
chopped and incorporated	-		.29
on-field burnt	1.76**(.77)	1.77[a]	.13
many	-		.14
Off-farm employment	1.21**(.47)	1.06[a]	.45
Constant	13.80*** (.76)		

Uncensored obs. = 107	
Wald chi2(10)	33.67***
	Probit model (selection)
Agro Environmental Schemes (none)	
soil fertility	-
others	-1.48**(.64)
Farm system (Specialist in cereals)	
Mixed arable crops	1.80***(.51)
Livestock rearing	-1.90***(.50)
Constant	.26**(.13)
lambda (λ)	-1.94**(.81)
Number of obs. = 170	
LR chi2(4)	53.87***
Log likelihood = -85.141	
Pseudo R^2 =.24	

Robust standard error in parentheses
[a]dy/dx for factor levels is the discrete change from the base level.
*Significant at 10%; ** Significant at 5%; ***Significant at 1%;

The Heckman model makes it possible to highlight influential variables on the farmer's willingness to sell cereal straw and the factors determining the WTA price. The selection model (probit) reports that a farm with mixed arable crops is more likely to agree to participate in the feedstock market; as predicted, farms specializing in livestock would be less likely to participate. At the same time, those engaged in other AES measures are less likely to sell their straw as feedstock. We find a significant λ in the Heckman model, with a negative estimate of -1.94 EUR ha^{-1}. Thus, the numerical value suggests that there are selection or truncation effects in these data, and those who choose to trade have higher straw prices than a random selection from the population of farmers with a comparable set of characteristics would demand. This shows that the average WTA of all cereal producers in Foggia Province is actually much less than those who would be willing to participate in the feedstock market.

Turning to the principal model findings, the level of compensation necessary for farmers to replace conventional burning with supplying straw to a power plant is estimated at 15.48 EUR ha^{-1}, with an average increase of 1.76 EUR ha^{-1} (marginal effect) over other current straw uses and practices. This figure confirms the initial hypothesis that the price demanded for straw currently unsold is higher than the current local market price. However, the model only explains the higher WTA for straw currently burnt, while the price rise hypothesis seems not to apply for straw that is currently chopped and incorporated into the soil. On the other hand, an additional 1.90 EUR ha^{-1} is found for farmers currently involved in the soil fertility-related AES. This means that of the farmers who currently practice soil incorporation, only those involved in the specific agro-environmental measure demand a higher price for their straw. Farmers who have a production contract to sell all their on-farm wheat and straw also demand a higher price for selling straw on the energy market. At present, the highest marginal effect is shown. Farmers with off-farm employment would also demand an average of 1.06 EUR ha^{-1} more, in line with Giannoccaro and Berbel's (2012) findings. Finally, farmers with a larger cereal area would also demand a higher price; the larger the farm, the higher the price asked. Considering the mean value of cereal area in the sample (15.78 ha), for an increase of 1 ha the price would rise by 0.05 EUR ha^{-1}.

Formally, the linear equation of cereal straw price is:

*WTA (EUR ha^{-1}) = 13.80 + 0.05 * on-farm cereal area (ha) + 1.76 (on-field burnt) + 1.90 (soil fertility AES) + 2.93 (full production under contract) + 1.21 (off-farm employment).* (3)

Finally, in addition to the variables discussed above, the econometric model also considered other variables as determinants, but none of these was found to be significant.

4.3 Supply curves

Straw is sold in-swath (43.5% of sample) on a cereal area of 1,541 ha (49.5% of sampled area) with 3,830 t annual straw yield, and is widespread across all the municipalities, except for the three small municipalities of Alberona, Castelfranco in Mistano, and Stornarella. By applying the inference procedure, we estimated that 37.33% of the collectable straw is currently sold in-swath. The supply curve of straw sold in-swath is shown in Figure 4; each point in the figure represents the average price calculated at the municipal level for which at least one valid value was available. The average amount of collectable straw was also calculated in each municipality on the basis of straw yield as declared by farmers. Thus, an equivalent EUR per ton value was calculated for each municipality, and this procedure was applied in order to transpose sample results to the regional scale.
As shown in Figure 4, a positive slope is reported with an average price elasticity of 2.6. The straw is currently sold in bulk at a price ranging from 6.5 to 12 EUR per ton.

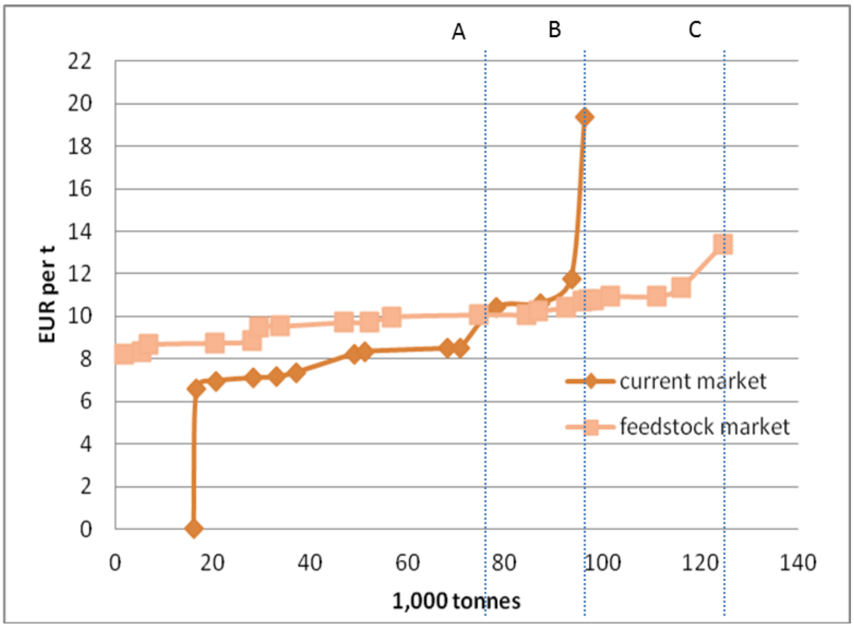
According to the sample data, 56.6% of respondents would be willing to supply cereal straw for energy purposes (Table 2). With the exception of two small municipalities (i.e. Castelfranco in Mistano and Pietramontecorvino), there is a high level of acceptance of the feedstock market. A total of 48.29% of the straw produced annually in the area and technically collectable would be available for in-swath sale on the feedstock market. As a consequence, the entry of a new buyer in the straw market increases trading volume. The change in current end-practices would involve a reduction in straw incorporated into the soil, and to a lesser extent in straw burning. This would actually represent the additional amount of straw traded in the feedstock market. However, most of the straw currently traded in-swath on the local market would become available on the energy feedstock market, while the straw used by livestock farmers for feeding and bedding would not be available for sale.

The supply curve for straw sold in-swath on the feedstock market is shown in Figure 4.

A shift in the supply curve is shown for the feedstock market, i.e. the straw supply curve goes up while it is highly elastic. This result is consistent with Altman et al.'s (2015) findings.

Three different sections are indicated in Figure 4. Section A, between zero and the crossing point, refers to the already sold in-swath straw that would be displaced to the feedstock market. The feedstock curve lies above the current curve, with a cross-point at 10 EUR per ton. From this point forward, straw that is currently incorporated into the soil and burnt enters the feedstock market. Section B refers to the volume of straw sold in-swath on the local market with a higher price than on the feedstock market. Therefore, the amount of straw in Section B already sold on the local market will not be switched to the feedstock market. Finally, Section C shows the net volume increase in straw traded as a consequence of a new buyer entering the market.

Figure 4: Supply curves of straw sold in-swath on the current and feedstock market



Source: our elaboration from survey data and ISTAT (2010)

In other words, the feedstock supply curve is shaped by suppliers already active on the local market (Section A) plus new suppliers (Sections B and C). While 40% of the volume of straw for energy purposes comes from new traders, the majority of the supply relies on the current straw suppliers. Since the new curve is mainly derived from the existing (local market) curve, the interplay with the current straw market is especially relevant. Other studies have supposed (Delivand et al., 2015) that the feedstock market curve of straw for energy use is an independent curve, but this is definitely not the case.

5. Conclusions and Policy implications

The study has enabled us to obtain a first picture of the current straw supply and the interplay with the supply of new emerging markets. Traditionally, estimation of the economic value of agricultural products starts with analysis of production costs to determine the "break-even point" of suppliers, which corresponds to the supply market price in the competitive market. In the case of new emerging markets, the assumption of perfect market competition is not acceptable, since scarce market participation of suppliers may lead to a situation in which demand for a resource exceeds supply, and the price will rise.

In this study, we have demonstrated that current straw uses and practices would influence a new feedstock market. Conversely, bioenergy production from cereal straw is likely to have a significant impact on the straw market, and hence the market price for straw. In general, despite the high level of farmer participation, the price of straw is expected to rise.

Therefore, we may conclude that in the case of a competitive straw market, price estimation using the cost method is not appropriate, and that correct price estimation should also consider farmers' preferences. In fact, the scarce participation or interest of farmers in the new emerging market is a typical case of market failure, commonly defined as an incomplete market.

According to our results, resistance and differentiated behaviour to new opportunities can be explained by normal profitability considerations rather than by strategic behaviour. In the case study, straw is a "valuable resource" and several alternatives actually offer different levels of benefits to farmers: i) traditional burning, generating perceived benefits in terms of pest and weed reduction for the next cultivation cycle; ii) sale to well established markets; iii) incorporation into the soil, to comply with GAEC or obtain a state subsidy according to the AES. In the case of a new market consequent to the creation of new agro-energy industry, farmers will simply re-shape their economic expectations in terms of the selling price for the resource they are going to sell.

The implication of this consideration is twofold, for agro-energy entrepreneurs and for policy makers. Entrepreneurs must be aware that the value of cereal straw will likely follow a similar trend to that of natural resources, where value does not depend on production costs, but rather on the scarcity of the resource. For instance, the recently constructed agro-energy plant in Sant'Agata di Puglia considered a reference price for the provision of straw based on the current market. According to our results, this assumption can lead to an underestimation of the cost of straw supply.

For policy makers, it is worth noting that agro-environmental schemes have some distorting effects on the straw market and on energy policy measures. While the Apulia Regional Government (i.e. the Agriculture Department) gives a financial subsidy to farmers willing to incorporate straw into soil to improve fertility, this environmental measure actually increases the price of straw, working against the efforts of the energy authority (i.e. the Energy Department) which subsidizes investments in agro-energy generation. This suggests that policy failures and market distortions may be avoided via closer policy coordination between different public departments (e.g. AES for straw incorporation limited to areas where no other market exists, or to small farms), supported by adequate economic and policy analysis.

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Appendix

	Census 2010				Sample				
		c	farms*			***g***	farms		(*c*-*g*)
Municipality	cereal land (ha)	relative weight	< 10 ha	>= 10 ha	cereal land (ha)	relative weight	< 10 ha	>= 10 ha	correction factor
Alberona	2198	0.0127	42	77	43.00	0.0138	2	2	-0.0011
Ascoli Satriano	19,867	0.1148	431	586	390	0.1253	8	11	-0.0104
Biccari	4949	0.0286	156	186	57	0.0183	3	1	0.0103
Bovino	3847	0.0222	147	129	132	0.0424	3	3	-0.0202
Candela	5791	0.0335	149	179	101	0.0324	4	3	0.0010
Carapelle	1433	0.0083	112	50	26	0.0084	2	1	-0.0001
Castelfranco in Miscano	2980	0.0172	69	135	65	0.0209	0	1	-0.0037
Castelnuovo della Daunia	3122	0.0180	107	113	40	0.0128	2	2	0.0052
Castelluccio dei Sauri	2934	0.0170	119	90	128	0.0411	3	5	-0.0242
Cerignola	16,319	0.0943	491	393	86	0.0276	4	5	0.0667
Deliceto	4072	0.0235	206	142	127	0.0408	4	4	-0.0173
Foggia	30,787	0.1780	1097	754	445.5	0.1431	25	13	0.0349
Lucera	20,718	0.1198	545	685	282	0.0906	9	10	0.0292
Manfredonia	15,212	0.0879	355	438	246	0.0790	7	13	0.0089
Ordona	1989	0.0115	74	64	70	0.0225	0	3	-0.0110
Orsara Di Puglia	3351	0.0194	239	88	80	0.0257	1	6	-0.0063
Orta Nova	3511	0.0203	206	112	42	0.0135	3	1	0.0068
Pietramontecorvino	3048	0.0176	104	123	5	0.0016	1	0	0.0160
Sant'Agata di P.	6002	0.0347	241	206	64	0.0206	2	4	0.0141
S.Marco l.Cat.	765	0.0044	30	31	4	0.0013	1	0	0.0031
Stornara	909	0.0053	45	23	53	0.0170	1	2	-0.0118
Stornarella	4434	0.0256	269	141	58	0.0186	3	1	0.0070
Troia	10,426	0.0603	407	316	467	0.1500	7	9	-0.0897
Volturino	4329	0.0250	172	153	102	0.0328	3	5	-0.0077
Total	172,993	1.0000	5813	5214	3113.50	1.0000	98	105	0.0000

*<= 1.99 ha is excluded.