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Production effects of wetland conservation: evidence from France

Abstract

This study takes a production function approach to examine the effects of farm wetland area for a set of producers in the Limousin region of France. By combining data from a recent survey of regional wetland areas with detailed farm-level production panel data, we find that maintaining wetland areas poses significant costs to farmers, in terms of foregone production value. These results help to explain the relatively low participation rate in agri-environmental schemes targeted to wetlands by farmers in this region. This represents a new application of the production function approach to estimate the cost of maintaining wetlands on working agricultural land, and is one of few studies to examine agricultural wetland costs outside of the US. This framework could be used to further inform payment incentives for agri-environmental schemes more generally.

Keywords: wetlands, agri-environmental schemes, agricultural production, conservation payments, France

JEL classification: Q15, Q51, Q53, Q58

Les impacts productifs de la conservation des zones humides : application française

Résumé

La productivité des zones humides agricole est étudiée par la spécification d'une fonction de production, estimée sur un ensemble de producteurs agricoles de la Région française du Limousin. L'analyse des données de panel rassemblant les comptabilités d'une centaine d'exploitation suivies pendant trois ans montre que le maintien agricole des zones humides implique des coûts significatifs en termes de pertes de production. Ces résultats aident à comprendre la relative faiblesse de l'adoption par les agriculteurs des mesures agro-environnementales ciblant les zones humides de cette région. Ce travail est une nouvelle application de l'approche par la fonction de production pour estimer le coût de maintien des zones humides, et l'une des rares applications sur ce thème, hors des Etats-Unis. La méthodologie peut être utilisée pour l'établissement de paiements incitatifs dans le cadre de programmes agri-environnementaux ou pour des services environnementaux en général.

Mots-clefs : zones humides, mesures agro-environnementales, production agricole, élevage, paiements pour services environnementaux, France

Classification JEL : Q15, Q51, Q53, Q58

Production effects of wetland conservation: evidence from France

1 Introduction

Wetlands provide a number of important and widely-known services, including support for biodiversity, improved hydrological function, recreation and scenic amenities. Many of the most critical wetlands in Europe and the United States extend across rural landscapes, where agriculture in particular benefits from greater flood control, water purification and biological pest control (Ma and Swinton, 2011). At the same time, agricultural runoff of nitrogen fertilizers and animal waste, as well as increased drainage and channelization of agricultural lands, pose some of the greatest threats to wetland condition (Brinson and Malvarez, 2002).

Given these linkages, designing policies to protect rural wetlands requires some understanding of agricultural land use decisions. In the U.S., the primary rural wetland policies, the Wetlands Reserve Program (WRP) and the Conservation Reserve Program (CRP), mainly offer incentives to farmers to take wetland areas out of production in the form of easement payments. In contrast, the various agri-environmental schemes (AES) employed by EU member states rely more on incentives to engage in less-damaging production practices, without necessarily ceasing production activities (Baylis *et al.*, 2008).

We examine the cost to farmers of maintaining wetlands on land used in production, in this case for a set of cattle and dairy farmers in the Limousin region of France. The Limousin, in the center southwest, is considered France's heartland and is known as the "area of 1,000 lakes." The region is also recognized for its high quality livestock production, supported by grazing on grassland areas, and its wetlands provide critical habitat to numerous freshwater fish and waterfowl species. AES participation in schemes targeted to wetlands by farmers in this region is relatively low (less than 10 percent), suggesting that current AES payments may not adequately compensate farmers for the associated compliance costs of wetland maintenance. Adequate compensation requires knowledge of these costs, and from a policy perspective, a better understanding of participation cost is important for designing effective AES incentives.

To estimate the costs of maintaining wetland areas to farmers, we take a production function approach to directly model the effects of farm wetland area on farm output. We apply this framework to panel data on farm-level production, similar in format to the EU Farm Accountancy Data Network (FADN) standards, coupled with data from a unique survey of agricultural wetlands conducted in the region. Our results indicate that average costs to farmers of maintaining wetland areas exceed prevailing wetland AES payments in this region, which is consistent with current low observed wetland AES participation rates.

More generally, this study contributes to the agri-environmental policy literature in two important ways. First, we estimate the opportunity cost to farmers of maintaining wetlands on land in production, rather than on retired lands. Second, our use of detailed farm production data allows us to estimate this cost directly, in terms of foregone production value, rather than implicitly through agricultural land values. We provide some background on agricultural wetlands and the French AES in the next section. We discuss the production model and identification strategy in Sections 3 and 4, and then present our empirical results in Section 5.

2 Background

The response to conservation incentives for agricultural wetlands depends largely on the relative benefits and costs of these policies at the farm level. On-farm benefits of maintained wetlands include water regulation, soil drainage, natural pest control from increased biodiversity, as well as recreational and aesthetic services (Ma and Swinton, 2011). The wetlands valuation literature is extensive[1], but includes relatively few studies that value wetland services to agriculture, of which the focus is primarily on wetland services to agriculture in the developing world (Acharya and Barbier, 2000; Nordblom *et al.*, 2012).

Wetland costs to agriculture arise primarily from diminished production capacity on wetland areas (Heimlich, 1994). In addition to reduced arable land area year round, natural draining and filling cycles can limit production activities (Shultz and Taff, 2004), and irregularly-shaped or widely-dispersed wetlands can impose nuisance costs related to navigating machinery around each hydrated area (Gelso *et al.*, 2008; Cortus *et al.*, 2011). The U.S. Fish and Wildlife Service (FWS) sponsored two early studies to value wetland costs to agriculture (Brown, 1976;1984) by measuring the effect of wetland easements on agricultural land values. The FWS then used the results of these studies to set location-specific easement payments. Despite their continued use in practice, Shultz and Taff (2004) note several potential flaws in the Brown studies, including an apparent double-counting of wetland acreage, small sample size and omitted variables bias related to non-eased wetland acreage. The authors address these weaknesses in their own study by working with a much larger set of land sales data, including agricultural revenues attributed to sale-specific cropping patterns and soil quality, and using geographical information system to control for hydrologic condition. They find that an additional acre of non-eased permanent wetlands decreased average sale price by 40%, or \$161 per acre at the time, while non-eased temporary wetlands had no statistically significant effect. Their estimated effect is greater for lands with easements in place, with a 79% or \$321 per acre decrease for eased permanent wetlands, but again, no significant effect for eased temporary wetlands. This lack of a land value effect for temporary wetlands across easement states suggests a lesser, or perhaps even ambiguous, effect of temporary wetlands on production capacity.

Lawley (2014) uses farm sales data from the prairie pothole region in Manitoba for the 20 year period 1990-2009 to estimate the change in implicit wetland costs over time. For the midrange

[1]Brander *et al.*(2006) conduct a meta-analysis of more than 190 wetland valuation studies, employing a range of valuation methods and with applications to a variety of international settings.

1998-2001 period, the author finds that a 1% increase in wetland acreage lowers per acre sale price by 1.15%, which translates to a \$456/acre discount for an average size parcel. Pooling the 1990-1993 period with the 2006-2009 period, the author estimates that implicit wetland costs increased by 40% over the 20 year period, and that this increase in wetland cost holds similarly for the 25%, 50% and 75% quantiles. Estimated implicit prices outweigh real offer payments under Manitoba's Wetland Restoration Incentive Program (WRIP) for the majority of sites, which Lawley notes, suggests the WRIP is primarily targeting low valued land in the region.

Gelso *et al.* (2008) allow for ambiguous wetland effects related to total wetland area and frequency of hydration, but an unambiguously negative effect for wetland dispersion, in an expected utility of income modeling framework. They measure the cost of wetlands as the certainty equivalent of producing on a field with zero wetland area. The authors carry out a contingent valuation survey for a large set of Kansas farms to estimate perceived costs for these wetland characteristics. They find that an additional percentage of wetland coverage increases perceived costs by \$0.60 per acre, and that if a given wetland area is dispersed into four separate areas rather than one, the additional cost is \$4.23 per acre. This dispersion cost increases to \$10.47 per acre for 16 separate wetland areas. They also find that hydration frequency increases wetland cost, by roughly \$1.00 per acre for wetlands that hydrate with more than 20% frequency.

Yu and Belcher (2011) directly survey farmers' willingness to accept (WTA) for enrollment in a hypothetical 10-year wetland and riparian conservation management program, using a closed-ended accept/reject bid payment question format. Employing a probit modeling framework, they estimate an average WTA of 75.32 CAD per ha. In addition to farm characteristics, such as size and soil quality, they find that farm operator attitudes and experience with wetlands significantly affect the conservation decision. For instance, farmers who believe that wetlands provide positive net benefits and those who already maintain riparian areas are more likely to enroll for a given payment level, while those who believe that wetlands have aesthetic value, increase operation costs, or are important for wildlife are less likely to enroll.

Production losses associated with on-farm wetlands can also influence the wetland conversion decision. In their simulation of potential exemptions under the US Swampbuster program, Claassen *et al.* (1998) base the decision to convert wetland area on whether the net present value of expected returns to the resulting crop production outweighs the total costs (including opportunity cost) of conversion. Working with a national dataset for agricultural wetlands and commodity production, they estimate that under baseline prices, conversion would be profitable for 5.6-12 million acres. They find that most conversion of cropped wetland area would take place in the Prairie Pothole region, and that conversion estimates are especially sensitive to commodity price changes.

Cortus *et al.* (2011) incorporate dynamic stochastic commodity prices and yields, weather variables and drainage time constraints into their simulation of wetland conversion in the Saskatchewan province of Canada. They estimate average annual private net benefits of conversion ranging from \$27.76/ha of wetland drained on a 4 quarter farm to \$40.66/ha for a 20 quarter farm, suggesting increasing returns to farm size for wetland conversion. They also find that net benefits of conversion are greater for positive nuisance costs, but that the effects of constant *versus* increasing nuisance cost scenarios are virtually the same. The authors note significant variability in their results, which they attribute to the use of stochastic price and yield data.

Turning to AESs in France, Chabé-Ferret and Subervie (2013) model the participation decision for several AESs related to surface water quality and employ a differences-in-differences with matching framework to estimate the effects of AES participation on farm practices. They find that AESs have increased the planting of cover crops by an average of 10 ha per farm, and the average use of grass buffer strips by 240 meters for participants. They also find that AESs increased conversion to organic farming by approximately 46 ha and account for 90% of all increases in organic farming from 2000-2005. Combining these with existing benefit estimates and reported program costs, they find that AESs for cover crops are likely not cost effective, due in part to large estimated windfall effects, and that buffer strips are likely only cost effective for larger watersheds. In contrast, they find that AESs for conversion to organic farming are likely highly cost effective. The AES measures targeted to wetlands in our study region include restrictions to tillage and drainage of wetland areas, fertilizer use, winter grazing, and animal density.

Previous studies have estimated wetland production costs implicitly using agricultural land sales data, or added them conceptually to a choice modeling problem. We estimate them directly from farm-level production data using a production function framework, which also represents a new application of this approach to agricultural wetland costs in the EU. We outline the production function and estimation methods in the next sections, and then present results from our application to farmers in the Limousin region.

3 The Production Model

We model farm output as a function of productive inputs (*e.g.*, land, labor, fertilizer, and capital), on-farm wetland area, and other farm characteristics such as age, commercial designation and subsidy participation. Let y_{it} be production output for farm i in time period t, so that

$$y_{it} = f(x_{it}, w_{it}, h_{it}), \tag{1}$$

where x_{it} is a vector of productive inputs, $w_{i,t}$ is on-farm wetland area and h_{it} is a vector of farm characteristics. A Cobb-Douglas specification of the production technology yields the econometric model,

$$\text{ln}y_{it} = \text{ln}x_{it}\beta_1 + w_{it}\beta_2 + h_{it}\beta_3 + \epsilon_{it}, \tag{2}$$

where ϵ_{it} is composed of unobserved farm-level fixed effects, a_i, and a time-varying disturbance, u_{it}.

Our output variable y_{it} represents farm annual value of final product. Conventional agricultural inputs in x_{it} include utilized land area measured in hectares and labor measured in hours, as well as total expenditures for fertilizer, seed, pesticide, feed, fuel, animals and capital asset value. We specify wetland area, w_{it}, as percent of total utilized agricultural area. Farm characteristics in h_{it} include the share of rented land area, family farm designation (as opposed to commercial) and farm operator age, as well as whether or not the farm lies in an area designated as mountainous or 'less favorable'. Less favored status is granted by the government to areas with inferior growing conditions, such as steep slopes or poor soil quality. We also include total annual coupled and decoupled subsidy payments under the EU common agricultural policy (CAP). Decoupled subsidy payments have been found to have small, but significant positive acreage effects in the US (Goodwin and Mishra, 2006) and largely negative effects on total factor productivity for crop production in France (Mary, 2013).

The coefficient on wetland area provides a measure of the effect of on-farm wetland area on farm value of final product, controlling for conventional productive inputs and other farm characteristics. Given previous estimates of implicit agricultural wetland cost (Shultz and Taff, 2004; Lawley, 2014), we expect this coefficient to be negative.

The production function approach to environmental valuation has been applied to various environmental-production relationships. Barbier (1994; 2007) develops a production function methodology to value tropical wetlands as an input into fisheries production. Acharya and Barbier (2000) use this framework to value wetland-supported groundwater recharge as an input into irrigated agricultural production. Klemick (2011) specifies a log-linear production function with spatial weighting to value the on-farm benefits and off-farm externalities of agricultural land fallowing. Laukkanen and Nauges (2011) use a translog cost function to estimate the production cost of conservation tillage practices, and to then derive input factor demands for fertilizer and chemical use. Laukkanen and Nauges (2014) use a similar framework to model producer land, fertilizer and pesticide use decisions in response to AES payment rates.

4 Identification Strategy

In our study case, farm production varies from year to year, while farm characteristics such as commercial or less favored area status, and importantly, our variable of interest, on-farm wetland area do not change over the three-year study period. A fixed effects (FE) specification effectively differences these time-invariant effects away, and would only allow us to identify the time-varying effects of the conventional production inputs. We could include the time-invariant factors in a random effects (RE) specification as long as both observed time-invariant factors (wetland area, commercial and less favored area status) and time-varying factors (land in use, labor, *etc.*) are exogenous to the unobserved fixed effects (Mundalk, 1978). This highlights the well known tradeoff between FE and RE (Hausman and Taylor, 1981; Baltagi *et al.*, 2003). Hausman (1978) tests of the difference between the FE and RE estimators indicate the RE strict exogeneity assumption is indeed violated in this case.

In order to exploit the panel nature of the production data without discarding information on the variable of interest, farm wetland area, we employ a Hausman-Taylor (HT) (Hausman and Taylor, 1981) estimation framework. The HT estimator relaxes the often problematic assumption of zero correlation between the included explanatory variables and the fixed effects a_i made in the standard RE model, while also accommodating observed time-invariant explanatory effects (Greene, 2003). In this framework, both time variant and invariant effects are separated into those that are correlated with the unobserved fixed effects a_i, commonly referred to as the endogenous variables, and those that are uncorrelated with a_i, referred to here as the exogenous variables. It is important to note that endogeneity in this framework refers to correlation between the observed explanatory variables and the unobserved fixed effects a_i, but not the time-varying disturbance, u_{it}.

The HT specification uses deviations in the time-varying variables within the model to instrument for the time-invariant variables. This allows for identification of the time-invariant variables without imposing the strict exogeneity assumption of RE. A HT specification of our log-linear production model in (2) yields

$$\ln y_{it} = x_{it}\beta + z_i\gamma + a_i + u_{it}, \tag{3}$$

where x_{it} represents the time-varying production factors, including the conventional inputs in log form, and z_i the time-invariant factors, including farm wetland area. We can decompose $x_{it} = [x_{1_{it}}\ x_{2_{it}}]$ and $z_i = [z_{1_i}\ z_{2_i}]$, where $(x_{1_{it}}, z_{1_i})$ denote the (K_1, L_1) exogenous variables (assumed uncorrelated with a_i) and $(x_{2_{it}}, z_{2_i})$ denote the (K_2, L_2) endogenous variables (assumed correlated with a_i).

The HT estimator makes use of the usual FE transformation of the time-varying variables to construct consistent estimators of β. Given its exogeneity to a_i, z_{1_i} serves as an instrument for itself, while the mean of $x_{1_{it}}$, $\bar{x}_1$ serves as an instrument for z_{2_i}. This makes $K_1 \geq L_2$ a necessary condition for identification. The instrumental variables for the HT model are thus $[(x_{1_{it}} - \bar{x}_1), ((x_{2_{it}} - \bar{x}_2), z_{1_i}, \bar{x}_1]$. Pre-multiplying the original variables by the square root of the variance covariance matrix of ϵ_{it} in the 2SLS model renders the HT relatively efficient (Hausman and Taylor, 1981; Baltagi *et al.*, 2003). Greene (2003) outlines a feasible weighting procedure using the residuals from the FE model.

One practical matter concerns distinguishing the exogenous variables from the endogenous variables. Because exogeneity in this framework surrounds the unobserved fixed effects, we can not directly test for correlation with the observed variables in the model. Instead, we use a Hausman pretest procedure, following Baltagi *et al.* (2003), to test for the exogeneity of both the time-varying and time-invariant regressors. This procedure extends the standard use of Hausman testing to choose between FE and RE to the HT estimator. If initial Hausman testing indicates violation of the exogeneity condition for RE, FE is preferred to RE. If Hausman testing on the HT model fails to indicate violation of the exogeneity condition, implying the chosen exogenous regressors have successfully instrumented for the endogenous regressors, HT is preferred to FE.

5 Empirical Application and Results

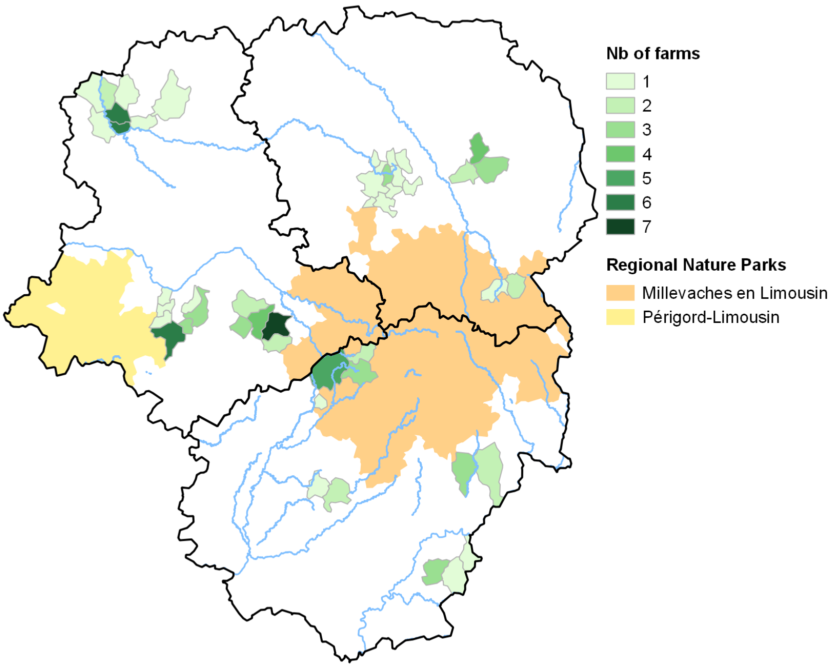
We apply our production modeling framework to a panel of farms in the Limousin region of France, compiled by the regional chamber of agriculture, la Chambre d'Agriculture de la Haute-Vienne. The ministry annually surveyed the production practices of 101 farms between 2007-2009, modeling the survey after the common EU Farm Accountancy Data Network (FADN) survey. We match this production data to a 2009 regional survey of farm wetland area to include total wetland area for each of the farms in our sample (Boyard, 2012). According to the 2010 agricultural census, the Limousin region counts 14,600 farms and 839,000 hectares of utilized agricultural area (Agreste, 2015). Wetlands represent 4.85% of the total forest and farmland area (Chabrol, 2006). Depending on the share of wetlands in forested areas, agricultural wetlands total between 40,000 and 58,000 hectares. These wetland areas belong to or overlap the 36 sites of special ecological interest designated according to the EU Habitats and Bird Directives, totaling 101,000 ha, with 43,000 ha of agricultural land (Préfecture de la Région Limousin, 2013). Figure 1 depicts the location of farms and wetland survey sites in the study region.

The farms in our study are majority livestock operations that use agricultural land area primarily for grazing purposes. Crop production is secondary, and mainly intended for supplemental feed. The primary costs posed by wetlands to these producers include reduced grazing area and concomitant increases to animal density. Table 1 summarizes the farm survey variables. Average utilized agricultural area (UAA) is roughly 126 ha, and farms produce an average of 96,613 € in annual value of final product. On average, wetlands cover 13.6% of farm UAA, which is higher than for the region as a whole, and this value ranges for the sample from a low of 0.4% to a high of 58%. Just over half of all UAA is rented and close to 40% of operations responded as family farms. More than half of all operations also receive Less Favorable Area (LFA) designation, mainly due to high altitude (over 600 m above sea level), and close to 40% of farms receive Mountain Area status. These designations qualify farms for additional decoupled subsidy payments. Decoupled subsidy payments average 20,541 € , and also include payments for participation in various AES. However, participation in AES targeted specifically to wetlands is less than ten percent. Coupled subsidy payments average 30,667 € and are mainly tied to arable land area and suckling cow livestock numbers.

Regarding AES payments, the most popular measure in the region is the national basic measure, PHAE2[2], also known as the agri-environmental grassland premium. Primarily, PHAE2 requires

[2]PHAE2 stands for "*Prime Herbagère Agro-Environnementale 2*" where 2 indicates the second generation of

Figure 1: Farm production and wetland survey areas in the Limousin region



that grassland areas comprise at least 75% of total utilized agricultural area. The average rate of grassland coverage in Limousin is 84%. Additionally, the farm eligible area must include 20% of protected biodiversity elements (*e.g.*, native vegetation, bird habitat), and maintain an animal grazing density of between 0.4 and 1.4 livestock units per hectare. A livestock unit is equivalent to one dairy cow. PHAE2 also imposes limits to tillage, mineral fertilizer and herbicide use. The basic measure grassland premium is 76 € /ha for both permanent and temporary grasslands. Wetlands serve as valuable assets to be eligible for the grassland premium since 1 ha of peat land counts as 20 ha of biodiversity elements, namely permanent grassland, or 100 linear meters of hedges. Hence, with very little wetland area, a farmer may declare a large portion of utilized agricultural land area (temporary, permanent, or wet) as temporary grassland, thus maintaining the option to convert permanent grasslands into temporary grassland area without losing the basic measure payment. In practice, the grassland premium tends to protect a very limited share of wetlands, instead providing payments for whole farm grazing land. There is also recent evidence that the grassland premium has failed to avoid, and in some cases has even encouraged, the conversion of permanent grassland in France (Desjeux *et al.*, 2015).

In addition to the basic measure grassland premium, the Limousin region implemented 20 local AESs during our 2007-2009 study period, each offering 5-year contracts to farmers. Of these, 17 target wetlands, frequently in combination with other areas of ecological interests such as species richness and dry natural grasslands. For the region as a whole, 111 farmers entered

this type of scheme.

2,400 ha into these AESs, representing 4% to 6% of total wet farmland area (DRAAF Limousin, 2009). The average per ha annual payment is 200 € , ranging from 34 € to 475 € , with 12 out of 17 schemes paying between 180 € and 280 € . The payment rates depend on the specific measures included in each scheme, as well as the designated area location within the region, and are based on ministry estimates of the additional costs incurred by each agri-environmental practice.

Compared to the grassland premium, these local AESs are offered in designated areas only, and do not necessarily involve the entire farm area of the beneficiary. They require management plans that combine several maintenance and restoration practices, adapted to each enrolled land area. Local AES management plans for wetlands typically include bans on mineral fertilizer and herbicide use, no-tillage requirements, prohibitions on grazing during periods deemed critical for biodiversity, delayed mowing dates to protect wild bird reproduction, specific maintenance practices for ditches and hedges, and the eradication of woody plants to prevent water loss in the soil (Préfecture de la Région Limousin, 2013). Higher payment rates correspond to increased commitments on the part of farmers. Producers may combine the local AESs with the basic measure over different portions of the same farm, but they may not receive payments from both programs for the same land area.

Table 1: Summary statistics

Variable	Mean	Std. Dev.	Min	Max
Value of Final Product	96,613	48,374	2,606	241,208
Utilized Agricultural Area (Hectares)	126.45	51.19	21.24	342.71
Labor (hours)	4,267	1,843	2,200	9,240
Fertilizer Expenditure	7,354	5,222	0.00	27,665
Seed Expenditure	2,383	2,191	0.00	15,106
Pesticide Expenditure	1,612	1,852	0.00	11,986
Feed Expenditure	19,414	14,932	129	168,867
Fuel expenditures	6,342	3,429	92	20,552
Animal Expenditure	3,463	8,111	0.00	60,879
Capital Expenditure	42,160	20,339	2,355	105,914
No Fertilizer	.035	.184	0.00	1.00
No Pesticide	.105	.307	0.00	1.00
No Seed	.058	.234	0.00	1.00
No Animal Expenditure	.450	.498	0.00	1.00
Percent Wetland	.136	.122	.004	.583
Percent Rented Area	.523	.304	0.00	1.00
Family Farm	.384	.487	0.00	1.00
Less Favorable Area	.547	.499	0.00	1.00
Mountain Area	.384	.487	0.00	1.00
Operator Age	41.54	10.05	22	63
Subsidies (Coupled)	30,667	18,043	4.82	89,558
Subsidies (Decoupled)	20,541	15,164	0.00	72,348

While our data set does not include disaggregated information on participation for each of the individual AES measures, we do know the maintained wetland area for each farm. We estimate the costs of maintaining these areas on working land, in terms of lost production value, using the production function in (2). We explore several alternative specifications across FE, RE, and HT estimators. Hausman tests of the RE specifications indicate a preference for the FE estimator, with test statistics generally significant below the 0.05 level. We then use the Hausman pretest procedure suggested by Baltagi *et al.* (2003) to partition the time-varying (x_{it}) and time-invariant (z_i) variables into exogenous $(x_{1_{it}},\, z_{1_i})$ and endogenous $(x_{2_{it}},\, z_{2_i})$ components. Based on the pretest results, we treat fertilizer, seed and coupled subsidies as endogenous to the unobserved fixed effects, while the remaining variables satisfy the exogeneity condition (fail to reject at any reasonable significance level) in the HT framework. We note that in our case, the endogenous variables are all time-varying, so that we need only use their mean deviations to serve as instruments. Additionally, to account for the presence of some farms with zero fertilizer, zero pesticide, zero seed expenditures or no purchase of animals to adjust the productive herd (variable named animal expenditure), we include indicators to allow for separate production function intercepts in these cases (Battese, 1997; Klemick, 2011).

We present the results of four specifications in Tables 2 and 3, alternately controlling for subsidy payments (coupled and decoupled) and land area designation (mountain area and less favorable area). The coefficient estimates for the production inputs and wetland area variables are generally robust to model specification. While the coefficient estimate magnitudes vary somewhat, the sign and significance levels remain largely the same across models.

The coefficient on wetland area is negative and significant across specifications, indicating that a tradeoff between wetland area and production does indeed exist for farms in this region. This is consistent with previous studies that also find that wetland areas pose additional costs to agricultural producers (Heimlich, 1994; Shultz and Taff, 2004; Gelso *et al.*, 2008; Cortus *et al.*, 2011). The significant coefficients on the standard productive inputs are all positive as expected, while land area, fertilizer, seed, and pesticide expenditures are not significant. We note that our sample consists primarily of cattle and dairy farms, which may explain the lack of significance for these standard crop inputs. The coefficient on percent wetland ranges from -0.48 to -0.68, which can be interpreted as the effect of a percentage point increase in wetland area in terms of percentage change in final production value.

Using our most conservative HT estimate, a coefficient of -0.48 implies that a one percentage point increase in wetland area results in a 0.48 percent decrease in final production value. To translate this to monetary terms, we can apply these estimates to average values for UAA and value of final product. This implies that an additional 1.26 ha of wetland area results in a loss of approximately 464 € in final production value. This estimated cost exceeds current AES payments, which are generally between 180 € and 280 € per ha. Moreover, for many farmers, our estimated loss takes into account the grassland premium of 76 € per ha that could not be combined with any of the local AES payments. This poses an additional opportunity cost. For

Table 2: Model Results Part I

	(1) FE1	(2) RE1	(3) HT1	(4) FE2	(5) RE2	(6) HT2
Log UAA	0.135	0.0345	0.0431	0.132	0.0554	0.0734
Log Labor Hours	0.0602	0.169**	0.166**	0.0399	0.136**	0.124*
Log Fert Exp	-0.00276	0.0222	-0.00317	-0.00890	0.0126	-0.0130
Log Seed Exp	-0.0135	0.00971	-0.00126	-0.0179	0.00468	-0.0109
Log Pest Exp	0.0256	0.0266	0.0343*	0.0333	0.0354*	0.0453**
Log Feed Exp	0.210***	0.273***	0.267***	0.229***	0.273***	0.264***
Log Animal Exp	0.0387**	0.0397**	0.0406**	0.0386**	0.0391**	0.0396***
Log Capital Exp	0.466***	0.321***	0.336***	0.236**	0.232***	0.219***
Log Fuel Exp	0.126	0.119***	0.124***	0.0738	0.0926**	0.0905*
No Fertilizer	-0.514*	-0.311	-0.542**	-0.550**	-0.341*	-0.574**
No Seed	-0.292	-0.114	-0.214	-0.357**	-0.145	-0.277*
No Pesticide	0.203	0.187	0.235*	0.226*	0.238**	0.292**
No Animal Exp	0.298*	0.282**	0.301**	0.272**	0.275**	0.281**
Percent Wetland	.	-0.462**	-0.480**	.	-0.580***	-0.683***
2008	-0.0725*	-0.0570*	-0.0673**	-0.0632*	-0.0646**	-0.0756**
2009	-0.0787**	-0.0617*	-0.0710**	-0.0870***	-0.0806***	-0.0925***
Log Subsidies (C)				0.149***	0.0986***	0.142***
Log Subsidies (D)				0.000350	0.0133	0.00280
Constant	1.694	1.979***	2.054***	3.191	2.309***	2.520***
R^2	0.827	0.857		0.812	0.856	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

producers currently receiving the grassland premium, AES payments would only provide an additional 104 € to 204 € per ha.

Table 3: Model Results Part II

	(1) FE3	(2) RE3	(3) HT3	(4) FE4	(5) RE4	(6) HT4
Log UAA	0.135	0.0345	0.0431	0.132	0.0554	0.0734
Log Labor Hours	0.0602	0.169**	0.166**	0.0399	0.136**	0.124*
Log Fert Exp	-0.00276	0.0222	-0.00317	-0.00890	0.0126	-0.0130
Log Seed Exp	-0.0135	0.00971	-0.00126	-0.0179	0.00468	-0.0109
Log Pest Exp	0.0256	0.0266	0.0343*	0.0333	0.0354*	0.0453**
Log Feed Exp	0.210***	0.273***	0.267***	0.229***	0.273***	0.264***
Log Animal Exp	0.0387**	0.0397**	0.0406**	0.0386**	0.0391**	0.0396***
Log Capital Exp	0.466***	0.321***	0.336***	0.236**	0.232***	0.219***
Log Fuel Exp	0.126	0.119***	0.124***	0.0738	0.0926**	0.0905*
No Fertilizer	-0.514*	-0.311	-0.542**	-0.550**	-0.341*	-0.574**
No Seed	-0.292	-0.114	-0.214	-0.357**	-0.145	-0.277*
No Pesticide	0.203	0.187	0.235*	0.226*	0.238**	0.292**
No Animal Exp	0.298*	0.282**	0.301**	0.272**	0.275**	0.281**
Percent Wetland	.	-0.462**	-0.480**	.	-0.580***	-0.683***
2008	-0.0725*	-0.0570*	-0.0673**	-0.0632*	-0.0646**	-0.0756**
2009	-0.0787**	-0.0617*	-0.0710**	-0.0870***	-0.0806***	-0.0925***
Log Subsidies (C)				0.149***	0.0986***	0.142***
Log Subsidies (D)				0.000350	0.0133	0.00280
Operator Age	.	0.00407	0.00472	.	0.00396	0.00443
Family Farm	.	0.0700	0.0657	.	0.0758	0.0683
Percent Rented Area	-0.221**	-0.116*	-0.141**	-0.221**	-0.115*	-0.139*
Mountain Area				.	-0.0923	-0.0808
Less Favorable Area				.	-0.0518	-0.0315
Constant	1.694	1.979***	2.054***	3.191	2.309***	2.520***
R^2	0.806	0.860		0.806	0.861	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Model Results Part III

	(1) FE1	(2) RE1	(3) HT1	(4) FE2	(5) RE2	(6) HT2
Log UAA	0.135	0.0345	0.0431	0.0825	0.0558	0.0618
Log Labor Hours	0.0602	0.169**	0.166**	0.0908	0.163**	0.164**
Log Fer Exp	-0.00276	0.0222	-0.00317	-0.00920	0.0193	-0.00643
Log Seed Exp	-0.0135	0.00971	-0.00126	-0.00875	0.00837	-0.00244
Log Pesticide Exp	0.0256	0.0266	0.0343*	0.0252	0.0258	0.0342*
Log Feed Exp	0.210***	0.273***	0.267***	0.221***	0.278***	0.275***
Log Animal Exp	0.0387**	0.0397**	0.0406**	0.0397**	0.0404**	0.0416**
Log Capital Exp	0.466***	0.321***	0.336***	0.398***	0.283***	0.296***
Log Fuel Exp	0.126	0.119***	0.124***	0.110	0.108**	0.114**
No Fertilizer	-0.514*	-0.311	-0.542**	-0.525*	-0.292	-0.516**
No Seed	-0.292	-0.114	-0.214	-0.227	-0.0868	-0.175
No Pesticide	0.203	0.187	0.235*	0.210	0.188	0.237*
No Animal Exp	0.298*	0.282**	0.301**	0.314**	0.300**	0.320**
Percent Wetland	.	-0.462**	-0.480**	.	-0.424**	-0.444**
2008	-0.0725*	-0.0570*	-0.0673**	-0.0649*	-0.0554*	-0.0653**
2009	-0.0787**	-0.0617*	-0.0710**	-0.0763**	-0.0645**	-0.0728**
Log Subsidies (D)				0.0319*	0.0335**	0.0325**
Constant	1.694	1.979***	2.054***	2.163	2.077***	2.128***
R^2	0.827	0.857		0.836	0.859	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Model Results Part IV

	(1) FE3	(2) RE3	(3) HT3	(4) FE4	(5) RE4	(6) HT4
Log UAA	0.132	0.0854	0.0891	0.132	0.0898	0.0937
Log Labor Hours	0.0769	0.172**	0.164**	0.0769	0.182**	0.175**
Log Fert Exp	-0.0182	0.0179	-0.0140	-0.0182	0.0158	-0.0153
Log Seed Exp	-0.0102	0.00716	-0.00237	-0.0102	0.00793	-0.00132
Log Pesticide Exp	0.0245	0.0254	0.0348*	0.0245	0.0271	0.0364*
Log Feed Exp	0.220***	0.285***	0.279***	0.220***	0.282***	0.278***
Log Animal Exp	0.0380**	0.0417**	0.0425***	0.0380**	0.0416**	0.0425***
Log Capital Exp	0.423***	0.276***	0.294***	0.423***	0.280***	0.296***
Log Fuel Exp	0.108	0.113**	0.119**	0.108	0.110**	0.116**
No Fertilizer	-0.589**	-0.309	-0.578**	-0.589**	-0.322	-0.583**
No Seed	-0.234	-0.0945	-0.172	-0.234	-0.0895	-0.161
No Pesticide	0.189	0.170	0.222*	0.189	0.180	0.231*
No Animal Exp	0.301**	0.313**	0.331**	0.301**	0.316**	0.334**
Log Subsidies (D)	0.0288*	0.0312**	0.0309**	0.0288*	0.0335**	0.0330**
Percent Wetland	.	-0.440**	-0.450**	.	-0.429*	-0.443*
Operator Age	.	0.00169	0.00151	.	0.00219	0.00205
Family Farm	.	0.0392	0.0293	.	0.0499	0.0419
Percent Rented Area	-0.169	-0.109	-0.120*	-0.169	-0.110	-0.120*
2008	-0.0656*	-0.0557*	-0.0673**	-0.0656*	-0.0560*	-0.0673**
2009	-0.0728**	-0.0599*	-0.0703**	-0.0728**	-0.0611*	-0.0710**
Mountain Area				.	-0.117	-0.121
Less Favorable Area				.	-0.122	-0.127
Constant	2.022	1.841**	1.997**	2.022	1.820**	1.964**
R^2	0.834	0.863		0.834	0.864	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

It is important to note that the connection of coupled subsidy payments to production factors, such as arable land area and livestock numbers, likely increases the potential for endogeneity in our model. Unfortunately, while the HT framework allows us to estimate the time-invariant effect of wetland area (our main variable of interest) by instrumenting for endogeneity to the unobserved fixed effect, a_i, it does not allow us to simultaneously instrument for endogeneity to the time-varying disturbance, u_{it}. Coupled subsidy payments are tied to production, likely violating exogeneity to u_{it}. To better understand the sensitivity of our results to coupled subsidy payments (separately from decoupled subsidies, which do not depend on production output), we examine an alternate specification of the four models above, omitting coupled subsidy payments entirely, in Tables 4 and 5. We find that the same general relationship between wetland area and production value holds, although our upper end HT estimate is now much closer in magnitude to the RE estimates across specifications. The HT wetland area coefficient now ranges from -0.44 to -0.48. An elasticity of -0.44 translates to roughly 425 € for an additional 1.25 ha of wetland area.

6 Conclusion

Agricultural wetlands are semi-natural habitats (Dupraz and Rainelli, 2004). High ecological and hydrological values of these wetlands are associated with particular practices characterized by the maintenance of permanent grassland with adapted fertilization, grazing, and mowing intensity. Due to lower agricultural productivity, well-functioning wetlands are threatened by either agricultural abandonment, leading to afforestation and drying, or conversion to intensive arable cropping by drainage (Russi *et al.*, 2013).

As policy emphasis increasingly shifts from land retirement to conservation practices on working land (Baylis *et al.*, 2008), it is important to understand the associated production effects for determining appropriate AES payment rates and predicting AES participation. We use a production function modeling approach to estimate the cost of maintaining wetland areas on agricultural land, for a panel of livestock producers in the Limousin region of France. We employ a Hausman-Taylor specification to jointly accommodate time-varying and time-constant factors of interest. Our data set includes detailed production information and farm characteristics, similar to the EU FADN, as well as information on farm wetland area. We find that wetland areas on working land do pose significant production costs for farms in our study area, and our results are relatively robust to multiple model specifications. Our most conservative HT elasticity estimate is -0.44, which translates to approximately 425 € in lost production value from an additional 1.25 ha of wetland area. For livestock farms, these costs arise mainly from the loss of productive grazing area and less arable land for producing crops to use as feed.

Our results indicate that the production costs of maintaining wetland areas on working land exceed related AES payments for the majority of producers in our study. This likely contributes to current low participation rates for wetland conservation programs in the region. We qualify these results by noting a few important limitations. First, we work with a relatively small sample of farms and limit our analysis to majority livestock (as opposed to crop) producers. Related to this, our panel covers just three years, during which wetland area on individual farms is constant. Ideally, we would like to model the production effects of changing wetland area over time, especially for understanding the effects of changing participation rates in the AESs. Another limitation concerns the potential for qualitative differences in wetland type. Our survey data does not distinguish between areas that remain saturated year round, *versus* areas that seasonally fill and drain. Nor does it provide information on the dispersion of wetland area across the agricultural area. These attributes likely affect the cost of a given wetland area (Shultz and Taff, 2004; Gelso *et al.*, 2008). That said, by connecting wetland area to detailed production information at the farm level, our data provides a unique opportunity to examine wetland costs directly, at a disaggregated scale.

We have also made a tradeoff here between instrumenting for endogeneity to the unobserved heterogeneity and being able to instrument for endogeneity to any time-varying unobserved factors. Using the HT specification to instrument for the time-invariant effect of wetland area prevents us from instrumenting for endogenous time-varying effects in this case. To mitigate the potential for bias, we include a number of controls for farm characteristics and examine several alternative specifications as a robustness check. We find that our estimates, particularly for wetland effects, are generally robust to model specification. But it is likely that at least some of the production inputs remain endogeneous, particularly variable inputs that are likely chosen with short term production objectives in mind.

Our main results on wetland area are consistent with previous findings that agricultural wetlands do indeed pose significant costs to producers. To our knowledge, this is the first study to apply the production function approach to estimate the cost of maintaining wetlands on working agricultural land. We believe this framework is particularly useful for analysis of AESs, because it allows for direct estimation of participation costs. This is also one of few studies to estimate wetland costs on working land in the EU. Our study contributes to the use of production modeling for estimating AES costs more generally, and we are interested in extending our analysis to better explain participation rates in wetland conservation programs and to modeling the effects of participation on other farm practices, such as the use of chemical inputs or tillage practices.

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