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Are EU subsidies a springboard to the reduction of pesticide use?

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Abstract:

Many farms are developing more environmentally-friendly practices in order to meet the phytosanitary requirements of both private actors and public authorities. This article analyses the essential contribution of EU subsidies to reducing pesticide use. We use the highly- accurate FADN database from 2007 to 2015y to measure pesticide use and relate it to public subsidies received by farmers within the implementation of the rural development policy for the period 2007 to 2013. The influence of EU subsidies on pesticide use is measured through an econometric model using panel data. In addition to the individual, structural and financial factors which usually explain the implementation of environmentally-friendly practices, our study emphasizes the role of EU subsidies. The results show that overall payments as well as payments from the 1st pillar increase pesticide use while payments from the 2nd pillar lead to a decreasing intensity of pesticide expenditure. Other key individual, structural and financial factors at farm level also have contrasting effects on pesticide use. The efficiency of public policies towards the issue of environmentally-friendly practices is therefore questioned.

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Abstract

Many farms are developing more environmentally-friendly practices in order to meet the phytosanitary requirements of both private actors and public authorities. This article analyses the essential contribution of EU subsidies to reducing pesticide use. We use the highly-accurate FADN database from 2007 to 2015y to measure pesticide use and relate it to public subsidies received by farmers within the implementation of the rural development policy for the period 2007 to 2013. The influence of EU subsidies on pesticide use is measured through an econometric model using panel data. In addition to the individual, structural and financial factors which usually explain the implementation of environmentally-friendly practices, our study emphasizes the role of EU subsidies. The results show that overall payments as well as payments from the 1st pillar increase pesticide use while payments from the 2nd pillar lead to a decreasing intensity of pesticide expenditure. Other key individual, structural and financial factors at farm level also have contrasting effects on pesticide use. The efficiency of public policies towards the issue of environmentally-friendly practices is therefore questioned.

Keywords: pesticides, EU subsidies, FADN, France.

1. Introduction

The implementation of environmentally-friendly practices has become more and more popular over the last few decades, mainly because of recent sanitary crises. These practices can take several forms, including a reduction in the application of phytosanitary products and the quantities used as well as the implementation of integrated pest management techniques (Fernandez-Cornejo, 1996). An illustration of this growing trend is the extension of organic farming in Europe and, more broadly, around the world (Eurostat, 2017; FIBL and IFOAM, 2017).

Reducing pesticides is a challenge to be taken up by all stakeholders, from producers to consumers, in order to ensure a more sustainable agriculture. Existing studies have proven that the process underlying the implementation of more environmentally-friendly practices requires a combination of several factors such as the implementation of new production and marketing patterns and the continuing education of farm operators. The existence of taxes and incentives may also play a key role insofar as farm revenue depends significantly on a public support.

The European Union has long been developing support policies for green agriculture. The Common Agricultural Policy is based on the concept of “multifunctionality”, which, according to the World Trade Organization, considers that “*agriculture has many functions in addition to producing food and fibre, e.g. environmental protection, landscape preservation, rural employment, food security*”. More specifically, organic farming is regulated by the Council Regulation (EC) No. 834/2007 on organic production and labelling of organic products, complemented by Commission Regulation (EC) No. 889/2008 with detailed rules for production, labelling and control. The CAP strategic framework for 2014-2020 reinforced the greening of EU agricultural policy (Westhoek et al., 2014).

In practice, the concept of the Common Agricultural Policy (CAP) is based on two pillars. The 1st pillar includes direct payments, which help farmers to stabilize their revenue, and market measures, which tackle specific market situations. The 2nd pillar concerns rural development policy and includes measures for promoting environmentally-friendly practices. Within this framework, farmers receive subsidies providing they comply with rules relating to the main public expectations with regard to the environment as well as public and animal health and welfare.

Within the framework of CAP 2007-2013 and 2014-2020, green practices have been strongly encouraged with specific budget guidelines. Some of them target the development of organic farming, but the range of possible actions actually includes all types of action leading to more environmentally-friendly practices. In total, about 28.9% of the total EU budget for agriculture is focused on measures directly linked to environmental and climate issues (Table 1).

Table 1. Key EU budget allocations for transitioning towards environmental and climate-friendly practices and organic farming under the CAP 2014–2020

While the previous table quantifies the efforts made in favour of green practices, it also describes a complex multi-layered structure of subsidies. The OECD (2017) annual report points out that most traditional agricultural support policies continue to target production rather than quality, which may prevent environmentally-friendly practices from gaining ground.

The aim of this research is to examine the influence of European payments on the implementation of environmentally-friendly practices in detail. The literature has already considered the influence of certain financial incentives on pesticide use. Most of this work has focused on the relationship between the subscription of crop insurance policies and pesticide application and expenses. Basically, both products aim at protecting farm yields, the latter by protecting the plants throughout the season and the former by compensating for losses if a climatic incident should occur. It should be noted that subscriptions are taken out before the season begins in order to avoid opportunism. The results found in these studies appear to be very contrasting: while some studies prove that pesticides and insurance policies are complementary (Horowitz and Lichtenberg, 2003), others show that they are substitutes (Mishra et al., 2005) while others show mixed evidence (Goodwin et al., 2004) or do not emphasize any relationship (Aubert and Enjolras, 2014a). In contrast, little attention has been paid to the potential impact of European payments on pesticide use. These subsidies can be considered either as a simple additional source of income, which increases the ‘certainty equivalent’ of the farm, or as a risk management tool which compensates for the market liberalization.

In order to complement the existing literature on these practices, the contribution provided by this paper is threefold. First, we propose an innovative analysis which considers the relationship between EU subsidies and pesticide use. Second, this analysis takes specific account of a set of individual, structural, economic and financial parameters as determinants of production choices. Third, we use data from the French Farm Accountancy Data Network for the period 2007-2015 because they provide a representative overview of professional French farms, particularly in terms of productive orientation, during the implementation of a specific rural development policy framework. Our study considers the French case in greater detail. This country is a relevant case study, as pesticide use is among the highest in Europe (Butault et al., 2012). Against such a backdrop, following the implementation of the EcoPhyto I (2008) and Ecophyto II (2015) frameworks, objectives were defined to reduce the intensity of pesticide use in French agriculture.

This article is organised as follows. In the first section, we develop the theoretical framework while in the second section we present the empirical strategy. In the third section, we develop the results using descriptive statistics and econometric models and in the fourth section we conclude and provide some perspectives.

2. Theoretical framework

The theoretical framework is founded on the growing literature relating to environmentally-friendly practices and organic farming. We set up a model and research hypotheses that will be tested using an empirical framework.

2.1 A model of pesticide use when agricultural production is subsidized

European subsidies contribute to increasing farmers' total income. While this financial support can help farmers to implement environmentally-friendly practices, the vast majority of the studies examine only their consequences on the economic potential of the farm (Rigby et al., 2001; Kallas et al., 2010). Few studies take account of the link between European subsidies and green practices (Fernandez-Cornejo et al., 1998; Stozle, 2016), while during the last decade more financial incentives have been implemented. Because Europe has set up an active regulation which can influence pesticide use, our study focuses specifically on the impact of such subsidies on farmers' behaviour.

Farmers used to apply pesticides with the goal of maximizing, or at least protecting, their income. We can thus formulate a general problem of profit maximisation which takes into account the key parameter of farm production studied in this article – pesticides and European subsidies. Following a usual modelling procedure (Adinolfi and Capitanio, 2009; Aubert and Enjolras, 2014a; Pannell, 1991; Rahman, 2003), the profit of a farm Π_i which the farmer wishes to maximise is:

$$\Pi_i = \sum_{k=1}^m A_{i,k} (p_{i,k} Y_{i,k} - q_{i,k} I_{i,k} + DP_{i,k}) - rF_i + EP_i \quad (1)$$

with: $Y_{i,k} = f(A_{i,k}, I_{i,k}, DP_{i,k}, F_i, EP_i, X_i)$ for $k = 1 \dots m$, and $\sum_{k=1}^m A_{i,k} \leq A_i$

For each farm i , $Y_{i,k}$ is the yield of each plot k and m is the total number of plots. It depends on the application of chemical inputs, I_i , the use of other production factors (either structural, e.g. land and workforce, or financial, e.g. capital), F_i , the relative area allocated to each plot, $A_{i,k}$, and a set of individual and exogenous parameters (e.g. risk-awareness of the farmer and weather conditions), X_i , which modify the production function. DP are payments related to the 1st pillar, including mostly decoupled subsidies, and EP are payments related to the 2nd pillar, including agri-environment payments. p , q and r represent the output prices, the input prices, and the prices of other production factors respectively.

The first-order conditions determine the demand functions for inputs (Pannell, 1991):

$$I_i = I_i(p_1, \dots, p_m, q_1, \dots, q_m, r, A_1, \dots, A_m, DP_i, EP_i, X_i) \quad (2)$$

Equation (2) shows that pesticide use depends on several parameters, such as the structure of the farm, its financial situation, European payments and certain exogenous factors.

2.2 European subsidies

Considering that the CAP is based on two pillars with different assigned objectives, one can assume that contrasting effects may be observed. Subsidies from the 1st pillar, designated by DP in our model, which are designed to increase, or at least stabilize, farmers' income through direct payments, may be more likely to incite farmers to use pesticides. As shown in Equation (1), payments received could be used by farmers as a way to finance their inputs and thus to develop their activity. In this case, European payments and pesticides would be deemed complementary. A similar effect was studied by Horowitz and Lichtenberg (1993) who showed that crop insurance could lead to an increase in chemical use.

H1a. European subsidies from the 1st pillar lead to an increase in pesticide use.

Conversely, subsidies from the 2nd pillar, denoted by EP in our model and which comprise rural development policies, seem to be better adapted to pesticide reduction. These subsidies mainly incorporate compensation for losses caused by adverse weather conditions and agri-environmental subsidies. The former may be considered as a means of support aimed at directly reducing income volatility. The latter provide incentives to adopt environmentally-friendly practices, including an explicit reduction in chemical input use. Such supports should discourage the application of pesticides. In this case, European payments and pesticides would be considered as substitutes, to the extent that subsidies should somehow compensate for the financial impacts of a reduction in pesticide applications (fall in yields and increased yield volatility). In this case, subsidies would increase the farmers' certainty equivalent (Gren, 1994). Similarly, Mishra et al. (2005) showed that crop insurance could lead to a decrease in chemical use.

H1b. European subsidies from the 2nd pillar lead to a decrease in pesticide use.

Because of the contrasting effects noted above, it seems unclear at first glance how subsidies from the 1st and 2nd pillars might act together and could result in a global decrease in pesticide use. However, the historical weight of payments from the 1st pillar (Table 1) gives reason to assume that the overall amount of European subsidies positively drives pesticide use.

H1c. Overall European subsidies lead to an increase in pesticide use.

2.3 Structural characteristics

Padel (2001) and Kallas et al. (2010) emphasize that small farms are more willing to adopt organic farming. Aubert and Enjolras (2017) show that larger farms may also be interested in this kind of farming because it offers a sufficient economic dimension.

H2a. Pesticide use increases with the size of the farm

According to Dinis et al. (2015) and Aubert and Enjolras (2017), farms reducing pesticide use are less diversified. The rationale lies in the production and certification constraints when adopting alternative production processes. However, Padel (2001), Hanson et al. (2004) and Kallas et al. (2010) find an opposite conclusion: farms which apply less pesticide may diversify their activities in order to mitigate the consequences of potential yield losses.

H2b. Pesticide use increases with the diversification of farm products

The workforce has continuously been acknowledged as a key factor leading to the adoption of environmentally-friendly practices (Jansen, 2000; Padel, 2001; Aubert and Enjolras, 2017). An increase in working hours is necessary because of additional activities, such as monitoring, required by a reduction in pesticide applications (Karali et al., 2014).

H2c. Pesticide use decreases when the workforce increases

Karali et al. (2014) show that available family workforce is one of the cheapest substitutes to pesticides use. Dinis et al. (2015) and Kallas et al. (2010) also prove that family farming is more fundamentally organic because of a reduced need for material investments when this type of workforce is available. Aubert and Enjolras (2017) demonstrate that, for small farms, family labour is essential to the adoption of environmentally-friendly practices.

H2d. Pesticide use decreases when family labour increases

2.4 Individual characteristics

Padel (2001), Sylvander and Schieb-Bienfait (2006), Kallas et al. (2010) and Aubert and Enjolras (2017) all show that the better education the farm holder, the more involved he is with environmentally-friendly practices.

H3a. A higher level of education for the farm holder decreases pesticide use

Sylvander and Schieb-Bienfait (2006) emphasize the need for the holder to be fully involved in his farming activity when adopting organic farming.

H3b. The time spent by the farm holder on his farm decreases pesticide use

2.5 Financial characteristics

Offermann and Nieber (2000), as well as Koesling et al. (2008), indicate that farms converting to organic farming may be motivated by the perspective of increased profitability.

H4a. Profitable farms reduce their pesticide use

Galt (2008) highlights the fact that indebtedness has a positive impact on the consumption of pesticides used per hectare while Sharma et al. (2011) showed that this effect is not significant. Farmers may prioritize expenditures such as pesticides because applying them can ensure yields.

H4b. Indebtedness leads to an increase in pesticide use

2.6 Control variables

Because of their particularities, mainly in terms of sensitivity to pests and disease, some specializations are more likely to use pesticides. As a matter of fact, while farms specializing in field crops used €134 of pesticide per hectare in 2006, farms specializing in wine growing used €394 per hectare (Butault et al., 2010).

H5a. Technical and economic specialization influences pesticide use

The location of the farm is also an important factor which reflects the environment in which farmers live and work. As our study aims to assess the impact of European support on pesticide use, location can be considered through a location in disadvantaged areas characterized by a lower population density, a higher degree of isolation and more complex farming activities (Caraveli, 2000). However, being located in a disadvantaged area may decrease the use of pesticides as farmers are encouraged to implement environmentally-friendly practices in order to preserve these areas (Rudow, 2014).

H5b. A location in a disadvantaged area increases pesticide use

Regardless of the location and the specialization, we are witnessing a rapid change in phytosanitary requirements for all farms imposed by private actors, public authorities and consumers (Lefebvre et al. 2014; Böcker and Finger, 2016). We therefore assume that pesticide use decreases over time.

H5c. Pesticide use decreases over time

These research hypotheses will be tested within the empirical framework developed hereafter.

3. Empirical framework

In this section, we present first the database used and second the econometric model implemented to understand the extent to which farmers' behaviour towards pesticide use is conditioned not only by individual, structural and financial characteristics but also by the level of European support.

3.1 Database

In order to understand farmers' practices in terms of pesticides used, our study is based on the European Farm Accountancy Data Network (FADN) for the period 2007-2015. This observation period allows us to observe the implementation of the rural development policy for the period 2007 to 2013, which was defined by the Council Regulation (EC) No. 1698/2005 of 20 September 2005 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD).

These data are both the most precise available at the individual level and the most complete and recent that we have. This database offers a reliable way to access structural and financial characteristics of professional farms. Professional farms correspond to farms on which standard output is higher than €25,000.

Because of the sampling methodology, farms belonging to the FADN-RICA do not correspond to perennial farms. From 2007 to 2015, 28,175 farms are surveyed, irrespective of the economic and technical orientation (ETO). In our study, we consider all professional farms, regardless of their specializations. Market gardeners, wine growers, fruit producers as well as sheep breeders are therefore considered.

The database allowed us to assess not only the individual characteristics of the farmer and the structural and financial characteristics of farms, but also the pesticides used. More precisely, the latter is measured in economic terms through declared expenditures. In order to neutralize size effects, expenditure is presented relative to farm sales.

Table 2 summarizes the variables used for this analysis, the underlying hypotheses and the direction of the effects.

Table 2. List of variables used in the analysis

3.2 Econometric models

The aim of our study is to understand the extent to which individual, structural and financial characteristics lead to an intensive use of pesticides and to what extent European support specifically drives farmers' behaviour. To achieve this goal, an unbalanced panel is used from 2007 to 2015. The renewal of farms in the sample from one year to another is random. This allows us to consider all farms present in the period and not only perennial ones. Hausman's test (1978) enables us to favour a random effects model rather than a fixed effects model. We therefore create a panel with random effects in order to consider not only individual effects but also temporal ones. We also carried out heteroscedasticity and autocorrelation tests (Wooldridge, 2002).

In order to assess the extent to which farmers implement environmentally-friendly practices, three main measures can be considered. The first directly examines the quantity of pesticides

used (Aubert and Enjolras, 2014a). The second is indirect, through the adoption of integrated pest management techniques (Fernandez-Cornejo, 1996; Fernandez-Cornejo and Ferraioli, 1999; Galt, 2008; McNamara et al., 1991). The third takes into account the adoption of certification, such as the “organic farming” label (Aubert and Enjolras, 2016). In our case, the database provides information on the measurement of total pesticide expenditure. To remedy a possible size effect, we have to divide this amount by the dimension of the farm, which can be either physical or economic. As our study considers all specializations, physical size cannot be taken into account. In fact, a farm specializing in wine growing will generate a standard output of €81,414 per hectare if located in Champagne-Ardennes and €4,134 per hectare if located in Lorraine. We therefore consider pesticide expenditures over sales as an objective indicator.

The econometric model explains the level of pesticide expenditure divided by sales and can be considered as follows:

$$Y_{it} = \alpha + \beta'ES_{it-1} + \gamma'SC + \delta'IC_{it} + \phi'FI_{it-1} + \zeta'ETO_t + \varphi'Year_i + \varepsilon_{it}$$

Where:

Y_{it} is the level of pesticide expenditure divided by sales

ES_{it-1} is the matrix of lagged European subsidies

SC_{it} is the matrix of structural characteristics

IC_{it} is the matrix of individual characteristics

FI_{it-1} is the matrix of lagged financial characteristics

ETO_i is a control variable relating to the economic and technical orientation of the farm

$Year_t$ is a control variable relating to the period

α is the constant,

$\beta, \gamma, \delta, \phi, \zeta$ and φ are (vectors of) parameters to be estimated

ε_{it} is a random error term

We estimate 3 models: the first considers the aggregated amount of European payments received by farmers for the 1st and 2nd pillar, the second considers the details of each payment and the third considers all European payments received. This choice is driven by the fact that the coefficients of correlation between European subsidies received by farmers from the 1st and 2nd pillars and within the 2nd pillar are low (Table 3).

Table 3. Correlation of European payments received by farmers

The results of the analyses are presented in the next section.

4. Results

4.1 Descriptive statistics

From 2007 to 2015, we observe that the level of pesticide expenditure is quite stable, although it varies according to the specialization (Figure 1). Farms specializing in field crops use more pesticides than farms specializing in fruit production and wine growing.

Figure 1. Dynamics of pesticide expenditure

When we consider the distribution of pesticide expenditure, we observe a heterogeneity of farms according to their environmental practices (Figure 2). Half of the farmers (50.1%) exhibit a very low level of expenditure (lower than 10 %), while for a small minority (3%) phytosanitary expenditure represents more than 40% of their sales.

Figure 2. Distribution of pesticide expenditure

More precisely, we observe that, on average, pesticide expenditure represents 12.9% of farm sales (Table 4). Almost all farmers benefit from at least one European subsidy. However, we notice that while almost 83% of farmers benefit from the 1st pillar, fewer than 40% benefit from the 2nd pillar. We also notice that support from the 1st pillar represents 13.19% of farm sales on average while support from the 2nd pillar represents 10.46% of farm sales.

Table 4. Relative importance of pesticide expenditure over sales

These results have to be put into perspective by considering a dynamic analysis (Figure 3). We observe some differentiated dynamics of farms depending on whether they benefited, or not, from support from the 2nd pillar in 2007. For farms which benefited from this support in 2007, we observe that the change in pesticide expenditure is twice as small as the change observed on farms which did not benefit from this support. Moreover, we also observe that this trend has to be put into perspective with the evolution of the amount paid for this support. While the former farms seem to adopt more environmentally-friendly practices and hence benefit from a higher support, the latter also benefit from higher support but to a lesser extent. More precisely, farms which benefited from the 2nd pillar support in 2007 also benefited from nearly 70% of additional support from this pillar for the whole period 2007-2015, while the increase is around 40% for the other farms. Such results tend to confirm that the financial support provided by European payments can act as a springboard to the implementation of environmentally-friendly practices.

Figure 3. Evolution of pesticide expenditure given European support from 2007-2015

Farms located in disadvantaged areas and specializing in field crops seem to implement the least environmentally-friendly practices (Table 5). As a matter of fact, while pesticide expenditures represent 12.90% of sales at national level, they represent respectively 12.98% and 24.76% for these farms.

Considering farmers' characteristics, descriptive statistics indicate that farmers who are better educated and who work more than $\frac{3}{4}$ time on their farm implement more environmentally-friendly practices. These practices also seem to be linked to the type of employment. Farmers employing only family members present a lower level of pesticide expenditure than farms with salaried workers.

Table 5. Relative importance of pesticide expenditure over sales according to farms and farmers' characteristics

4.2 Econometric models

The econometric model enables us to assess the dynamics of pesticide expenditure considering both individual and temporal dimensions (Table 6).

Table 6. Econometric models

The results highlight the role of European support on farmers' behaviour. With regard to the 1st pillar, the model underlines the fact that this support has a strong positive influence on pesticide use when considered both in an aggregated way and through decoupled payments (H1a validated). These subsidies appear to be a springboard to develop production and consequently to encourage pesticide expenditure. With regard to the 2nd pillar of European support, the results demonstrate that the global amount and most types of subsidies translate into a reduction of pesticide expenditure. Because these supports target an improvement to the environment, our results confirm the effective importance of such support to the implementation of environmentally-friendly practices. We note one exception regarding compensation for losses caused by adverse weather conditions. In this case, farmers may be willing to use these subsidies to purchase pesticides in order to preserve their production (H1b partially validated). Finally, we observe that the overall amount of European subsidies positively drives the use of pesticides (H1c validated). This result is not surprising given the weight of the 1st pillar subsidies compared to the 2nd pillar.

Beyond the individual characteristics of farmers, the level of pesticide expenditures appears to be conditioned by structural characteristics. Farms which apply more pesticides are more likely to be larger (H2a validated) and less diversified (H2b not validated). The results also highlight the fact that farms on which there is a larger workforce are more likely to reduce their use of pesticides (H2c validated). This confirms the fact that pesticides and workforce are substitutes. To reduce the use of pesticides, farmers need to employ a workforce for direct observation and treatments. Moreover, family farms are more likely to reduce pesticide use (H2d validated).

The results also highlight the importance of farmers' characteristics. We confirm that farmers who are better educated are more likely to implement environmentally-friendly practices (H3a validated). However, the time spent on the farm by the holder has no influence on pesticide use (H3b not validated).

When we consider the financial situation of farms, the results underline the fact that the level of profitability reduces the relative importance of pesticide expenditures (H4a validated). Moreover, the results confirm that farmers who are more indebted apply less pesticide. This can reflect the fact that these farmers may use environmentally-friendly practices as a way to reduce their indebtedness (H4b not validated).

The econometric model confirms the specificity of specialization, especially regarding field crops (H5a validated), as well as the importance of location. Farmers who are located in disadvantaged areas are more likely to apply pesticides than farmers located in other areas. The reason may lie in the risk-decreasing effect of pesticides in these specific areas (H5b validated). Annual effects are highly contrasting in both models. They tend to prove that pesticide use is driven by annual factors, such as weather conditions (H5c not validated). While public policies in favour of the environment and organic farming have been progressively reinforced over the period, we do not observe a clear trend in favour of pesticide reduction.

5. Conclusion

In this article, we have analysed the influence of EU subsidies on pesticide use. This question is salient as an increasing number of farms are progressively converting their production to environmentally-friendly practices in order to meet phytosanitary requirements. This study focused on French farms using data from the FADN for the period 2007-2015. This database appears well suited to providing precise information regarding the farms individual, structural and financial characteristics, including pesticide expenditure and the details of EU subsidies.

The results primarily show that EU subsidies have contrasting effects on environmental practices. While the overall amount of subsidies as well as decoupled subsidies received by farmers from the 1st pillar tend to increase pesticide use, payments from the 2nd pillar appear to have the opposite effect and act in favour of greener practices. The reason lies in the targets of each kind of subsidy. The 1st pillar primarily promotes production quantity, for which pesticides represent a strategic input, while the 2nd pillar fosters production quality, which is not in line with pesticide use. In these conditions, the progressive shift of subsidies from the 1st to the 2nd pillar is likely to be favourable to environmentally-friendly practices, provided that transferred payments target that aim.

Beyond these specific effects, the results do not show evidence of dynamics in favour of a reduction in pesticide use. Other key factors positively drive pesticide use, such as farm size and location in disadvantaged areas. Rationales for intensive pesticide use may be different according to the types of farm. While large farms are production-oriented, farms located in disadvantaged areas use pesticides as a way to secure their yields. Conversely, family farming leads to a decrease in pesticide use. The results also confirm that sectorial differences exist, some sectors such as field crops being more pesticide-intensive.

These results provide new insights into the strategic role of EU subsidies, especially through the 2nd pillar, in promoting green practices at the farm level. To that end, incentives nowadays mainly target production practices directly in the fields. Some additional policies could also be promoted in order to encourage the reduction in pesticide use, such as short food supply chains. Moreover, research would benefit from more detailed data on EU subsidies targeting environmentally-friendly practices so as to assess their effectiveness.

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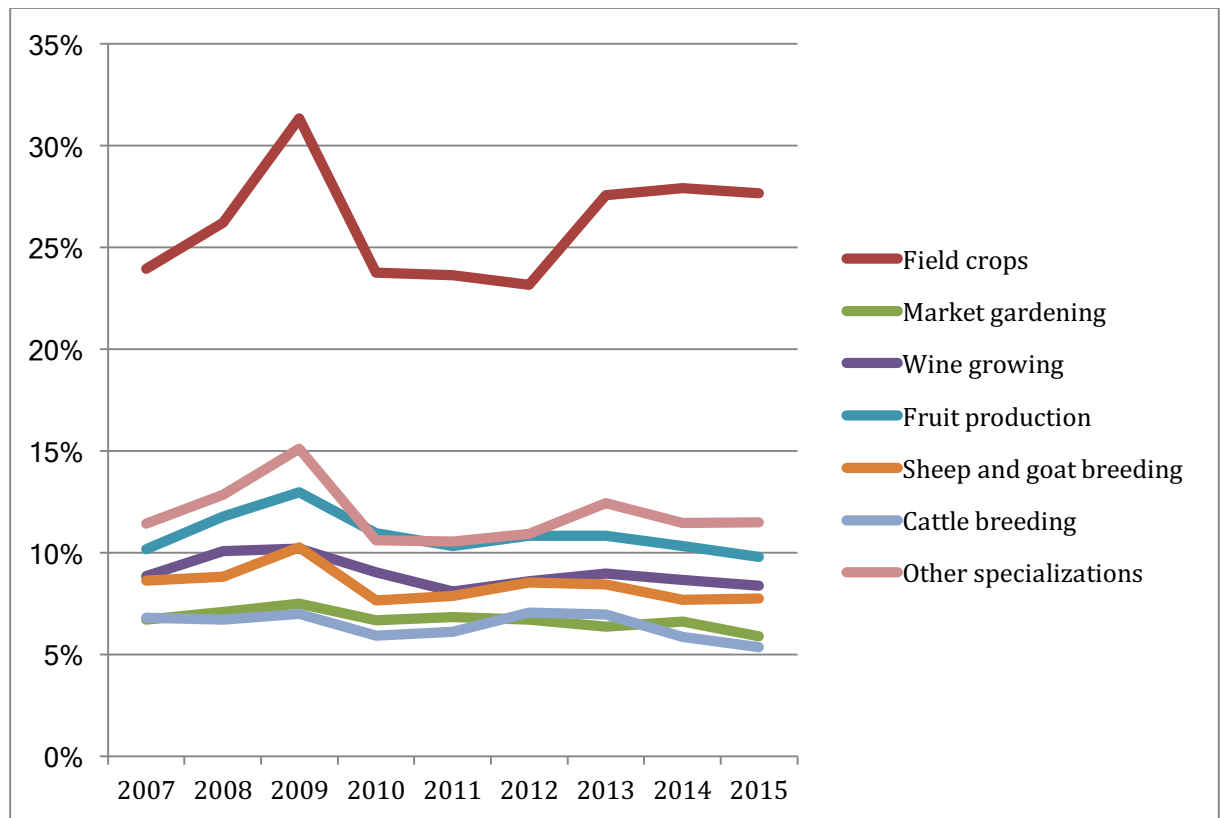
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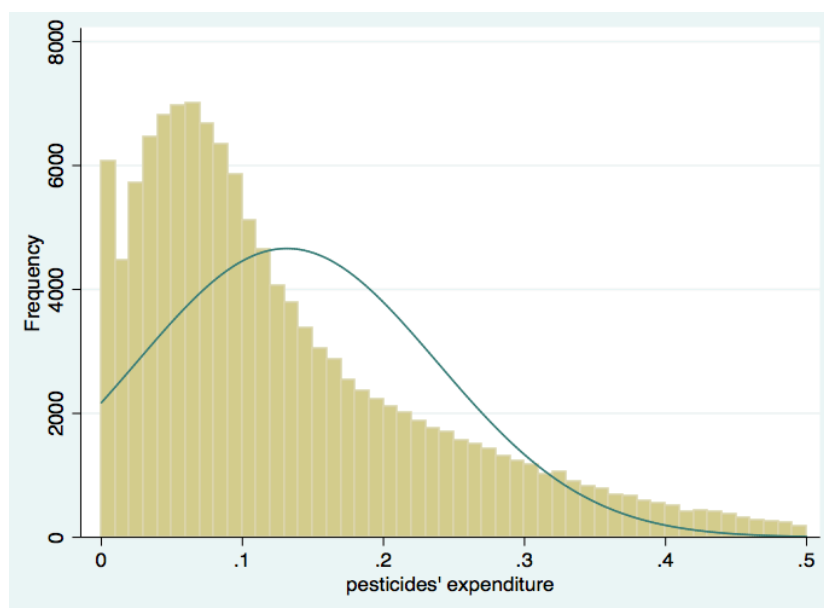
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Figure 1. Dynamics of pesticide expenditure



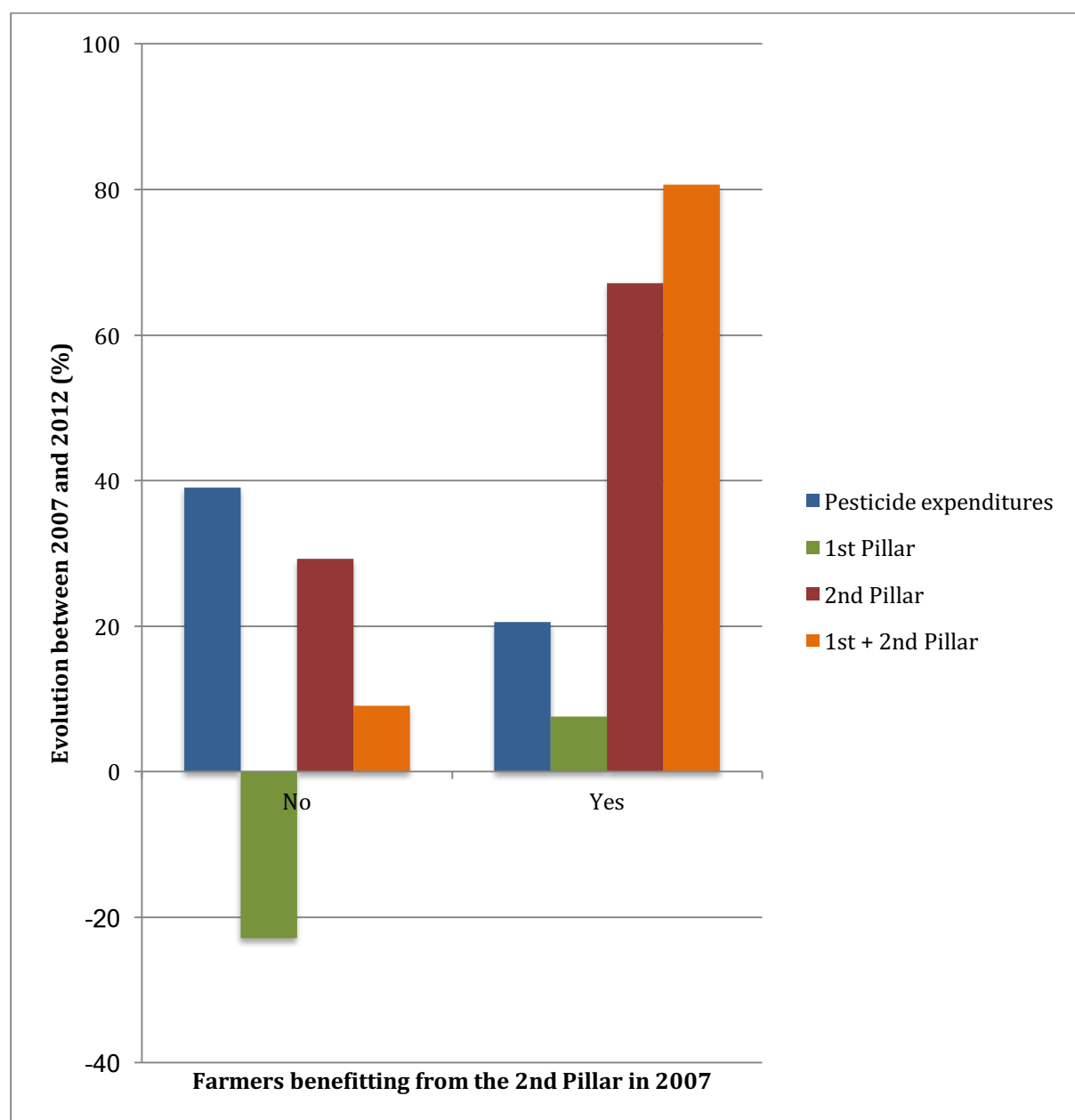
Key: This figure presents the change in pesticide expenditure relative to sales.
 Source: Own representation, based on FADN 2007-2015.

Figure 2. Distribution of pesticide expenditure



Source: Own representation, based on FADN 2007-2015.

Figure 3. Change in pesticide expenditure, given European support from 2007-2015



Source: Own representation, based on FADN 2007-2015.

Table 1. Key EU budget allocations for transitioning towards environmental and climate-friendly practices and organic farming under the CAP 2014–2020

Budget allocation	Billion euros	% of total EAFRD	% of total EU budget for agriculture
Budget allocation for pillar 1 and pillar 2			
1. Pillar 1 – Market-related expenditure and direct payments	312.7		76%
2. Pillar 2 – Rural development	99		24%
3. Total EU budget for agriculture (pillar 1 + pillar 2)	411.7		100%
Greening component (pillar 1)			
4. Total national ceilings for direct payments 2014 - 2020	297.6		72.3%
5. Greening component (maximum 30% of direct payments)	89.3		21.7%
Climate and environment issues (pillar 2)			
6. Contribution to environment & climate issues - including organic farming (minimum 30% of EAFRD)	29.7	30%	7.2%
Organic farming support (conversion and maintenance payments)			
7. EAFRD organic farming support (measure 11)	6.3	6.4%	1.5%
8. Total public expenditure (EU and member states) for organic farming support (measure 11)	9.9		
Total environmental and climate change spending for agriculture (pillar 1 and pillar 2)			
9. EU budget for transition towards environmental and climate-friendly agriculture	119		28.9%

Source: Stolze et al. (2016).

Table 2. List of variables used in the analysis

	Definition	Hypotheses	Direction of the effect
Dependent variable			
Pesticides	Value of pesticide expenditure (€/sales)	/	/
Explanatory variables			
<i>Hypothesis 1: European subsidies</i>			
1st pillar	Value of EU subsidies from the 1 st pillar (€/sales)	H1a	+
<i>Decoupled subsidies</i>	Value of decoupled subsidies from the 1 st pillar (€/sales)		
2nd pillar	Value of EU subsidies from the 2 nd pillar (€/sales)	H1b	-
<i>Adverse weather conditions subsidies</i>	Compensation for losses caused by adverse weather conditions (€/sales)		
<i>Agri-environmental grazing subsidies</i>	Agri-environmental grazing subsidies (€/sales)		
<i>Other agri-environmental subsidies</i>	Other agri-environmental subsidies (€/sales)		
Overall European subsidies	Value of all EU subsidies	H1c	+
<i>Hypothesis 2: Structural characteristics</i>			
Usable agricultural area	Total usable agricultural area of the farm (hectares)	H2a	+
Diversification	Number of different crop produced on the farm (counter)	H2b	+
Total workforce	Total workforce (in agricultural work units, AWU)	H2c	-
Family farm	The farm employs only family workforce (dummy)	H2d	-
<i>Hypothesis 3: Individual characteristics</i>			
General education	General education of the farm holder (4 categories: no education, primary, secondary, higher)	H3a	-
Time spent by the farm holder on the farm	Time spent by the farm holder on his farm (3 categories: less than ¼ time, between ¼ and ¾ time, more than ¾ time)	H3b	-
<i>Hypothesis 4: Financial characteristics</i>			
Profitability	Profitability measured by the return on assets (ROA)	H4a	-
Indebtedness	Indebtedness measured by the debt-to-assets ratio	H4b	+
<i>Hypothesis 5: Control variables</i>			
Economic and technical orientation	Economic and technical orientation (1: field crops; 2: market gardening; 3: wine growing; 4: fruit production; 5: sheep and goat breeding; 6: cattle breeding; 7: other specializations)	H5a	/
Disadvantaged area	The farm is located in a disadvantaged area (dummy)	H5b	+
Year	The year considered from 2007 to 2015	H5c	-

Table 3. Correlation of European payments received by farmers

	1 st Pillar	Decoupled subsidies	2 nd Pillar	Compensation for losses caused by adverse weather	Agri-env. grazing subsidies	Other agri-env. subsidies
1st pillar	1.0000					
<i>Decoupled subsidies</i>	0.4294***	1.0000				
2nd pillar	-0.1692***	0.4279***	1.0000			
<i>Compensation for losses caused by adverse weather</i>	-0.0279***	0.1308***	0.3670***	1.0000		
<i>Agri-environmental grazing subsidies</i>	-0.1435***	0.3516***	0.7085***	0.1597***	1.0000	
<i>Other agri-environmental subsidies</i>	-0.0345***	0.1526***	0.4201***	0.0528***	0.0657***	1.0000

Key: *, ** and *** denote significance at the 10%, 5% and 1% levels respectively.

Source: Own calculation, based on FADN 2007-2015.

Table 4. Relative importance of pesticide expenditure over sales

	Farmers who benefit from European subsidies (%)	Pesticide expenditure	
		Mean	Std. dev.
Pesticide expenditures	100.00%	12.90%	0.109
1st pillar	82.88%	13.19%	0.099
<i>Decoupled subsidies</i>	82.66%	13.20%	0.099
2nd pillar	39.68%	10.46%	0.088
<i>Compensation for losses caused by adverse weather</i>	12.69%	10.52%	0.083
<i>Agri-environmental grazing subsidies</i>	16.63%	7.17%	0.066
<i>Other agri-environmental subsidies</i>	12.55%	11.94%	0.096

Key: Values are expressed relative to sales.

Source: Own calculation, based on FADN 2007-2015.

Table 5. Relative importance of pesticide expenditure over sales according to farms and farmers' characteristics

		Mean	Std. dev.
Disadvantaged area	No	9.38%	0.081
	Yes	12.98%	0.099
Education	No	13.66%	0.098
	Primary	11.97%	0.096
	Secondary	10.48%	0.089
	Higher	10.84%	0.093
Family farm	No	12.76%	0.101
	Yes	11.15%	0.088
Time spent by the farm holder on the farm	Less than ¼ time	4.41%	0.051
	Between ¼ and ¾ time	13.87%	0.104
	More than ¾ time	12.01%	0.096
Economic and technical orientation	Field crops	24.76%	0.089
	Market gardening	6.31%	0.046
	Wine growing	8.06%	0.065
	Fruit production	10.50%	0.059
	Sheep and goat breeding	8.56%	0.056
	Cattle breeding	6.41%	0.065
	Other specializations	12.17%	0.091

Key: Values are expressed relative to sales.

Source: Own calculation, based on FADN 2007-2015.

Table 6. Econometric models

	Model 1	Model 2	Model 3
European subsidies			
<i>1st pillar (/sales)</i>	0.048***		
Decoupled subsidies		0.049***	
<i>2nd pillar (/sales)</i>	-0.006***		
Compensation for losses caused by adverse weather		0.006**	
Agri-environmental grazing subsidies		-0.044***	
Other agri-environmental subsidies		-0.011***	
Overall European subsidies			0.080***
Farm structure			
Usable agricultural area	0.000***	0.000***	0.000***
Diversification	-0.003***	-0.005***	0.004***
Disadvantaged area	0.004	-0.008***	0.026***
Workforce			
Total workforce	-0.007***	-0.007***	-0.006***
Family farm	-0.017***	-0.017***	-0.014***
Time spent by the farm holder on the farm (reference: less than 1/4 time)			
Between 1/4 and 3/4 time	0.041*	0.043*	0.033
More than 3/4 time	0.029	0.032	0.026
Farm holder's general education (reference: no education)			
Primary	-0.009***	-0.009***	-0.009***
Secondary	-0.016***	-0.015***	-0.017***
Higher	-0.009**	-0.009**	-0.009**
Financial situation of the farm			
Profitability (ROA) ⁻¹	-0.024*	-0.023*	-0.022*
Indebtedness (debt-to-asset ratio) ⁻¹	-0.000**	-0.000**	-0.000**
ETO (reference: field crops)			
Market gardening	-0.077***	-0.075***	-0.098***
Wine growing	-0.087***	-0.085***	-0.105***
Fruit production	-0.055***	-0.056***	-0.070***
Sheep and goat breeding	-0.154***	-0.147***	-0.159***
Cattle breeding	-0.167***	-0.156***	-0.179***
Other specializations	-0.111***	-0.109***	-0.113***
Year (reference: 2007)			
2008	0.012***	0.012***	0.013***
2009	0.032***	0.033***	0.033***
2010	-0.009***	-0.008***	-0.008***
2011	-0.008***	-0.007***	-0.006**
2012	-0.005*	-0.005*	-0.001
2013	0.009***	0.009***	0.013***
2014	0.002	0.002	0.007**
2015	0.002	0.002	0.006**
Constant	0.166***	0.176***	0.158***
R-Square	0.506	0.521	0.518
Number of observations	1 087 535		

Key: *, ** and *** denote significance at the 10%, 5% and 1% levels respectively.

⁻¹ denotes a lagged variable.

Source: Own calculation, based on FADN 2007-2015.