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▶ **To cite this version:**

Magali Aubert, Geoffroy Enjolras. Intensive and extensive impacts of EU subsidies on pesticide expenditures at the farm level. Journal of Environmental Economics and Policy, 2022, 11 (2), pp.218-234. 10.1080/21606544.2021.1955749 . hal-03331693

HAL Id: hal-03331693
https://hal.inrae.fr/hal-03331693

Submitted on 18 Aug 2022

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Intensive and extensive impacts of EU subsidies on pesticide expenditures at the farm level

Abstract

This paper studies the intensive and extensive effects of European subsidies on pesticide expenditures at the farm level. Intensive effects refer to the relative value of pesticide expenditures to sales while extensive effects consider acreage effects. Our approach is original insofar as we consider the consequences of EU policies at the farm level. The analysis relies on the French FADN database from 2007 to 2015 which provides detailed information on farm structure and accounting. The influence of subsidies on pesticide expenditures is measured through a simultaneous equation model using panel data. Even if the aggregate value of EU subsidies does not seem to influence pesticide expenditures, each of the pillar has for its part a significant influence: the 1st pillar contributes to increase pesticide expenditures while the 2nd pillar leads to decreasing pesticide expenditures. Overall and 1st pillar subsidies have also a significant and positive impact on farm acreage. In all models, the education level and indebtedness contribute to reduce pesticide expenditures while a high degree of specialization contribute to increase farm size. The very contrasted effect of European subsidies on pesticide expenditures thus questions the effectiveness of public policies towards the issue of environmentally-friendly practices.

Keywords: Pesticides, EU subsidies, FADN, France.

Postprint version.

Published in Journal of Environmental Economics and Policy, 11(2), 218-234.
https://doi.org/10.1080/21606544.2021.1955749

1. Introduction

Reducing pesticide use is a challenge taken up by all stakeholders, from producers to consumers, in order to ensure a more sustainable agriculture. The European Union has long been developing support policies for green agriculture. The Common Agricultural Policy (CAP) 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.

Within the framework of CAP 2007-2013 and 2014-2020, green practices have been strongly encouraged with specific budget guidelines (Westhoek et al., 2014). 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. Possible actions include all types of action leading to more environmentally-friendly practices, including conversion of organic farming. In total, about 28.9% of the total EU budget for agriculture is focused on measures directly linked to environmental and climate issues (Stolze et al., 2016). Most of the support in favour of green practices is concentrated within the 2nd pillar related to rural development policies. Moreover, the large weight of the 1st pillar subsidies focus on traditional agricultural support policies that target production rather than quality. In practice, organic farming is progressively gaining ground in Europe and, more broadly, around the world (Eurostat, 2020; FIBL and IFOAM, 2020). However, the OECD (2020) annual report points out that the structure of subsidies may prevent a wider development of environmentally-friendly practices.

Considered jointly, the relationship between pesticides and EU subsidies is somehow complex. Both are considered by the literature as risk management instruments. Basically, subsidies are an additional source of income which compensates for the consequences of market liberalization, the implementation of green practices, or the occurrence of unfavourable weather conditions. Subsidies increase or at least preserve the 'certainty equivalent' of the farm (Femenia et al., 2010; Gren, 1994). Pesticides also act as a risk management tool whose applications protect farmers' yields against the consequences of unfavourable weather and pest conditions, thus preserving the farm income (Pannell, 1991).

This paper questions the nature of the interactions between these two risk management instruments. In the literature, many papers have examined the influence of European subsidies on pesticide expenditures at the farm level. At the intensive margin, i.e. all things being equal, Serra et al. (2005), Skevas et al. (2012) and Böcker and Finger (2016) show that the implementation of subsidies can reduce pesticide use. These two instruments thus appear to be substitutable. Yet, European subsidies also influence farm choices at the extensive margin, e.g. acreage decisions. Moro and Sckokai (2013) show that decoupled payments may lead to an increase in overall farm risk. Following the reasoning exposed by Horowitz and Lichtenberg (1993), an increased volatility of farm income might be balanced by more intensive pesticide use.

Our analysis is original to the extent that we consider the relationship between EU subsidies and pesticides simultaneously at the intensive and at the extensive margins. We adopt a financial approach which measures explicitly incoming cash flows provided by EU subsidies and outcoming cash flows resulting from pesticide purchase. For that reason, EU subsidies are considered as a revenue while pesticides are considered as an expenditure that has to be

compared to all farm sales. Because of the potential simultaneity between pesticide expenditures and acreage decisions, we implement a simultaneous equation model with unbalanced panel data. We can then consider effects at the intensive and the extensive margins. We also make a clear distinction between the influence of subsidies from the 1st pillar and from the 2nd pillar of the CAP.

Our dataset relies on 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. These data also offer a set of individual, structural, economic and financial parameters which can be considered as determinants of production choices.

France appears as a relevant case study, as pesticide use in its agriculture is among the highest in Europe (Butault et al., 2012). Against such a backdrop, following the implementation of the EcoPhyto I (2008), Ecophyto II (2015) and Ecophyto II+ (2018) frameworks, objectives were defined to reduce by 50% quantities of pesticide use in French agriculture. Targets for action include the implementation of low-input growing practices (Jacquet et al., 2011). A pesticide tax was also established in 2014, whose rate is equal to 0.2% of pesticide sales (Böcker and Finger, 2016). Recent data show that EcoPhyto I and II plans failed to change practices, pesticide use being increased over the last years (Guichard et al., 2017).

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. Background

The theoretical background is founded on the growing literature relating to environmentally-friendly practices and organic farming. We present the main factors that may have an influence on pesticide expenditures and that will be tested using an empirical framework.

2.1 European subsidies at the crossroads of the intensive and extensive margins

European subsidies contribute to increasing the 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; Stolze, 2016), while during the last decade more financial incentives have been implemented. Yet, EU subsidies can generate externalities at two margins. The 'intensive margin' occurs when subsidies provide changes to pesticide expenditures while the 'extensive margin' occurs when subsidies increase cultivated acreage.

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, which are designed to increase, or at least stabilize, farmers' income through direct payments are likely to be used by farmers as a way to develop their activity (Chabé-Ferret and Subervie, 2013; Serra et al., 2005; Skokai and Anton, 2005). Consequently, subsidies may be more likely to induce farmers to purchase more protection crop products (Serra et al., 2005). In this case, European payments would lead to increase the cultivated acreage and pesticide expenditures, thus playing a role at the extensive margin.

H_{1a}. Pesticide expenditures increase with European subsidies from the 1st pillar

H_{1b}. Cultivated area increases with European subsidies from the 1st pillar

Conversely, subsidies from the 2nd pillar, which comprise rural development policies, seem to be better adapted to pesticide reduction. These subsidies mainly incorporate compensations 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 purchase of pesticides and play a role at the intensive margin (Serra et al., 2008). 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 purchase, e.g. fall in yields and increased yield volatility (Serra et al., 2006).

H_{2a}. Pesticide expenditures decrease with European subsidies from the 2nd pillar

H_{2b}. Cultivated area decreases with European subsidies from the 2nd pillar

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 gives reason to assume that overall European subsidies should positively drive pesticide purchase.

H_{3a}. Pesticide expenditures increase with overall European subsidies

H_{3b}. Cultivated area increases with overall European subsidies

2.2 Drivers at the intensive margin: Structural, individual and financial characteristics

Several parameters have been identified in the literature as significantly influencing pesticide expenditures. Kallas et al. (2010) and Padel (2001) show that the organization of small farms is suited to environmentally-friendly practices. However, Aubert and Enjolras (2017) show that larger farms are more willing to change toward environmentally-friendly practices because they benefit from a sufficient economic dimension. Small farms would take more risk in terms of yield losses if they decide to reduce their use of phytosanitary products.

H_4. Pesticide expenditures decrease with farm size

Aubert and Enjolras (2017), Kallas et al. (2010) Padel (2001), Sylvander and Schieb-Bienfait (2006) all show that the farm holder plays a key role in the adoption of environmentally-friendly practices. His level of education plays a positive role in the adoption of organic farming or at least the reduction of pesticide consumption.

Environmentally-friendly practices are also in line with a strong implication of the farm holder in his farming activity. Indeed, implementing more environmentally-friendly practices directly translates into an increased need for plant observation (Fanariotu and Skuras, 1991). In that case, farmers trigger treatments only as a last resort and the identification of the key time point lies on a necessarily increased involvement of farm holders on their farms (Aubert and Enjolras, 2017; Lohr and Park, 2002).

H_5. Pesticide expenditures decrease with the farm holder's level of education

H_6. Pesticide expenditures decrease with the time spent on the farm by the farm holder

Offermann and Nieber (2000) and Koesling et al. (2008), indicate that farms converting to organic farming may be motivated by the perspective of increased profitability. Dasgupta et al. (2007) show that an environmentally friendly agriculture increases farm profit as pesticide costs decrease while production remains unchanged.

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 their use can ensure yields.

H_7. Pesticide expenditures decrease with the farm profitability

H_8. Pesticide expenditures increase with the farm indebtedness

2.3 Drivers of the extensive margin: Structural characteristics

In their seminal article, Chavas and Holt (1990) emphasized that structural characteristics of the farms primarily matter in acreage decisions. They focused their analysis on both risk and wealth effects. To the extent that pesticides protect agricultural yields, more intensive pesticide use encourages farmers to increase the farm cultivated area and to change the respective shares of cultivated crops (Möhring et al., 2020; Urruty et al., 2016).

In that line, the specialization of farms also plays a protective role through an effect of diversification (Dinis et al., 2015). An acknowledged measure of farm specialisation is provided by the Herfindahl-Hirschman index (Makate et al., 2016):

$$HH_i = \sum_{j=1}^{n} s_{i,j}^2 \text{ and } s_{i,j} = \frac{Area_{i,j}}{Total\ area_i} \quad (1)$$

Where j is the number of cultivated crops on the farm, s_j is the proportion of the j^{th} crop, measured by the ratio between the area under the i^{th} crop and the total area of the farm. In the French context, forty-nine different types of crops can be identified.

H_9. Cultivated area increases with pesticide expenditures

H_{10}. Cultivated area increases with farm diversification

Workforce has continuously been acknowledged as a key factor leading to farm development (Hostiou et al., 2020). An increase in working hours is necessary when the farm extends its activities, either on a higher acreage or for the development of additional production practices (Karali et al., 2014). In that case, the involvement of the family represents a strategic resource because it allows to accompany the growth of the farm (Dinis et al., 2015; Kallas et al., 2010).

H_{11}. Cultivated area increases with total workforce involved on the farm

H_{12}. Cultivated area increases with family farming on the farm

2.4 Control variables

We also consider several control variables to reinforce the robustness of the models. Because of their particularities, mainly in terms of sensitivity to pests and disease, some productive orientations are more likely to purchase pesticides (Sckokai and Anton, 2005; Serra et al., 2005; Urruty et al., 2016). As a matter of fact, while field crop farms used €134 of pesticide per hectare in 2006, wine-growing farms used €394 per hectare (Butault et al., 2010).

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 purchase in France, we consider more specifically a location in less-favoured areas characterized by natural handicaps such as a hilly landscape, lower population density, a higher degree of isolation and more complex farming activities (Caraveli, 2000; Huber et al., 2017). These areas are characterized, among other things, by smaller farms that consume more pesticides (Möhring et al., 2020).

Regardless of the location and the productive orientation, 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). Thus, pesticide purchase evolves over time in line with the implementation of public policies. At the same time, the number of European farms follows a decreasing trend while the average farm size is regularly increasing (Guiomar et al., 2018). Although structural, these changes are accompanied by the developments of public policies.

Table 1 summarizes the variables used for this analysis, the underlying hypotheses and the direction of the effects.

Table 1. List of variables used in the analysis

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 purchase 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 expenditures, 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).

FADN 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 which renews on average

10% of farms each year, sampled farms do not correspond to perennial farms. From 2007 to 2015, 28,175 farms are surveyed, irrespective of the productive orientation. In our study, we consider all professional farms, regardless of their productive orientation. Market gardeners, wine growers, fruit producers as well as sheep breeders are therefore considered. The database allows us to assess not only the individual characteristics of the farmer and the structural and financial characteristics of farms, but also pesticides used. However, no information is related to a possible adoption of organic farming.

Pesticide use is measured in economic terms through declared expenditures. Without any precise data on active substances used by farmers, we should expect a close positive link between pesticide expenditures, the amount of active substances, and their environmentally harmful effect (Osteen and Fernandez-Cornejo, 2013). On the other hand, one could argue that less harmful active substances might be more expensive than their harmful counterparts (Pimentel and Burgess, 2014). In practice, pesticide cost share (relative to all input costs) have decreased since 1998 and they represent on average a small share of operating costs (Fernandez-Cornejo et al., 2014). We also assume that possible stocks of pesticides compensate from one year to another.

We choose to present pesticide expenditures and EU subsidies relative to farm sales in the analysis. By comparison with other common measures, such as values expressed in euros per hectare (Böcker and Finger, 2016) or frequency of treatments (Urruty et al., 2016), this economic measure allows to consider the relative weight of pesticide expenditures and subsidies with respect to the value of the production and without accounting for size effects. Pesticide use is then considered in terms of relative costs rather than in terms of relative applications, which provides a different insight compared to existing studies.

3.2 Econometric models

The econometric analysis aims to determine the influence of European payments on pesticide expenditures and area cultivated, by controlling endogenous and exogenous factors. 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).

Because of the potential simultaneity between indicators at the intensive and extensive margins, we implement simultaneous equation models with unbalanced panel data. In addition to considering the consequences of European payments on pesticide use and acreage decisions, these models allow to measure the interaction between pesticide use and acreage themselves.

Since intensive and extensive margins have common drivers such as the location of the farm, we correct the model from any endogeneity bias. Hence, each indicator is instrumented when estimating equations. More than common drivers, the intensive margin is instrumented by both individual characteristics of the farmer and the financial dimension of his farm; while the extensive margin is instrumented by the structural characteristics of the farm.

The structure of the models can therefore be written as follows:

$$\begin{cases} Y_{1it} = \beta_1 + \beta_2{}'EP_{it-1} + \beta_3{}'X_{it} + \beta_4{}'FI_{it-1} + \beta_5{}'ETO_t + \beta_6{}'Year_i + \\ \qquad + \beta_7{}'Y_{2it}(\varphi_1 + \varphi_2{}'S_t + \varphi_3{}'ETO_t + \varphi_4{}'Year_i) + \varepsilon_{it} \\ Y_{2it} = \alpha_1 + \alpha_2{}'EP_{it-1} + \alpha_3{}'S_{it} + \alpha_4{}'ETO_t + \alpha_5{}'Year_i + \\ \qquad + \alpha_6{}'Y_{1it}(\phi_1 + \phi_2{}'X_{it} + \phi_3{}'FI_{it-1} + \phi_4{}'ETO_t + \phi_5{}'Year_i) + \mu_{it} \end{cases} \quad (2)$$

Where:

- Y_{1it} is the level of pesticide expenditures divided by sales,
- Y_{2it} is the area cultivated, EP_{it-1} is the matrix of lagged European payments, considered either related to the aggregated amount received by farmers for the 1st and 2nd pillars (Model 1) or to the detail of each payment received by farmers (Model 2),
- FI_{it-1} is the matrix of lagged financial characteristics,
- X_{it} is the matrix of individual characteristics,
- S_{it} is the matrix of structural 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_1 and β_1 are the constants,
- $\beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \varphi_1, \varphi_2, \varphi_3, \varphi_4, \phi_1, \phi_2, \phi_3, \phi_4, \phi_5$ are the parameters to be estimated,
- ε_{it} and μ_{it} are random error terms.

3 different models are estimated, in order to reflect the diversity of European payments. Model 1 considers the aggregated amount of European payments received by farmers. Model 2 considers the aggregate amounts for the 1st and 2nd pillars. Model 3 considers the details of each payment within the two pillars. 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 2).

Table 2. Correlation of European payments received by farmers

4. Results

4.1 Descriptive statistics

From 2007 to 2015, we observe that the level of pesticide expenditures compared to sales is quite stable, although it varies according to the productive orientation (Figure 1). Moreover, pesticide expenditures are relatively higher for field crops than for fruit production and wine growing. This result is caused by the high value of the production for wine and fruits compared to field crops, which proportionately reduces the intensity of pesticides expenditures.

Figure 1. Dynamics of pesticide expenditures

We observe that, on average, the value of pesticide expenditure represents 12.9% of farm sales (Table 3). Almost all farmers benefit from at least one European subsidy. However, we notice that while almost 83% of farmers benefit from the 1st pillar, less than 40% benefit from the 2nd pillar. We also notice that, for farms benefiting from the 1st pillar, pesticides expenditures

represent 13.19% of farm sales on average but only 10.46% for farms benefiting from the 2nd pillar. Pesticides expenditures are logically smaller for farms benefiting from agri-environmental subsidies but the acreage of these farms is not significantly smaller than other farms.

Table 3. Relative importance of pesticide expenditures and area cultivated

The time spent on the farm is strongly correlated to the farm size because involved farmers are able to operate larger farms (Table 4). Moreover, very involved farmers (i.e. with an implication higher than a ¾ time) use a bit less pesticides than farmers partly involved (i.e. between ¼ and ¾ time). Very involved farmers may be able to better adjust their pesticide applications. As expected, we also notice that the more a farmer is educated and the less he uses pesticides. However, family farming is not associated to differences in acreage.

Table 4. Descriptive statistics related to pesticide expenditures and cultivated area

Pesticides represent a very important operating charge for field crop producers (24.76% of sales), which denotes the strong dependence of this extensive production on chemical inputs. When considering the other agricultural productions, pesticide expenditures only account for 6% to 12% of sales. Farms located in less-favoured areas are unsurprisingly of small size and their pesticide expenditures account for a larger share of their sales compared to other farms (15.29% versus 9.29%). In that case, pesticides are intensively used to reduce risks.

We consider for continuous variables their correlation with pesticide expenditures and the cultivated area (Table 5). We first notice that financial indicators (profitability and indebtedness) have very little or no correlation to both pesticide expenditures. Moreover, total workforce on the farm allows a larger area to be cultivated. Diversification is also associated with a significant higher cultivated area, which is probably related to the need for a minimum surface dedicated to each production.

Table 5. Correlation of pesticide expenditures and cultivated area with continuous variables

4.2 Econometric models

The econometric model enables us to assess the dynamics of pesticide expenditure considering both individual and temporal dimensions (Table 6). The results highlight the mixed role of European support on farmers' behaviour regarding the intensity of pesticide expenditures.

Table 6. Econometric models

With regard to the 1st pillar, the model underlines the fact that this support has a strong positive influence both on pesticide purchase and on the area cultivated when considered either in an aggregated way and through decoupled payments (H_{1a} and H_{1b} validated). These subsidies appear to be a springboard to develop production intensity and consequently to encourage pesticide expenditures, which is in line with the previous literature (Serra et al., 2005). To some extent, the extensive margin drives the intensive margin.

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 expenditures at the intensive margin while no effect is noticed for the acreage at the extensive margin (H_{2a} validated, H_{2b} not validated). Agri-environmental grazing subsidies and other agri-environmental subsidies efficiently achieve their objective (Matthews, 2013). Because the 2nd pillar subsidies 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 the compensation for losses caused by adverse weather conditions. In this case, concerned farmers may be more affected by pests and diseases, thus willing to use these subsidies to purchase pesticides in order to preserve their production.

The value of overall subsidies has no particular influence on pesticide use, while significantly contributing to the increase of the cultivated area (H_{3a} not validated, H_{3b} validated). This seems to indicate a compensatory effect between pillars regarding pesticides use. The positive effects of CAP greening may also be offset by the increase in cultivated area as noted by Gocht et al. (2017). The fact remains that European policies as a whole favour the concentration of farms and the increase of their average size (Jurkėnaitė and Baležentis, 2020).

The intensity of pesticide expenditures appears to be conditioned by structural characteristics and more precisely by the physical dimension of the farm. In all our models, farms which increase their pesticide expenditures are more likely to be larger, thus being more exposed to pests and diseases (H_4 not validated). Individual parameters such as the level of education of the farmer plays a key role in the reduction of pesticide expenditures. As shown by previous studies, educated farmers are indeed more aware about the risks related to pesticides and may balance more accurately their respective costs and benefits (H_5 validated). However, the time

spent by the farm holder has no specific influence on pesticide expenditures which probably reflects the predominance of productive patterns over individual involvement (H_6 not validated). When we consider the financial situation of farms, the results underline the fact that profitability has no impact on pesticide expenditures while indebtedness is associated with lower pesticide expenditures (H_7 and H_8 not validated). Rather than being influenced by the farm's financial situation, pesticide expenditures rather depend on the individual and structural factors mentioned above.

While the physical dimension has a positive impact on pesticide expenditures, the opposite is not significant (H_9 not validated). Farmers who increase their pesticide expenditures are not likely to increase their cultivated area, thus taking advantage of risk-reducing effects associated with pesticides. Farm specialization also plays a significant and positive role in acreage decisions (H_{10} validated). As expected, the extension of acreage is driven by the total workforce involved on the farm but the involvement of family members does not play any role in this dynamic (H_{11} validated, H_{12} not validated). Because, family farming has no specific influence, it is rather the number of workers that matters.

Regarding control variables, the econometric models also confirm the influence of the productive orientation, which drives significantly pesticide expenditures. In particular, field crops farms are greater pesticide consumers compared to all other productions. These results are in line with the findings of the descriptive statistics. Moreover, farmers who are located in less-favoured areas are more likely to increase their pesticide expenditures than farmers located in other areas, while reducing their cultivated area. The reason may lie in the risk-decreasing effect of pesticides in these specific areas. Annual effects are somehow contrasting in both models. They tend to prove that pesticide purchase globally increases over the considered

period of time, particularly in the last few years. While public policies in favour of the environment and organic farming have been progressively reinforced over the period, their influence in favour of pesticide reduction is not visible. Over the same period, farm size increased. Combined together, increasing pesticide expenditures and farm size probably reflect the underlying pressure on farms, especially regarding the more volatile prices of agricultural commodities. Because they cannot properly hedge market risks, farmers rather focus on strategies aimed at managing production risks both at the intensive and extensive margins.

5. Conclusion

In this article, we have examined the influence of EU subsidies on pesticides expenditures at the farm level. This question is salient as an increasing number of farms are progressively converting their production to environmentally-friendly practices. The CAP supports these changes, especially through payments from the 2nd pillar which are dedicated to rural development. So far, however, few studies have examined the link between EU subsidies and pesticide expenditures.

When receiving a financial support, farmers adapt not only their farming practices, such as pesticide expenditures, but also the structure of their farms, such as acreage. It seems necessary to consider these two parameters simultaneously as they account for intensive and extensive margin effects. The influence of subsidies on pesticide expenditures is therefore measured through a simultaneous equation model using panel data. Data come from the French 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 even if the aggregate value of EU subsidies does not seem to influence pesticide expenditures, each of the pillar has for its part a significant influence: subsidies from the 1st pillar contribute to increase pesticide expenditures while subsidies from the 2nd pillar leads to decreasing pesticide expenditures. Overall subsidies and subsidies from the 1st pillar have also a significant and positive impact on farm acreage, while no effect is observed regarding the 2nd pillar subsidies.

The reason for these contrasted effects lies in the targets of each kind of subsidy. The 1st pillar primarily promotes production quantity, for which pesticides represent a strategic input and acreage an efficient means of action. The 2nd pillar fosters production quality, which is not necessarily in line with pesticide purchase and farm growth. 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. Public policies should ensure that the structural increase in the size of farms in the European Union does not result in a relative increase in pesticide consumption. Our results at the aggregate scale indeed suggest that size effects are likely to neutralize the efforts made to reduce the use of phytosanitary products.

Insofar as public policies mostly subsidize farms, these financial efforts would benefit from an additional support to help farmers change their practices. In particular, our results show that the education level contributes to reduce pesticide expenditures. In addition, special attention should be paid to certain productive orientations and unfavoured areas for which pesticides are a critical resource for securing yields. Compared to wine growers and fruit producers whose value of production is higher and less volatile, field crops producers devote a higher share of

their sales in pesticide expenditures in order to preserve their yields. Then, they would more sensitive to an increase in pesticide prices which would result from increased taxation. Producers for which pesticide expenditures are low with respect to their sales would be less affected. Future research should consider these aspects along with additional policies that could 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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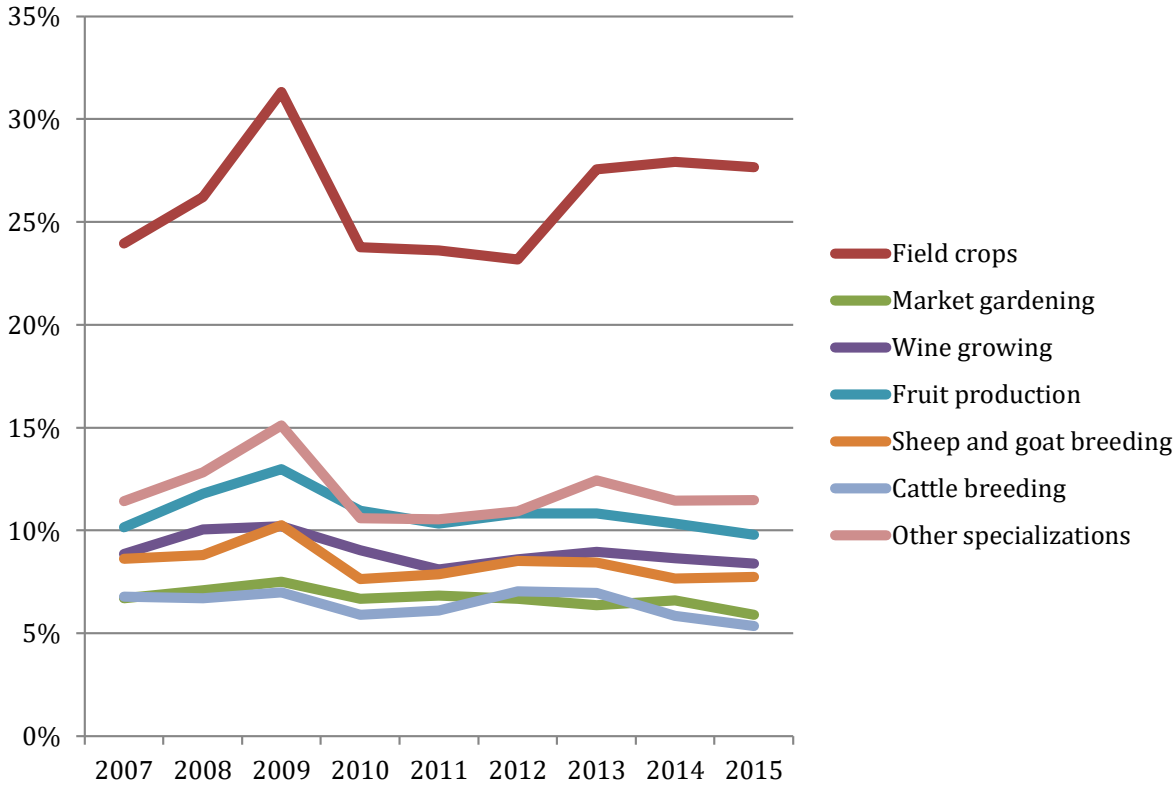
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Figure 1. Dynamics of pesticide expenditures



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

Table 1. List of variables used in the analysis

	Definition	Unit	Expected influence on pesticide expenditures	Expected influence on cultivated area
Common explanatory variables of pesticide expenditure and area cultivated: European subsidies				
1st pillar	Value of EU subsidies from the 1st pillar	€/sales	H_{1a} (+)	H_{1b} (+)
Decoupled subsidies	Value of decoupled subsidies from the 1st pillar	€/sales		
2nd pillar	Value of EU subsidies from the 2nd pillar	€/sales	H_{2a} (-)	H_{2b} (-)
Adverse weather conditions subsidies	Compensation for losses caused by adverse weather conditions	€/sales		
Agri-environmental grazing subsidies	Agri-environmental grazing subsidies	€/sales		
Other agri-environmental subsidies	Other agri-environmental subsidies	€/sales		
Overall European subsidies	Value of all EU subsidies	€/sales	H_{3a} (+)	H_{3b} (+)
Explanatory variables of pesticides expenditures: Individual and financial characteristics				
Usable agricultural area	Total usable agricultural area of the farm	hectares	H_4 (-)	
Agricultural education	Agricultural education of the farm holder	4 categories: no education, primary, secondary, higher	H_5 (-)	
Time spent 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	H_6 (-)	
Profitability	Profitability measured by the return on assets	%	H_7 (-)	
Indebtedness	Indebtedness measured by the debt-to-assets ratio	%	H_8 (+)	
Explanatory variables of cultivated area: Structural characteristics				
Pesticide expenditures	Relative value of pesticide expenditures	€/sales		H_9 (+)
Specialization	Number of cultivated crops on the farm	Herfindahl index		H_{10} (+)
Total workforce	Total workforce	Agricultural work units (AWU)		H_{11} (+)
Family farm	The farm employs only family workforce	Dummy		H_{12} (+)
Control variables				
Productive orientation	Economic and technical orientation of the farm	7 categories: field crops, market gardening, wine growing, fruit production, sheep and goat breeding, cattle breeding, other		
Less-favoured area	The farm is located in a less-favoured area	Dummy		
Year	The year considered from 2007 to 2015	Year		

Table 2. Correlation of European payments received by farmers

	1st Pillar	**2nd Pillar**	***Compensation for losses caused by adverse weather***	***Agri-environmental grazing subsidies***	***Other agri-environmental subsidies***
1st pillar	1.00				
2nd pillar	-0.16***	1.00			
Compensation for losses caused by adverse weather	-0.02***	0.36***	1.00		
Agri-environmental grazing subsidies	-0.14***	0.70***	0.15***	1.00	
Other agri-environmental subsidies	-0.03***	0.42***	0.05***	0.06***	1.00

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

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

Table 3. Relative importance of pesticide expenditures and cultivated area

	Farmers who benefit from European subsidies (%)	**Pesticide expenditures**		**Cultivated area**	
		Mean	**Std. dev.**	**Mean**	**Std. dev.**
All farms	100.00%	12.90%	0.10	98.83	78.05
1st pillar	82.88%	13.19%	0.09	107.49	77.07
Decoupled subsidies	59.12%	18.59%	0.14	114.27	81.42
2nd pillar	39.68%	10.46%	0.08	94.12	67.48
Compensation for losses caused by adverse weather	12.69%	10.52%	0.08	81.33	65.13
Agri-environmental grazing subsidies	16.63%	7.17%	0.06	85.80	65.90
Other agri-environmental subsidies	12.55%	11.94%	0.09	92.44	76.91

Key: Values are expressed relative to sales.

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

Table 4. Descriptive statistics related to pesticide expenditures and cultivated area

		Pesticide expenditures				Cultivated area			
		Mean	**Equality of means**	**Std. Dev.**	**Equality of Std. Dev.**	**Mean**	**Equality of means**	**Std. Dev.**	**Equality of Std. Dev.**
Agricultural education	**No**	15.40%	reference	0.14	reference				
	Primary	13.60%	***	0.12	***				
	Secondary	12.93%	***	0.12	***				
	Higher	12.41%	***	0.12	***				
Time spent by the farm holder on the farm	**Less than ¼ time**	6.12%	reference	0.06	reference				
	Btw ¼ and ¾ time	18.16%	***	0.16	***				
	More than ¾ time	13.72%	***	0.12	***				
Family farm	**No**					83.40	**	59.19	***
	Yes					87.95		88.70	
Productive orientation	**Field crops**	29.17%	reference	0.14	reference	122.09	reference	80.27	reference
	Market gardening	6.36%	***	0.05	***	9.33	***	18.89	***
	Wine growing	8.81%	***	0.08	***	23.33	***	28.67	***
	Fruit production	11.08%	***	0.09	***	31.62	***	33.80	***
	Sheep/Goat breeding	8.18%	***	0.05	***	96.32	***	56.43	***
	Cattle breeding	5.76%	***	0.05	***	78.70	***	66.70	***
	Other productions	12.29%	***	0.10	***	95.72	***	76.42	***
Less-favoured area	**No**	9.29%	***	0.08	***	99.49	***	67.60	***
	Yes	15.29%		0.13		80.50		73.56	

Key: For each variable and modality, pesticide expenditures are expressed relative to sales (%) and cultivated area is in hectare. H0: there is no difference in terms of means (or standard deviation) for the variable considered vs H1: *,**,*** Significant correlation at the 10, 5 and 1 percent thresholds, respectively, n.s. not significant.

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

Table 5. Correlation of pesticide expenditures and cultivated area with continuous variables

	Pesticide expenditures	**Cultivated area**
Profitability	-0.01	
Indebtedness	-0.02***	
Specialization		0.26***
Total workforce		0.08***

Key: H0: there is no correlation between variables considered vs H1: *, ** and *** denote significance of the correlations at the 10%, 5% and 1% levels.

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

Table 6. Econometric models

	Model 1		Model 2		Model 3	
	Pesticide expenditures	**Cultivated area**	**Pesticide expenditures**	**Cultivated area**	**Pesticide expenditures**	**Cultivated area**
European payments						
Overall European subsidies	0.00	5.57***				
1st pillar			0.02***	6.87***		
Decoupled subsidies					0.02***	7.02***
2nd pillar			-0.03***	2.22		
Adverse weather conditions subsidies					0.03**	4.49
Agri-environmental grazing subsidies					-0.09***	4.74
Other agri-environmental subsidies					-0.03*	4.87
Explanatory variables of pesticide expenditures (intensive margin)						
Usable agricultural area	0.00***		0.00***		0.00***	
Farm holder's agricultural education (reference: no education)						
Primary	-0.00*		-0.01*		-0.01*	
Secondary	-0.01***		-0.01***		-0.01***	
Higher	-0.02***		-0.02***		-0.02***	
Time spent by the farm holder on the farm (reference: less than 1/4 time)						
Between 1/4 and 3/4 time	-0.00		-0.00		-0.00	
More than 3/4 time	-0.01		-0.01		-0.01	
Financial situation of the farm						
Profitability (ROA)$^{-1}$	0.00		0.00		0.00	
Indebtedness (debt-to-asset ratio)$^{-1}$	-0.00***		-0.00***		-0.00***	
Explanatory variables of cultivated area (extensive margin)						
Pesticide expenditures		-105.60		-99.95		-100.72
Specialization		0.00***		0.00***		0.00***
Total workforce		0.36*		0.38**		0.38**
Family farm		0.14		0.15		0.16
Control variables						
Productive orientation (reference: field crops)						
Market gardening	-0.10***	-24.82***	-0.11***	-23.70***	-0.11***	-24.13***
Wine growing	-0.10***	-39.11***	-0.10***	-37.83***	-0.10***	-38.30***
Fruit production	-0.08***	-27.10***	-0.08***	-26.14***	-0.08***	-26.48***
Sheep and goat breeding	-0.11***	-9.74*	-0.11***	-9.21*	-0.11***	-9.29*
Cattle breeding	-0.12***	-12.41*	-0.13***	-11.78*	-0.13***	-11.82*
Other productions	-0.08***	-10.75**	-0.08***	-10.28**	-0.08***	-10.38**
Farm location						
Less-favoured area	0.01***	-3.28***	0.01***	-3.28***	0.01***	-3.33***
Year (reference: 2007)						
2008	0.01***	2.27**	0.01***	2.21**	0.01***	2.24**
2009	0.04***	5.52**	0.04***	5.32*	0.04***	5.38*
2010	-0.01***	1.72***	-0.01***	1.74***	-0.00***	1.76***
2011	-0.01***	2.16***	-0.01***	2.20***	-0.01***	2.23***
2012	-0.00	3.04***	-0.00	3.10***	-0.00	3.11***
2013	0.01***	4.75***	0.01***	4.73***	0.01***	4.77***
2014	0.01***	4.81***	0.01***	4.81***	0.01***	4.84***
2015	0.01***	4.85***	0.01***	4.86***	0.01***	4.91***
Constant	0.19***	104.15***	0.19***	102.85***	0.18***	103.03***
Prob > F	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
Number of cases			27753			

Key: *, ** and *** denote significance at the 10%, 5% and 1% levels. $^{-1}$ denotes a lagged variable.
Source: Own calculations, based on FADN 2007-2015.