Ex-post analysis of the crop diversification policy ofthe CAP Greening in France

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Abstract

In this article we aim at quantifying the impact of the crop diversification measure implemented in France as part of the 2013 CAP greening reform. While numerous studies assess the impact of the measure using simulation models, none uses causal treatment methods or ex-post data. We exploit a discontinuity in the constraints imposed on farms over and under 30ha, respectively, and apply an OLS-FE method with a regression discontinuity set-up on land use data collected from a representative sample of French farmers before and after reform implementation. We find that the crop diversification measure increases both compliance with the measure and the number of crops grown by farms greater than 30ha. Furthermore, graphical analyses suggest that farms over and under 30ha responded differently to the reform.

Keywords: Common Agricultural Policy; Greening; Crop diversification; France; Regression discontinuity design.

JEL: Q15; Q18; Q25; Q28; Q53.

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1 Introduction

In recent decades, the intensification of agriculture has caused serious environmental and public health issues. One popular policy approach to reducing the adverse impacts of agricultural activity are 5-year contracts called "agri-environmental schemes" (AES), which subsidize farmers for voluntarily adopting environmentally-friendly practices. Since 1992, this type of incentive-based policy has been employed in the second pillar of the European Union (EU)'s Common Agricultural Policy (CAP) .

The 2013 CAP reform that entered into force in 2015 introduced a small revolution as incentive-based policy for the adoption of environmentally-friendly practices was also present in the first pillar of the CAP. The reform stipulated that 30% of a farmer's first pillar payment would be conditional on certain agri-environmental criteria. This so-called "greening" of the 2013 CAP reform was based on three mandatory measures: crop diversification, the maintenance of permanent grassland areas, and the allocation of land to Ecological Focus Areas (EFAs).

While numerous studies have attempted to evaluate the impact of the reform, most employ simulation models calibrated using FADN data to derive their predictions. Some articles focus on a specific country or crop (Czekaj *et al.*, 2013; Solazzo *et al.*, 2014; Cimino *et al.*, 2015; Vosough Ahmadi *et al.*, 2015; Solazzo & Pierangeli, 2016; Cortignani *et al.*, 2017; Cortignani & Dono, 2019). Some provide results for all or at least a broad set of EU member states (Van Zeijts *et al.*, 2011; Mahy *et al.*, 2015; Gocht *et al.*, 2017; Louhichi *et al.*, 2017b,a).[1] Depending on the country in question, studies predict that 0 to 25% of eligible farms will change their soil occupation to comply with the crop diversification measure. For France, Louhichi *et al.* (2015) and Louhichi *et al.* (2017a) estimate that 3.5% of French farm will do so.

Simulation models are very useful for predicting the impact of a reform. Nevertheless, models are generally calibrated using pre-reform data and rely on simplified behavioral assumptions (such as maximization of the expected utility of future profits) and exogenous pa-

[1] The literature mentioned in the core text is completed by the study of Donati *et al.* (2015), which uses surveys and the theory of planned behavior to predict the impact of the CAP reform.

rameters and do not integrate all the information on farmers' behavioral responses to financial incentives (Colen *et al.*, 2016; Erjavec & Lovec, 2017). One alternative method to evaluate the CAP would be to use experimental approaches, as argued in Thoyer & Préget (2019). Ex-post impact analyses carried out with econometric methods are particularly suitable as they do not require behavioral assumptions since the complexity of farmers' decision-making mechanisms is taken into account thanks to the choice of a proper identification strategy. Indeed, one challenge with econometric impact evaluation is constructing a valid control group.

There is a wide variety of strategies for attempting to draw causal inference from observational data (Athey & Imbens, 2017). These strategies include regression discontinuity designs (RDD), which enable the estimation of causal effects by exploiting discontinuities in an individual's ability to receive the treatment. Such is the case with the crop diversification measure of the greening, whose requirements differ for farms whose utilized agricultural area (UAA) is greater than 30ha and less than 30ha.[2]

Our contribution in the present study is to use data before and after the implementation of the crop diversification measure to evaluate its impact on the soil occupation of French farms. We use land use panel data collected from a representative sample of French farmers before and after the CAP reform's implementation. We conduct a rich set of preliminary tests which leads us to use Ordinary Least Square - Fixed-Effects (OLS-FE) estimators with an RDD set-up as in Pettersson-Lidbom (2012) and Leonardi & Pica (2013). Our analysis provides two kinds of results. First, the regression analysis shows that the measure increased the share of farms over 30ha that meet the crop diversification requirements by 5 percentage points more than that of farms under 30ha. Moreover, farms greater than 30ha have adjusted their soil occupation so that their two main crops do not occupy more than 95 percent of their total arable land by allocating a smaller share to the second largest crop, and have added an additional crop in the rotation in one farm over eight compared to the farms below 30ha. Second, the graphical analysis suggests that, following the CAP reform, both farms over and under 30ha increased their compliance with the crop diversification measure and their number of crops and decreased

[2]One ex-post analysis has already been produced for the crop diversification measure in the case of Italy Bertoni *et al.* (2018). Nevertheless, this study is qualified as preliminary by the authors, and they do not use any of the strategies listed in (Athey & Imbens, 2017) that would allow one to draw causal inference from observational data.

the share of land occupied by the main crop. Nevertheless, the two types of farms used the lands previously occupied by the main crop differently. Farms with less than 30ha substantially increased the share occupied by their second- and third-largest crops, while farms greater than 30ha increased the share occupied by their third- and fourth-largest crops, consistent with the design of the measure.

Section 2 presents the precise application of the crop diversification measure in France, and Section 3 presents the data used for the analysis. Section 4 discusses the potential identification strategies given our data setting. Section 5 presents the empirical tests and results. A general discussion is offered in Section 6.

2 The crop diversification measure

Along with the maintenance of permanent grasslands and the obligation to allocate 5% of the utilized agricultural area (UAA) to EFAs, crop diversification is one of the three greening measures of the 2013 CAP reform's. More diversified agricultural landscapes are expected to support biodiversity and ecosystem services including water quality, pest and disease control, and soil quality (Lin, 2011; Thoyer *et al.*, 2014; Beillouin *et al.*, 2021).

The crop diversification measure lays out different requirements for three distinct categories of farm size. Farms whose UAA is less than 10ha are exempt. Farms with 10-30 hectares of arable land must grow at least two different crops, and the main crop cannot exceed 75 percent of the farm's total arable land. Farms with over 30 hectares are required to grow at least three crops; the main crop must not cover more than 75 percent of the farm's arable land, and the two largest crops together cannot cover more than 95 percent of the farm's total arable land.

Furthermore, farms with more than 75 percent of their total eligible land covered by grasslands or with 75 percent of their arable area cultivated with forage (if the remaining area is less than 30ha) are not subject to the measure's requirements. The same applies for farms with perennial crops or organic plots.

According to Louhichi *et al.* (2017a), about 60% of French farms are subject to the crop diversification measure.[3]

3 Data

3.1 Sample

To evaluate the impact of the crop diversification measure, we have built a database on land use with a representative sample of French farms from the 2010 agricultural census and from two surveys carried out in 2013 and 2016 by the French Ministry of Agriculture. These three data sources were paired on the basis of a unique identifier for agricultural holdings (the French business identification 'SIRET' number). Our original sample includes all eligible farms surveyed at least once in 2016 and in a pre-reform year (2010 or 2013), i.e., 24,919 farms. Nevertheless, for the main analysis we focus on farms whose arable area is near the threshold of 30 hectares (see Section 4).[4]

3.2 Outcomes

From the available data, we constructed several indicators to assess the likely impact of the crop diversification measure. The set of variables includes all the indicators directly impacted by the measure: whether or not the farmer complies with the requirements for farms over 30ha (a dummy variable that takes on the value of "1" if yes, "0" elsewhere, whatever the size of the farm), the number of crops cultivated on the farm, the percentage of the largest crop in the arable area (the main crop), the percentage of the second-largest crop in the arable area, and the percentage of the two main crops in the arable area.

It should be mentioned that in some cases, the data available did not allow us to accurately reconstruct the number of crops on the farm. Indeed, the information relating to the cultivation of "fresh vegetables, melon and strawberries" collected in the surveys is aggregated so that if three different crops (strawberries, zucchini and cucumber, for example) are grown on the farm, we can only count one. This problem only affects market gardening farms, which

[3] See also Hart & Menadue (2013) and Hart (2015) for a presentation and discussion of implementation across member states.

[4] Data can be accessed through the secure data hub of the CASD: `https://www.casd.eu/en/`.

represent a limited number of total farms. In addition, farms with more than 75% of their soil occupied by maize are permitted to plant specific cover crops, and make it count as one crop by obtaining a certification. We drop “market gardening" and "maize" farms from the sample in the descriptive statistics and main estimations but reintegrate them in the robustness checks to test the sensitivity of the estimates to their presence.

4 Empirical strategy and preliminary tests

Given the panel data nature of our sample (2010, 2013, 2016) and the implementation of the reform in 2015, several methods could be used to study the impact of the crop diversification measure: regression discontinuity design (RDD), difference-in-differences (DiD), or a combination of both. Preliminary tests detailed below rule out the validity of the first two methods.

It should be noted that for any of the methods proposed, we will compare farms over 30ha to farms below 30ha. The measure’s requirements are the same regarding the main crop (it must not exceed 75 percent of the arable land). Thus, our comparison will shed light on the impact of the two additional rules imposed on farms over 30ha, i.e., that they must grow at least three crops and that their two main crops must occupy less than 95 percent of the total arable land.

4.1 Regression discontinuity design

When units (here farms) receive a treatment (here crop diversification constraints) on the basis of whether their value of an observed covariate (here the arable land area of the farm) is above or below a known cutoff (here 30 ha), one potential identification strategy is to use RDD. The idea is that the probability of receiving the treatment conditional on this covariate jumps discontinuously at the cutoff, making the treatment assignment unrelated to potential confounders (Calonico *et al.*, 2014a). By comparing units close to the cutoffs (i.e., within a defined bandwidth), it becomes possible to create conditions close to a randomized control trial. Lee & Lemieux (2010) refer to this as "local randomization".

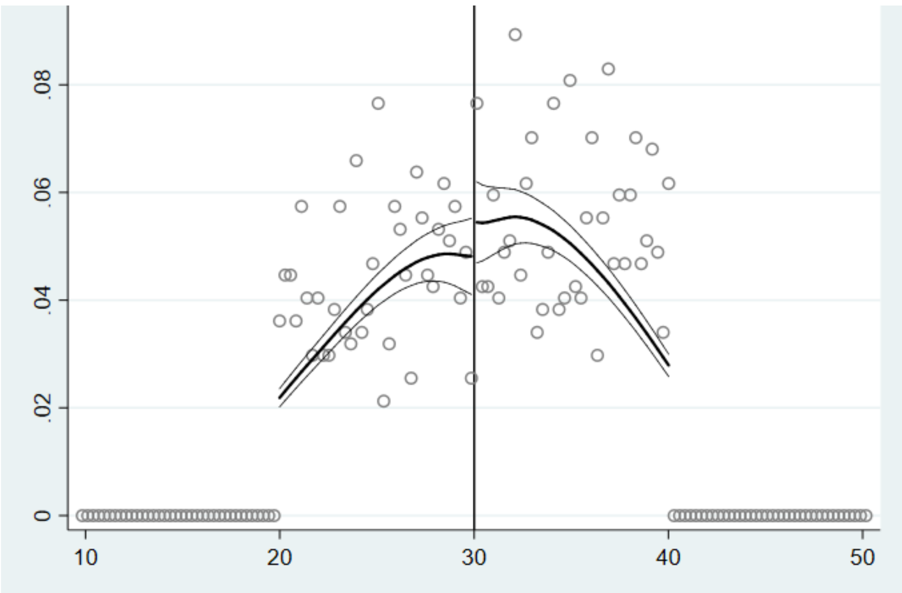
Consequently, we propose estimating the impact of the crop diversification measure using an equation on 2016 data such as:

$$Y_i = \alpha + \beta_1 I[arable\_area_i > 30] + \varepsilon_i \quad (1)$$

Where Y_i is one of the outcomes of farm i described in Section 3.2, I[.] is an identity function that takes the value "1" if the farm arable area is greater than 30ha[5], and ε_i is an error term. Equation 1 can be estimated with local estimators, using observations around the bandwidth. The bandwidth can be defined by the researcher, or optimal bandwidth can be determined using automated selection procedures (see Calonico *et al.*, 2014a). Both possibilities are explored in this paper.

To test the validity of an RDD estimation, we follow the recommendations of Lee & Lemieux (2010). First, we check for the absence of threshold manipulation, which would prevent us from having local randomization. McCrary (2008) propose a Wald test that we implement here (H0: discontinuity is zero). The absence of discontinuity in the density of farms around the cutoff of 30 ha is not rejected by the statistical test (test value: 0.122, standard error: 0.106, t-ratio: 1.151), so there is no evidence of manipulation of the threshold. A graphical test is shown in Figure 1 (Bandwidth: 10, bin size: 0.282).

Figure 1: McCrary threshold manipulation test



(Bandwidth: 10, bin size: 0.282)

[5]As defined in Section 2.

Second, as for randomized control trials (RCT), covariate values must be balanced between treated and control observations for the design to be valid. Balancing tests on a short list of covariates presented in Table 1 do not reveal that farms over and under 30ha are different based on observable pre-treatment characteristics (in 2010).

Table 1: Balancing tests, 2010 data

	Treated			Control			
Variable	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Standardized Differences
Gender of the head of farm (male=1)	0.813	0.390	905	0.811	0.392	736	0.004
Birth year of the head of the farm	1962	8.942	905	1961	9.397	736	0.060
Nb. of partners	0.731	1.094	905	0.690	1.171	736	0.026
Workforce on the farm (FT)	2.049	6.420	905	2.205	10.846	736	-0.012
Irrigable parcels (yes=1)	0.256	0.437	905	0.306	0.461	736	-0.078

Finally, as balancing tests do not allow us to check the similarity of many of the farm characteristics (the unobservables), we implement a falsification test. We run an RDD on 2010 data using the 30ha cutoff as a placebo treatment. Most indicators seem affected by the placebo treatment, as shown Table 2. This means that our two farm groups differ along unobservable characteristics. The validity of an RDD estimator in our context is thus rejected.

Table 2: Impact of the crop diversification measure using an RDD on 2010 data (placebo test)

Outcome	Coef.	Std. Error	t	P-value	Nb obs	Nb of farms	Bdw	Y_1
Compliance (yes=1)	-0.040	0.046	-0.971	0.331	1,417	1,417	9.027	0.837
Number of crops	-0.102	0.063	-1.795	0.073	8,485	8,485	4.055	4.074
Share of the first crop	0.021	0.008	2.906	0.004	7,128	7,128	3.391	0.517
Share of the second crop	-0.006	0.004	-1.563	0.118	11,737	11,737	5.602	0.268
Share of the two main crops	0.009	0.006	1.644	0.100	8,392	8,392	4.008	0.785

Note: The column labeled "Coef." gives the impact of the crop diversification measure, estimated by the RDD method on the 2010 data. Robust standard errors are reported in the third column. Y_1 (all) gives the mean value of the outcome in the group of treated farms that are inside the bandwidth.

4.2 Difference-in-difference

Given that we have data prior to the implementation of the measure, another potential strategy is to lead a difference-in-difference (DiD) analysis. This allows us to control for individual factors that are invariable over time as well as for common annual shocks. Thus, we estimate the following equation on data from 2010 to 2016, using OLS-FE regressions:

$$Y_{it} = \alpha + \beta_1 I[arable\_area_{it} > 30] * Post_{2013} + \gamma_t + \mu_i + \epsilon_i, \tag{2}$$

where $Post_{2013}$ is a dummy variable equal to 1 for years after the CAP reform (first year of application = 2015), γ_t is a vector of year dummies t and μ_i a vector of farm dummies.

To check whether DiD is a valid identification strategy in our case, we need to test for the existence of a parallel trend between the small and large farms prior to the implementation of the reform. To do so, we estimate a fixed-effects model from panel survey data collected in 2010 and 2013. Table 3 displays the results, which indicate that we can reject the null hypothesis of no impact, for most indicators. This suggests that the parallel trend assumption does not hold when considering the whole sample of farms. This is not surprising as we are comparing very different farms; farms in the control group are between 10 and 30ha, and some in the treatment group are over 200ha in size.

Table 3: Parallel trends in crop diversification indicators

Outcome	Coef.	Std. Error	t	P-value	Nb obs	Nb of farms
Compliance (yes=1)	0.001	0.021	0.050	0.958	25,555	20,287
Number of crops	-0.111	0.053	-2.110	0.035	25,555	20,287
Share of the first crop	0.017	0.009	1.970	0.049	25,555	20,287
Share of the second crop	-0.017	0.007	-2.320	0.020	25,555	20,287
Share of the two main crops	0.001	0.006	0.160	0.877	25,555	20,287

Note: The column labeled “Coef.” gives the impact of the crop diversification measure, estimated by the difference-in-difference method over the pre-reform period. Robust standard errors are reported in the third column.

4.3 Combining FE and RD set-up

As shown in the previous subsections, we cannot apply an RDD, because units around the cut-off are not directly comparable in years prior to the reform. Nor can we use a DiD design, because large and small farms were on differential land use trends before the program began. We thus exploit two sources of variation, before/after 2015 and just over /under 30 hectares and use a OLS-FE approach combined with a regression discontinuity set-up, as in Pettersson-Lidbom (2012) and Leonardi & Pica (2013) to identify the effects of the reform. This consists in applying the OLS-FE estimator to the subset of farms around the threshold.[6]

Formally, we estimate Equation 2 on observations within a bandwidth determined using the mean squared error optimal bandwidth selector (Calonico *et al.*, 2014b). The bandwidths differ according to the outcome of interest and the year considered, which can make results complicated to analyze since the sample of farms is then considered different for every regression. As all automated selected bandwidths in the main estimates were around 10, we fix the bandwidth to 10 in most of our analyses, but check the robustness of our results to the use of bandwidth of 8 and 12, as well as automated selected bandwidths.

A validity assumption for our empirical strategy is again the existence of parallel trends between the small and large farms before the reform begins. To do so, we estimate a fixed-effects model from panel data survey collected in 2010 and 2013, with a placebo treatment in 2013. Table 4 displays the results. In all cases we cannot reject the null hypothesis of no impact, which supports the parallel trend assumption for the subset of farms around the cut-off.[7] Note that the absence of threshold manipulation is also a condition for the validity of this estimator. As previously shown in Figure 1, threshold manipulation does not seem to be an issue in our sample.

[6] An alternative strategy would have been to use a difference-in-discontinuity design, as in Grembi *et al.* (2016), but their estimator does not include individual fixed-effects, which is essential here to control for unobservable characteristics, and for many farms we wanted to use not one but two pre-treatment periods (2010 and 2013) in order to improve identification.

[7] This result holds when we use automatically selected bandwidths (see Table A.1).

Table 4: Parallel trends in crop diversification indicators with a bandwidth = 10

Outcome	Coef.	Std. Error	t	P-value	Nb obs	Nb of farms	Y_1
Compliance (yes=1)	0.012	0.040	0.290	0.774	2,260	1,845	0.739
Number of crops	-0.143	0.100	-1.430	0.154	2,260	1,845	3.894
Share of the first crop	-0.005	0.014	-0.380	0.705	2,260	1,845	0.551
Share of the second crop	0.002	0.010	0.240	0.810	2,260	1,845	0.264
Share of the two main crops	-0.003	0.011	-0.260	0.792	2,260	1,845	0.815

Note: The column labeled "Coef." gives the impact of the crop diversification measure, estimated by OLS-FE over the pre-reform period. Robust standard errors are reported in the third column.

Thus, we analyze the impact of the crop diversification measure of the CAP greening reform by combining the use of OLS-FE estimators with an RD set-up.

5 Results

5.1 Descriptive statistics

Table 5 displays descriptive statistics on the outcomes of interest in 2016 for the sample used in the main estimates, i.e., a subset of the 1,667 farms distributed around the 30-ha threshold with a bandwidth of ten. Table 5 indicates that a large majority of these farms comply with the requirements of the crop diversification measure. They cultivate, on average, 3,873 different crops. The two main crops occupy, on average, 80 percent of the arable area (52 percent for the largest crop and 28 percent for the second-largest). Yet, as we will see further on, these statistics hide a great heterogeneity between farms over and under 30 ha.

Table 5: Descriptive statistics

	N	Mean	Std. Dev.	Min.	Max.
Compliance (yes=1)	1,667	0.847	0.360	0	1
Number of crops	1,667	3.873	1.150	1	9
Share of the first crop	1,667	0.521	0.138	0.175	1
Share of the second crop	1,667	0.280	0.088	0	0.5
Share of the two main crops	1,667	0.801	0.131	0.339	1

Note: The values are computed from the survey carried out in 2016 by the Ministry of Agriculture. The sample includes the farms used in the main estimates (around the 30 ha threshold with a 10 ha bandwidth).

5.2 Main results

The results from our OLS-FE estimations on farms around the bandwidth are displayed in Table 6.

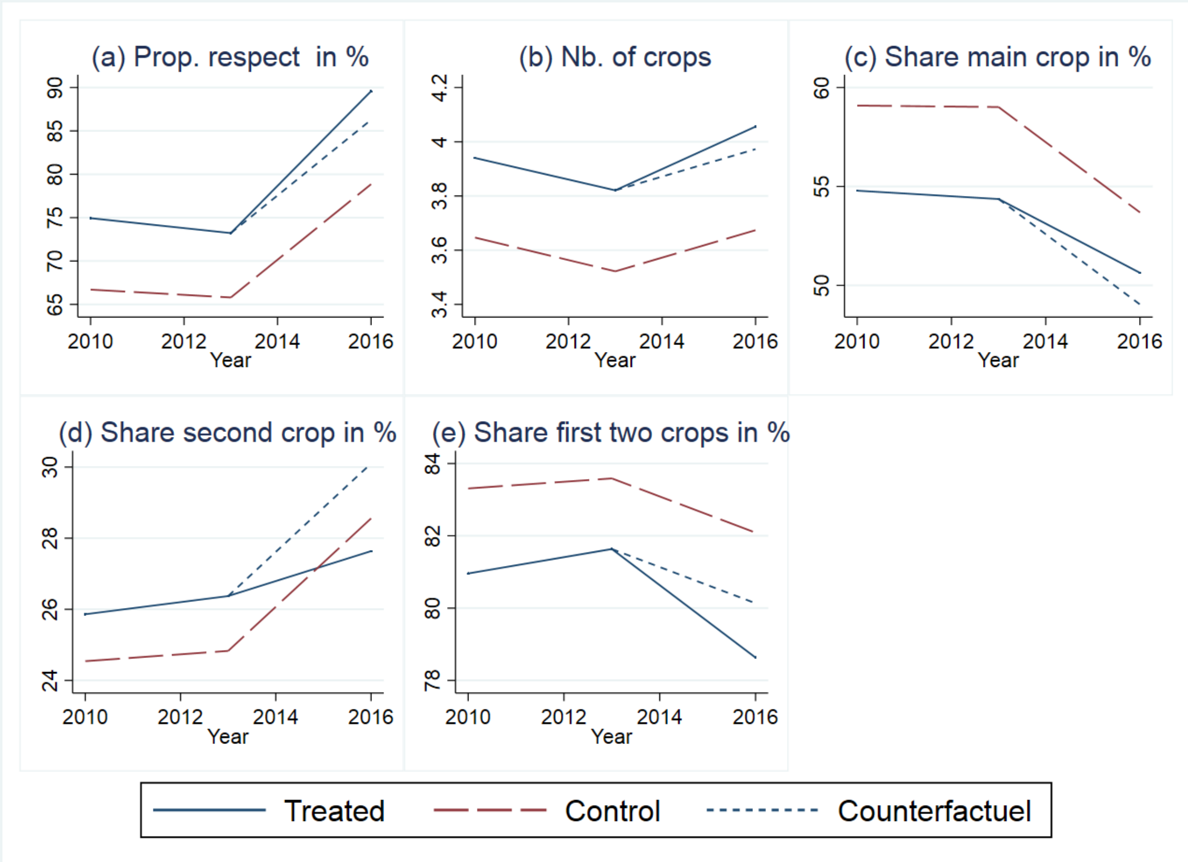
Table 6: Impact of the crop diversification measure on the subset of 20-40 ha farms

Outcome	Coef.	Std. Error	t	P-value	Nb obs	Nb of farms	Y_1
Compliance (yes=1)	0.051	0.023	2.250	0.024	3,710	1,667	0.897
Number of crops	0.123	0.059	2.080	0.038	3,710	1,667	4.044
Share of the first crop	0.004	0.008	0.510	0.613	3,710	1,667	0.510
Share of the second crop	-0.019	0.005	-3.550	0.000	3,710	1,667	0.276
Share of the two main crops	-0.015	0.006	-2.440	0.015	3,710	1,667	0.786

Note: The column labeled "Coef." gives the impact of the crop diversification measure, as estimated by the OLS-FE method. Robust standard errors are reported in the third column. Y_1 gives the mean value of the outcome in the group of treated farms that are inside the bandwidth.

As we can see, the measure increased by 5 percentage points the farms over 30ha that meet the crop diversification conditions, i.e., from 85 to 90 percent, compared to the farms under 30ha. The results, moreover, show a significant difference between the two groups in the number of crops cultivated ($+0.12$), suggesting that the measure made it possible for more than one in eight farms to add an additional crop on their soils. As expected, the results do not show an effect on the percentage of land occupied by the main crop. The estimates, however, indicate a decrease of two percentage points in the share of land occupied by the second largest crop on farms over 30ha compared to that of those under 30ha.[8] While these results are interesting, plotting the average value of the outcomes over time helps us to understand the mechanisms at play.

Figure 2: Main results



First, the existence of parallel trends from 2010 to 2013 found Table 4 can clearly be seen in Figure 2. Figure 2.c and regression results Table 6 show that, as expected, farmers in both groups reacted in the same way to the rule dictating the surface area occupied by the main crop. The curves suggest that both groups decreased the percentage of land occupied by their main crop. Figure 2.d reveals part of the mechanism at play here. We see that farms under 30ha seem to increase the land area occupied by the second crop by 3.5% as a response to the increase in the percentage of surface area occupied by the main crop, while farms over 30ha increase it by only 1.5%. This is consistent with the fact that farms over 30ha also face a constraint on the surface area that can be occupied by their two largest crops.

[8]Results hold when we use automatically selected bandwidths, see Table A.2.

To understand how both groups of farms responded to the measure, it is useful to lead the analysis for other crops as well. Table 7 presents the regression results, while the average value of the outcomes over time are plotted in Figure 3.[9]

Table 7: Impact of the crop diversification measure on additional crops on 20-40 hectare farms

Outcome	Coef.	Std Error	t	P-value	Nb obs	Nb of farms	Y_1
Share of the third crop	0,0050	0,0040	1,250	0,212	3710	1667	0,1383
Share of the fourth crop	0,0084	0,0027	3,140	0,002	3710	1667	0,0554
Share of the fifth crop	0,0012	0,0014	0,850	0,395	3710	1667	0,0162
Share of the sixth crop	-0,0002	0,0008	-0,290	0,772	3710	1667	0,0034
Share of the seventh crop	0,0003	0,0004	0,940	0,346	3710	1667	0,0007
Share of the eighth crop	0,0002	0,0002	0,990	0,324	3710	1667	0,0001

Note: The column labeled "Coef." gives the impact of the crop diversification measure, estimated by the OLS-FE method. Robust standard errors are reported in the third column. Y_1 gives the mean value of the outcome in the group of treated farms that are inside the bandwidth.

[9] A test for the existence of parallel trends for these alternative outcomes is presented in Table A.3.

Figure 3: Secondary results

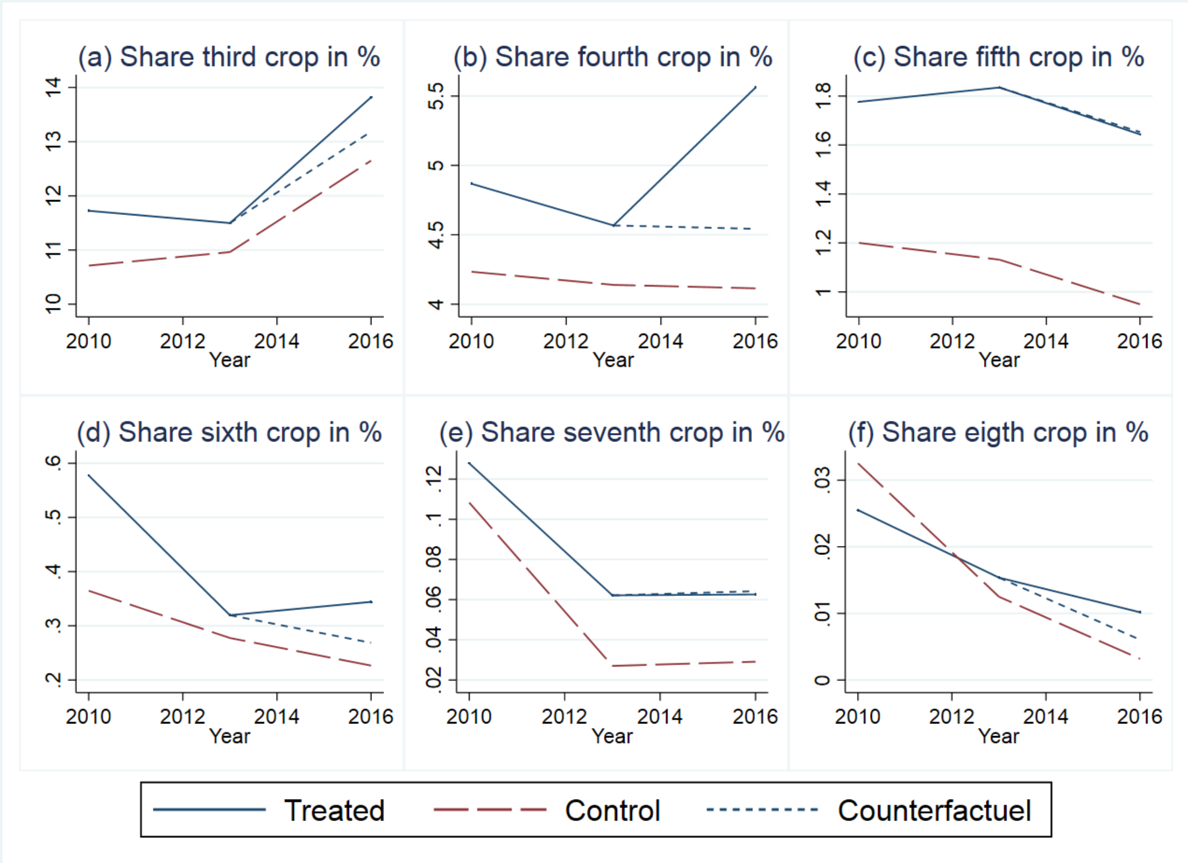


Figure 2.a suggests that both groups increased the area occupied by their third-largest crop (difference in increase between the two groups not significant). Figure 2.b suggests that the treated group increased the surface area occupied by the fourth-largest crop significantly more than did the control group. For the fifth-, sixth-, seventh- and eighth-largest crops, we do not observe a significant difference between the two groups (see Table A.1). Furthermore, these crops represent a very low share of farms' total area (less than 1%).

To summarize, the additional rules for farms over 30ha had an effect on farmers' behavior, increasing both their compliance with the measure and the number of crops grown. Furthermore, the graphical analysis, while not causal (as we do not have a pure control group completely unaffected by the reform), is informative. It suggests that both groups increased their compliance with the legislation and decreased the share of land occupied by the main crop but that the groups responded differently in terms of the crop they chose to increase in order to comply with the legislation.

5.3 Robustness checks

We use three methods to test the robustness of the main estimates.

First, we vary the bandwidth to verify that the main results still hold even when the window is slightly increased or decreased. This is a way of verifying that the results are not driven by observations at the edge of the window. Table A.4 displays the results when running the estimates from the subset of the 1,335 farms distributed around the 30 ha threshold, the size of which varies between 22 and 38 hectares (bandwidth $= 8$). Table A.5 displays the results when running the estimates from the subset of the 2,005 farms distributed around the 30 ha threshold, the size of which varies between 18 and 42 hectares (bandwidth $= 12$). The results hold.

Second, we re-estimate the model but keep in the same sample farms that do market gardening or have corn as a main crop. Table A.6 displays the results, which are closely aligned with the main results.

Third, we apply a last falsification test. To define the treated and control groups, we use thresholds for which there should be no treatment effect. Table A.7 displays the results when using 40 hectares as a threshold, and Table A.8 displays the results when using a 100 ha threshold. Again a bandwidth of 10 is used. In both cases, we cannot reject the null of no impact, which supports the validity of our identification strategy and main results.

6 Discussion and conclusion

We estimate the impact of the crop diversification measure of the 2013 CAP greening reform in the context of French farms. We use an OLS-FE approach combined with an RD set up and propose an uncommonly rich set of placebo and falsification tests to select the best approach and check its validity.

We find that the additional requirements for farms over 30ha increase farmers' compliance with the measure as well as the number of crops grown. Furthermore, the graphical analysis, while not causal, is informative. It suggests that both farm-size groups (over and under 30 ha) increased their compliance with the legislation and decreased the share of land occupied by their main crop but that the groups responded differently in terms of the crop they chose to increase in order to comply with the legislation. In the group of farms over 30 ha, we observe an increase in the share of the farmland occupied by the third- and fourth-largest crops, while in the farms under 30ha, we observe an increase in the share of farmland occupied by the second- and third-largest crops.

Regarding external validity, the results found are valid for farms around 30ha in size. Indeed, discontinuity designs produce LATE (local average treatment effects). We suspect the magnitude of the effects decreases with farm size, as in our 2010 data 76% of 30-40 ha farms were already satisfying the crop diversification requirements, while this figure was 87% of 70-80 ha farms and 91% of 100-110 ha farms. Larger farm size seems to facilitate the satisfaction of crop diversification requirements, for instance, that of cultivating at least three crops.

To conclude, while shedding light on the impact of the measure on soil occupation of 30ha farms, our study confirms the suspected large windfall effects of the measure.

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Appendices

Table A.1: Parallel trends in crop diversification indicators with an automated selected bandwidth

Outcome	Coef.	Std. Error	t	P-value	Nb obs	Nb of farms	Bandwidth	Y_1
Compliance (yes=1)	0.012	0.043	0.280	0.779	2,071	1,684	9.209	0.737
Number of crops	-0.134	0.128	-1.040	0.298	1,434	1,181	6.407	3.849
Share of the first crop	-0.001	0.014	-0.080	0.938	2,389	1,953	10.740	0.548
Share of the second crop	-0.001	0.011	-0.070	0.941	2,100	1,707	9.328	0.266
Share of the two main crops	-0.012	0.013	-0.880	0.382	1,434	1,181	6.405	0.816

Note: The column labeled "Coef." gives the impact of the crop diversification measure, estimated by the OLS-FE method on data around an automated selected bandwidth over the pre-reform period. Robust standard errors are reported in the third column. Y_1 gives the mean value of the outcome in the group of treated farms that are inside the bandwidth.

Table A.2: Impact of the crop diversification measure (automated selected bandwidth)

Outcome	Coef.	Std. Error	t	P-value	Nb obs	Nb of farms	Bandwidth	Y_1 (all)	Y_1 (inside bw)
Compliance (yes=1)	0.045	0.023	1.930	0.054	3,487	1,564	9.421	0.971	0.896
Number of crops	0.128	0.061	2.080	0.037	3,464	1,553	9.399	5.048	4.056
Share of the first crop	0.008	0.007	1.170	0.242	4,332	1,953	11.836	0.482	0.506
Share of the second crop	-0.021	0.005	-4.290	0.000	4,503	2,030	12.173	0.244	0.276
Share of the two main crops	-0.013	0.006	-2.160	0.031	3,918	1,762	10.657	0.727	0.786

Note: The column labeled "Coef." gives the impact of the crop diversification measure, estimated by the OLS-FE method on data around an automated selected bandwidth. Robust standard errors are reported in the third column. Y_1 (all) gives the mean value of the outcome in the treated group, i.e., the farms above the cut-off. Y_1 (inside bw) gives the mean value of the outcome in the group of treated farms that are inside the bandwidth.

Table A.3: Parallel trends in crop diversification indicators (other crops) on the subset of 20-40 ha farms

Outcome	Coef.	Std Error	t	P-value	Nb obs	Nb of farms	Y_1
Share of the third crop	0,0048572	0,0070347	0,69	0,49	2260	1845	0,1144
Share of the fourth crop	-0,0006983	0,0047769	-0,15	0,884	2260	1845	0,0465
Share of the fifth crop	0,0015656	0,0027325	0,57	0,567	2260	1845	0,0181
Share of the sixth crop	-0,0024203	0,0018407	-1,31	0,189	2260	1845	0,0040
Share of the seventh crop	-0,0003424	0,0006226	-0,55	0,582	2260	1845	0,0012
Share of the eighth crop	-0,0000941	0,000214	-0,44	0,66	2260	1845	0,0002

Note: The column labeled "Coef." gives the impact of the crop diversification measure, estimated by the difference-in-discontinuity method, over the pre-reform period. Robust standard errors are reported in the third column. Y_1 gives the mean value of the outcome in the group of treated farms that are inside the bandwidth, which is determined using an automatic procedure.

Table A.4: Impact of the crop diversification measure on the subset of 22-38 ha farms

Outcome	Coef.	Std. Error	t	P-value	Nb obs	Nb of farms	Y_1
Compliance (yes=1)	0.038	0.025	1.500	0.135	2,976	1,335	0.892
Number of crops	0.121	0.067	1.810	0.071	2,976	1,335	4.043
Share of the first crop	0.002	0.009	0.260	0.798	2,976	1,335	0.509
Share of the second crop	-0.019	0.006	-3.220	0.001	2,976	1,335	0.276
Share of the two main crops	-0.017	0.007	-2.460	0.014	2,976	1,335	0.785

Note: The column labeled "Coef." gives the impact of the crop diversification measure, estimated by the OLS-FE method. Robust standard errors are reported in the third column. Y_1 gives the mean value of the outcome in the group of treated farms that are inside the bandwidth.

Table A.5: Impact of the crop diversification measure on the subset of 18-42 ha farms

Outcome	Coef.	Std. Error	t	P-value	Nb obs	Nb of farms	Y_1
Compliance (yes=1)	0.048	0.021	2.270	0.023	4,449	2,005	0.905
Number of crops	0.098	0.055	1.790	0.074	4,449	2,005	4.069
Share of the first crop	0.009	0.007	1.260	0.210	4,449	2,005	0.507
Share of the second crop	-0.021	0.005	-4.210	0.000	4,449	2,005	0.276
Share of the two main crops	-0.012	0.006	-2.130	0.033	4,449	2,005	0.784

Note: The column labeled "Coef." gives the impact of the crop diversification measure, estimated by the OLS-FE method. Robust standard errors are reported in the third column. Y_1 gives the mean value of the outcome in the group of treated farms that are inside the bandwidth.

Table A.6: Impact of the crop diversification measure including farms that do market gardening and grow corn as their main crop

Outcome	Coef.	Std. Error	t	P-value	Nb obs	Nb of farms	Bandwidth	Y_1
Compliance (yes=1)	0.055	0.022	2.490	0.013	3,917	1,760	10	0.858
Number of crops	0.138	0.057	2.420	0.016	3,917	1,760	10	3.979
Share of the first crop	0.002	0.007	0.270	0.785	3,917	1,760	10	0.525
Share of the second crop	-0.018	0.005	-3.430	0.001	3,917	1,760	10	0.268
Share of the two main crops	-0.016	0.006	-2.680	0.007	3,917	1,760	10	0.794

Note: The column labeled "Coef." gives the impact of the crop diversification measure, estimated by the OLS-FE method. Robust standard errors are reported in the third column. Y_1 gives the mean value of the outcome in the group of treated farms that are inside the bandwidth.

Table A.7: Impact of the crop diversification measure on the subset of farms around the threshold of 40 ha

Outcome	Coef.	Std. Error	t	P-value	Nb obs	Nb of farms	Bandwidth	Y_1
Compliance (yes=1)	0.000	0.020	0.010	0.995	4,157	1,871	10	0.916
Number of crops	0.001	0.056	0.020	0.987	4,157	1,871	10	4.188
Share of the first crop	-0.001	0.006	-0.180	0.859	4,157	1,871	10	0.501
Share of the second crop	0.002	0.004	0.470	0.638	4,157	1,871	10	0.274
Share of the two main crops	0.001	0.006	0.160	0.873	4,157	1,871	10	0.775

Note: The column labeled "Coef." gives the impact of the crop diversification measure, estimated by the OLS-FE method. Robust standard errors are reported in the third column. Y_1 gives the mean value of the outcome in the group of treated farms that are inside the bandwidth.

Table A.8: Impact of the crop diversification measure on the subset of farms around the 100 ha threshold

Outcome	Coef.	Std. Error	t	P-value	Nb obs	Nb of farms	Bandwidth	Y_1
Compliance (yes=1)	-0.003	0.012	-0.240	0.813	4,160	1,853	10	0.983
Number of crops	0.074	0.058	1.260	0.207	4,160	1,853	10	5.042
Share of the first crop	-0.001	0.004	-0.260	0.795	4,160	1,853	10	0.477
Share of the second crop	-0.002	0.003	-0.710	0.478	4,160	1,853	10	0.246
Share of the two main crops	-0.003	0.004	-0.780	0.438	4,160	1,853	10	0.723

Note: The column labeled "Coef." gives the impact of the crop diversification measure, estimated by the OLS-FE method. Robust standard errors are reported in the third column. Y_1 gives the mean value of the outcome in the group of treated farms that are inside the bandwidth.

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