ADOPTION OF INNOVATION IN EUROPEAN AGRICULTURE[1]

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ABOUT THE FLINT PROJECT

FLINT will provide an updated data-infrastructure needed by the agro-food sector and policy makers to provide up to date information on farm level indicators on sustainability and other new relevant issues. Better decision making will be facilitated by taking into account the sustainability performance of farms on a wide range of relevant topics, such as (1) market stabilization; (2) income support; (3) environmental sustainability; (4) climate change adaptation and mitigation; (5) innovation; and (6) resource efficiency. The approach will explicitly consider the heterogeneity of the farming sector in the EU and its member states. Together with the farming and agro-food sector the feasibility of these indicators will be determined.

FLINT will take into account the increasing needs for sustainability information by national and international retail and agro-food sectors. The FLINT approach is supported by the Sustainable Agriculture Initiative Platform and the Sustainability Consortium in which the agro-food sector actively participates. FLINT will establish a pilot network of at least 1000 farms (representative of farm diversity at EU level, including the different administrative environments in the different MS) that is well suited for the gathering of these data.

The lessons learned and recommendations from the empirical research conducted in 9 purposefully chosen MS will be used for estimating and discussing effects in all 28 MS. This will be very useful if the European Commission should decide to upgrade the pilot network to an operational EU-wide system.

PROJECT CONSORTIUM:

1	DLO Foundation (Stichting Dienst Landbouwkundig Onderzoek)	Netherlands
2	AKI - Agrargazdasagi Kutato Intezet	Hungary
3	LUKE Finland	Finland
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5	INTIA - Instituto Navarro De Tecnologias e Infraestructuras Agrolimentarias	Spain
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LIST OF ACRONYMS

CAP	Common Agricultural Policy
EU	European Union
FADN	Farm Accounting Data Network
FLINT	Farm Level Indicators for New Topics
SO	Standard Output

EXECUTIVE SUMMARY

Innovation and adoption of innovation are considered key indicators of competitiveness and sustainability and have therefore received ample attention in public policy. The project FLINT (Farm Level Indicators on New Topics in policy evaluation) collected farm-level indicators on innovation and related aspects. Analysing data from 821 farms from eight Member States of the European Union, this study provides insight into different adoption rates of five types of innovation in agriculture across Europe and suggests the potential effects of different factors on farmers' decision to innovate. Econometric analysis suggests that farm type and farm size are likely to be the main determinant of process and organisational innovation. Subsidies appear to have significantly positive effect on the adoption of process innovation. Farms with younger holders are in general more likely to innovate. The FLINT database, in combination with Farm Accountancy Data Network (FADN) database, is shown to have potential for supporting policy on competitiveness and sustainability.

1 INTRODUCTION

The Common Agricultural Policy (CAP) is aimed at helping European Union's (EU) farmers meet the need to feed more than 500 million Europeans. Its main objectives are to provide a stable, sustainably produced supply of safe food at affordable prices for consumers, while also ensuring a decent standard of living for 22 million farmers and agricultural workers. Within this context and as discussed in the European Parliament, innovation is seen as one of the key drivers for a competitive and sustainable agriculture. Within the CAP, the EU's rural development policy, frequently called 'the second pillar', helps the rural areas of the EU to meet the wide range of economic, environmental and social challenges of the 21st century. There are more than hundred different Rural Development Programmes (RDPs) in the 28 Member States for the period 2014-2020. Member States and regions draw up their rural development programmes based on the needs of their territories and addressing at least four of the six common EU priorities. One of these six priorities is enhancing the viability and competitiveness of all types of agriculture, and promoting innovative farm technologies and sustainable forest management.

There has been a large body of literature addressing the question whether competitiveness and sustainability can indeed be stimulated by innovations. According to Ghazalian and Furtan (2007), increased R&D expenditure, as a proxy for innovation, has enhanced exports in the primary agricultural sector. Their study used panel data covering 21 OECD countries for the period 1990-2003. Rumanovska (2013) concludes that the innovative projects realized through RDPs in Slovak Republic in the period 2007-2013 have positive impact on the competitiveness of agricultural subjects. The possibilities of EU financial support for innovative projects in Slovak Republic provide an important boost for the introduction of new innovative technologies into production process, which can significantly contribute to improved competitiveness of agricultural subjects in the future. No in-depth study, however, has been found on the impact of innovation on the sustainability of farming in EU Member States. The lack of data on the state of innovation and sustainability performance may have made such studies infeasible.

Against this background, the FLINT project collected farm-level indicators on innovation and related aspects. Indicators on innovation distinguish three main types of innovations, namely, product innovation, process innovation, and market and organisational innovation. Product innovations are products (or services) (for marketing) that are new or significantly improved with respect to the base features (a new product), technical specifications, features such as taste, colour, race, for example, packaging or the usability or durability. Process innovations refer to new or significantly improved technologies, and new or improved methods for the manufacture and supply of products. Consider, for example, new machines, installations, stables or greenhouses, or computer systems. Examples of market innovation are the introduction of a new brand with associated labelling, the introduction of a new or significantly improved website, the introduction of a product to a new or different sales channel like direct sales to restaurants, schools, farm sales, or internet sales. Organisational innovations may include e.g. the introduction of supply chain management systems or quality management systems, the introduction of new management structures, changes to the business entity structure (legal form), or the entry into a formal partnership with other firms or public (research) organisations.

A further distinction is made between innovations on products or processes that are new to the market and those that are not new to the market. Together, the aforementioned indicators for innovation cover all types of innovation commonly discussed in policy and research. Besides data on new topics such as innovation, the FLINT database also contains additional information on sustainability, and is merged with data collected by the FADN. The FLINT database makes it possible to obtain quantitative insights into the state of innovation and potential determinants. Based on the analysis of 821 farms surveyed within the FLINT project from eight Member States, this study presents the state of innovation across

farm types and different Member States and assess the potential impact of different factors on innovation through econometric analysis. In the sections that follow, we first describe the methodology of the analysis, present results of adoption rates and its determinants and discuss the main findings.

2 METHODOLOGY, SAMPLING AND DATA

2.1 Methodology

2.1.1 Theoretical considerations

It is a common phenomenon that farmers, like entrepreneurs in other sectors, do not adopt innovations at the same time as they appear on the market. Two main approaches have been developed to describe the diffusion of adoption (for overviews see for example Geroski, 2000, and Sunding and Zilberman, 2001). The first approach regards the process of diffusion as a disequilibrium process. The epidemic diffusion model is the main model that describes innovation adoption as determined by such a process of information spread (Diederen *et al*., 2003b). The second approach is of a decision-theoretic nature and regards the diffusion process as an equilibrium process. From this perspective, gradual innovation diffusion is not due to market imperfection, but to variation of the adoption benefits over the potential adopters (Diederen *et al*., 2003b). The probit model is the most prominent model within the decision-theoretic literature where the dependent variable represents a dichotomous choice (Diederen et *al*., 2003a). The probit model, pioneered by Davies (1979), is the main empirical model that relates innovation diffusion to variation in characteristics and in benefits.

If a farmer decides to innovate, he/she can choose to be the first user of an innovation among his/her competitors or to adopt an innovation which is already used by others but which is still relatively new, or he/she chooses to invest in a well-known business opportunity such as farm expansion (Diederen *et al*., 2003b). Literature on innovation typically distinguishes different types of innovation. Two main types of innovation studied are product innovation and innovation in the production process, i.e. process innovation (see for example van Galen and Ge, 2009). In some other studies both types of innovations are expanded with the type of market innovation and organizational innovation (for example Deuninck *et al*., 2008).

The adoption of each type of innovation is often hypothesized to be influenced by numerous determinants. For example, Diederen *et al*. (2003a) find that innovation adoption is positively related to labour resources, market position, access to information and past adoption behaviour, and negatively to solvency and the degree of market regulation. Next are the structural characteristics traditionally used in decision-theoretical models, such as farm size, market position and solvency. Diederen *et al*. (2003b) also used behavioural variables that reflect mainly the searching for, handling of and sharing of information. In this study the authors collected survey and interview data.

Diffusion of innovation in agriculture is analysed less frequently. A common approach is to distinct early adopters versus late adopters. For example, Diederen *et al*. (2003b) found that structural characteristics (i.e., farm size, market position, solvency and age of the farmer) explain the difference in adoption behaviour between innovators and early adopters on the one hand and laggards (late adopters and non-adopters) on the other. They also find that early adopters and innovators do not differ from each other regarding structural characteristics. However, they appear to differ in behavioural characteristics:

innovators make more use of external sources of information and they are more involved in the actual development of innovations.

2.1.2 Econometric model

Following the literature as described in previous section, adoption of different types of innovation is analysed as a discrete choice problem. Considering the nested nature of farm data within farming types and countries, multi-level mixed-effects probit models were used to estimate the fixed effects of a set of explanatory variables and random effects that are associated with factors related to farming type and Member State. The model is estimated using the meprobit procedure of Stata® (13.1)[2] with Member State and farming type as the two levels with random intercepts.

2.2 Sampling procedure

In the FLINT selection plan the heterogeneity of the farming sector was explicitly considered. In designing the selection plan the same stratification was used as in FADN (EC, 2009) which is based on type of farming and size class. The theory of stratified sampling shows that the optimal allocation of the sample size across strata depends on the number of units (farms) in the strata and the homogeneity of farms in a stratum (Cochran, 1977). The outcome of this step (the optimal sample design) was further restricted to fit the purpose of the project. Given the pilot nature of the FLINT project, the objective was not to be representative for each Member State as a whole, but to test the feasibility and added value of collecting this type of data. Firstly, at least 25 observations per farming type were required for meaningful statistical analysis. Secondly, at least two Member States were selected for each main farming type to enable cross-country comparison. Therefore the sample was limited to the most important farm types in each Member State.

The data collection was organised in different ways in each of the participating Member States (Vrolijk *et al*., 2016). There were differences in who collected the data (students, data collectors, bookkeepers) and how the data was collected (self-reported, face to face interview or use of external documents). This approach was in line with the regular FADN data collection, to fit the data collection as much as possible to the local circumstances and possibilities. Data collection processes and strategies were designed and data collectors were trained to ensure uniform data gathering with respect to the additional risk management indicators. Data collection was finalised in the spring 2016 and relate to accountancy year 2015, except for Germany for which it is 2014. Hence, the FADN and FLINT data relate to accountancy year 2015, except for France and Germany for which it is 2014.The innovation indicators (and other additional indicators collected in FLINT) were merged with the FADN database. The analysis in this paper is based on data from 821 farmers collected in eight Member States.

2.3 Data source: FLINT and FADN

The adoption models focused on the actual participation decision. However, knowledge on adoption of innovation is not available in FADN. Missing information was elicited by means of a FLINT questionnaire. First, a long list of farm-level indicators was identified by reviewing the literature. Secondly, a number of focus groups with farmers, food industry and policy makers were organised to prioritise the indicators. New farm-level indicators that have been identified are subsequently defined, standardised and

[2] http://www.stata.com/manuals13/memeprobit.pdf

decomposed into data-variables that could be collected by or from the farmer or administrative sources related to the farm.

Five types of innovation indicators and one aggregated indicator were distinguished in the dataset, namely (see for more information also Appendix A):

- Product innovation that is new for the company within the last three years, but not new for the market (*product not new*) (Z3_IN_1011_IC)[3]
- Product innovation new for the market (*product new*) (Z3_IN_1012_IC)
- Process innovation that is new for the company within the last three years, but not new for the market (*process not new*) (Z3_IN_1021_IC)
- Process innovation new for the market (*process new*) (Z3_IN_1022_IC)
- Market and organizational innovation (*organizational*) (Z3_IN_1030_IC)
- Having one or more of the abovementioned types of innovation (*farms with innovations*).

Within product and process innovation a distinction is made between new for a farm and new for the market. This classification makes a comparison possible with previous research of Diederen *et al*. (2003b) and Van der Meer and van Galen (2016) in which distinction was made between innovators (new for the market) and early and late adopters (not new for the market). The FLINT data collectors received a detailed explanation with examples of different types of innovations. The five types of innovation are coded as dummy variables in the dataset that take the value of 1 for adopters and value of 0 for the non-adopters.

The adoption of innovation is considered to be influenced by numerous explanatory variables (see for example Diederen *et al*., 2003b). In the multi-variate regression analysis explanatory variables available in FADN are included that describe farm structure, farm income, farm financing and personal characteristics.

Farm structure variables explicitly consider the heterogeneity of the farming sector and include two main components with respect to production, namely farm size and farm type. The hypothesis is that farmers with larger business are more likely to adopt relatively new innovations. Farm size is one of the first and most widely used factors on which empirical adoption literature has focused. Most studies find a positive relation between size and adoption (see for example David, 1969; Perrin and Winkelmann, 1976; Diederen *et al*., 2002; Diederen *et al*., 2003b; Deuninck *et al*., 2008). With Regulation (EC) No 1242/2008, the economic size of an agricultural holding is measured as the total Standard Output (SO) of the holding expressed in euro. The SO is the average monetary value of the agricultural output at farm-gate price of each agricultural product (crop or livestock) in a given region. The SO is calculated by Member States per hectare or per head of livestock, by using basic data for a reference period of 5 successive years. Holdings may be classified in economic size classes, the limits of which are also expressed in euros. Within FADN in total 14 economic size classes are defined. The range in size classes is from 0 – 2,000 euro SO in size class 1 till more than 3,000,000 euro SO in size class 14. Because of the different farm structures in the EU, it is necessary to specify separate thresholds for each Member State. This threshold differs between the Member States participating in FLINT from 4,000 euro SO (size class 3) in Hungary, Greece and Poland till 25,000 euro SO (size class 6) in Germany and the Netherlands.

Economic size of farm is included as a linear variable and expressed in SO. The hypothesis with regard to farm type is that farmers producing for heterogeneous markets are likely to adopt innovations earlier. Falcon (1977) and Diederen *et al.* (2003b) studied this hypothesis and found the expected impact. In this research the general types of farming based on Eurostat's farm typology are applied (FADN code GENERAL). In total 8 farming types are listed as dummy variables in the analysis, segmenting farms with mainly field crops, horticulture, permanent crops, grazing livestock, granivores, mixed cropping, mixed livestock holdings or mixed activities (i.e., crops and livestock). It should be noted that the classification of farms according to type is based on the (relative) mix of their output. Based on Eurostat's farm

[3] In brackets the code in the FLINT database.

typology farms in horticulture and vegetables produce for more heterogeneous markets than farms in dairy and meat.

Three variables were included as indicators for farm income and performance, namely farm net value added (FADN code SE415), farm net income (FADN code SE420) and total subsidies received (FADN code SE605). Farm net income is the remuneration to fixed factors of production of the farm (labour, land and capital) and reward, or loss of income, to the entrepreneurs' risks. The total amount of subsidies received on current operations included EU-financed and co-financed decoupled and coupled payments. In the EU, farm incomes are supported by mean of direct payments that represent around 30% of farm income (but differ between farming types) (Van Asseldonk *et al*., 2016). Higher farm net value added, farm net income and total subsidies received gives the entrepreneur more financial opportunities to adopt innovations. The reverse situation could be hypothesized for farmers with deprived incomes.

Also the financial structure of the farm is often tested in explaining adoption of innovation. Farmers with larger amounts of debt (total liabilities, FADN code SE485) would be expected to adopt innovations earlier by using debt capital. There is mixed evidence on the credit constraint hypothesis. For example von Pischke (1978) en (Diederen *et al*., 2003b) found evidence to support this hypothesis and Lipton (1976) and Agriculture Issues Centre (1994) did not. Also the amount of cash flow (FADN code SE526) was included. Cash flow is the holding's capacity for saving and self-financing in terms of receipts minus expenditure for the accounting year, not taking into account operations on capital and on debts and loans. The hypothesis is that farmers with higher cash flow are more likely to adopt innovations. The previous described FADN indicators for financial structure are all included as explanatory variables.

Other explanatory variables included are the age of the farmer and the number of advisory contacts by the farmer in a year. This last information is derived from the FLINT-database. Older farmers on average have a lower level of education, which may be correlated with the ability to judge opportunities to innovate. Also they may have a shorter time horizon and be less inclined to invest in novelties. Schnitkey *et al.* (1992) argued that age is related to farm expertise. They will rely less on external information, and therefore do not get in touch with innovations in the market as early as their younger colleagues (Diederen *et al*., 2003b).

2.4 Data source (alternative): FADN only

Similar analysis is performed using FADN data only to provide insights into the usefulness of the additionally collected FLINT data. At this time specific information on adoption of innovation are not available in FADN. However, innovation requires upfront investments. Financial data on investments could be deducted from the development in total assets (FADN code SE501). This data is recorded in FADN and could be seen as a proxy for innovation.

3 RESULTS

3.1 Adoption of innovation

The state of innovation as shown by the adoption rates of different types of innovation varies greatly across the eight Member States in the survey (Table 1). On average, about 41% of the farms have innovated in one or more of the three types of innovation within the last three years. The level of innovation is high in Finland, Germany, Hungary, Poland and Greece. In all eight Member States except Finland, most farms innovate in processes that are not new to the market. The case that most innovations took place in process innovation was also found in Dutch and Flemish FADN surveys (Diederen *et al*., 2003b; Deuninck *et al*., 2008; van der Meer and van Galen, 2016).

Table 1: Adoption of innovation in terms of share of farms (%), and total number of observations (n) per Member State (type of innovation)

Member State	product not new	product new	process not new	process new	organizational	farms with innovation	n
Finland	12	2	32	8	36	56	**50**
Germany	17	6	31	2	31	52	**52**
Greece	16	1	44	0	7	50	**124**
Hungary	17	3	41	1	20	52	**102**
Ireland	0	0	2	0	0	2	**65**
Netherlands	5	2	17	4	16	32	**155**
Poland	24	0	40	0	10	52	**146**
Spain	12	3	25	2	9	33	**128**
Total sample	**13**	**2**	**30**	**2**	**14**	**41**	**821**

Source: the authors

Within product and process innovation, the FLINT data make a comparison between new for the market (innovators) and not new for the market (early and late adopters) possible. The percentage of innovators on product and process is overall around 2%, which is much lower than the early and late adopters.

For The Netherlands, a comparison can be made with the farm-level innovation monitor. This panel-data set covers the period from 2005 onwards. In 2014 about 2% of Dutch farmers (including horticulture) were innovators and 16% could be seen as early or late adopters. The proportion of innovators in agriculture has been fluctuating for several years around 2%. Since 2011 the proportion of early or late adopters has been increasing (van der Meer and van Galen, 2016). The Dutch FLINT results are consistent with results obtained from the Dutch innovation monitor. Relative small deviations could be explained by the definition of innovation. In the innovation monitor the question is about an innovation that took place in the last year where as in the FLINT project this period is three years.

3.2 Results using FADN and merged FLINT data set

The economic size and type of farming are two of the most important structure characteristics of farms. Following the hypothesis that farmers with larger business are more likely to adopt relatively new innovation, we examined the level of innovation across different size classes. As shown in Table 2, a higher percentage of larger farms (size class 12 and 13; SO between 1,000,000 – 3,000,000 euro) innovated in new products and new processes. Organisational and market innovations are also more frequently adopted on the largest farms (size class 13 and 14; SO 1,500,000 euro and higher). Innovations in product and process that are not new to the market seem to be less dependent on farm size.

Table 2: Adoption of innovation in terms of share of farms (%), and total number of observations (n) per size class (type of innovation)

Farm economic Size class	product not new	product new	process not new	process new	organizational	farms with innovation	n
3	0	0	22	0	6	22	18
4	15	0	24	0	4	29	55
5	15	0	29	0	6	37	65
6	18	4	36	2	11	46	143
7	18	3	31	1	16	46	159
8	10	1	24	1	16	37	185
9	10	1	33	2	13	44	87
10	15	0	44	0	24	56	34
11	0	0	33	0	22	44	18
12	5	9	18	9	9	23	22
13	19	8	31	12	27	50	26
14	17	0	50	0	33	67	6
Total	**13**	**2**	**30**	**2**	**14**	**41**	**819**

Source: the authors

With regard to the type of farming, the hypothesis is that farmers who are producing for heterogeneous markets are likely to adopt innovations earlier. Based on Eurostat's farm typology, farms in horticulture and vegetables produce for more heterogeneous markets than farms in dairy and meat. As shown in Table 3, specialist farms in permanent and field crops and mixed farms (crops – livestock) have the highest percentage of innovation. Organisational and market innovations are quite homogeneous between the different farm types. In horticulture, most innovations took place for new products and processes.

Table 3: Adoption of innovation in terms of share of farms (%), and total number of observations (n) per farm type (type of innovation)

Type of farming	product not new	product new	process not new	process new	organizational	farms with innovation	n
Specialist field crops	20	2	36	1	15	48	179
Specialist horticulture	19	8	11	6	17	36	36
Specialist permanent crops	23	0	47	0	16	58	104
Specialist grazing livestock	8	2	21	3	13	33	313
Specialist granivores	12	0	25	1	10	36	77
Mixed cropping	14	5	18	0	14	32	22
Mixed livestock holdings	0	0	44	0	11	44	9
Mixed crop - livestock	10	3	43	0	14	48	79
Total	13	2	30	2	14	41	819

Source: the authors

Results of the multi-level mixed effect logistic regression are shown in Table 4. The estimated coefficients of the explanatory variables suggest that farm type and farm size are likely to be the main determinants of process and organisational innovation. Subsidies appear to have a significantly positive effect on the adoption of process innovation. Farms with younger holders are in general more likely to innovate.

Among financial indicators of the farm, farm net income has a positive effect on production innovation and organisational innovation and a negative, albeit not significant, effect on process innovation. Somewhat surprisingly, high cash flow seems to have a negative effect on innovation in general and on organisational innovation in particular. This might be explained by the fact that farms with high cash-flow are likely to be more conservative in taking on innovations. Another reason may come from the reverse causality that may be present in the data used: as innovation is informed for the three previous years while cash flow is observed for the current year, innovation may have caused a reduction of cash flow in the first years of implementing the innovation (similar to the investments' adjustment costs).

Table 4: Estimates of the adoption models (parameters are odds ratios) and standard errors in parentheses for innovations [1]

Variables	product not new	product new	process not new	process new	organizational	farms with innovation
Fixed effects						
Economic size class	0.0422	0.0859	0.131***	0.103	0.0806*	0.0940**
	(0.0508)	(0.0922)	(0.0466)	(0.0756)	(0.0489)	(0.0417)
Farm net income	2.29e-06**	2.19e-06	-2.42e-07	-1.05e-06	1.88e-06**	1.63e-06*
	(1.07e-06)	(1.50e-06)	(8.41e-07)	(1.07e-06)	(8.06e-07)	(8.54e-07)
Total subsidies	1.73e-06	3.66e-07	4.06e-06**	3.97e-06**	-1.75e-06	1.91e-06
	(1.98e-06)	(3.22e-06)	(1.73e-06)	(1.92e-06)	(1.94e-06)	(1.85e-06)
Total liabilities	-2.12e-07	-1.39e-07	-1.85e-07	1.41e-07	9.50e-09	-4.64e-08
	(1.40e-07)	(3.43e-07)	(1.37e-07)	(1.56e-07)	(1.16e-07)	(1.22e-07)
Total assets	3.96e-10	-1.19e-07	8.92e-08	1.72e-08	1.47e-08	8.65e-08
	(6.74e-08)	(1.86e-07)	(5.67e-08)	(9.12e-08)	(5.71e-08)	(6.03e-08)
Cash flow	-5.60e-07*	-3.65e-07	-1.77e-07	1.89e-07	-6.28e-07*	-6.58e-07**
	(3.37e-07)	(4.49e-07)	(2.60e-07)	(3.59e-07)	(3.22e-07)	(2.73e-07)
Age	-0.0127**	-0.0165	-0.0116**	-0.0252**	-0.0234***	-0.0175***
	(0.00638)	(0.0124)	(0.00506)	(0.0127)	(0.00623)	(0.00485)
Advisory	-0.0113	0.00205	0.0176***	-0.00383	-0.00925	0.0115*
	(0.00958)	(0.0136)	(0.00664)	(0.0135)	(0.00951)	(0.00651)
Constant	-0.913*	-2.025**	-1.256***	-1.888**	-0.639	-0.321
	(0.509)	(0.855)	(0.461)	(0.811)	(0.482)	(0.438)
Random effects						
Member State	0	0	0.270	0	0	0.340
	(0)	(0)	(0.194)	(0)	(0)	(0.247)
Type of farming	0.453**	0.148	0.0736	0.0156	0.318**	0.0750
	(0.197)	(0.213)	(0.0649)	(0.118)	(0.144)	(0.0582)
Observations	782	782	782	782	782	782
Number of groups	8	8	8	8	8	8
[1] *** p<0.01, ** p<0.05, * p<0.1						

Source: the authors

3.3 Results (alternative) using FADN only

The analysed financial indicator of the farm, total assets, is positively associated with process and organizational innovation and partly positively and negatively with product innovation (Table 4). None of these effects was statistically significant. We did not further analyse the development of assets on the farm between years. One of the problems with the development of assets over time is the lack of information on the type of investment. An increase in assets may well be the result of investments in innovations as well as replacement investments or investments to expand the farm. However, from the development in assets in FADN this distinction could not be made. Another problem is that in most cases only process innovations, for example new machines, installations, stables or greenhouses, are captured in asset changes. Product and organizational innovations remain, in many cases, out of consideration analysing only the development of assets. Based on deficiencies noted above, we conclude that data recorded in FADN on assets could not be seen as a robust proxy for innovation since FADN data on assets has too many limitations to provide information about innovations.

4 CONCLUSION

In the current study adoption rates and potential determinants of different types of innovation are quantified. Adoption rates vary substantially across types of farming and across Member States. On average 41% of the farms innovate in product, process or market and organization within the last three years. Monitoring and evaluating the aforementioned adoption rates and determinants of innovation is important to evaluating CAP policies where targeting is relevant. Within the CAP (2014-2020) the RDP offers Member States the opportunity to promote innovative farm technologies. It is now timely and relevant to focus on innovation indicators and data collection that are or can be employed to help in understanding policy targeting.

Up till now, an important obstacle in doing this analysis has been the lack of data. This study shows the potential of overcoming this problem by using data such as those collected via the FLINT project. The available data in the FLINT database is only limitedly suitable to study time lag effects of innovation. The data covers only one year. Non-adopters of an innovation within the last three years could be farmers who innovated previously (Van der Meer and van Galen, 2013). This time lag not only holds when comparing farmers but also Member States which might differ in the default level of innovation. Besides this, differences in understanding of the definition of innovations might hamper robust estimations. For policy evaluations it is relevant to know how innovations are defined exactly. The interpretation of innovation by a farmer in the different Member States is partly subjective because it is very complex to establish a list of types of innovation valid for all Member States, farm types and farm sizes. With the current dataset on innovation a comparison in the level of innovation is not feasible. The interpretation should be linked with currently innovation-seeking policies and laws in the Member States. To overcome the difference in the baseline between Member States, a link with the average level of investment in a Member State may be an indirect opportunity since innovation requires upfront investments. Financial data on investments are recorded in FADN.

In the FLINT database it is not recorded which representative of the farm responded (i.e., holder or manager). Moreover, in most Member States agriculture is mainly based on family farms (including spouses and potential successors). It might make a difference which of these entrepreneurs responded. In the current analysis this is the case with the number of advisory contacts by the farmer in a year as explanatory variable. This makes the interpretation of this indicator less reliable.

In summary, if data collection would be continued for several years the trends in adoption rates can be analysed as well as the impact on the economic and sustainability performance of farms could be estimated. The integrated character of the FLINT+FADN database allows combining economic, social and environmental aspects of farming. For policy analyses these innovation indicators are a step forward for determination of the net impacts and establishment of counterfactuals on the long run with FADN for measuring the impact of the CAP at farm level.

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APPENDIX A: FLINT DATA DEFINITIONS

Description of the categories

Category	Column	Notes
Group of information IN – Innovation		
Product Not new to the Market Product innovations are products (or services) (for marketing) that are new or significantly improved with respect to the base features (a new product), technical specifications, features such as taste, colour, race, for example, packaging or the usability or durability. The innovation must be new for the company within the last three years	*Innovation Class* *Z3_IN_1011_IC*	Indicate who has developed these products. Allowed values are: 1 = Your own agricultural enterprise 2 = A separate company (partly) owned by you 3 = Your company in collaboration with other enterprise 4 = By other companies or institutions
Product new to the Market Product innovations are products (or services) (for marketing) that are new or significantly improved with respect to the base features (a new product), technical specifications, features such as taste, colour, race, for example, packaging or the usability or durability. The innovation must be new for the company and for the market within the last three years	*Innovation Class* *Z3_IN_1012_IC*	Indicate who has developed these products. Allowed values are: 1 = Your own agricultural enterprise 2 = A separate company (partly) owned by you 3 = Your company in collaboration with other enterprise 4 = By other companies or institutions
Process Not new to the Market Process innovation is new or significantly improved technologies, and new or improved methods for the manufacture and supply of products. Consider, for example, new machines, installations, stables or greenhouses, or computer systems. The innovation must be new for your company within the last three years.	*Innovation Class* *Z3_IN_1021_IC*	Indicate who has developed these products. Allowed values are: 1 = Your own agricultural enterprise 2 = A separate company (partly) owned by you 3 = Your company in collaboration with other enterprise 4 = By other companies or institutions
	Costs *Z3_IN_1021_C*	The total cost over the last three years of this new means of production in local currency
Process new to the Market Process innovation is new or significantly improved technologies, and new or improved methods for the manufacture and supply of products. Consider, for example, new machines, installations, stables or greenhouses, or computer systems. The innovation must be new for your company and new for the market within the last three years.	*Innovation Class* *Z3_IN_1022_IC*	Indicates who has developed these products? Allowed values are: 1 = Your own agricultural enterprise 2 = A separate company (partly) owned by you 3 = Your company in collaboration with other enterprise 4 = By other companies or institutions
	Costs *Z3_IN_1022_C*	The total cost over the last three years of this new means of production in local currency

Market and organisational innovation The innovation must be new for the organization of your company and new for the market within the last three years.	*Innovation Class Z3_IN_1030_IC*	Allowed values are (multiple values are allowed): 1 = Business organization and management as offices opened, new company was established, set up new partners in company, change of legal form 2 = Marketing, as new form of packaging of products, new contracts/agreements with customers, or modified sales channels, start home sales 3 = New partnerships for example, establishment or membership of, a marketing organization (such as producer organization), study club or other entrepreneurial network; cooperation with educational institutions (such as internships and presentations) 4 = Quality Assurance, new certification or quality marks 5 = Other market and organization innovation (e.g. collective grazing practice, collective acreage, etc.)

Examples for recording of innovation:

Product innovation: Agricultural product innovations are e.g. new varieties of arable products, fruit or vegetables, new breeds of pigs or cattle, new farm-made products, or entirely new products that were introduced from other countries. The first to the firm production of a farmhouse cheese would be a product innovation. If a farm starts e.g. agri-tourism activities or a farmer shop, that would be product innovation if it is new to the firm and within the boundaries of the existing firm. Agricultural contracting for other farms (e.g. sowing, harvesting, milking services) would also be categorized as a product innovation (i.e. a new service added to the firm's product range). However, new activities clearly outside of the scope of the existing firm (start of a new business that is unrelated to the existing firm or start of work outside of the firm) are not product innovation. An example of changes to the intended uses of a product is e.g. the first (to the market or to the firm) production of sugar beet for the production of biofuels or the first (to the market or to the firm) production of eggs for pharmaceutical applications.

A new form of consumer packaging is not a product innovation if the product is not altered, but can be a marketing innovation. A new form of wholesale packaging is not a product innovation but can be process innovation. An existing product that is now sold with a certificate of sustainable production (e.g. organic) is not a product innovation, but a marketing innovation. Changing the production method from conventional to organic is a process innovation. Selling products under a (new) brand is not a product innovation but a marketing innovation. It is not a (product) innovation if a firm decides to stop doing something, like selling a particular product. Obvious alterations to the products characteristics from e.g. weather influences are not product innovations, nor are regular changes such as crop rotation.

Process innovation: Process innovation can be intended to decrease costs of production or delivery, to increase quality, or to produce or deliver new or significantly improved products. Changes to the method of production in order increase the sustainability of production (e.g. organic) is a process innovation. The first application (to the market or to the firm) of a new tractor, harvester or packaging ma-chine with improved functionality is a process innovation. The first (to the market or to the firm) use of a new tracking and tracing device or system (like RFID, GS1 or other global traceability standards, GPS tracking systems) is a process innovation. Improvements to support activities like purchasing, sales or storage can be process innovation, as long as they include technological changes to the work processes. New processes that are introduced to the firm because of the introduction of a new product are process innovations, unless they are not significantly different from existing processes in the firm. E.g. a farm that introduces a new breed of pigs may have to make minor changes to the stable or the feed mix, which are not considered a process innovation. If the stables or feed mix and system is significantly different it may be classified as a pro-cess innovation.

Simple capital replacement or extensions are not process innovations; the purchase of a new or second-hand tractor which has no added functionality compared to the replaced tractor or the purchase of another tractor of the same type is not a process innovation. The same holds for updates of software, ordinary maintenance or replacement of parts with no obvious improvement in specifications. Second-hand machinery that is a significant improvement to the farm can be a process innovation. Regular

changes to logistics that have no fundamental effect on efficiency or sales or have been used before are not process innovations.

Market and organisational innovations: Examples of marketing innovations are the introduction of a new brand with associated labelling, the introduction of a new or significantly improved website, the introduction of a product to a new or different sales channel like (first to the firm) direct sales to restaurants, schools, farm sales, or internet sales. The selling of a product to a new customer in an existing sales channel or the selling of an existing product in a new geographical area with the same marketing methods is not a marketing innovation. Seasonal or regular changes to the marketing methods that are already used before by the firm, are not marketing innovations. Regular changes to packaging that have no fundamental effect on sales or have been used before are not marketing innovations. Changes to the characteristics of the agricultural products itself (such as taste, appearance, form, genetics) can be categorized as product innovations, if they are significant improvements/changes in the view of the entrepreneur (contrary to Oslo Manual guidelines).

Organisational innovations may include e.g. the introduction of supply chain management systems or quality management systems, the first (to the firm) introduction of new management structures, changes to the business entity structure (legal form), or the entry into a formal partnership with other firms or public (research) organisations. Outsourcing of parts of the work previously done by the firm can be an organisational innovation. However, stopping to perform certain activities (without outsourcing to other firms) is not an innovation. Mergers and acquisitions, are not organisational innovations. They may however cause the firm to implement other organisational innovations.