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Foreword

Studies in Agricultural Economics is a peer-reviewed Web of Science™ journal and is 'platinum' open access, i.e. there are no publication or access fees of any kind. Coupled with the fact that it is published in print and online, this means that it is well placed to support the European Union's (EU) aspirations to increase accessibility to the results of the research it funds.

This fact is clearly recognised by Wageningen Economic Research, the coordinators of the EU Framework 7 project FLINT (Farm-level Indicators for New Topics in policy evaluation), and they have opted to publish a thematic issue of their research papers in *Studies in Agricultural Economics*. FLINT (www.flint-fp7.eu) brings together 11 partners from nine EU Member States (the Netherlands, Finland, France, Germany, Greece, Hungary, Ireland, Poland and Spain) in a consortium that combines universities with a track record on sustainability issues with research organisations with a long tradition in data collection and policy analysis. With this profile of expertise behind them, the results of the research are likely to be of real interest to this journal's target audience of researchers, academics, policy makers and practitioners.

Poppe, Vrolijk, Dolman and Silvis set out the rationale behind FLINT. For policy evaluation, there is an increasing need for a broader set of farm-level data in the EU, especially on sustainability issues. FLINT was designed to test the feasibility and added value of collecting such data via the Farm Accountancy Data Network (FADN), the EU-wide system for collecting representative farm-level data.

The availability of sustainability indicators and the criteria for defining and choosing them are reviewed by Latruffe, Diazabakana, Bockstaller, Desjeux, Finn, Kelly, Ryan and Uthes. Economic indicators have a long tradition and target a relatively small number of well-defined themes but there has recently been an 'explosion' of environment-related indicators. Social indicators tend to be difficult to measure as they are more qualitative and subjective.

Data collection is more feasible if stakeholders consider the data to be important. Herrera, Gerster-Bentaya and Knierim demonstrated differences in the stakeholders' perceived feasibility and usefulness of collecting farm-level sustainability indicators, especially for those indicators which are not useful for farm-level decision making. These results were used in the selection of indicators in the FLINT project.

There is a wide variety of FADN systems. Drawing on a theoretical evaluation and the practical experiences of collecting sustainability data on more than 1,000 farms, Vrolijk, Poppe and Keszthelyi concluded that data collection could be extended to a wider set of sustainability issues across a range of organisational settings. The trust between the data collector and the farmer is an important success factor.

Several empirical analyses were conducted to show the added value of FLINT sustainability data. Brennan, Ryan, Hennessy, Cullen and Dillon examined the use of extension services by farm households and observed stark differences between eight Member States that are attributable primarily to national policies. Furthermore, they found that the extent to which households engage with extension services has implications for farm-level sustainability.

The FLINT data have made it feasible to assess the adoption of risk management strategies by farmers and the determinants of farmers' choice for complementary or substitute instruments. Van Asseldonk, Tzouramani, Ge and Vrolijk show that adoption rates of instruments such as insurance contracts, price contracts, off-farm income, other risk reduction measures and other gainful activities vary significantly across Member States and farming types.

Analysis of farm economic sustainability using FADN data traditionally focuses solely on income from farming activities. The FLINT dataset facilitates the assessment of a group of farms categorised as 'sustainable', i.e. which are economically vulnerable but are deemed sustainable via off-farm labour. O'Donoghue, Devisme, Ryan, Conneely, Gillespie and Vrolijk identified differences in farm viability and sustainability across the eight Member States surveyed.

Finally, Van Der Meulen, Van Asseldonk and Ge used the FLINT data to analyse the different adoption rates of innovations in European agriculture. They described the impact on innovation rates of farm structure, financial characteristics, farmer characteristics, and the impact of subsidies and use of advisory services on the adoption rates.

As Editor-in-Chief, I would like to record my sincere thanks to Dr. Hans Vrolijk, the co-Coordinator of FLINT, for his outstanding support in bringing this thematic issue to fruition. Coordinators of other international research projects are invited to contact me with a view to producing similar thematic issues in the future.

Andrew Fieldsend
Budapest, November 2016

Workshop report

DANUBIONET open innovation workshop

Budapest, 6 October 2016

Danube-INCO.NET (Advancing Research and Innovation in the Danube Region, https://danube-inco.net/) is a coordination and support action funded under the European Union's (EU) 7th Framework Programme for Research and Technological Development. It seeks to overcome obstacles hindering social and economic development in the Danube Region by advancing research and innovation.

DANUBIONET (Building a Bioeconomy Research and Advocacy Network in the Danube Region, https://danube-inco.net/object/project/16564) is a 'pilot action' within Danube-INCO.NET. It intends to foster the development of a sustainable bio-based economy, with a particular focus on the Middle Danube area and on biomass feedstock from agricultural and forestry activities and organic industrial by-products.

DANUBIONET held its first 'Open Innovation Event' in Budapest on 6 October 2016, in association with the 2016 European Rural Development Network conference. The workshop, jointly organised by PANNON Pro Innovations Ltd, Budapest and the Central European Initiative, Trieste, brought together 13 experts from six countries of the Danube Region, with the aim to develop approaches to promote the use of sewage sludge based products in agriculture, in the spirit of sustainable farming and the circular economy.

In her introductory presentation, Juhász Anikó, General Director of the Research Institute of Agricultural Economics, which hosted the workshop, endorsed the need for a specific regional approach in the Danube Region. She noted that the workshop fits well with the BioEast strategic research agenda which aims to catalyse bioeconomy development in the Danube Region by showing that a regional approach and excellence are complementary measures (see *Studies in Agricultural Economics* volume 118 number 2 for details). While there is significant knowledge in the region, it is still necessary to learn how to sell it and manage innovation. She concluded that now is the right time to launch BioEast as the scoping paper for the final three years programming for the EU's Horizon 2020 programme for research and innovation has been published, and she encouraged participants to use the workshop to develop new ideas and cooperation possibilities.

The topic of the workshop had been put forward by DOW Agrosciences, a multinational company that has been active in agriculture since 1952. The company's innovation performance has been awarded several times with the Green Chemistry Awards in the USA. The 'challenge owner', as the entity seeking solutions is called in these workshops, asked participants to contribute original ideas for improving the public perception and end-user acceptance of sewage sludge based compost in agriculture. This type of material, which is rich in nutrients, especially nitrogen, has multiple benefits with respect to soil preservation, cost reduction and productivity, but it is burdened with preconceptions, doubts and concerns among various groups of actors. The workshop therefore facilitated the elaboration of possible solutions to overcome end-users' reluctance and apprehension by focusing on the economic and environmental benefits of nutrient recycling.

Building on the results of the DANUBIONET capacity building survey, completed earlier by 95 stakeholders, the experts developed their ideas relating to the specific factors of societal perception and awareness, available standards and labelling, as well as sound business models. This interactive process was facilitated by Be-novative Hungary and Demola Budapest. As a first step, participants took part in a virtual brainstorming to generate ideas on how to overcome the challenge. A cloud-based platform was used through which users could anonymously share their thoughts and ideas on the question 'How can the communication and marketing tools be used to convince buyers about the safety and compliance of sewage sludge based products?'. In only 20 minutes this session yielded 81 automatically evaluated ideas for overcoming this challenge, including a variety of solutions from communication to test fields and education.

Using these first ideas, the participants continued their work in teams, mixing the ideas and finding synergies and possible collaborations in order to create proposals convincing enough for the 'challenge owner' and mature enough to form the basis of future projects. The tool used here was building a 3D prototype based on the method of Demola Budapest. These prototypes – built of everyday materials such as paper, straws and plasticine – acted as a visualisation of the project concepts and hence as tangible representations of abstract or complex thoughts. This creative and playful approach makes it easy to reveal connections and schemes. Finally, a proposal was drawn up as a result of the creative work that contributed to find the complementary activities of the participants.

Sándorfy András of DOW Agrosciences concluded that the workshop was an excellent platform for learning new, valuable and interesting approaches. Under the leadership of PANNON Pro Innovations Ltd. and Central European Initiative the proposal from the workshop will be further developed with a view to implementing the idea, thereby creating a circular economy of nutrient recycling.

More information about DANUBIONET, the series of Open Innovation Events and their outputs is available by email from Gyalai-Korpos Miklós PhD, Project Development Manager at PANNON Pro Innovations Ltd, at miklos.gyalai@ppis.hu.

Krijn POPPE*[1], Hans VROLIJK*[2], Mark DOLMAN* and Huib SILVIS*[3]

FLINT – Farm-level Indicators for New Topics in policy evaluation: an introduction

Societal expectations about agricultural production are changing. There are increased demands on issues such as food safety, animal welfare and the impact of agriculture on the environment (land, water and air). These changes have been reflected in the European Union's (EU) Common Agricultural Policy (CAP), but information on these issues is lacking and this complicates the required evaluation of policies. The EU Framework 7 project FLINT tries to close this gap by analysing the feasibility of collecting data on these new topics. FLINT has established a data infrastructure with up-to-date farm-level indicators for the monitoring and evaluation of the CAP. The project created a pilot network of more than 1,000 farms to collect a set of sustainability indicators at farm level. The pilot represents farm diversity at EU level, including the different administrative environments in the Member States. This paper sets out the context and the main contributions of the project.

Keywords: policy analysis, data needs, farm performance, sustainability

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Introduction

The grand challenge for agriculture is to attain higher levels of production of safe and good quality food, while preserving the natural resources upon which agricultural productivity depends (Folke *et al*., 2002; Robertson and Swinton, 2005; Tscharntke *et al*., 2012; Ringler *et al*., 2013). Individual farmers play a crucial role in the agri-food supply chain which connects input industries, food industry and retail, and is governed by both markets and policies (Tilman *et al*., 2002). The changing societal expectations towards agriculture in Europe are reflected in the evolution of the European Union's (EU) Common Agricultural Policy (CAP) (EU, 2012; EC, 2013).

According to Article 39 of the Treaty of Rome (1957)[4], the objectives of the CAP are to increase agricultural productivity, to ensure a fair standard of living for the agricultural community, to stabilise markets, to assure the availability of supplies and to ensure that supplies reach consumers at reasonable prices. In the early period of the CAP, most attention was devoted to market and price policies with the central objective of fostering a reasonable level of income in agriculture. However, over recent decades, several changes have been made to the CAP, mainly in response to production surpluses, budgetary problems, market disruption for third countries and pressures on the environment. Starting in 1992, the CAP has been through successive reforms, which have increased the market orientation for agriculture, while providing income support and safety net mechanisms for producers, improved the integration of environmental requirements, and reinforced support for rural development across the EU.

The policy for 2014-2020 continues along this reform path, moving from product to producer support and increasingly to a more land-based approach. The European Commission (EC) has identified three challenges for the CAP for this time period (EC, 2013). Firstly, an *economic challenge* including concerns over food security and globalisation, a declining rate of productivity growth, price volatility, pressures on production costs due to high input prices, and the deteriorating position of farmers in the food supply chain. Secondly, an *environmental challenge* that relates to concerns on resource use efficiency, soil and water quality, and threats to habitats and biodiversity, and thirdly, a *territorial challenge*, where rural areas are faced with inadvertent demographic, economic and social developments, including depopulation and relocation of businesses.

The role of the current CAP is to provide a policy framework that supports and encourages producers to address these challenges while remaining coherent with other EU policies. This translates into three long-term CAP objectives, namely viable food production, sustainable management of natural resources and climate action, and balanced territorial development (EC, 2013). To achieve these goals, the CAP instruments have been adapted. The reform for the period 2014-2020 focused on the operational objectives of delivering more effective policy instruments, designed to improve the competitiveness of the agricultural sector and its sustainability over the long term.

These changes in the societal expectations of agriculture, as well as the reforms of the CAP, have created a demand for new information. The role of evidence-based policy making and evaluation has been strengthened to improve the effectiveness of policies, and especially to improve the targeting of measures and prevent perverse effects (EC, 2009). To enable the effective management of a change programme, such impact assessments and monitoring and evaluation efforts are ideally based on empirical data. This requires a monitoring tool that empirically documents important trends in a way that developments can be attributed to the relevant policies and separated from other influences.

Data needs and data provision

Changing data needs

The availability of information has been criticised by different stakeholders at different moments in time. In 2002, the European Court of Auditors (ECA, 2003) asked the EC to expand its view on the income of farmers and not only focus

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4 Copied in the Treaty on the Functioning of the European Union as Article 33.

on the income from agricultural production. In response, the Farm Accountancy Data Network (FADN) started to collect and include data on other gainful activities (such as farm tourism, processing of products, farm sales). Evaluators of rural development programmes (applying the Common Monitoring and Evaluation Framework, CMEF) found a lack of adequate micro-economic data for policy evaluation (Ahner, 2004). Also, researchers identified information gaps. Several EU-funded research projects recommended to improve measurement and data collection for (policy) research, either in general (SEAMLESS; van Ittersum *et al*., 2008), or on specific topics such as organic farming (EISfOM; Recke *et al*., 2004) or sustainability (SVAPPAS; Van Passel, 2008). In a more recent report (ECA, 2016), the European Court of Auditors addresses the difficulties of monitoring the CAP objectives and the limitations of the available data.

In the current situation the availability of relevant data is a bottleneck for the monitoring and evaluation of these new topics. Although a set of well-established agricultural statistics is available for policy analysis, these are very much focused on structure (Eurostat, Farm Structure Survey; EC, 2008) and monetary economic results of farms (FADN system; EC, 2009). Some changes in data collection have been made in the last few years (new FADN Farm Return including N, P and K use and SAPM survey by Eurostat[5]) but, in general, the official statistics are not sufficiently adapted to new information needs.

Current initiatives

As a response to this lack of data on sustainability issues, many international indicator frameworks have been developed that especially focus on environmental indicators (e.g. EAA (EAA, 2003), Eurostat (EC, 2006), FAO (FAO, 2010), OECD (OECD, 2013)). The Millennium Development Goals and Sustainable Development Goals[6] take a wider perspective and present a set of indicators measuring different dimensions of sustainability. Although very appropriate for identifying relevant topics and the definition of these topics, most of these frameworks do not allow for farm-level policy analysis. The indicators are often specified at more aggregated levels (regional or national) and not at farm level.

Also the agri-food sector responds to these new needs. The UN Global Compact[7] principles and the Sustainable Development Goals highlight directions to pursue on sustainable development that relate to, among others, food security, resource efficiency and environmental impacts in agriculture (Griggs *et al*., 2013). Food and beverages processing companies often express their commitment to improve on these internationally-recognised goals and principles in their corporate social responsibility reports. Reporting guidelines set by organisations such as the Global Reporting Initiative provide direction to what indicators could be included, and which data are needed to report against these indicators (Vigneau *et al*., 2015). Another example where there is a farm-level data need is for certifications schemes such as Global G.A.P.[8] or the Irish *Bord Bia* Quality Assurance Schemes[9]. Data assembling is often in place, or linked with farm management systems. Alongside standards and certifications that are being developed to measure sustainability performance, there are also sector-based initiatives that pursue alignment across initiatives such as the Sustainable Agriculture Initiative (SAI) Platform[10]. The SAI Platform works on tools and guidance that enhance the support for both global and local sustainable practices and sourcing. Another more sector-specific example is the Dairy Sustainability Framework (DSF)[11]. The DSF is a programme of the Global Dairy Agenda for Action (GDAA) that aims to align and connect sustainability initiatives in the dairy supply chain.

At a national level, there are several initiatives on the development of empirical indicator frameworks which are directly linked to data collection to capture the sustainability performance of farms at farm level (Boone and Dolman, 2010; Dillon *et al*., 2010; Platteau *et al*., 2014). Although these initiatives are successful in measuring (certain aspects of) farm-level sustainability, a current limitation is that the measurement and data collection are not harmonised among countries. This lack of harmonisation and especially the fact that this information is only available for a limited set of countries hampers its use in EU policy evaluation.

Data collection

The collection of sustainability data at farm level for policy evaluation purposes is still in its infancy. Although the FADN system was renewed in recent years, and a new data collection form ('Farm Return') with some new environmental indicators was introduced in 2014, it has been difficult to adjust the FADN system to the new policy realities in the CAP. Some progress with data collection on new farm-level indicators has taken place in some Member States. The Dutch FADN has for many years included an extended set of sustainability indicators (Boone and Dolman, 2010), as well as data on innovation by farmers (Van Galen and Poppe, 2013), and several countries have collected and analysed data on knowledge transfer in the farming sector (Floriańczyk *et al*., 2012; Läpple and Hennessy, 2015; Dillon *et al*., 2016). The Irish FADN has also collected Triple P sustainability data for policy analysis (Dillon *et al*., 2010). The Irish dataset is currently being further developed to arrive at estimates of the carbon footprints of farms using methodologies approved by the Carbon Trust. The FADN in Vlaanderen, Belgium gathers information for a barometer on farm managers' business confidence. At recent Pacioli meetings, successful developments in sustainability indicators at national level were presented (Vrolijk, 2013). Van Calker *et al*. (2007) distinguished several indicators relevant for rural sociology.

There are several reasons why this progress could not be achieved at EU level yet. An important reason is the divergence in data collection systems among EU Member States (Vrolijk *et al*., 2016). Some systems are easier to adapt than

[5] http://ec.europa.eu/eurostat/statistics-explained/index.php/Survey_on_agricultural_production_methods
[6] https://sustainabledevelopment.un.org/?menu=1300
[7] https://www.unglobalcompact.org/
[8] http://www.globalgap.org/uk_en/
[9] http://www.bordbia.ie/industry/farmers/quality/pages/qualityassuranceschemes.aspx
[10] http://www.saiplatform.org/
[11] http://dairysustainabilityframework.org/

others. The development of new indicators has been further complicated by the challenge for DG AGRI to include the 'new' Member States into the FADN system. Furthermore, the decision making is influenced by expectations about the feasibility and willingness of farmers to participate, which have never been tested in practice.

Future data infrastructure at EU level

The existing initiatives to improve data provision differ in level of measurement (farm, regional or national level), empirical implementation (some frameworks exist on paper but it is unclear how data should be collected), or are not harmonised across countries. Therefore, enhanced efficiency, coherence and synergies require further development of the FADN farm-level dataset, with a view to monitoring the full behaviour of farmers and how they integrate the different policy incentives in their decision-making processes and how that affects their sustainability performance. However, this has raised concerns vis-a-vis the voluntary participation of the farmers in the network and the feasibility of collecting this type of data. Any extension of the data collection will be limited by (a) the current data collection methods in each Member State, (b) the willingness of farmers to voluntarily supply additional data, and (c) the cost of collecting additional data.

There are several ways to address these challenges. The crucial thing is not to separate information needs for policy making and research from what is happening in the agricultural sector. Considering the trends of big data, internet of things and precision agriculture, the availability of information will only further increase. Also, the need for information in the agri-food sector increases continuously. Agricultural statistics should be an integral part of the whole system of information needs and information flows throughout the agricultural sector (Vrolijk and Poppe, 2016). Two aspects are important, increased use of registrations and information flows which already take place in the agricultural sector and maximum use of modern information technologies for data exchange.

Increased use of existing data concerns for example the use of other sources such as administrative data, the agricultural census, data from the paying agencies on direct payments (the IACS system), remote sensing data and Geographic Information Systems (GIS). Solutions can also be found in connecting with private sector developments. At farm level, farmers are already asked to collect and provide data on sustainability and food safety issues for schemes such as Global G.A.P. and the British Retail Consortium (BRC). Leading management tools are the Keystone Field to Market, the BASF Ag Balance tool, the Cool Farm Tool, RISE and the Stewardship Index for Specialty Crops, as well as farm software packages with a regional installed base. This plurality of tools also poses a challenge, an initiative such as SAI tries to harmonise the indicators to allow the exchange of information between these schemes.

Also the information technologies for data exchange support the re-use of data. The construction of data infrastructures for farm-level indicators may benefit from developments in this field. EDI standards (promoted by, for example, GS1 and UN/CEFACT[12]) have been developed that facilitate information exchange between companies. SDMX[13] is a standard for the exchange of statistical data. Standard Business Reporting defines XBRL standards to exchange information between banks, businesses and the government. These initiatives facilitate the efficient exchange of information and thus allow the re-use of information.

Contributions and approach of FLINT

The EU Framework 7 project FLINT (Farm-Level Indicators on New Topics in policy evaluation) was created to address the gap between the data needs for policy evaluation and research and the currently-available agricultural statistics. The monitoring and evaluation of the CAP requires data (preferably at farm level) which are not available at the moment in the EU information systems. Attempts have been made to modernise these systems but decisions were strongly influenced by expectations about the feasibility of data collection and the willingness of farmers to participate. FLINT provides an opportunity to test the feasibility and to show the added value of having a wider set of sustainability indicators to monitor and evaluate the agricultural policies and design more targeted policy measures.

Main contribution and research questions

The foregoing leads to the two key objectives of FLINT: (a) to demonstrate the feasibility of collecting policy-relevant data in different administrative environments with newly-developed farm-level indicators on economic, environmental and social issues, and (b) to demonstrate how the new farm-level indicators can be used to evaluate policy and improve the targeting of policy initiatives in such a convincing way that the EC can establish an operational EU-wide system to collect the extended set of farm-level indicators.

To achieve these contributions, the FLINT project formulated five key questions:

- What data are desirable? What farm-level data are needed for the CAP evaluation?
- What data can be feasibly collected in the value chain? Data collection is costly and depends on the collaboration of farmers. What is the farmers' level of awareness and what is their willingness to share this information? What information do farmers already share with the food industry?
- What is a feasible pilot network? What and how do we test in a pilot network and how can up-to-date ICT support such a European infrastructure?
- What data are useful? Are the newly-collected farm-level data really essential in policy evaluation? To which extent could proxies be used? Is it really necessary to gather all data in an integrated way at individual farm level?
- What level of ambition is acceptable? The usefulness of data in policy monitoring does not guarantee that

[12] http://www.gs1.org/edi
[13] https://sdmx.org/

stakeholders and data collectors will collect them. So, what are acceptable scenarios for the future data infrastructure in an era of tight budgets?

Approach of FLINT

FLINT evaluated existing policy measures and accompanying methodologies, such as agri-environmental indicators and the CMEF covering the CAP as a whole. The contribution of other sources, such as the OECD, or other initiatives, such as EU strategies or Member State schemes, which are related to farm-level practice and outcomes, were taken into account. Following this analysis of policy evaluation needs, FLINT reviewed the data and indicators currently available through FADN sources and identified gaps and deficiencies in the current data availability. The stock of variables available in the various Member State FADN datasets varies and the capacity/willingness of the various countries to collect additional data is also variable. Hence a pilot in a number of countries with different data collection methods and coming from different starting points was set up.

FLINT established a pilot network of more than 1,000 farms (representative of farm diversity at EU level, including the administrative environment in the different Member States) that is well suited for gathering data on the basis of farm-level indicators to test indicators and methodologies. Testing the data infrastructure required that the identified farm-level indicators are defined, standardised and decomposed into data items that can be collected at farm level (including data from other sources such as administrative data, farm structure survey, commercial data). Software was developed and/or adapted to collect these data, test the data and calculate the indicators. In this way, the pilot provided invaluable information about the operational structure, the feasibility and the time-frame required to collect such data and develop such indicators.

The value added of the newly-developed indicators is tested in the analysis of a number of policy-relevant analyses. The lessons learned from the project are used to advise the EC on upgrading the data collection and indicator development to an operational EU-wide system.

Identification of indicators

At the start of the project, FLINT analysed the developments in the CAP and related environmental policies to determine the impact on information needs. Furthermore, an extensive review of the literature and national initiatives in all nine partner countries produced an inventory of relevant indicators already developed or applied (Latruffe *et al.*, 2016). A comparison of the policy needs and the identified indicators has resulted in the identification of 33 sustainability themes to be included in the FLINT project. The themes cover the three sustainability dimensions of people, planet and profit (see Hererra *et al.*, 2016) for a description of the indicators). The list of environmental indicators themes is the longest, indicating the serious lack of data at farm level on these issues. The environmental indicators cover important topics such as use of pesticides, nitrogen balances, water consumption, greenhouse gas emissions, farm practices with respect to soil erosion, nitrate leaching and soil organic matter. There are fewer economic indicators but these refer exclusively to those not yet included in FADN. They cover topics such as risk management, innovation, sales channels, farm succession and the use of contracts. The social indicators are the most qualitative by nature and involve issues such as education and training (use of advisory services), engagement in the farming sector and rural society, quality of life and working conditions.

To align the information needs from the sector with the information needs of policy makers, the selection of indicator themes also included a stakeholder analysis. The underlying idea is that collection of data is more feasible if the information is also relevant for the farmers themselves. If information needs overlap, this would improve the availability of data, the quality of the data and the farmers' interest. In the stakeholder analyses, the indicators were assessed by stakeholders from the agricultural sector (Herrera *et al.*, 2016).

Pilot data collection

The pilot data collection required the development of an appropriate IT structure and the implementation of data collection and data management processes.

The indicators are not directly measurable at farm level because of the level of aggregation (for example N balance or greenhouse gas emissions). Therefore, each of the themes was translated into a well-defined set of variables with a detailed explanation and instruction for data collection[14]. In theory, around 1,000 new data items were added to the existing dataset, in practice (owing to the fact that only a subset of items is relevant for a specific farm) about 300-400 items were added at farm level.

The FLINT variables were collected in addition to the regular FADN variables. For each country a practical approach for data gathering at farm level was designed. This was necessary because the systems and processes of FADN data collection differ strongly between countries (Vrolijk *et al.*, 2016). The objective of FLINT was not to harmonise FADN data collection across Europe, but to find ways to collect sustainability data that fit the local situation and make use of the local infrastructure and already existing data sources.

An IT infrastructure was developed to collect data, to upload the data to a central FLINT database, to check the data using the test engine for the regular FADN data of DG-Agri, and to disseminate the data to the users of the FLINT database. Owing to the differences between countries, the data collection tools were not fully harmonised. Some countries used a data entry form developed for FLINT, while others integrated the data collection into their normal FADN data collection systems and processes. The testing was done in a similar way as the FADN data is tested. FLINT specified a number of testing rules (especially to test the magnitude of the values and the consistency between different data elements). These testing rules were implemented in the FADN test engine of the EC in Brussel. This approach also made it possible to test the consistency between the FLINT and the FADN variables.

[14] See FLINT farm return at www.fp7-flint.eu.

Use of sustainability

Besides evaluating the feasibility of the data collection, another important objective of FLINT is to demonstrate the added value of having a wider set of data at farm level on the measurement of the sustainability performance. FLINT has defined a set of cases to evaluate and illustrate the added value. The cases are linked to the policy priorities described above and aim to cover the main themes of data collected in FLINT. In principle, three categories of applications can be distinguished:

- Establishing the impact of existing policy measures on other sustainability issues. FLINT can better help to assess if the CAP can reach its long-term goals of viable food production, sustainable management of natural resources and balanced territorial development. FLINT allows for the integrated evaluation of the current policies by also taking into account the performance on other sustainability indicators;
- Evaluating the usefulness of other instruments of the current CAP. For example, FLINT can assess the impact of risk management strategies or innovation on the sustainability performance of farms;
- Simulations that can help design a new CAP. For example, whether farmers are currently far from the new requirement levels or evaluate new target indicators that are not covered by the current CAP such as pesticide use, or assessments of how measures affect the economic performance of farms.

A list of cases has been defined, including topics such as: impact of innovation on productivity and sustainability, impact of subsidies on technical efficiency (excluding and including environmental outputs), impact of young farmers on sustainability and productivity, market outlets, risk management and farm income, energy use and sustainability, greenhouse gas emissions and productivity (dairy), fragmentation and sustainability and general trade-offs between economic, social and environmental dimensions.

Discussion and conclusions

Owing to the changing societal concerns about agricultural production and its impact on agricultural policies, the present data infrastructure for policy evaluation is outdated on some relevant issues. There is an increased demand to measure the sustainability performance of farms. The current set of agricultural statistics provides only very limited information on these issues.

In the project, lessons have been learned from previous work on international sustainability frameworks and national initiatives on sustainability measurement. These frameworks have been important in defining the concepts of sustainability (especially environmental) but often do not have a link with farm-level data collection. Some national initiatives have proven beneficial because they have tested the collection of farm-level data, but these have the drawback that they are not harmonised and have a different focus in sustainability issues.

The FLINT project has developed a new data infrastructure for the collection and use of a broader set of sustainability indicators at farm level. It has tested the feasibility of collecting farm-level data and experiences of farmer participation and has tested the feasibility in different administrative environments in the partner countries. An integrated data assembly at the micro level has several benefits. Extending FADN with environmental and social performance indicators allows for the integrated analysis of policy questions. The trade-offs between sustainability indicators can be analysed, for example the economic impacts of specific environmental or social policy measures, evaluation of the cost-effectiveness of environmental or animal welfare measures, and the trade-off or jointness between the environmental and economic performance of farms (e.g. Dolman *et al.*, 2012). This enables better policy analysis and the design of more targeted policy measures. It also provides benefits for the farming sector. Reporting sustainability performance to farmers allows for increased understanding and identification of improvement options. The harmonised approach followed in FLINT facilitates an international comparison of sustainability performance.

The project will conclude with recommendations for the future. The project findings have been discussed at the FADN committee meeting, Pacioli workshop and FLINT advisory board meeting. The most promising scenarios have been selected, and further developed and quantified. These most promising scenarios range from a follow-up to the FLINT project (but then including all Member States) to a full integration into FADN. In such a full integration, options range from collecting FLINT data on a subsample of farms to reducing the full FADN sample to compensate for the additional work of collecting FLINT data. The impacts on costs, quality of the estimates and the sampling plans are being quantified. Even so, some recommendations are already clear. Data collection should become more efficient. All stakeholders agree that re-use of existing data should be stimulated. This not only requires that projects experiment with this sharing of experiences among Member States but also the development of legal frameworks to facilitate this. Furthermore, there is a strong interest in international cooperation for the development of software and systems for data collection.

A positive impact of FLINT is that several of the participating countries have indicated a wish to continue with part of the FLINT data collection for national purposes.

Looking to the future, there are opportunities for further integration of sector and policy initiatives. The FLINT project objective is to provide quantitative information that helps policy makers to make decisions or to evaluate the impact of decisions for a country or farm type. There are many initiatives that measure sustainability performance in agricultural systems. The goal of the initiative determines what data should be assembled and which tools and indicators could be used to measure processes and practices. Despite the differences in goal and scope, there are opportunities for harmonisation and alignment between measurement frameworks, tools and data assembling systems. At product level, for example, the EC initiated the Product Environmental Footprint (PEF). The PEF is a multi-criteria measurement framework for the environmental performance based on a life cycle approach (Lehmann *et al*., 2015). Within the PEF, primary and secondary data needs are identified. Primary data need to be provided by a company, whereas secondary data are data from PEF-designated data sources. Data from the FLINT project could strengthen these secondary data sources, and might even provide primary data for a food producing company. Another product-level example is The Sustainability Consortium (TSC). TSC convenes stakeholders in consumer good supply chains and develops science-based key performance indicators (KPI) that measure environmental and societal performance per product category based on a life cycle approach. Quantifying KPIs often requires farm-level data or regional estimates from a sub-country area or agricultural zone, which FLINT could provide.

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Measurement of sustainability in agriculture: a review of indicators

In recent decades, the concept of sustainability has become increasingly prominent in agricultural policy debates. This has led more and more stakeholders to pay attention to the questions of monitoring and evaluation of agricultural practices, and raised the question of appropriate indicators to assess sustainability aspects of given practices. We provide here a review of indicators of sustainability for agriculture. We describe sustainability indicators used in the literature following the typology based on the three sustainability pillars: environmental, economic and social. The literature review shows that the environmental pillar has undergone an 'indicator explosion', due to the multitude of themes covered and the attention given by society to this dimension of sustainability. By contrast, economic indicators target a relatively small number of themes. Social indicators typically cover two main themes: sustainability relating to the farming community and sustainability relating to society as a whole. The measurement of these social indicators is challenging as they are often qualitative and may therefore be considered subjective. Careful attention should be given to the choice of indicators, since the data measured will influence the calculation of that indicator and therefore the outcome of the analysis. It should first be decided whether individual or composite indicators are preferable, and whether single indicators or a set of indicators should be used. Also, sustainability assessments should be validated, credible and reproducible. Several selection criteria are provided in the literature, such as representativeness, transferability, adaptability and measurability at an acceptable cost.

Keywords: indicator typology, indicator selection, composite indicators, stakeholders, data

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Introduction

The concept of 'sustainable development' was introduced by the 'Brundtland report' in the late 1980s (WCED, 1987). The report attempts to reach a consensus on the perception of the concept, defining sustainable development as an 'economically viable, environmentally sound and socially acceptable development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. Since then, 'sustainability', 'sustainable development' and 'sustainable intensification' have often been used as catch-phrases with different interpretations to qualify actions undertaken to reduce the impacts of human activities on the environment. Nevertheless, the concept is increasingly prominent in current agricultural policy debates.

The principle of sustainability has been integrated into the objectives of the European Union's (EU) Common Agricultural Policy (CAP), however the application of this concept to agriculture has resulted in a multiplicity of definitions. Efforts have been made to produce an integrated definition of this term: the application of the concept of sustainable development in agriculture is of interest both for the sustainability of the agricultural system itself and its contribution to sustainable development (Alkan Olsson *et al*., 2009a). For farms, the contribution to sustainable agriculture often involves: (a) the production of goods and services (economic function); (b) the management of natural resources (ecological function); and (c) the contribution to rural dynamics (social function). The harmonious combination of these three interconnected functions constitutes the backbone of sustainable agriculture. To move towards sustainability, it is necessary to achieve acceptable results in all dimensions of sustainability. A key point in agriculture is the dependence of sustainability assessment on farm-scale indicators: the farm is the unit of decision-making and there is high variability across farms, even within given individual contexts and farming systems.

In practice, sustainability assessment generally involves dividing the individual dimensions into various issues of concern – called objectives, attributes or themes (see Figure 1 in Ode *et al*., 2016) – and assessing these objectives using indicators. Indicators are variables (qualitative/quantitative data observed, measured or calculated from other data) which supply information on other variables (criteria) which are more difficult to access and which can be used as a benchmark for decision making. Indicators are "statistical constructs which support decision-making by revealing trends in data" (Dillon *et al*., 2014, p.3). The last fifteen years have seen an international proliferation of methods based on sets of indicators to assess various issues under one or more dimensions of sustainability (over 200 identified, see Rosnoblet *et al*., 2006) or to evaluate a specific problem (Bockstaller *et al*., 2009a) (see Diazabakana *et al*., 2014 for a more detailed review).

We provide here an overview of how sustainability is measured in an agricultural context. We firstly describe the three main sustainability pillars that are generally used in the literature and discuss the main themes of indicators within each of the pillars. We then provide some guidance on how to choose indicators.

Typology of indicators based on the three sustainability pillars

Environmental pillar

Lebacq *et al*. (2013) grouped environmental indicators found in the literature into ten environmental themes/topics that focus either on discernible physical aspects of the

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environment or on human activities with substantial environmental impact. These themes relate to nutrients, pesticides, non-renewable resources (i.e. energy and water), land management, emissions of greenhouse gases (GHG) and acidifying substances, biodiversity, and physical, chemical and biological soil quality. More generally, three groups of environmental themes can be distinguished:

- themes related to local or global impacts, which have consequences on the functional units used to express the indicators (Halberg *et al*., 2005);
- themes according to the action chain, namely the ultimate goal (e.g. human health), the process to achieve the goal (e.g. balance of environmental function) and the means (e.g. protecting environmental compartment) (Alkan Olsson *et al*., 2009b);
- themes based on goal-oriented frameworks (where themes are goals to be achieved) and frameworks oriented towards system properties (where themes are system properties) (Bockstaller *et al*., 2007).

An 'indicator explosion' (Riley, 2001) is particularly evident for the environmental dimension. Over the last 20 years, a plethora of initiatives has been proposed with a very broad array of indicators (Rosnoblet *et al*., 2006), due to 'the growing concern for environmental issues and sustainability' (Bockstaller *et al*., 2008). Although literature reviews are available for sustainability assessment methods based on indicators for specific themes, such as pesticides (e.g. Reus *et al*., 2002), nitrogen (Buczko and Kuchenbuch, 2010) or biodiversity (Dennis *et al*., 2009; Bockstaller *et al*., 2011), there is relatively little integration of these topics into whole-farm assessments across indicator sub-themes, and then across the three dimensions.

A key feature of many environmental indicators is their reliance on a valid cause-and-effect relationship, and that indicator data can then be used to measure some combination of causes and effects. The well-known Driving force – Pressure – State – Impact – Response (DPSIR) (EEA, 2005) framework is inspired by this cause-effect chain. One major drawback is the impression of linearity between pressure, state and impact given by the framework, whereas the reality is more complex and closer to a causal network than to a chain. Bockstaller *et al*. (2008) further elucidated the concept of impact by dividing it successively into state/exposure/impact, so that impact means the final effects on human health or the economy. In Life Cycle Analysis (LCA), indicators of final impacts are qualified as 'endpoint impact' indicators, whereas indicators related to the cause-effect chain somewhere between emissions and end-point are 'midpoint' indicators (see Figure 1 in Payraudeau and van der Werf, 2005; Bare and Gloria, 2006; Teillard *et al*., 2016). Another typology based on four categories was proposed by Lebacq *et al*. (2013): practice-based, system-state, emission and effect-based indicators. However, the authors recognised that system-state indicators are intermediate and can be grouped with emission indicators as in Bockstaller *et al*. (2008).

Bockstaller *et al*. (2011 and 2015) considered the nature or structure of environmental indicators (Figure 1) and proposed three categories for environmental indicators that may address a single theme: (a) simple indicator based on a causal variable or a simple combination of variables; (b) predictive indicators based on outputs from models of varying complexity; and (c) measured indicators based on field measurement or observation. Both (a) and (b) correspond to pressure variables while (c) correspond to state variables.

Some authors differentiate between (a) practice-based indicators (van der Werf and Petit, 2002) or action-oriented indicators (Braband *et al*., 2003) using information on farmers' practices or other causal variables (corresponding to most of pressure indicators); and (b) effect-based indicators or result-oriented indicators, based on an assessment of the effect at different stages of the cause-effect chain (from emission to impact indicators) (Figure 1). With regard to biodiversity, indicators are often categorised in indirect (practice-based, e.g. nitrogen use on grassland as a predictor of vegetation diversity) or direct (effect-based, e.g. number of species in grassland vegetation) indicators (Clergué *et al*., 2005). The more reliance on effect indicators, the more reliance on the validity of the cause-and-effect model e.g. the predictive indicators in Figure 1.

The importance of valid cause-and-effect relationships cannot be understated. In an assessment of agri-environmen-

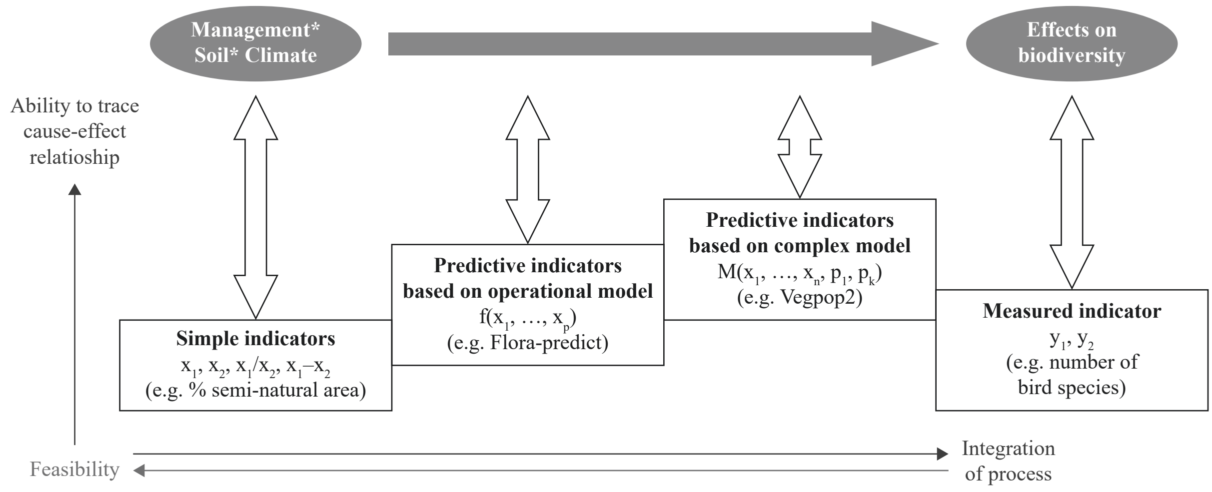

Figure 1: Typology of indicators according to their nature.
Source: Bockstaller *et al*. (2011)

tal policy measures in seven EU Member States, 51 per cent of management prescriptions were based on common-sense judgements about their possible impact rather than on documented evidence of the relationship between policy objectives, farming practices and environmental outcomes (Primdahl *et al*., 2010). Only a sixth of the measures studied were based on well-tested quantitative models. There are more general lessons from this example for policies that promote sustainability and for measurement of their effects. The absence of cause-and-effect models in policy design and assessment makes it difficult to assess the effects and to choose among alternative options. It also makes it difficult to identify the reasons for policy success; in the event of policy failure it hinders ability to identify and implement corrective actions.

Economic pillar

As suggested by van Cauwenbergh *et al*. (2007, p.238), agriculture should "provide prosperity to the farming community". In this context, economic sustainability is generally viewed as economic viability, namely whether a farming system can survive in the long term in a changing economic context. Changes in the economic context may be driven by variability in output and input prices, yields, output outlets, and public support and regulation. The concept of 'long term' can be understood as during the professional life of the farmer, or across generations. The latter is related to durability, i.e. the capacity of a farm to be transferred to a successor.

Economic viability is mainly measured through profitability, liquidity, stability and productivity. Profitability is calculated by comparing revenue and cost, either as a difference or as a ratio, or proxied by income variables such as farm income. Liquidity measures the availability of cash to meet immediate and short-term obligations, and stability is usually measured by the share and development of equity capital. Productivity is a measure of the ability of the factors of production to generate output. It is generally measured as a partial productivity indicator which is a ratio of output to one input, but also by measures that account for the possibility of input substitution or output substitution, such as total factor productivity (TFP) and technical efficiency (see Latruffe, 2010). Profitability and productivity indicators are mainly quantitative indicators and are expressed in monetary terms or as ratios; more rarely, reference scales are used.

Although measurement of economic sustainability does not typically extend beyond such economic indicators, a wider range of indicators has been proposed to capture other economic properties of farming systems that are associated with sustainability. Some studies refer to 'autonomy' (or dependence) as an indicator of economic sustainability. Autonomy is essentially a measure of one of the basic properties of every system: freedom (Bossel, 1999). For this reason, autonomy may also be seen as a social indicator. It can be viewed in terms of inputs, meaning that farms that rely less on external inputs (such as feed or fertilisers) are less sensitive to input availability and price fluctuations. Autonomy is also viewed in terms of financing, in other words with regard to the pressure of debts. Another aspect of autonomy is the diversification of income (whether farm income or household income). Farm income can be diversified by implementing non-agricultural activities on the farm such as direct sales, on-farm processing or agritourism, while household income can be diversified by off-farm employment held by farmers or their families (this is called income diversification). Subsidy dependence is another aspect of autonomy: if farms are highly dependent on public support, any policy reform that reduces subsidies could put farm sustainability at risk.

Social pillar

Social sustainability relates to people, and two main categories can be distinguished (Terrier *et al*., 2013). Firstly, there is social sustainability that matters at the level of the farm community. This is related to the well-being of the farmers and their families. Lebacq *et al*. (2013) grouped the indicators found in the literature into three main categories: education; working conditions (measured by working time, workload including pain, and workforce); and quality of life (measured by isolation and social involvement). Van Cauwenbergh *et al*. (2007) considered only quality of life as a social theme, but separated it into physical well-being (indicators related to labour conditions and health) and psychological well-being (indicators related to education, gender equality, family access to infrastructures and services, and the farmer's feeling of independence). Other aspects of well-being can also be considered, such as the physical health of workers (e.g. van Calker *et al*., 2007), although this can also be viewed as a consequence of working conditions.

Secondly, there is social sustainability that matters at the level of society. This is "related to society's demands, depending on its values and concerns" (Lebacq *et al*., 2013, p.315). Here Lebacq *et al*. (2013) grouped the indicators found in the literature into three main categories: multifunctionality (this includes quality of rural areas, contribution to employment and ecosystem services), acceptable agricultural practices (this includes environmental impacts and animal welfare), and quality of products (this includes food safety and quality processes). Van Calker *et al*. (2007) considered the contribution to the rural economy, which is less strict than the contribution to employment but could also be included in Lebacq *et al*.'s (2013) quality of rural areas. Van Cauwenbergh *et al*. (2007) added equity, as well as heritage, cultural, spiritual and aesthetic values. Also, the succession theme is sometimes included in the social sustainability dimension. For example, Gómez-Limón and Sanchez-Fernandez (2010) measured intergenerational continuity in agriculture, and Dillon *et al*. (2009) considered demographic viability.

Unlike most environmental and economic indicators, many social indicators are qualitative. They are difficult to quantify as they are often subjective. Indicators relating to the farm community are often based on farmers' self-evaluation through surveys or interviews.

Selection of indicators

As underlined by Lebacq *et al*. (2013), the choice of an indicator is crucial as it influences conclusions. It is crucial to use a procedure for selection of indicators that is well-defined, robust and transparent, so that the assessment is validated, credible and reproducible (Dale and Beyeler, 2001; Niemeijer and de Groot, 2008a). Therefore, careful choices have to be made before launching the process of sustainability assessment. For example, in the case of agri-environment schemes (AES), Mauchline *et al*. (2012, p.326) reported that "two evaluation methodologies applied to the same scheme produce two different overall conclusions when conducted by a multi-disciplinary team compared with an ecologist alone".

Selection processes

One of the primary challenges associated with indicator selection is highlighted by de Olde *et al*. (2016, p.2) who report a "startling lack of consensus" among a broad range of sustainability experts who were asked to rank the relative importance of criteria for selecting individual indicators and for balancing a collective set of indicators. The study suggests that while differences may arise as a result of different expert perspectives in relation to social and economic contexts, farming systems and end-users, the divergence in views also has a positive dimension, as a broad range of expertise and perspectives can improve our understanding of sustainability issues, lead to a more rigorous selection process and ultimately to the improved design of indicators.

The importance of a strong focus on the process of indicator selection is highlighted by de Olde *et al*. (2016) as being critical in the development of transparent, transformative and enduring indicators. Lebacq *et al*. (2013) described two main stages in the selection of indicators: (a) contextualisation of the assessment; and (b) comparison of indicators. In the first stage, also called the 'pre-modelling phase' (Alkan Olsson *et al*., 2009a) or the step of 'preliminary choices and assumptions' (Bockstaller *et al*., 2008), the purpose of the assessment needs to be clarified (in terms of precise objectives and end-users), and the system boundaries (in terms of issues/themes of concern, scope, time and spatial scales and the involvement and role of stakeholders in the assessment). In the second stage, comparisons should be based on various criteria which need to be precisely defined in advance. Lebacq *et al*. (2013) listed three main criteria: (a) relevance; this is related to the appropriateness of the indicator to the context and scale; (b) practicability, which consists of measurability, quantification and compatibility of the data with the aggregation method selected, and transferability to other farm types; and (c) end user value, relating to the appropriateness of the indicator to stakeholders' expectations in terms of clarity, comprehension and policy relevance.

Rice (2003) proposed additional criteria that can guide the selection of indicators: (a) representativeness, namely 'Can the dynamics of the indicator be taken to reflect more than the dynamics of the specific times and places where the data were collected?'; (b) availability of historic data, so that the performance of an indicator can be evaluated; (c) the theoretical basis, in particular 'the consistency of an indicator with ecological theory, but also the degree to which the diversity of professional views all accept the theoretical arguments'.

The criteria described above are 'ideal' criteria. However, one aspect that should not be forgotten is the operational capacity of an indicator in terms of cost. As explained by Pingault (2007), data should be available at an acceptable cost, and the cost related to the design and calculation of the indicator should also be tolerable. More generally, the author suggested considering the implementation cost, the cost of using the indicator, and the cost of adapting it to changes in the context.

Several authors highlighted the need to consider indicators as a set instead of single indicators for specific themes (e.g. Lyytimäki and Rosenström, 2008). Niemeijer and de Groot (2008a and 2008b), referring to environmental sustainability, stressed that indicators have to be selected on the basis of how they jointly provide an answer to our environmental questions. They recommended considering causal networks and the various causal chains that are inter-related within the networks. Lebacq *et al*. (2013) indicated three criteria for selecting a set of indicators: (a) parsimony, i.e. indicators should be as few as possible and not redundant; (b) consistency, i.e. all necessary indicators are in the set; and (c) sufficiency, that is to say that the set is exhaustive in the sense that it embraces all sustainability objectives.

Development of composite indicators

Individual indicators are built from raw/input data, and they may be aggregated to form aggregated indicators. Composite indicators are then the combination of individual and/or aggregated indicators representing different dimensions of sustainability (Figure 2).

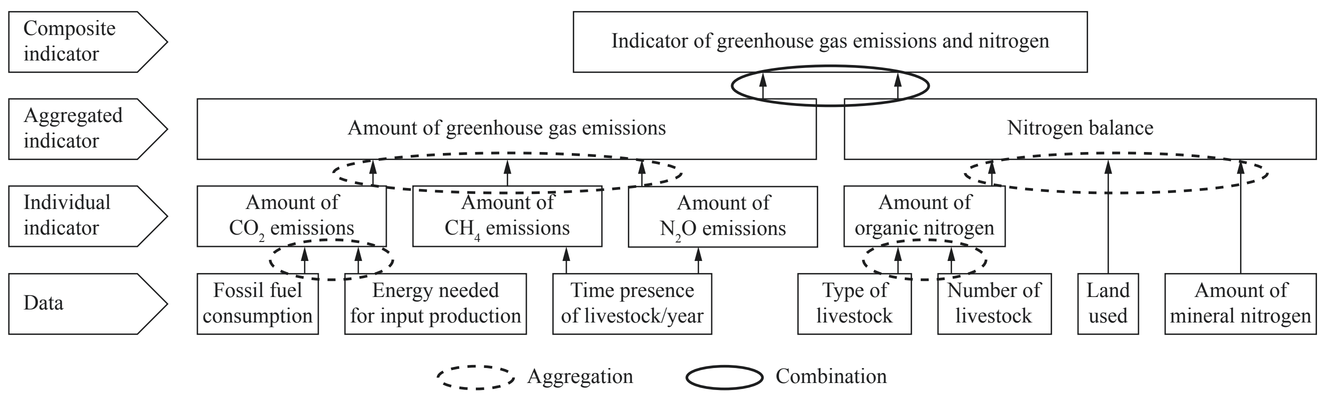

Figure 2: From raw data to composite indicators: an illustration.
Source: own composition

Many approaches are based on lists of indicators which are organised in more or less well-structured frameworks (see van der Werf and Petit, 2002; Géniaux *et al*., 2009; Singh *et al*., 2009). However, the question of aggregation arises when the objective is to comment on the sustainability outcome of a policy, or to compare two or more policy options via a set of indicators. There is a need for a methodology to combine diverse information in an explicit, consistent and transparent way, whilst presenting it in an easily intelligible form to facilitate policy evaluation. There are two general schools within the indicators community.

'Aggregators' prefer to combine different sources of information into a single value, with a sum or a weighted mean or using normalisation technique: linear scaling techniques, Gaussian normalisation distance to target, ranking by experts, categorical scales etc. (Géniaux *et al*., 2009). A crucial issue here is to choose the weights carefully. This may be done with the help of experts' and stakeholders' opinions (Finn *et al.*, 2009). Another aggregation approach is to convert all values into the same unit, monetary or physical (e.g. ecological footprint). Aggregation methods based on a common monetary unit as in cost-benefit analyses raise the complex issue of how to value non-market goods and services such as environmental assets, water quality, biodiversity etc.

By contrast, 'non-aggregators' caution about the subjectivity involved in aggregating and about the potential pitfalls in adding 'apples' and 'oranges' and the potential for loss of information in the aggregation process. A possible solution to these problems is multi-criteria analysis, which is a methodology for selecting between, or prioritising, different options described by a set of criteria (Sadok *et al*., 2008). Qualitative approaches can also be considered as a way to aggregate. These types of approaches lead to a conclusion in the form of a score for multiple classes of a given criterion (e.g. sustainability). There may be multiple scores, one for each of the major sub-themes (e.g. biodiversity, profitability). Such approaches are based on decision rules expressed as 'if then' rules, i.e. presented either as decision trees based on qualitative multi-attribute decision modelling or in the form of a dashboard (Bockstaller *et al*., 2009b). Reconciling both schools, Bockstaller *et al*. (2008) suggest to use both aggregated and individual indicators, where the former are used to compare systems and the latter are used to analyse each system. More generally, it may be necessary to use several methods in combination, as they may not produce the same results.

New indicators

Society's values and expectations of farming systems are changing and new principles have been added to the definition of sustainability such as governance, solidarity, transmission capital, local knowledge (e.g. Mancebo, 2006) and, more recently, innovation (e.g. Hennessy *et al*., 2013).

Many approaches to accomplishing the dual challenge of increasing agricultural production, while reducing its environmental impact, are based on increasing the efficiency of agricultural production relative to resource use and relative to unintended outcomes such as water pollution, biodiversity loss and greenhouse gas emissions (Bennett *et al*., 2014). This calls for a new category of indicators which measures the efficiency of production in relation to both inputs and environmental impact. In recent years there has been a concerted effort to monitor progress towards sustainable intensification (see, for example, Frater and Franks, 2013; Barnes and Thomson, 2014).

Innovation is a broad concept but it is fundamentally about embracing novelty. Thus, indicators of innovation can be used to gauge what farmers may be doing today that will impact on their future sustainability (OECD and Eurostat, 2005). The use of innovation or practice adoption as a measure of the long-term sustainability and resilience is relatively novel (van Galen and Poppe, 2013) and there is scope to broaden significantly the development of indicators of this aspect of sustainability (Ryan *et al*., 2016).

As the climate change debate intensifies, the concept of 'climate-smart agriculture' which builds on sustainable intensification to additionally take climate change into account, is gaining in prominence. However, according to Campbell *et al*. (2014), sustainable intensification is a 'cornerstone' of climate smart agriculture as increasing resource use efficiency contributes to both mitigation and adaptation by impacting positively on farm incomes and reducing emissions per unit product.

As our understanding of the interactions between the intensity of farming, its impact on the environment and climate change, and the role of innovation in these interactions become more important, new and more sophisticated indicators will have to be developed to quantify these interactions.

Conclusion

This overview underlines crucial decisions that need to be considered prior to an assessment of sustainability in agriculture. Choices should be made regarding the number of indicators, whether the selected indicators should apply to all case studies or whether they need to be adapted (in terms of indicator selection or setting threshold levels) to each case study (country, context, type of farming). Also, when simple indicators related to farm management practices (e.g. semi-natural area, or risk protection instruments respectively) are used instead of measured indicators measuring the sustainability outcome (e.g. biodiversity, or resilience respectively), then the causal direction between the simple indicator and the sustainability outcome should be fully clear. It should also be kept in mind that the effect of policies depends also on exogenous factors, that is to say on factors beyond the control of farmers such as climatic and topographic characteristics of their location, or position of the farm in its life cycle. In the words of Russillo and Pintér (2009, p.45): "The producer does not want to be held accountable for outcomes he or she cannot control". The participation of stakeholders within the process is crucial, as society's demands are constantly changing and therefore the range of indicators and frameworks need to be adapted (Lyytimäki and Rosenström, 2008; Lebacq *et al*., 2013). In addition, farmers who are surveyed within a sustainability assessment need to be convinced to provide their information: "Those collecting the data need to compensate the farmer through information that has value or other incentives" (Russillo and Pintér, 2009, p.45).

We highlight several themes for which few indicators are available. These typically concern social themes which to date are poorly investigated in the literature. Agriculture contributes to the quality of life in rural areas in terms of economic contribution (e.g. the level of farm output is crucial for the viability of upward and downward industries; the presence of farms helps keep a minimal level of public services in rural areas) and environmental contribution (e.g. creation of landscape; reduction of pollution). Hence, the social sustainability of farms (and, more broadly, of agriculture) is the dimension that would need the most development of indicators in the future. Indicators of innovative practices that promote more efficient use of natural resources and the resilience of farmers are also likely to become more important in the context of climate smart agriculture.

While this paper describes the concepts around indicator importance and selection, the range of farm-level data available limits the indicators that can be currently developed. Although this limitation can be addressed by collecting additional data and by using existing datasets or expert opinion, the most valuable use of sustainability indicators lies not in the interpretation of the (absolute or relative) values in any time period, but in the evaluation of trends in indicators over time that are of concern to stakeholders generally and policy makers in particular.

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Stakeholders' perceptions of sustainability measurement at farm level

Increased attention for sustainability in agricultural production within the food sector has enhanced the need for farm-level information. This article aims to explore stakeholders' perceptions of sustainability measurement at farm level in an established monitoring system. Qualitative research, including discussion groups and semi-structured interviews in nine European countries, identifies existing divergences in perceptions, especially for those indicators not expected to be used for farm-level decision making. The perception of feasibility and usefulness of an indicator is determined by (a) indicators' intrinsic attributes, (b) the measurement system in which it is inserted, (c) farm characteristics and (d) farmers' attitudes toward the measurement. Identifying stakeholders' perceptions could help to improve the discussion between researchers and users in the selection, communication and use of sustainability information along the agricultural sector.

Keywords: stakeholder involvement, farm level sustainability indicators, qualitative research

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Introduction

As a response to the multiple pressures of climate change, natural resource degradation, societal demands and global markets, the food sector is facing the challenge of moving toward more sustainable ways of production, driven by regulatory frameworks and changes occurring along the agricultural supply chain (Higgins *et al*., 2010). Operationalising the concept of sustainability is believed to be necessary to define goals, track performance, induce behavioural changes and help to solve disputes (Bosch *et al*., 2015).

Owing to the multiple functions of indicators as a scientific unit, measurement unit and policy element (Joumard and Gudmundsson, 2010), the selection of a set of indicators has been argued to be both a scientifically and politically iterative process (Mccool and Stankey, 2004), located in a fuzzy area between the production and use of scientific knowledge (Turnhout *et al*., 2007). While considering users' perspectives in the selection of indicators helps to achieve transparency, relevance, ownership and public legitimacy (Moxey *et al*., 1998), it requires a dialogue between designers and users. This dialogue is considered an 'untamed problem', where multiple values are in conflict, outcomes are uncertain and there exists significant scientific disagreement (Batie, 2008). The aim of this study is to explore stakeholders' perceptions regarding the feasibility and usefulness of the introduction of sustainability indicators in an existing farm level monitoring system. Using the definition of stakeholders of Freeman (1984), we consider the perceptions of those individuals or groups who affect, or are affected, by the introduction of sustainability indicators. This research is part of the European Union (EU) Framework 7 project FLINT (Farm Level Indicators for New Topics in Policy Evaluation), the objective of which is to test the feasibility of establishing a common standard set of farm-level indicators for policy evaluation in nine EU Member States, ideally linked with the Farm Accountancy Data Network (FADN). This paper describes the methods used to collect stakeholders' perceptions, the main results and the conclusions.

Theoretical background

Agricultural information systems include both the production of data and the transformation of these data into information that is useful for a policy decision or a problem solution (Bonnen, 1975). Those systems rely on the measurement process, in which a concept is linked to one or more latent variables, and these are linked to observed empirical variables (Bollen, 1989). If the concept is complex or has different meanings for several actors – such as sustainability along the food chain – we can expect that the concepts and information derived from those systems have different values for the different actors. The values and perceptions of stakeholders can be divergent in conflicting ways, turning a complex problem into a 'wicked' one that cannot be solved, only managed (Peterson, 2013). Stakeholder involvement has been considered as a way to increase the likelihood of evaluation utilisation (Taut, 2008), a missing step in indicator validation (Cloquell-Ballester *et al*., 2006) and an important input while dealing with complexity, uncertainty and ambiguity (Renn, 2015).

Sustainability is identified as an untamed problem because of the complex and dynamic nature of the problem definition and radically different understandings (Batie, 2008). Nevertheless, in order to be measured, analysed and communicated, the sustainability concept is reduced to a limited number of indicators (Schindler *et al*., 2015). Indicators are defined as a *quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, in order to reflect the changes connected to an intervention, or to help assess the performance of a development actor* (DAC-OECD, 2002, p.25). The assessment of indicator quality is made through a list of criteria. The more frequently used criteria are those developed by OECD (2001): policy relevance, responsiveness, analytical soundness and data availability. However, in general, there is no universal set of criteria to judge indicators, and there is no common understanding regarding the definitions of the criteria. Selection approaches such as rating, standardisation, weighting and combining (Rice and Rochet, 2005) have until now been a science-led process where the political or managerial context in which indicators are used is not fully

Table 1: Indicators of sustainability at farm level by dimension of sustainability.

Environmental	Economic and innovation*	Social
E1 Permanent grassland	***EI1*** Innovation	***S1*** Advisory services
E2 Ecological Focus Areas	***EI2*** Producing under a label or brand	***S2*** Education and training
E3 Semi-natural farmland areas	***EI3*** Types of market outlet	***S3*** Ownership-management
E4 Pesticide usage	***EI4*** Past/future duration in farming	***S4*** Social engagement/participation
E5 Nutrient balance (N, P)	***EI5*** Efficiency field parcel	***S5*** Employment and working conditions
E6 Soil organic matter in arable land	***EI6*** Modernisation of the farm investment	***S6*** Quality of life/decision making
E7 Indirect energy usage	***EI7*** Insurance: production, personal and farm (building structure)	***S7*** Social diversification: image of farmers/ agriculture in local communities
E8 Direct energy usage	***EI8*** Share of output under contract with fixed price delivery contracts	
E9 On-farm renewable energy production	***EI9*** Non-agricultural activities	
E10 Farm management to reduce nitrate leaching		
E11 Farm management to reduce soil erosion		
E12 Use of legumes		
E13 GHG emissions per ha		
E14 GHG emissions per product		
E15 Carbon sequestering land uses		
E16 Water usage and storage		
E17 Irrigation practices		

* Indicators that form part of the current FADN Farm Return are not included in this list
Source: own compilation

recognised (Turnhout *et al*., 2007; Rametsteiner *et al*., 2011).

Considering the increasing availability of data and the different users of information (Pannell and Glenn, 2000), the value of sustainability indicators is argued to rely on the relevance of data for optimising farm efficiency (Fountas *et al*., 2006) or the use of the information in the supply chain for creating competitive advantages through transparency and innovation (Beske-Janssen *et al*., 2015). An appropriate combination of methods to involve stakeholders would lead to the integration of scientific expertise, rational decision making and public values (Renn, 2015).

Methodology

To explore stakeholders' perceptions, a mixed-methods research approach was used, simultaneously collecting both quantitative and qualitative data in a concurrent embedded strategy within a qualitative predominant method (Creswell, 2009). Qualitative approaches are appropriate when it is necessary to involve participants with a specific interest and personal experience (Bitsch and Olynk, 2007), the results do not need to be generalised to a population (Patton, 2015) and the results could be used for evaluation and the development of policy recommendations as well as in action research (Bitsch, 2005). Four steps were conducted in order to involve stakeholders, of which steps 1 to 3 were conducted by project partners in each country.

The list of indicators (Table 1) was selected after an extensive literature review, analysis of information gaps and discussions within the project team. Stakeholders were identified based on who is involved in collecting, storing, analysing, reporting and using the information generated. Considering the expected level of availability of stakeholders and the list of preselected sustainability indicators, visualised group discussion tools and semi-structured interviews were designed and pilot-tested with farmers and farm advisors.

Sixteen group discussions and 42 individual interviews were conducted between September 2014 and January 2015. In total, 174 stakeholders were consulted through discussion groups, face-to-face individual interviews, group interviews, interviews by telephone and interviews by email. The discussion groups and semi-structured interviews tools consisted of two parts. Firstly, stakeholders answered three open-ended questions related to their experience about the collection of sustainability data (*Q1: How is farming being influenced by changes and demands coming from society, consumers, policy, trade partners? Q2: What kind of data are requested from you/do you request? Q3: What is your experience collecting and/or using those data?*). Secondly, stakeholders scored the feasibility and usefulness of each of the 33 indicators using a two-pole scale (--, -, +/-, + and ++) and giving their reasons for the assessment.

Eight stakeholder groups can be identified among the participants (Table 2). Farmers and farm data collectors of the FADN system account for 33 and 26 per cent respec-

Table 2: Stakeholder groups consulted about their perceptions of sustainability.

Group	Description
Farmers (58)	Diary, beef, arable and mixed crops farmers.
Farm advisors (13)	Technical experts or specialists, extension agents, and advisory and accountancy services whose work is realised at farm level.
Farm data collectors (46)	Professional data collectors and farm advisors who are involved in FADN data collection.
FADN representatives (9)	Contact persons of FADN liaison institutes, statistical offices, national representatives, coordinator or contact persons of national FADN systems.
Policy makers and / or policy evaluators (9)	Experts and head of units of agricultural authorities, directorates for agricultural ministries sections, policy evaluators and planners, rural development experts.
Scientists and academics (11)	Professors of universities, scientists of research institutes.
Farmers representatives (3)	Policy expert of a chamber of agriculture, a research director of farmers' union and a farmers' union representative.
Value chain actors (14)	Sustainability manager, farm service director and representative of dairy processors' and milk cooperative, director of a sugar company, director of a trade company, representative of a federation of agri-food industry, members of institutes for organic food associations and food chain quality, an organic bakery, marketing personnel of a food company.

Source: own compilation

tively of the persons consulted, and more than 50 per cent of them came from Spain and Poland. FADN representatives and actors involved in national policy evaluation initiatives make up 10 per cent of the respondents. Other stakeholders not directly involved in the current FADN measurement system, but potential users of the information (such as farmers' representatives, researchers and value chain actors), represent 28 per cent of the participants.

The quantitative scores assigned by stakeholders were used to generate the average numeric assessment of indicators. The analysis of the answers of the open-ended questions and qualitative comments on the indicators was made with the help of the 'ATLAS.ti7' software for qualitative analysis (ATLAS.ti Scientific Software Development GmbH, Germany). The coding was conducted in two steps: (a) an initial open coding of the qualitative answers, aiming to delimit categories, commonalities and differences; and (b) a second coding based on the categories established in the first stage, searching for patterns and generalised relations following grounded theory analysis principles.

Results and discussion

Here, the results of the coding process are presented, as are the quantitative scales that were used to classify indicators.

Identification of current sustainability monitoring systems

Stakeholders consulted identify three types of farm-related measurement systems: (a) regulations-based measurement; (b) market-led measurements; and (c) own farm measurement system. Regulations-based monitoring systems have as a purpose compliance with government rules or policy evaluation, for example cross-compliance mechanisms. Market-led measurement initiatives request information based on the commercial arrangements between farmers and their customers, for example information that is requested by traders, retailers or consumers. Farm monitoring systems include all the data and information management (digitalised or not) managed within the farm (Figure 1). According to the interviews, those systems have their own incentives and characteristics, being complementary or even 'redundant', depending on the features and requirements of the supply chain and the national contexts.

Interviewees agreed that the management of data and exchange of information is a time-consuming and costly process, with a high level of variability among farmers on the willingness to participate. Three factors affecting the exchange of information about sustainability were identified: (a) alignment of the farm system information with the required information and with the objectives behind the indicator; (b) expectations of the information exchange, including trust among actors, expected benefits and expected risks; and (c) cooperation of users beyond the farm level with regard to the calculation, analysis and the availability of information.

Alignment of required information with own farm management information system and farm objectives. Information exchange is determined by the availability of the information at the farm level. The current state of bookkeeping and use of digitalised information tools at this level is highly variable, according to the type of farming and the region. Gathering of variables that requires additional investments, time or knowledge from the farmers' side adds difficulties to the collection. Closely related is the compatibility of the objectives of the external actor to the farm's objectives: interviewees stated that information provision makes more sense if the information can be used for farm-level planning and decision making regarding business strategies or production factors use. Nutrient balance, for example, "can be used as part of a nutrient management plan".

Expected outcome of the information exchange. Farm advisors and other non-farm stakeholders mentioned that data gathering is not a one-sided data provision, but an exchange of knowledge, even in the short term. The level of trust between actors is identified as extremely important: the provision of accurate information can be highly influenced if the data are linked to an incentive or penalty. Also, a data collector should be a reliable agent, trained about the information to be collected and knowledgeable of the area and local farms in order to validate the data during the collection phase. Three main perceived benefits of information exchange were mentioned: professional support to the farmer, a farm-level customised report and the possibility of benchmarking.

Beyond farm level: cooperation among sustainability information users. Data gathering is the first step of knowledge generation. The conversion of the data into usable information includes calculating, interpreting, inferring, communicating and influencing decisions. During this process, issues arise outside of the farm level: (a) calculation of indicators is not standardised; (b) interpretation and inference of indicators can be misled without the necessary control variables and knowledge of the context; (c) indicators should be communicated back to the farmers, society or consumers in an understandable and complete way; and (d) conflicts between sustainability goals among actors requiring information. For all these issues, cooperation between stakeholders is needed. Potential conflicts between databases could be avoided with "collective databases that can be accessed by different parties" or the implementation of "unique data codes for indicators". Both solutions imply the creation of norms that are not yet developed.

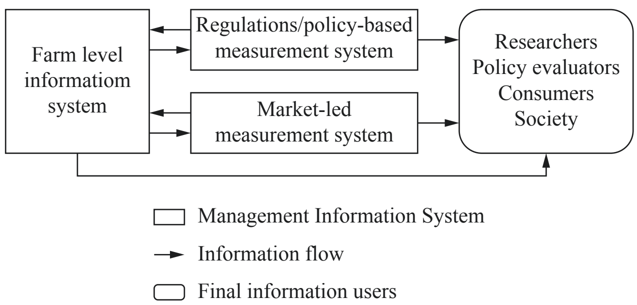

Figure 1: Schema of current sustainability information measurement systems and flows identified by stakeholders.
Source: own construction

Assessment of feasibility and usefulness of sustainability indicators

Across the whole group of surveyed stakeholders, on average, all indicators were considered useful and, with the exception of greenhouse gas (GHG) emissions, all the indicators were considered feasible. Nevertheless, few indicators are considered as being very useful (Figure 2).

The reasons for the differences in assessment of indicators are identified by grouping the concepts derived from the perceptions toward the indicators into categories.

Factors that determine perceived feasibility

The assessment of the feasibility of an indicator would not only depend on the characteristics of the indicator itself (type of data and evidence, level of measurement and allocation) but also on the characteristics of the measurement system in which it is embedded (availability of matching information), the farm characteristics (type, size, fragmentation) and the attitude of the farmer towards the measurement (Table 3).

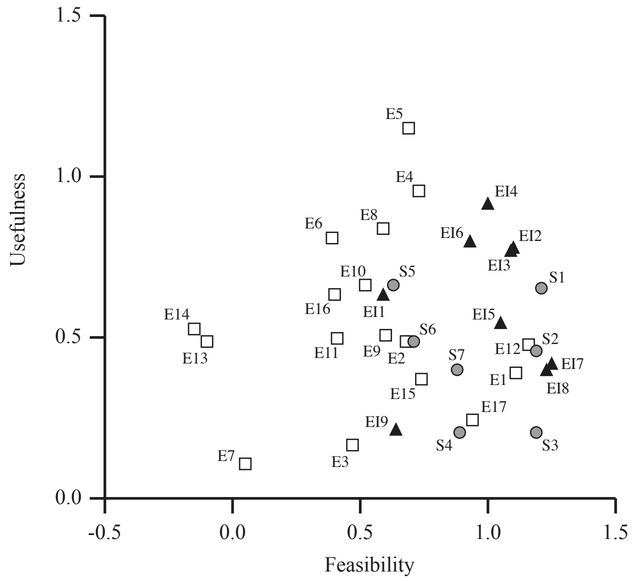

Figure 2: Stakeholders assessment of indicators according to perceived feasibility and usefulness**.**

Scale: 2=++; 1=+; 0=+/-; -1=--; -2=--
See Table 1 for names of indicators
Source: own composition

Table 3: Factors that determine the perceived feasibility of indicators of sustainability.

	Categories and coded attributes	Description and examples
Indicator's attributes	***Type of data***	
	Evidence-based data	Data that are measured with an established instrument and which is ascertainable, e.g. invoices, soil organic matter content.
	Best-estimated data	Data that are estimated or approximated according to the knowledge of the farmer, e.g. manure usage, farm practices, water usage, innovation, advisory services.
	Calculation	Information that is deducted using normative scales or standard coefficients, e.g. GHG emissions.
	Perceptions	Subjective opinions which are not possible to measure physically, e.g. quality of life perceptions.
	Level of data breakdown in collection and calculation	
	Household level	Level at which the measurement or collection of variables of the indicators take place, e.g. soil organic matter is measured in sampling plots; pesticide usage can be measured at crop, parcel or farm level; emissions can be calculated by hectare or product.
	Farmer level	
	Farm level	
	Plot /parcel/crop/field level	
	Product level	
Measurement system	***Availability of data***	
	Part of the recording system of the farm	Data and information are kept in different types of recording systems within the farm: books, software, databases and sheets. In some cases, they are digitalised. Example: farmers keep registers about pesticide usage, fertilisation, cattle movements, investments, contracts, and financial bookkeeping.
	Part of existing external and accessible databases	Farm level information that is collected and stored in databases outside the farm, e.g. Land Parcel Identification System, projects' databases.
	Agent requesting it	
	Regulations: mandatory at farm level	Information that is requested for compliance with regulatory issues, e.g. pesticide usage for regulations, cross compliance checks.
	Requested by clients: desirable or mandatory at supply chain level	Information that is required by traders or consumers, e.g. antibiotics usage, quality assurance per product, certification schemes labelling.
	Special programmes: optional	Information that is requested by special programmes, e.g. certification schemes, research projects, rural development programmes.
Farm	***Farm characteristics***	
	Size	Size of the farm: small/big farms.
	Type	Type of agricultural system, e.g. livestock, horticulture, orchards.
	Fragmentation	Dispersion of the fields and parcels.
	Region	Region, context in which the farm is located.
Farmer	***Farmer attitude toward information provision***	
	Sensitivity of the information	Information which provision can be seen as potentially harmful for the farmer, e.g. personal/private information, part of their business strategy.
	Trust in researchers and policy makers	Degree of trust on the use of information, e.g. doubts about how the information will be used: new taxes, regulations, new requirements.

Source: own compilation

Factors that determine perceived usefulness

Indicator usefulness depends mostly on the relevance for the stakeholders of the objective behind the indicator (Table 4). In two farmers' discussion groups, however, it was stated that is meaningful to collect some indicators even when they are not usable at farm level: a difference in the value for the farmer and the public value was highlighted.

For the interviewees, an indicator is a simplified metric of a complex reality expected to change; therefore, how well the indicator represents this reality is the second factor influencing the usefulness criterion. To infer and make valid conclusions, the adequate judgment would need to use contextual factors and control variables. As one consulted researcher pointed out: "There are facts, lies and statistics. It is not difficult to collect data; it is much more difficult to understand the data".

Perceptions toward indicators according to sustainability dimension

Crossing indicator assessment and using the schemes presented in Tables 3 and 4, this section discusses the stakeholders' perceptions of the indicators categorised in the three dimensions of sustainability.

About *environmental indicators*, stakeholders pointed out the importance of explaining the rationale and links between indicators, taking into account the 'cycles' in agriculture. National sustainability objectives could be translated at a farm level only if information could be consolidated or aggregated using a farm-level balance. Evidence-based data (soil organic matter, water use, energy production, energy consumption) is perceived as costlier and difficult to measure accurately; however, much significant information is already available from farm records (e.g. fertilisers, pesticide usage). Many variables of the indicators are best estimates: farm practices, percentages of allocation (between crops, activities or at the farm/household level) or calculations (water usage, manure usage). Those indicators that measure changes in quality of production factors were identified as usable for farm planning and management to reduce costs, increase productivity and foresee future demand (E5, E12, E10, E8, E9, E6, E16). Those related with greening were linked with access to subsidies (E1, E2, E3). The pesticide usage indicator was associated with complying with regulations and customers' requirements. GHG emissions, on the contrary, is an 'important' indicator used 'to inform', not usable at farm level, and important for the consumer; therefore, highly valued by the value chain actors and policy makers and poorly valued by farmers. Most of the stakeholders – except for value chain actors – considered measuring it as difficult. Indicators related to pesticide usage and nutrient balance were considered as possible sensitive indicators. The link between farm practice and impact was also stressed: there is the need to collect enough information to make the causality link possible; however, the complexity in some environmental indicators to establish this link was also identified: "some activities will lead to measurable changes over 20 years". The need for match information sources and methods using multiple databases, or measurement ini-

Table 4: Factors that determine the perceived usefulness of indicators at farm level.

	Categories and coded attributes	Description and examples
Indicator's attributes	***Relationship of the indicator with sustainability objectives***	
	Causality	Clear causality relationship between variables collected and objectives measured. From the scientific point of view, if the indicator is a valid representation of the expected problem to be measured.
	Interpretation	Existence of sufficient knowledge to interpret the indicator properly and link with management actions.
	Context variables	Availability of knowledge of 'context variables' that make it possible to infer valid conclusions and compare across time, farmers, countries and regions.
	Level of breakdown in reporting	
	Farmer level Farm level Plot /parcel/crop/field level Product level	Level at which the data is transformed into information that can be used for decision making, e.g. pesticide usage can be reported at crop, parcel or farm level; emissions can be calculated by hectare or product or reported by farm.
Measurement system	***Perceived relevance of problem measured with the indicator***	
	Farmer Farm advisors Policy makers Consumers Society	Relevance of the objective measured through the indicator for the stakeholder, e.g. farm advisors are interested in to know overall performance of the farm; consumers and society are interested in pesticide usage and emissions.
	Perceived potential use of the indicator	
	Decision making	Potential to use the indicators for planning and management at farm level, advisor level, sector level, national level, policy level.
	Inform or communicate	Indicator main use is to inform other actors: researchers, policy makers, consumers, community.
Farm	***Farm characteristics***	
	Size	Size of the farm: small/big farms.
	Type	Type of agricultural system, e.g. livestock, horticulture, orchards.
	Region	Region, context in which the farm is located.
Farmer	***Farmer objectives***	
	Farmer objectives	Objectives, e.g. profit maximisation, organic agriculture, protect the environment.

Source: own compilation

tiatives with the same indicators were concepts particularly claimed by policy makers, FADN representatives and data collectors.

Indicators of social sustainability at farm level are perceived by stakeholders as best estimated data and perceptions. In general, they are not currently requested, except in specific rural development programmes or specific research surveys. Like the other indicators, the need for clearer definitions of variables was mentioned. Social indicators are perceived as indicators for informative purposes: they are information already known by the farmer, with low relevance for farm decision making, high usability for policy making and low importance in regard to informing consumers. Policy makers and researchers discussed the importance that social indicators have, and how they have been less present than economic and environmental indicators within the sustainability discussion, while farmers, farm advisors and value chain actors questioned to what extent their analyses will be effectively used. The indicator for employment and working conditions was assessed as the most useful one, despite the complexities of calculating seasonal labour and the number of working hours. Policy makers in particular found a link between social indicators and rural development programmes, even though the fact that having a common exhaustive list that could be relevant and applicable for all regions could be a challenging task.

The indicator based on subjective perceptions (S6) prompted divergent opinions from all stakeholder groups. Many stakeholders emphasised the importance of this measurement but, for others, personal perceptions were regarded as beyond the objectives of policy, and the subjective nature of the questions and the influence of multiple non-controllable factors make their analysis only useful for longitudinal research. Possible sensitive indicators identified were S1, S4, S6 and S7.

Most of the *economic indicators* presented to stakeholders are best estimates or are already accessible using existing bookkeeping on the farm, except for the innovation indicator EI1. This needed to be explained further; while some stakeholders mentioned its importance as part of the objectives of the EU's Common Agricultural Policy, there was a high level of divergence on the concept, the way to measure it, the objective behind its measurement and how it would be analysed. For some other indicators, the relationship with sustainability was not clear (EI2, EI, EI8). Market indicators such as labels and fixed contracts stimulated many different opinions: they have a value important for the farm, but they do not represent a sustainability objective in themselves. Possible sensitive indicators were also identified (EI8, EI9, EI6, EI4).

Conclusions

We have conducted a stakeholder analysis of the measurement of sustainability at farm level. Stakeholders acknowledge sustainability measurement as an important trend in the agricultural sector in which three information systems are identified: own farm system, regulation-based system and market-led system. Every system has its own institutional arrangements, goals and incentives. Information exchange within those systems is influenced by (a) the level of alignment between the farm and the agent requesting it: objectives, information requirements, trust, expected benefits and expected risks and (b) the cooperation of users of indicators beyond the farm level.

Stakeholders assessed 33 sustainability indicators based on feasibility and usefulness criteria. Overall, all indicators are perceived as useful and, except for GHG emissions, all are considered feasible to measure at the farm level. Environmental indicators are perceived as the most useful for all eight groups of stakeholders, especially those indicators expected to be related to farm productivity. Innovation and economic indicators (different from indicators already included in FADN) are perceived more feasible but less useful for sustainability measurement. Social indicators are perceived as important from the policy and research point of view but less useful from the farmers' and value chain actors' perspectives. In general, divergences between stakeholders' perceptions arise for those indicators that are not expected to be used for planning and management at the farm level. The differences in perceptions on how feasible and useful an indicator is could be explained not only by the intrinsic attributes of the indicators but also on the measurement system requiring it, the farm characteristics and the attitude of the farmer towards the measurement. This confirms the value of scientific but also societal criteria in the selection of indicators.

Although the testing of indicators in a monitoring system will be done in the subsequent steps of the FLINT project, stakeholders' consultation elicits the main arguments and different points of view that potentially could improve communication between researchers and users of information. Further assessment is needed of the influence of stakeholders' analysis in the process of introduction of a set of indicators of sustainability and its contribution to the current discussion about efficiency, trade-offs and sustainability development at farm, sector or supply chain level.

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Collecting sustainability data in different organisational settings of the European Farm Accountancy Data Network

The European Farm Accountancy Data Network (FADN) collects detailed financial economic information on a sample of farms in Europe. These data are used intensively for the evaluation of the European Union's Common Agricultural Policy. Owing to changes in policies, there is a need for a broader set of farm level data, especially on the sustainability performance of farms. This paper describes the different types of FADN systems in Europe and evaluates how these types affect the feasibility of collecting sustainability data. In addition to a theoretical evaluation, the practical experiences of collecting sustainability data on more than 1,000 farms in Europe are described. The paper concludes with a discussion on the advantages and challenges of extending the scope of FADN data collection with sustainability data.

Keywords: liaison agency, sustainability indicators, data collection

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Introduction

The European Farm Accountancy Data Network (FADN) provides detailed financial economic information at farm level on more than 80,000 farms in Europe. The data are collected in a systematic way on an annual basis and the information collected for each sample farm contains more than 1,000 variables. FADN contains harmonised farm-level data across Europe: the data elements to be provided to the European Commission (EC) and bookkeeping principles (such as depreciation) are the same in all countries. The data to be uploaded and the exact definition of each data element are defined in the FADN Farm Return (EU, 2010).

Income support is one of the main aims of farm policies in the European Union (EU) and elsewhere and, to provide reliable information on farm incomes in the EU, income is monitored at farm level by Member States in FADN. Until recently, analyses have mainly focused on analysing the economic impacts of policy making (e.g. Vrolijk *et al*., 2010; Jongeneel *et al*., 2016), and FADN is a source of standardised micro-economic data. It provides a wealth of material for analysing variation in farm incomes, differences in the composition of farm incomes, or assessing the impact of changes in agricultural policies at individual farm level (Vrolijk *et al*., 2004).

Owing to changes in the agricultural policies and the increasing societal demands with respect to the economic, environmental and social sustainability of agricultural production, information needs change. An increasing number of studies try to use data from FADN as proxies for environmental variables (Povellata and Longhitano, 2016) or use a limited set of environmental indicators depending on data availability (Coderoni *et al*., 2016). Given the increasing need for data on the sustainability performance of farms (Eurostat, 2011; ECA, 2016), FADN is a potential starting point to collect this kind of information. Several countries already have an extended data collection in their national FADN systems to cover sustainability issues (see, for example, Boone and Dolman, 2010; Dillon *et al*., 2010; Dolman *et al*., 2012; Platteau *et al*., 2014). Types of information that are already collected at national level range from information themes such as irrigation practices, where more than two thirds of the countries already collect some information, to engagement in local community, quality of life and working conditions where only one or even no countries collect this information (Table 1). About one out every five countries already collects data on key environmental variables such as nutrient balance, greenhouse gas emissions and pesticide usage.

The fact that most indicators are already collected in some EU Member States indicates that it is feasible to collect sustainability data in the scope of FADN. Extending this data collection to the EU level is a promising option as FADN is

Table 1: Sustainability information already collected at national level in the European Union.

Type of information	Member States %
Irrigation practices	0.71
Education and training	0.67
Ownership of farm	0.67
Insurances	0.67
Greening	0.61
Age of assets	0.58
Producing under (quality) labels	0.43
Renewable energy production	0.39
Use of legumes	0.36
Use of contracts	0.35
Nutrient balance (quantities)	0.27
Farm succession	0.25
Direct energy use (quantities)	0.25
Semi-natural areas	0.23
Pesticide usage (quantities)	0.22
Greenhouse gas emissions	0.21
Risk management practices	0.17
Water usage (quantities)	0.17
Involvement in farming organisations	0.13
Innovation	0.13
Soil organic matter	0.13
Nitrate leaching management	0.13
Location and distances to parcels	0.13
Sales channels (cooperatives, consumers etc.)	0.13
Soil erosion management	0.08
Working conditions	0.04
Quality of life	0.04
Engagement in local community	0.00

Source: own data

Table 2: Advantages (+) and disadvantages (–) of collecting sustainability data in FADN or a separate environmental network.

Integrated data collection FADN + FLINT	Separate network for environmental variables
(+) Jointness and trade-off between objectives / indicators	(–) No or weak link with economic performance and farm management
(+) Allows integrated policy analysis	(–) No direct link with policies, policy measure more difficult to evaluate
(+) Use of existing procedures and quality mechanisms	(–) Needs to be established (requires time and resources)
(–) Increased complexity of data collection	(+) Possibility to optimise design for specific variables
(–) Possible need to reconsider field of observation	(+) Optimised design results in more reliable estimates
(–) Wide variety of objectives complicates sample design	(+) Burden can be distributed among farmers
(–) Need for re-adjusting current systems and working processes	

Source: own compilation

the only well-established farm level data collection system on the performance of farms in Europe. In exploring this option, it is worthwhile to consider the advantages and disadvantages of doing so (Table 2). To clarify these aspects, a comparison is made between integrating environmental (and social) issues in FADN or setting up a separate environmental data network.

The Farm Return is the point in the entire data chain of FADN where the system is harmonised. All the processes before uploading the data are NOT harmonised. Each country has its own data collection processes, IT infrastructure, organisational design, incentives for farmers etc. (Bradley and Hill, 2015). Although this could be seen as a weakness because it might introduce a methodological bias, in practice it provides important benefits because the data collection system can be adapted to local circumstances. This is crucial because the agricultural sector, taxation rules, legal obligations to keep accounts, use of IT in the agricultural sector and the extent of electronic data exchange differs strongly between countries. Setting up an FADN system requires selecting data sources and designing working processes that fit to these local circumstances.

This paper analyses the extent to which the differences in national FADN systems affect the opportunities to adapt the data collection. This paper will describe the different FADN systems in Europe, will discuss the implications and possibilities of extending data collection with FLINT type of sustainability indicators in the scope of FADN and will describe the practical experiences of collecting sustainability data in the EU Framework 7 project FLINT (Farm-Level Indicators for New Topics in policy evaluation; http://www.flint-fp7.eu).

Different approaches of data collection in Europe

The starting point of an FADN data collection system is the interaction between a data collector (such as a book keeper, farm advisor or researcher) and the individual farmer. The farmer provides all kinds of information (plus supporting documents) to the data collector who does the further processing to complete the accounts for this farm. Based on the completed accounts, the farmer gets a feedback report with a description of the financial economic situation of the farm, and sometimes a benchmark report to compare their own results with those of similar farms.

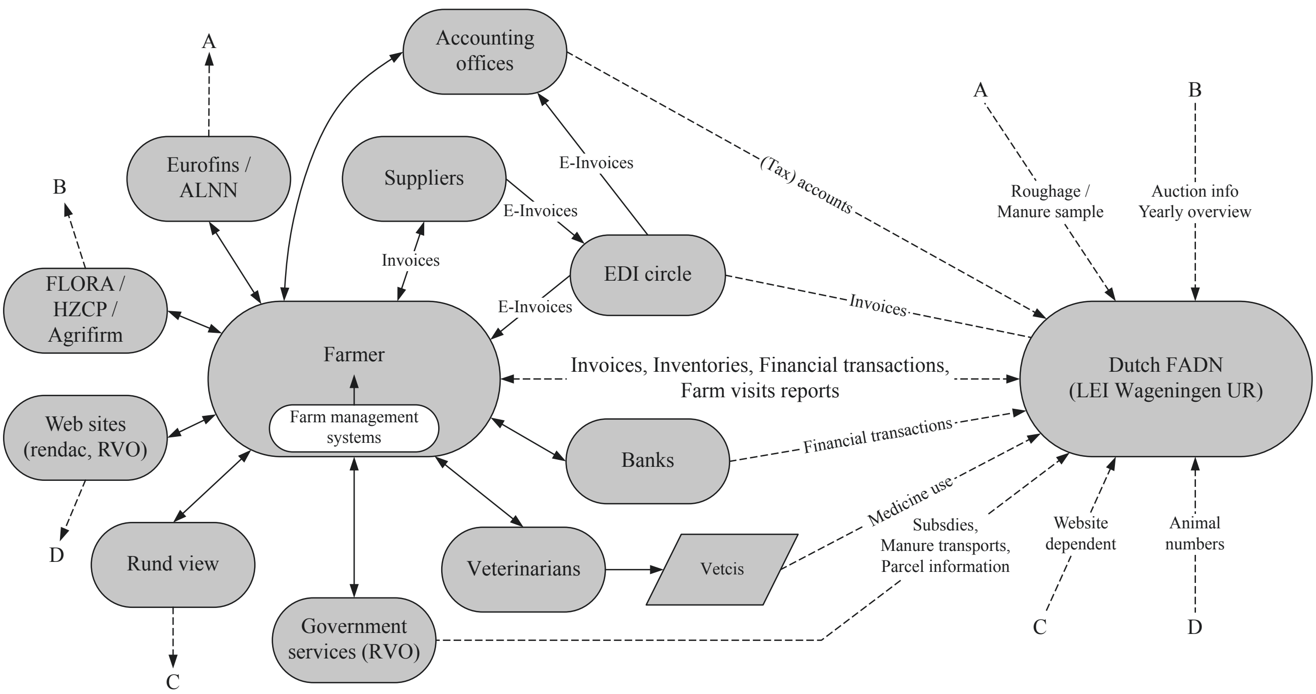

Figure 1: Use of data sources from the network of a farmer to compile accounts (case of the Netherlands).

Source: Vrolijk and Poppe (2016)

This is still the common way of working in most countries. There is however an increasing amount of information that could be collected from other sources. A farmer operates in a network of private businesses of suppliers, traders, processors, banks, insurance companies, auctions and so on, but also of government institutions such as tax office, ministry, paying agency and statistical office. In many cases there is an information flow and information exchange between these organisations and the farmer. This information flow can be verbal, on paper or in an electronic (data exchange) format.

These information flows contain a broad range of relevant information for the data collector to complete the accounts of a specific farm. Re-using this information provides a few potential benefits. The most obvious one is the reduction of the administrative burden on a farmer. All information which can be gathered from an existing source does not have to be collected or asked from the farmer. Re-using information flows also allows the collection of a wider set of data. Invoices, for example, not only contain financial information but also relevant information on, for example, N, P and K mineral content in artificial fertilisers or the types of pesticides bought by the farmer. Furthermore, re-using data provides better opportunities to 'ground truth' the information; it allows easier checking of completeness and consistency between financial and material flows.

More and more countries are experimenting with the use of other sources of information, especially administrative sources such as the subsidy payments or animal numbers. A survey conducted by the FLINT project shows that 70 per cent of the members of the Committee for the FADN make use of administrative sources for the compilation of FADN. Bottlenecks experienced are legal restrictions in combining data sources and the identification of the (same) farm in different systems. The Netherlands is one of the few countries with a more extensive re-use of data from not only administrative but also from commercial information flows (ECA, 2016; Hill *et al*., 2016). The farmer interacts with all kinds of private and governmental organisations and for the compilation of the farm accounts the data collector uses information from these information flows (Figure 1). Access to these information flows is dependent on the explicit permission of the farmer.

The information flows used in the current FADN data collection system affect the possibilities to adopt changes in the data collection processes. Besides the data collection processes, the organisational structure also has an influence on the flexibility.

A typology of organisational structures of FADN in Europe

The organisational structure of FADN differs strongly between EU Member States. In describing the functioning of an FADN system a number of roles at national level should be distinguished, namely the client, the liaison agency and the data collection. These various roles can be conducted by one organisation or can be placed in different organisations. In all countries the client is the responsible ministry, in most cases the Ministry of Agriculture. The ministry has the formal obligation to comply with the *acquis communitaire*, of which FADN is an integral part. The ministry can be the liaison agency, or a governmental or private organisation (i.e. a research institute) can be appointed to fulfil FADN obligations and to coordinate data collection. The personnel of the liaison agency can collect the data or the data collection can be delegated to another organisation (i.e. accounting office or advisory service). Furthermore, there are some supporting tasks which can be outsourced (for example, IT support by a software company, or statistical support by a national statistical office). Different organisational combinations of data collection and liaison agency can be observed in one or more EU Member States (Table 3). Several countries use more than one organisation in the data collection.

Poppe (1997, 2002) defined a typology of FADN systems labelled type Y and type X (Table 4). A crucial distinction between the types is whether the information collection is primarily dedicated to the FADN task or that existing (accounting data) is re-used to fulfil FADN data needs.

In type Y, FADN data collection is done by the FADN liaison agency. Staff of the liaison agency collect the data for FADN purposes. Data collection for the primary purpose at hand, in this case FADN, is defined as primary data collection (Green *et al*., 1988). The data collection is fully dedicated to FADN. This makes it a relatively expensive way to collect FADN data because the whole system is set up and maintained for fulfilling FADN requirements. A major advantage is that it is more flexible to adapt to new information needs. It is easier to instruct and adapt the working flow of own staff to collect additional data elements. This makes it much more cost-efficient to make changes in the data collection. It is a

Table 3: Organisational settings of FADN in Europe (liaison agency and data collection).

Liaison Agency	Data collection		
	Accounting offices	**Advisory service**	**Own liaison agency staff**
Ministry	Spain, Slovenia, France, Estonia, Czech Republic, Belgium, UK, Portugal	Estonia, Romania	Luxemburg, UK, Estonia, Cyprus, Bulgaria, Malta, Portugal, Greece, Belgium
Research institute	Finland, Austria, The Netherlands, Germany, Hungary	Latvia, Finland, Italy, Lithuania, Slovakia, Poland	Ireland, Slovakia, The Netherlands,
Statistical office	Denmark	Sweden	Sweden
Advisory service		Croatia	

Source: own compilation

Table 4: Typology of FADN systems in Europe.

	Type Y	Type X
Primary/secondary	Primary data collection	Secondary data collection
Data collected by	own staff	buying from accounting office
Fixed costs	High	Low
Marginal costs	Low	High
Information feedback to farmers	High	Low
Interest by farmers	High	Low
Data use by research	Often (critical success factor)	Incidentally

Source: based on Poppe (2002)

system with relatively high fixed and low marginal costs for data collection. Within this type, still two common groups can be distinguished. In some countries the data collection is done by farm advisors who divide their time between data collection and advisory tasks. In the second group data collection is done by specialised data collectors.

In type X, data are provided by (fiscal) accountants. The data used to compile the farm accounts are re-used from tax accounts. There is still some additional work needed to make the fiscal accounts suitable for FADN purposes (mainly on the valuation and depreciation of assets) but in general it is relatively cheap because the cost of bookkeeping is already covered by farmers. The farmer pays for the service of the accounting office to keep (tax) accounts. Only the additional work is accounted for in the FADN budget. Although type X is therefore relatively cheap, at the same time it is more difficult to make changes in the data collection. Accountants have their own way of working to compile the tax accounts and it is more difficult to adapt their working procedures for just a small group of clients who participate in FADN. Such a system has relatively lower fixed costs but a high marginal cost and much resistance to additional data.

Type Y or X strongly determine the flexibility of the data collection and therefore the opportunities and limitations for collecting sustainability in the scope of FADN.

Collecting sustainability data in the different types of FADN

The flexibility to adapt the data collection differs strongly between the types of FADN systems in Europe. In the types where liaison agency personnel are responsible for the FADN data collection, changing information needs can be adopted in the data collection system. Collecting new variables can be fully implemented within the own organisation. It requires the definition of the new variables, instructions for data collectors, training of data collectors, adaptation of the IT system to record and process the new data and if useful, an extension of the feedback report to farmers.

An important element in collecting new variables is the analysis how to collect good quality data at the right moment in time. For quality reasons, systematic recording is strongly preferred in comparison to the use of farmer recollection. As previously mentioned, the farmer interacts in a network of different private organisations and governmental institutes, with different types of information exchange. For the new data elements an evaluation should be made as to which potential sources exist and under which conditions they can be used (legal restrictions or privacy regulations), and what the practical challenges are (identification of farms in different systems, format of data availability etc.). For efficiency reasons it is easiest to get access to the data of all relevant farms directly from the source, but if this is not possible the data can sometimes be obtained from the farmer side of the information exchange (e.g. subsidy payments for all farmers from the paying agency vs. use of a notification of the paying agency to an individual farmer about the eligible subsidies). The work flow should be designed to facilitate the chosen option.

In practice, the same could be applied when data collection is outsourced but, as this requires a change of work flows of an external organisation (accounting office) for whom FADN is not the primary business activity, this will be much more difficult to achieve. Owing to the EU law, these accounting offices are selected based on a tender procedure and contracted for one or several years. It is less obvious for accounting offices to redesign their primary working processes for the sake of FADN. A private accounting office needs a clear business model to make these changes, or by getting a fair compensation from the FADN budget or with a business model of collecting these data for their normal clients, the farmers. An example of the latter is the compilation of mineral accounts/balances if there is a legal obligation or farming need to establish these accounts (Breembroek *et al*., 1996). In that case, farmers are willing to pay and accounting offices are often willing to compile them.

If it is not or only partly possible to get the new data elements from the accounting offices, alternative strategies should be implemented. One option is the use of staff of other organisations to collect the data elements which cannot be provided by the accounting office. Given the advantages described above, preferably this additional data collection is at least partly based on the same supporting documents as used in the normal accounting workflow, in order not to fall back immediately on the least preferred option of farmer recollection.

In the FLINT project, different examples of data collection processes and different organisational systems were represented among the project partners. How the data collection was designed in the different countries and what the experiences are with this data collection is described next.

Sustainability data collection in FLINT

The farm-level indicators were selected using a three stage process: identification of existing policy needs, review of current literature and feedback from different stakeholders. Altogether 33 different indicator topics were identified. These 33 topics were defined at a higher level (e.g. innovation or N balance) and could not be measured directly at farm level. Therefore, for each of the 33 topics an exact specification was made regarding which variables to collect. A document was prepared with definitions of each of the variables. In line with the FADN Farm Return, this document was called the FLINT Farm Return. For practical reasons the required data were rearranged into ten tables and structured and described according to FADN standards. This way the data collection could be better integrated in the national FADN systems and more importantly it allowed the use of the current data checking infrastructure (RICA-1) of the EC to check the FLINT data. FLINT data were crosschecked with FADN data at farm level to enhance data quality.

In the FLINT Farm Return about 1,060 new variables were defined. Not all variables are relevant on a specific farm (a farm only has a selection of crops or animal categories), so on average 300 to 400 data items were collected at farm level in addition to the existing FADN dataset. The feasibility of data collection was tested in nine countries with a

Table 5: Methods of data collection in the FLINT project by EU Member State.

Member State	Number of farms		Integration with FADN	Data collected by	Method of data collection
	Selection plan	Data collected			
Type 1: own staff data collection					
Greece	110	124	Separate	FADN data collectors	Farm visit
Ireland	65	64	Integrated	FADN data collectors	Farm visit
The Netherlands	150	155	Integrated	FADN Data collectors	Other sources and farm visit
Poland	140	146	Integrated	FADN data collectors (farm advisors)	Farm visit and other sources
Spain	165	165	Separate	FADN Advisors and FADN accounting office	Farm visit and other sources
Type 2: Outsourced data collection					
Type 2a: Ministry supervision					
France	150	297	Separate	Students	Farm visit
Germany	95	52	Separate	Researchers	Postal questionnaire
Type 2b: Research institute supervision					
Finland	50	49	Integrated	FADN accounting office	Farm visit
Hungary	100	102	Integrated	FADN accounting office	Farm visit

Source: own compilation

wide range of data collection processes and FADN systems. For some countries the FLINT data collection was integrated with the regular FADN data collection process, in others the FLINT data were collected in a separate process (Table 5). The objective was to collect data on 1,000 farms during the pilot phase. A selection plan was designed to decide how many farms in each farming type and in which size classes should be included in the FLINT sample.

The participating countries generally achieved the number of farms to be collected. The only exception was Germany where legal restrictions made it more difficult to get access to the contact information of FADN farmers. This made recruiting farms a much more difficult process, which resulted in fewer participating farmers.

During and after the data collection, the experiences with the data collection were monitored. The experiences were brought together in a FLINT online questionnaire. The results are summarised in four parameters, (a) *Feasibility*: whether data can be collected according to the given structure, (b) *Complexity*: ability to cope with complexity (c) *Availability*: the extent to which data are collectable on the farm or from other administrative sources, and (d) *Data quality*: the reliability of collected data. These items were scored on a five point Likert scale, ranging from poor to excellent, and the scale was assumed to be ratio-scaled.

To analyse the impact of different organisational settings with respect to data collection the categories adopted in Table 5 were used. A distinction was made between ‘own staff data collection’ (type 1) and ‘outsourced data collection’ (type 2). This latter category had the sub types ‘ministry supervision’ (type 2a) and ‘research institute supervision’ (type 2b). A comparison between type 1 and type 2 only showed very minor differences. This implies that FLINT data collection can be achieved in both FADN environments, irrespective whether data are collected by own staff or outsourced to a third party. However, within the ‘outsourced data collection’ a substantial difference was observed between type 2a and type 2b (Figure 2). Ministry supervision scored lower on feasibility, data availability and data quality, while the ability to deal with the complexity showed a smaller difference.

In interpreting this finding it is important to note that the countries belonging to ‘ministry supervision’ belong to Type X of the Poppe typology. FADN data are bought from

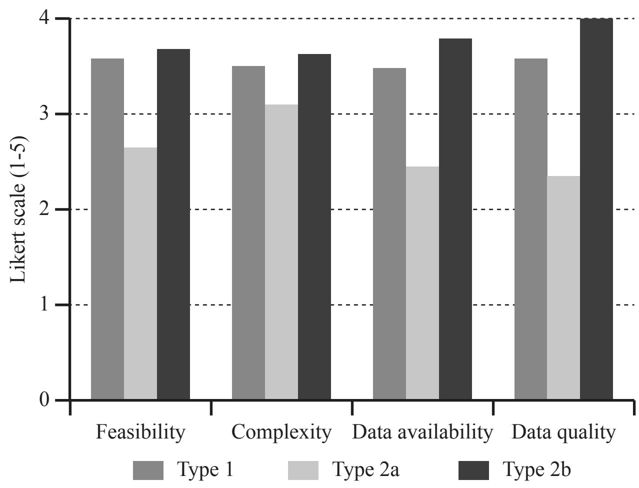

Figure 2: FLINT data collection experiences in different organisational settings.

For definitions of data collection types, see Table 5
Source: own data

accounting offices, there is not a very strong link between the FADN system and the individual farmer, and farmers do not get much feedback from the FADN system. Owing to national circumstances, FLINT data had to be collected in a separate process. In this setup no use could be made of the strong link between data collector and farmers which was perceived to be very important in other countries.

Discussion and conclusions

An increasing need for sustainability data has led to the question how to make these data available for policy making. This paper explores the opportunities to collect sustainability data in the scope of FADN. The pilot project in nine countries including 1,000 farms has shown that in general it is feasible to collect this type of data. The findings show that sustainability data can be collected independently of whether the data collected are collected by own staff or the task is outsourced to a third party. What does make a difference is the relationship between the farmer and the FADN system and especially the FADN data collectors. The built-up trust is an important factor in the willingness of farmers to share the FADN data but also the additional FLINT data.

Using FADN to collect sustainability data further provides the opportunity to make use of the existing quality mechanisms. This does not only concern the quality of the collected data but also the quality of the processes (Ehling and Körner, 2007). The collection of sustainability data would benefit from existing quality processes ranging from the definition of the selection plan and the evaluation of the sample to work flows, instructions and training sessions for data collectors. The quality can also benefit through the strong linkage between the collection of environmental and social data in combination with the economic data.

Collecting more data does increase the complexity of data collection. The step from collecting economic data to sustainability data might seem substantial, but analysing the impacts reveals that the main step is from systematically recording the financial economic aspect of the flows going in and out of the farms to also recording the relevant physical/ material aspects of these same flows. Often the same source documents can be used. If a farmer buys pesticides, fertilisers, petrol etc., the data collector / accountant records the financial amounts from the invoice. On the same invoice there is (in most cases) also information on the physical flows, such as quantity and product name of pesticides, quantity and N, P and K content of fertilisers, quantity and type of energy source etc. If a data collector is clearly instructed to not only record the financial amounts but also the important physical attributes on the same invoice, a major step has been made in collecting the data needed to calculate indicators of the environmental aspects of sustainability performance (e.g. use of active substances of pesticides, N balance at farm gate, greenhouse gas emissions etc.).

Utilising this connection between financial and physical flows provides big advantages for the quality of the collected data, the completeness of the collected data and the burden on farmers. The quality can be enhanced by the opportunities of cross-checking financial and physical flows. The completeness is better assured because the information is based on systematic recording and less emphasis is put on farmer recollection. Ssekiboobo and Zake (2016) show that direct estimations from farmers over (or under) estimate variables such as production when compared to the results of a systematic recording. The administrative burden of farmers can be reduced because the information which can be collected from invoices or other documents does not have to be requested from the farmer.

There are also some statistical aspects in extending FADN to other sustainability issues. FADN is often claimed to be designed to be representative for economic issues (Oenema *et al*., 2011; Koester and Loy, 2016). Although this claim is often not made more precise, a few aspects should be distinguished. These are the demarcation of the field of observation and the sample design of FADN. With respect to the demarcation of the field of survey, FADN is aimed at covering commercial farms, namely those that produce for the market and are larger than a certain minimum economic size (EU, 2010). This threshold differs between countries to reflect the different agricultural structures and different economic situations in countries.

Farms smaller than the threshold are not included in FADN but do have an impact on the environment and the social dimensions of rural areas, especially in those regions with a large number of small and/or semi-subsistence farms (Tocco *et al*., 2014; Tudor, 2015). Here it is important to be aware of the fact that FADN is designed as a tool to monitor and evaluate the EU's Common Agricultural Policy (CAP), which is mainly targeted at and affects commercial farms. Collecting sustainability data on FADN farms does not provide data on very small farms, but does provide the opportunity to evaluate the impacts of the CAP on economic, social and environmental objectives. If the CAP would be focused on smaller farms, changing the field of observation of FADN should be considered, irrespective whether sustainability data are collected or not.

The FADN sample is stratified based on two dimensions, economic size and type of farming. Both dimensions are based on the concept of Standard Output (SO) which is a standardised measure for the expected output of a farm based on the agricultural activities on the farm. The sample allocation (how many farms to include in each strata) is based on different allocation methods, such as proportional or optimal allocation (Vrolijk, 2002). Although SO is defined as an economic indicator to be able to sum different agricultural activities to establish the size of the farm, the practical impact of this choice is very limited. Also for collecting data on environmental and social issues, type of farming and size of farming would be important stratification variables. Owing to the very strong correlation between physical size and economic size (especially within a type of farming) the resulting sample structure is likely to be very similar. What could be different is the exact allocation of the sample size to the different strata. When applying proportional allocation the result would be the same. With optimal allocation, the sample size within each stratum can differ based on the choice of the variable to define the homogeneity of farms in a stratum.

In case sustainability data would be collected in a separate environmental network, the quality of environmental estimates would improve in terms of a reduced variance of the estimates, because the sample can be designed to minimise this variance for the specific environmental variable. A major disadvantage of a separate environmental network is the loss of a direct link with policy measures. Policy measures do not directly affect the environment. Policy measures affect decision makers (in this case farmers), and the behaviour and the change in behaviour of farmers can lead to different farm management decisions and farming practices and these affect the environment. To understand and evaluate the impact of policy measures it is therefore necessary to understand the structure and the farm practices of individual farms. These farm structures and farm practices are recorded in the current FADN.

Although the nine countries included in the FLINT project cover the different types of FADN systems in Europe, the collection of sustainability data in all 28 Member States still poses some challenges. The extension of data collection is dependent on the political support in countries. This requires a trade-off between the financial costs and the burden on farmers on one side and the value of the collected data on the other side. A complicating factor is that policy makers are very concerned with the burden on farmers in their country while the added value of the data for policy making is to a large extent at the European level. Extending the system means that more countries, more farmers and more data collectors will be involved. This will require proper incentives for all those stakeholders affected. Incentives are not limited to financial incentives but can also exist through added value from the collected data.

To balance the workload of farmers it is important to intensify the use of existing data in all countries and not only in those who have already made progress in this. Best practices and experiences in collecting data from existing administrative and commercial information flows should be shared. This makes the data collection more cost-efficient, increases the data quality and assures a better alignment between information needs from different stakeholders.

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Going beyond FADN: The use of additional data to gain insights into extension service use across European Union Member States

This paper examines the use of extension services by farm households across eight European Union (EU) Member States, exploring the type of extension service engaged with, the degree of engagement and the type of information sought. The impact of extension on economic, environmental and social sustainability is also considered. European data utilised are those collected from a pilot sample of 820 households in 2015/2016 as part of the EU Framework 7 project FLINT, from which the Irish results are incorporated further with Irish Farm Accountancy Data Network data. The results outline the key contrasts across the countries investigated and suggest that the degree to which households engage with extension services is primarily influenced by national policies. In addition, this analysis indicates that the extent of this engagement has implications for sustainability at the farm level. The final conclusions and policy recommendations in this paper support the development of a large-scale version of the FLINT pilot survey.

Keywords: agricultural sustainability, extension use by farmers

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Introduction

The global demand for food is increasing rapidly, resulting in agricultural expansion and a growth in associated environmental degradation. It has been projected that by 2050 the demand for crops will be 100-110 per cent higher than 2005 levels. If current trends in agricultural production in developed and developing nations continue, then one billion hectares of land will be cleared globally by 2050, resulting in vast increases in CO_2 emissions and nitrogen use (Tilman *et al.*, 2011). As the global population edges towards 9 billion, the required increase in food production must become more sustainable, socially, environmentally and economically. The provision of knowledge, research and innovative technologies through farm advisory systems will play a vital role in this sustainable development (EU SCAR, 2012).

In Ireland, two key policies which focus primarily on increased food production have been introduced: Food Harvest 2020 and Food Wise 2025. The first of these policies, published in 2010, aims to increase the value of the primary output of the agriculture, fisheries and forestry sector by 33 per cent over the 2007-2009 average; to improve the value added in the sector by EUR 3 billion; to achieve an export target of EUR 12 billion; to increase milk production by 50 per cent; to add 20 per cent to the value of the beef sector and to double the industry spend on research and development by 2020 (DAFM, 2010). Food Wise 2025 expands on this, with the core aims of increasing the value of agri-food exports by 85 per cent; increasing value added in the agri-food, fisheries and forestry sector by 70 per cent; increasing the value of primary production by 65 per cent and creating 23,000 direct jobs in the agri-food sector by 2025 (DAFM, 2015). An environmental analysis of Food Harvest 2020 concluded that, in a scenario without best practice knowledge and innovation, the policy could lead to negative impacts on biodiversity, flora and fauna, water quality, air quality and climatic factors. This report indicated that the introduction of best practice technology from farm advisors through increased knowledge and skills could mitigate these negative impacts and enhance environmental outcomes (Farrelly *et al.*, 2014).

The European Union (EU) has introduced measures designed to achieve continued food security while also maintaining environmental and social sustainability standards. Under the 2003 Common Agricultural Policy (CAP), EU Member States were obliged to introduce a formal system to advise farmers on land and farm management, known as the Farm Advisory System (FAS). The primary goal of the FAS was to assist farmers in becoming aware of issues relating to the environment, food safety, animal health and welfare, and to fulfil EU requirements and avoid any associated financial penalties. Farmer participation in this scheme was voluntary. While the FAS did improve farmers' awareness of issues related to the environment, food safety and animal welfare, the effectiveness of the programme was limited as few farmers actively sought advice (EC, 2010).

From a policy perspective, the contribution of extension services to the general sustainability of farms will become increasingly important as the policy goal of sustainable agriculture rises in importance. The sustainability of agriculture can be measured through the use of farm-level sustainability indicators (Dillon *et al.*, 2016). The role of extension in the sustainable intensification of agriculture which will be addressed in this paper has not been heretofore been examined in detail although Nordin and Höjgård (2016) outline the positive impact of extension contact on land use management and fertiliser use efficiency in Sweden. Furthermore, it is widely accepted that an improved understanding and uptake of technologies as well as advances in areas such as agroecology, biogeochemistry and biotechnology are crucial for the continued sustainability of agriculture (Tilman *et al.*, 2002) and extension contact is the most logical mechanism for the transfer of such knowledge to farmers. In an Irish context, several studies have investigated the

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economic impact of extension service interaction (Hennessy and Heanue, 2012; Bogue, 2014; Heanue and O'Donoghue, 2014; Cawley *et al*., 2015).

This research differs from those cited as the environmental and social impacts of extension use are also explored. In addition, a more in-depth examination of the type of extension services utilised, the specific information requested and the frequency of engagement are taken into account. This work investigates pilot data from eight EU Member States participating in the EU Framework 7 project FLINT (Farm-Level Indicators on New Topics in policy evaluation), and incorporates the Irish results with data from the Teagasc National Farm Survey (NFS) Irish Farm Accountancy Data Network (FADN) data. The FLINT data include information on issues not otherwise available from FADN surveys such as information and knowledge, working conditions and quality of life, innovation, land management and pesticide usage. This analysis examines the value of these additional data on extension service participation and analyses the impact of the intensity of extension service use on sustainability outcomes.

Agricultural extension services and output

Agricultural extension services are a mechanism by which policy-relevant research can be transferred to the farm level. They comprise public and private sector activities relating to technology transfer, education, attitude change, human resource development, and the dissemination and collection of information (Marsh and Pannell, 2000). Such services can assist farmers by assessing their socio-economic situation and informing them of their potential and barriers to development. This can be conducted through direct or indirect interaction with the farmer by way of an agent or intermediary organisation and with the use of education services and information provision via mass media.

In Ireland, Teagasc (The Agriculture and Food Development Authority), a state body, acts as the primary provider of advisory services to farmers, delivering research, advice and training. Private sector planners also provide extension services. Since the mid-1990s, Teagasc has moved towards a model of participatory extension which sees farmers as full collaborators in research and extension (Mahon *et al*., 2010). One such form of extension is that of discussion groups, which consist of a group of local farmers who meet regularly on farms to see, discuss and learn about technologies and practices that may be applied on their own farms. These discussion groups are becoming increasingly popular in Ireland and are used widely to transfer knowledge (Hennessy and Heanue, 2012).

In line with international research, extension services in Ireland have been found to have positive impacts on financial outcomes for farmers. Heanue and O'Donoghue (2014) conducted a descriptive and econometric analysis of results from the Teagasc NFS during the period 2000-2011. They found that family farm income was highest for those households where the farmer had obtained an agricultural certificate or had gone to agricultural college. Both the private returns (costs and benefits to the farmer) and social returns (impact on the state of output and other income streams relative to the cost of providing the education) to investment of agricultural education were positive. Agricultural education improved a farmer's technical and allocative efficiency in three ways. Firstly, education assisted farmers in making better use of information and in finding solutions to issues which made them more efficient in allocating their resources. Secondly, education meant that farmers had improved access to the information they required. Thirdly, due to this improved information, educated farmers were more likely to be early adopters of new technology or products.

Hennessy and Heanue (2012) assessed the effectiveness of dairy farm discussion groups (a form of participatory extension) in Ireland using discrete choice models. Discussion group membership was associated with increased use of technology and higher farm profits. It is suggested that the learning atmosphere associated with discussion groups, i.e. a positive, familiar, trusting environment, can facilitate greater social and interactive learning. Similarly, Bogue (2014) highlights the positive benefits to farmers which resulted from participation in beef discussion groups run by Teagasc. On average, discussion group members had higher output and an overall higher average gross margin per hectare than non-members. Sixty-one per cent of discussion group members made improvements to their overall profit and half of the participants experienced a financial benefit from taking part in the group.

Cawley *et al*. (2015) utilised an instrumental variable approach to establish the impact of the decision to participate in extension programmes on farm-level outcomes. They established that omitted variable and self-selection bias may be present within the sample, i.e. that farmers' ability or motivation would have an impact on the decision to engage and that higher-skilled farmers may choose to take part due to their capacity and willingness to improve their business. On the contrary, these high achievers may be less likely to engage given their propensity to succeed without assistance. Therefore, the decision to engage may be endogenous and so instrumental variables must be used. Using the distance to the local advisory service and the introduction of the Single Farm Payment Scheme in 2005 as instruments, on the assumption that distance and the complex new scheme may influence a farmer's decision to take part in a way that is unrelated to performance, this study found a positive net benefit to extension engagement.

Although these studies show that extension services can contribute to economic sustainability, there is a gap in the literature with respect to the potential impact of engagement with extension services on social and environmental sustainability. Similarly, little has been written about the effect that frequency of farmer engagement with extension services may have on these outcomes. In the following sections we explore whether the use of the additional data provided by the FLINT study can shed light on these issues. We hypothesise that engagement with extension services will have a positive influence on sustainability indicators; the degree of engagement and type of advisory services used will differ among the EU Member States due to national policy differences and that more intensive engagement with extension services will result in more sustainable farm outcomes.

Methodology

Sustainability indicators

The concept of sustainable development was first introduced in the late 1980s by the 'Brundtland report' (WCED, 1987). It is defined from an economic point of view as preserving or enlarging capital stock in the form of economic, social and natural capital (Pingault, 2007). Concerns regarding both the sustainability of agriculture itself and its contribution to sustainable development are becoming increasingly important to policymakers (Bockstaller *et al*., 2009). Sustainability of agriculture is measured as a function of three parts: economic (the production of goods and services), environmental (the management of natural resources) and social (the contribution to rural dynamics) (Diazabakana *et al*., 2014). These three categories are known as the sustainability pillars.

Measuring sustainability allows for comparisons, in this case between farmers who use extension services and those who do not. To do this, indicators, defined by OECD (2001) as 'a representative measure involving raw data on a phenomenon that is important for policy makers', are selected under each of the pillars. Indicators for this study (Table 1) were chosen with consideration for both the available data and the topic of extension services under consideration and are based on those designed by Hennessy *et al*. (2012). These measures provide a 'snapshot' of the farm's current productivity. It is possible that high gross output per ha this year could lead to soil degradation in subsequent years. Therefore, although the farm appears sustainable this year, it may not be in the longer term. As the analysis in this paper focuses primarily on one year's worth of data, long-term analysis is not conducted.

Table 1: Sustainability indicators used in this study and their method of calculation.

Indicator	Measure	Unit
Economic		
Productivity of land	Gross output per ha	EUR per ha
Profitability	Market-based gross margin per ha	EUR per ha
Productivity of labour	Family farm income per unpaid labour unit	EUR per labour unit
Viability of investment	Farm is economically viable*	1= viable, 0= not viable
Market orientation	Output derived from market	Per cent
Environmental		
Greenhouse gas (GHG) emissions	Emissions per ha using IPCC estimates**	kg CO_2 equivalent per ha
Risk to water quality	Nitrogen per ha	kg N surplus per ha
Social		
Household vulnerability	Farm is not viable and no off farm employment	1= vulnerable, 0=not vulnerable
Education	Agricultural education attainment	1= educated, 0=not educated
Isolation risk	Live alone	1=yes, 0= no
Work-life balance	No. hours worked	No. hours worked on the farm

* Farm is viable if the farm can pay for family farm labour at the minimum agricultural wage plus a 5 per cent return on non-land assets.

** The methodology utilises a combination of Tier 1 and Tier 2 approaches to estimate GHG emissions per farm (tonnes of carbon dioxide equivalent, tCO_2eq) by applying relevant Intergovernmental Panel on Climate Change (IPCC) coefficients to animal numbers (on the basis of age category). IPCC Tier 1 utilises simple methods with default values. Tier 2 methods include country-specific emission factors. Tier 3 includes more complex approaches, possibly models.

Source: own compilation

In order to assess if there are statistically significant differences between those who engage with extension services and those who do not, the differences in the means of extension services users and non-users for each of the sustainability indicators are tested using either a t-test or chi square test using Irish FADN data. Eleven OLS regressions were conducted, one for each indicator. These indicators will be the dependant variable. Each regression includes the same independent variables, outlined in the following section, which include information on farm system, soil type etc. The independent variable of interest is 'extension'; a dummy variable taking a value of 1 if the respondent engages with extension services.

Using the new information provided by the FLINT data, respondents are classified as 'low' or 'high' extension service engagers. With this information, the difference in means of those who engage with extension services less frequently and more frequently is tested using either a t-test or chi square test. Following this, two sets of OLS regressions are conducted using the selected sustainability indicators. The first set of regressions using the sustainability indicators as the dependent variable selects a dummy variable representing 'low' extension participants as the independent variable of interest. The second set selects a dummy variable representing 'high' extension participants as the independent variable of interest.

FADN Data

Irish FADN data for 2015, collected through the Teagasc NFS, which surveys a statistically-representative random sample of farms, are used for this analysis. Face-to-face interviews were conducted by a professional data collection team. The NFS also provides more detailed information used to supplement the FADN in this study. This analysis looks at all the farm systems on which data are collected, namely dairy, cattle rearing, cattle other, sheep, tillage and other. These are classified on a standard gross margin basis. The FADN data are used to examine the impact of extension participation on each indicator listed in Table 1. Other variables included in this analysis are a range of farm characteristics including the farm system (detailed above) and soil type. This variable is comprised of three classifications: class 1 indicating soil with little or minor limitations in terms of agricultural use; class 2 comprising of soils with more limitations, poorer drainage and those that are generally unsuitable for tillage; and class 3, consisting of soils that are greatly limited in terms of agricultural use, primarily found in the West of Ireland and mountainous areas. Variables are also included to classify those areas designated as 'less favoured'[6]. Three dummy variables are included: the first consisting of those regions not classed as disadvantaged; the second comprising of less severely disadvantaged areas and the third, indicating regions regarded as severely disadvantaged. The number of people in the household is also included. Region variables

[6] In accordance with Council Directive 75/268/EEC of 28 April 1975 on mountain and hill farming and farming in certain less-favoured areas.

are also included; however the Dublin region is excluded from the analysis due to the small sample size.

Results

Summary statistics using Irish FADN data

The differences in means of extension services users and non-users for each of the sustainability indicators used in this study are presented in Table 2. The significance of these differences is tested using either a t-test or chi square test. This preliminary analysis indicates that there are significant differences between the two groups for all but one of the indicators, isolation risk. Extension users have a higher output per hectare on average by more than EUR 600 compared to their non-extension user counterparts. Extension users are also doing better on average for all of the other economic indicators. The environmental indicators show the opposite with extension users faring worse in both the GHG per hectare measure and nitrogen surplus per hectare. This is consistent with the results of Lynch *et al*. (2015).

Socially, extension users scored better on both household vulnerability and education, but worked over 200 hours more than non-extension users.

These calculations do not take into account the presence of self-selection bias. Farmers who already run their farms more efficiently than their counterparts often are those who choose to participate in extension programmes (Dercon *et al*., 2009). On the other hand, it may be the poorer performing farmers, in greater need of advice, who seek out the extension programmes. This would result in the over or under estimation of the effect of extension services, especially in relation to economic variables.

As only one year of data (2015) was available for this analysis, more elaborative analysis, such as instrumental variable regressions or endogenous switching regression analysis, could not be conducted due to a lack of suitable instruments. However, these data are used subsequently in our OLS analysis described below, which provides a basic outline of the importance of extension participation and the level of engagement in extension programmes for economic, environmental and social indicators.

FLINT data

The Irish FADN data provide a range of information on economic, environmental and social outcomes, but they are limited in terms of detail on the degree of farmer engagement with extension services. More detail is provided by the FLINT data, including types of advisory services used, information obtained and the mean number of engagements per farmer. The FLINT data are subsequently incorporated with the FADN data in OLS regressions, as described below. Following the methodology used above, the sustainability indicators are the dependent variables of interest. The FLINT data can then provide two important independent variables: a binary variable indicating whether or not the farmer is a low extension user and a binary variable indicating whether or not he or she is a high extension user. As above, the FADN and NFS data provide the other explanatory variables such as farm system, soil type etc. The full FLINT sample in this paper includes data from 820 farms for eight EU Member States, namely Finland (50), Germany (52), Greece (124), Hungary (102), Ireland (64), the Netherlands (155), Poland (145) and Spain (128). Although not nationally or geographically representative, it provides useful pilot information on the type of information and extension services availed of by the sample respondents.

Extension service use

The FLINT data provide greater detail of the type of extension service being used and the frequency of engagement with these service providers. Such information is useful as the intensity of participation or level of interaction with extension services is an important factor in increasing net farm income (Akobundu *et al*., 2004). The mean numbers of engagements with each advisory service in 2015 for the countries in the FLINT sample (Figure 1) reflect the number of times a farm obtained information from the relevant advisory services on a range of topics. Each instance of a specific information request is regarded as an additional engagement regardless of whether or not the farmer has used the same service on the same day e.g. requesting accountancy information and crop information from a public advisory service in one day is calculated as two engagements.

Table 2: Difference in means for sustainability indicators for non-extension and extension users.

	Non-extension		Extension		Difference	
	mean	s.d.	mean	s.d.	value	t
Output per ha	1567.26	1053.87	2208.98	1255.15	-641.73	-7.90***
Gross margin per ha	684.37	612.60	1058.29	745.94	-373.92	-7.84***
Family farm income per labour unit	23166.60	22851.69	38584.11	36652.14	-15417.52	-7.60***
Viability	0.39	0.49	0.58	0.49	-0.20	29.19***(χ^2)
Market orientation	0.70	0.15	0.77	0.14	-0.07	-6.60***
GHG per ha	4.44	2.59	5.62	3.06	-1.18	-5.91***
Nitrogen per ha	65.79	60.44	96.39	74.92	-30.60	-6.46***
Household vulnerability	0.44	0.50	0.31	0.46	0.13	13.26***(χ^2)
Education	0.47	0.50	0.65	0.48	-0.18	26.66***(χ^2)
Isolation	0.16	0.36	0.13	0.34	0.02	0.32(χ^2)
Hours worked	1854.72	710.36	2088.29	710.81	-233.56	-4.53***
N	280		597		877	

*** p<0.01, ** p<0.05, * p<0.1
Source: own calculations

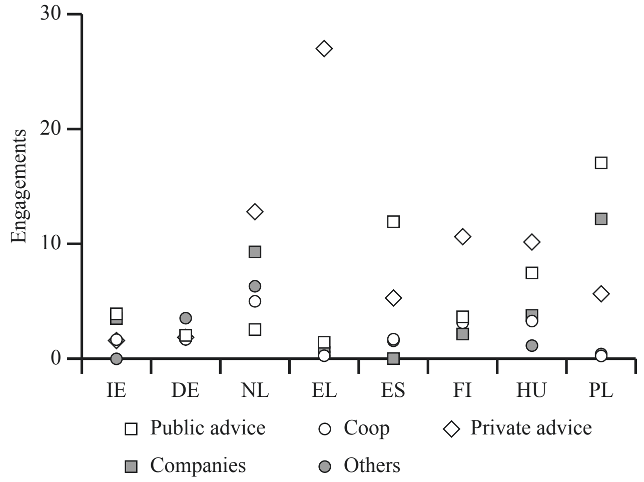

Figure 1: Mean number of engagements per farm with each advisory service in 2015 per EU Member State: full FLINT sample.
Source: own data

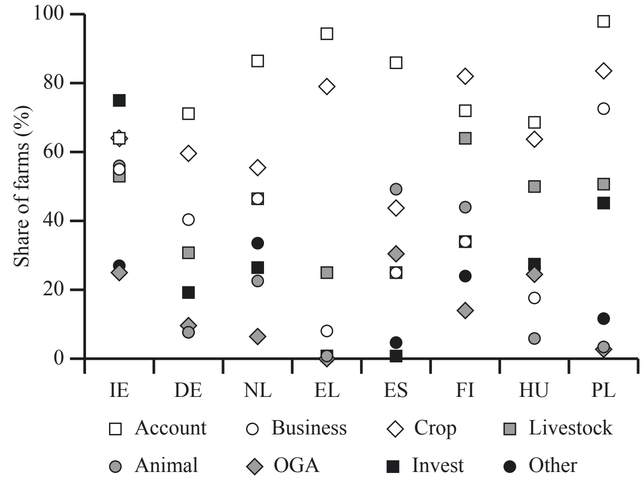

Figure 2: Percentage of respondents requesting information in 2015 by information type per EU Member State: full European sample.
Source: own data

'Public advice' refers to all public advisory services or public extension agents offering direct advice services to the farmers e.g. advisory centres, chambers of agriculture, agricultural authorities, state-owned advisory firms and public research institutes. Poland has the highest number of engagements with this advisory type for the FLINT sample, with a mean of 17 in 2015. The lowest for this category is found in Greece, with a mean of just 1.4. The next service type includes farmers' cooperatives or organisations which offer direct advisory services to the farm. This service type is most popular in the Netherlands, with a mean engagement of 5, and least popular in Poland with a mean of 0.25. 'Private advisors' include all independent private consultants or consultancy firms e.g. accountancy firms, veterinary experts and private advisory companies. Greece presents an interesting result for this service type, with a mean engagement of 27 per farm in 2015. One farm in Greece interacted with private advisors 315 times in 2015, and four farms engaged with private advisors over 100 times in total. Excluding these four farms brings the mean number of engagements to 22, which still remains the highest mean for all service types. 'Companies' includes all firms downstream and upstream along the value chain whose principal business is not the provision of advisory services. These include input traders, processors and wholesalers (for example: input shops, bank officers, buyers). Poland avails of this service the most, with a mean engagement of 12, and Spain the least, with just two farms in the Spanish sample using this type of service.

The survey provided to respondents also included an 'others' and 'other farm-based providers' category, which incorporated all of the providers not covered in the previous categories; such as universities, environmental NGOs, private research institutes and religious organisations. This service type was used the most in the Netherlands, with approximately six engagements per farm, and the least in Ireland, with no farm using this type of service.

In Ireland, approximately 71 per cent of the 64 respondents availed of public advisory services; farmers' cooperatives were used by 58 per cent of the sample, private advisory services were consulted the least by respondents, with just 36 per cent of the sample using this service type. Companies were used by 77 per cent of the sample, the highest for all service types in Ireland. The mean number of engagements with all extension services for the Irish sample was ten. Four respondents did not engage with any extension services in 2015. Forty-four per cent of respondents in the Irish FLINT sample were classified as low extension users; i.e. they engaged with extension services between 0 and 8 times in 2015, and 22 per cent were classified as medium extension users, availing of extension services between 8 and 12 times in 2015. Finally, 34 per cent of the Irish FLINT sample respondents were categorised as high extension users, using extension services 13 times or more in 2015.

Information requested by farmers

The FLINT data also provide greater detail on the type of information requested by each farm in the sample (Figure 2). Approximately 98 per cent of the Polish sample asked for accountancy assistance. This includes advisory services for bookkeeping, accountancy, taxes and FADN. For all countries except Ireland and Finland, this category was the most sought after by the sampled farms. The Irish farmers were least interested in this type of information, with just 64 per cent of the sample seeking accountancy assistance. Advisory services for planning, monitoring or executing plans included business/financial/marketing planning, human resources, management, marketing advice and marketing information services. Again, Polish farmers were the most interested in this type of information with 73 per cent of the sample seeking help for these issues. The lowest proportion of respondents (just 8 per cent) requesting assistance on this topic came from Greece.

As regards advisory services which deal with issues related to crops production, Polish farmers were again the keenest to gain advice on this issue, as 83 per cent of the sample requested information. Spanish farmers sought this advice the least, as just 44 per cent of the sample requested this type of assistance. Finnish farmers requested assistance on issues related to livestock production the most (64 per cent) and Spain and Greece were joint lowest with just 25 per cent of each country's sample expressing an interest in

Table 3: Difference in means for sustainability indicators for low extension and other extension users: Irish FLINT sample.

	Non-extension		Extension		Difference	
	mean	s.d.	mean	s.d.	b	T
Output per ha	2132.02	1356.93	2703.08	1438.66	571.06	1.61*
Gross margin per ha	1059.94	853.12	1269.05	855.86	209.11	0.97
Family farm income per labour unit	37981.44	36290.34	35607.91	27510.59	-2373.53	-0.30
Viability	0.50	0.51	0.61	0.49	0.11	0.79 (χ^2)
Market orientation	0.77	0.14	0.81	0.12	0.03	1.21
GHG per ha	5.71	3.02	7.22	3.45	1.50	1.81**
Nitrogen per ha	97.75	72.68	144.47	93.66	46.71	2.2***
Household vulnerability	0.42	0.50	0.28	0.45	-0.15	1.59 (χ^2)
Education	0.46	0.51	0.69	0.47	0.23	2.48** (χ^2)
Isolation	0.14	0.36	0.14	0.35	0.00	0.00 (χ^2)
Hours worked	2019.00	643.19	2245.63	478.71	226.64	1.61*
N	22		42			

*** $p<0.01$, ** $p<0.05$, * $p<0.1$
Source: own calculations

livestock issues. For advisory services which aim to solve problems and implement solutions relating to animal products and services, this information was requested most in Ireland (56 per cent) and least in Greece with just one farm asking for this information.

Other gainful activities (OGA) covered advisory services which assist with issues related to other activities not comprised of farm work but which are directly related to the holding, e.g. tourist facilitation. This was sought most in Spain (30 per cent) and least in Greece, where no farms demanded this information. Investment included all advisory services related to a determined investment. This advice was requested most in Ireland, with 75 per cent of the sample seeking this information. Spanish and Greek sample farms were equally disinterested in this topic, as only one farm in each sample demanded investment assistance. The final category covered all other advice provided to the farm. While 34 per cent of farmers in the Netherlands sample sought this advice, no Greek farmers requested this information.

In Ireland, 75 per cent of respondents sought information about investment issues in 2015, the largest proportion of any FLINT country sample for this information type. The two national policies, Food Harvest 2020 and Food Wise 2025, may have encouraged these farmers to seek investment advice in order to increase their productivity and improve their efficiency.

Summary statistics using Irish FADN and FLINT data

The significance of the difference in means for the Irish FLINT sample of low extension services users (fewer than 8) and those which were categorised as medium and high users (8 or more), incorporating the sustainability indicators from the Irish FADN database was tested using either a t-test or chi square test. There were significant differences between the two groups for several of the indicators (Table 3). Low extension users had a lower output per hectare on average by approximately EUR 571 in comparison to their higher extension user counterparts. As with the FADN difference in means outlined earlier, the environmental indicators showed the opposite with low extension users faring better in both the GHG per hectare measure and nitrogen surplus per hectare. Low extension users received less agricultural training than the others in the sample, and worked over 226 hours fewer than medium and high extension users.

Table 4: Irish FADN extension coefficients for each regression with sustainability indicator as the dependent variable**.**

Indicator	Extension	SE	R-squared
Economic			
Output per ha	129.1**	55.41	0.634
Gross margin per ha	79.16**	33.33	0.649
Family farm income per labour unit	6,469***	1872.00	0.295
Viability	0.058*	0.034	0.268
Market orientation	0.0155**	0.01	0.608
Environmental			
GHG per ha	0.141	0.13	0.65
Nitrogen per ha	5.24	3.56	0.552
Social			
Household vulnerability	-0.053	0.04	0.139
Education	0.080**	0.03	0.189
Isolation	-0.000	0.03	0.037
Hours worked†	88.51*	50.37	0.228

N=872 except †N=871; robust standard errors reported for OLS
*** $p<0.01$, ** $p<0.05$, * $p<0.1$
Source: own calculations

In the following two sections the regression results for the Irish FADN and Irish FLINT data are outlined. The coefficients of the extension variables are presented for each of the OLS regressions conducted, along with standard errors and R-squared results. Full regression results are available from the authors.

Irish FADN

The results of the Irish FADN regressions given in Table 4 incorporate only questions which are part of the Irish FADN and NFS survey, including that outlining whether or not a farmer engaged with an extension service. These data include the full Irish FADN database of 877 farms, though outliers are excluded from the sample, as discussed previously, leaving 872 observations for all indicators except hours worked, which has 871 observations due to one farm not completing this question correctly. Although this paper focuses primarily on the extension variable, in summary the most statistically significant variables for each of the economic indicators include: farm system and number of residents in household. For the environmental and social indicators the farm system dummy variables were statistically significant for each indicator.

These results indicate that participation in extension programmes has a positive impact on economic indicators, with all suggesting positive outcomes. Family farm income in particular is significant, with those who participate in extension programmes experiencing on average EUR 6,469 in additional farm income per labour unit. The environmental indicators suggest that those who participate in extension programmes have the poorest performance in terms of greenhouse gas emissions and risk of loss of nutrients to water (nitrogen per ha), though this result is insignificant. The results for the social indicators suggest that those who participate in extension schemes are more likely to be educated. On average, farmers who participate in extension schemes work 88.5 more hours per annum than those who do not.

Irish FLINT

Table 5 presents the supplementary Irish FLINT results for those who partook in extension activities fewer than eight times in 2015 (low extension) and 13 times or more in 2015 (high extension), incorporated into FADN and NFS data. These regressions are run only for those farms who participated in the FLINT study. One farm was excluded as an outlier, leaving 63 observations. As above, these results focus primarily on those of the extension variable; however the only determinants which were significant for the majority of the economic, environmental and social indicators were farm system.

The economic results indicate that low extension farms are significantly less viable than those that use extension services more frequently. The remaining economic indicator results suggest that these respondents have a lower output per hectare, lower family farm income per labour unit, are less likely to have market orientation and have a slightly higher gross margin per hectare, though these results are not statistically significant. Though the results for the environmental indicators are not statistically significant, they suggest that these farms have lower GHG and nitrogen emissions per hectare. In terms of social indicators, low extension households are statistically more likely to be vulnerable than those that use services more frequently and are less likely to be educated. These respondents are less likely to be isolated and would appear to work, on average, 166 fewer hours per annum than their more participatory counterparts, though these results are not statistically significant.

Though not significant for the majority of indicators, probably due to the small sample size, the results suggest that low participation rates with extension services have a negative influence on farming viability. The results for the environmental indicators are not statistically significant. In terms of social indicators, high extension households are statistically more likely to be educated. In contrast, low extension households are more likely to be vulnerable than their less engaged counterparts.

Discussion and conclusion

The literature on extension use has indicated that participation can have a positive impact on economic (Läpple *et al*., 2013; Cawley *et al*., 2015) social (Van den Berg and Jiggins, 2007) and environmental (Mancini *et al*., 2008) indicators of sustainability. While many of these studies focus on a specific extension service such as farmer discussion groups (Hennessy and Heanue, 2012; Bogue, 2014) and/or the impact of extension use versus no extension use (Cawley *et al*., 2015; Dillon *et al*., 2016), in general, little attention has been given to the range of extension service on offer, the sort of information that is requested and the level of engagement between the farmer and the extension provider. To the best of our knowledge, this is most likely due to the limited availability of data on these topics.

The results provided in this paper point to stark differences in the preferred extension service for each country in the European FLINT sample. In Ireland, Spain and Poland, public extension services provide the most frequent interaction with farming households; whereas in the Netherlands, Greece, Finland and Hungary private advisory services are most commonly used. This reflects the different policy frameworks across Europe. In Ireland, Teagasc is the primary advisory service for farmers providing advice on a

Table 5: Irish FLINT low and high extension coefficients for each regression with sustainability indicator as the dependent variable.

Indicator	Low extension			High extension		
		SE	R-squared		SE	R-squared
Economic						
Output per ha	-83.6	310.50	0.741	332.4	302.70	0.749
Gross margin per ha	6.775	180.30	0.748	197.80	173.50	0.756
Family farm income per labour unit	-5,040	8097.00	0.577	12,342	8,207	0.596
Viability	-0.230*	0.118	0.502	0.0743	0.115	0.364
Market orientation	-0.00874	0.02	0.882	0.0129	0.02	0.883
Environmental						
GHG per ha	-0.515	0.72	0.708	0.994	0.81	0.718
Nitrogen per ha	-28.75	19.20	0.685	34.71	22.25	0.692
Social						
Household vulnerability	0.312**	0.135	0.404	-0.192	0.129	0.258
Educated	-0.317**	0.145	0.371	0.309*	0.158	0.312
Isolation	-0.031	0.087	0.264	-0.0271	0.088	0.410
Hours worked	-166.6	178.30	0.361	180	181.50	0.364

N=63; robust standard errors reported for OLS; *** $p<0.01$, ** $p<0.05$, * $p<0.1$
Source: own calculations

wide range of issues including farm management, nutrition, investment and up-to-date research to fee-paying clients, with basic advisory contracts starting at EUR 145 per annum. This broad range of advice is reflected in the somewhat even spread of the type of information being requested. Over 50 per cent of farmers in the Irish sample requested information on issues related to accountancy, business, crop, livestock, animal welfare and investment opportunities.

In Spain, the type of advice being provided by public advisory services has changed in recent times, moving from their traditional role of personalised advice to farmers to focus primarily on the management of grants to farmers from CAP or other issues related to EU regulations (Esparcia *et al*., 2014). Again, this is represented in the type of information requested, with 86 per cent of farmers requesting information on accountancy issues but fewer than 50 per cent seeking information on any other issue. In Poland, the majority of advisory services became public in 1995, meaning that all farmers can now avail of free advice (Kania *et al*., 2014). The results from this paper indicate that this policy influences the uptake of services, as Polish farmers in the sample engage with public advisory services more frequently than any other country and Polish farmers are more likely to seek information on issues related to accountancy, business and crop production than in any other country.

One apparent outlier in terms of the number of engagements with advisory services is Greece. This country had by far the largest number of mean engagements with private advisory services and fewer engagements with public advisory services than any other country in the sample. This result is perhaps a reflection of the lack of funding and organisation for public agricultural advisory services in Greece. Over the last 30 years, the provision of public agricultural extension services in Greece has been limited and focused primarily on maximising outputs and subsidies to farmers rather than training and education. Though attempts were made in 2005 by the Ministry for Rural Development and Food (MRDF) to establish Local Centres for Rural Development, these Centres were closed in 2010 due to funding issues. All levels of the MRDF are understaffed and restrictions on travelling minimise the degree of contact possible between advisors and farmers. Owing to a lack of public advice, private advisors have become the main supporters of farmers. Some private advisors make a living by selling inputs to farmers. These advisors provide information on improvement of quality and quantity, cost reduction and environmental protection. Others are paid fees by farmers and provide information on participation in and application preparation for specific EU programmes (Young Farmers, Capitals for Early Retirement Scheme etc.) (Koutsouris, 2014). This focus on funding is reflected in the results in this paper, with 94 per cent of Greek farmers seeking information on accountancy issues.

The results of this analysis also highlight the type of information considered most valuable to farmers. In most of the surveyed countries, accountancy information was sought by the greatest majority of respondents. This is not surprising given the complicated processes involved in claiming benefits and due to new schemes such as the Basic Payment System, Greening and the Young Farmer's top-ups which came into effect in 2015. In Ireland, for example, many farm advisors have been overwhelmed with requests for assistance because of these additions (Coughlan, 2015).

The results also suggest that a large proportion of farmers requested advice on crop production. This could have arisen due to the introduction of the Greening payment in 2015. This payment obliges all farmers with 10 acres or more of arable crops (unless they qualify for an exception) to sow a number of different crops. Farmers with more than 15 acres of arable land must declare at least 5 per cent of their land as an 'Ecological Focus Area' (DAFM, 2015).

The Irish FADN and FLINT regression results outline the importance of engagement with extension services, and specifically the impact that greater degrees of engagement has on economic and social indicators, corresponding with the findings of Van den Berg and Jiggins (2007), Hennessy and Heanue (2012) and Bogue (2014). Though the Irish FLINT study consisted of only 64 cattle and dairy farms, these preliminary results suggest that lower engagement can have a detrimental impact on farm viability and household vulnerability in particular. However, these results are inconclusive as regards the influence of extension services on environmental indicators, with the difference in means analysis suggesting negative outcomes and the regressions providing insignificant results. It is possible that, at least in Ireland, economic indicators of sustainability are the primary focus of extension service providers and those who engage with them. This is reflected in the results of the Irish FADN regressions which suggest positive outcomes from engagement for all economic indicators and the type of information which is sought most by those in the Irish FLINT sample (accountancy and investment). These preliminary results highlight the need for specific extension services which focus on 'double dividend' economic indicators which also have environmental benefits, such as reducing agricultural emissions. Given the suggested positive results for economic indicators in this paper it is likely that engagement on environmental schemes of this kind could also be successful.

Despite the limitations of this research, the findings indicate that a large-scale FLINT study could prove very useful as a measure of farming sustainability throughout Europe. Future work of this kind could provide policymakers with information on the types of extension service that are most valuable to farmers in their country and with data on possible improvements to services that may be required. With this information in place, policymakers could anticipate the information burden that a new policy will place on farmers, and provide adequate expertise and education in these areas in advance of its introduction. This information could be used to measure the success of various extension services, information provision and specific national and EU policies in terms of their impact on economic, environmental and social indicators of sustainability.

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Adoption of risk management strategies in European agriculture

Given the increased attention to risk management in the European Union's (EU) Common Agricultural Policy (CAP), it is important to monitor and evaluate the rates of adoption by farmers and their determinants over time. Current European agricultural statistics (Farm Accountancy Data Network) capture few indicators that assess such strategies, but complementing data collected during the EU Framework 7 project FLINT have allowed the adoption of risk management strategies and the determinants of farmers' preference for complementary or substitute instruments to be assessed. Adoption rates of risk management instruments such as insurance contracts, price contracts, off-farm income, other types risk of reduction measures and other gainful activities vary significantly across EU Member States and farming types. Econometric analysis indicates that larger farms more often adopt crop insurance, occupational accident insurance, price contracts and diversification but are less likely to adopt credit avoidance and off-farm employment (at a significance level of 1 per cent). For policy analyses these indicators are a step forward for the determination of the net impacts and establishment of counterfactuals in the long term (i.e. time series encompassing also adverse years) for measuring the impact of the CAP at farm level.

Keywords: insurance, contracts, off-farm income, diversification, gainful activities

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Introduction

Farming is a heterogeneous sector in a complex and multi-faceted environment facing a variety of sources of risk beyond the control of farmers (McElwee and Bosworth, 2010). Farm income is subject to a wide range of environmental, technological and economic perturbations, as well as structural changes in policy and institutions. These multifaceted dynamics and conflicting demands generate unexpected outcomes with volatile income streams for the entire agricultural value chain (Darnhofer *et al.*, 2016). Within this context, farmers need to apply strategies and instruments to balance their income and risks and to achieve income stability (Hardaker *et al.*, 2004). The reduction of risks to income over time will improve farmers' well-being, their competitiveness and the ability to expand their operations through innovation and the appropriate investment decisions (EP, 2014).

Extensive theoretical and empirical research has been conducted to understand the issue of risk and to develop instruments to support farmers (see, for example, OECD, 2009; Kimura *et al.*, 2010). Options include risk-transfer strategies (marketing contracts, production contracts, hedging on future markets, participation in mutual funds and insurance) or on-farm measures (selection of products, diversification, self-insurance, farm financial management and savings/credit) (Meuwissen *et al.*, 1999).

Diversification is widely used in agriculture to deal with multiple sources of risk. Through diversification, being either multi-commodity farm activities or combining on-farm and off-farm income or a combination of both, risks are mitigated, enabling more stable incomes to be generated (Hardaker *et al.*, 2004; Bowman and Zilberman, 2013; Barnes *et al.*, 2015). Certain characteristics are associated with diversification, for example, age, education, farm size, financial structure, labour use and farming experience (Bowman and Zilberman, 2013; Barnes *et al.*, 2015).

Marketing or production contracts transfer risk along the food chain. A marketing contract is an agreement between a farmer and a buyer to sell a commodity at a specified price before the commodity is ready to be marketed (Goodhue and Hoffmann, 2006). The risk shifting characteristics of the received contract depend mainly on its terms (e.g. variable benchmark price versus fixed price). The farmer keeps full responsibility for all production management decisions but he/she loses the opportunity of achieving a higher price on the open market. Although the empirical literature highlights the main determinants of choosing marketing channels, such as locational and geographical disparities, temporal specificities, and transaction costs in combination with farm and farmer characteristics, there is little information available about the risk transfer throughout the value chain (OECD, 2000).

Production contracts typically give the contractor control over the production process. This kind of contract specifies the quality and the quantity of the product, the price to be paid to the farmer and the inputs to be used. For example, uptake of price contracts is a common practice applied on Dutch arable farms. Approximately 50 per cent of the Dutch arable farmers have some kind of potato price contract of which the pool contracts and fixed price contracts are the most common (Van Asseldonk and Van der Meer, 2016). Farmers shift the price risk to the processor but are dependent on only one buyer. In the USA, production contracts have been shown to reduce income risk to a large extent, increase specialisation on farms, help create lower costs and improve efficiency (Harwood *et al.*, 1999). However, production contracts have been criticised because they limit farmers' entrepreneurial capacity, reduce farmers' autonomy, and may increase other types of risks such as quality, investment and contractual risks (OECD, 2000).

Agricultural insurance has a long history and plays a significant role in the compensation of crop damage (hail, drought), livestock disease outbreaks, farm assets and disability of farmers (Hardaker *et al.*, 2004). Insurance tools have been included in the risk management toolkit of the recently-reformed Common Agricultural Policy (CAP) (EC, 2013a). The tools available to manage agricultural risk through

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insurance are very diverse and not common for all EU Member States. There are mainly single-risk insurance tools (such as hail or frost insurance) while some Member States (e.g. France, Italy and Spain) also have multi-peril risk insurance schemes that secure against different kinds of weather risks, but yield and revenue insurances are far less developed (Bielza *et al.*, 2008). In contrast, in some non-European countries more sophisticated tools are available (Mahul and Stutley, 2010). The agricultural insurance spectrum ranges from Member States in which the public sector provides no support (private non-subsided insurance schemes), those in which governments heavily subsidise agricultural insurance up to Member States, such as Greece and Cyprus, where the system is public and mandatory (Bielza *et al.*, 2008).

In practice, agricultural insurance has been a costly way of transferring the risk from farmers to governments and other insurers (Nelson and Loehman, 1987). In the EU there is a discussion on the role of policy measures and the development of the corresponding market. Furthermore, farmers' preferences, the perception of risks, farm and farmer characteristics are factors that influence the demand for agricultural insurance. Agricultural insurance also faces the problem of asymmetric information which refers either to moral hazard or adverse selection problems. Some attempts aim to alleviate these problems (e.g. farmer mutual funds, index-based insurance) with the support of the CAP reforms (2014-2020) that allow premium subsidies.

Thus, European farmers may choose from three general types of risk management strategies: on-farm (e.g. diversification), price risk transfer (e.g. contracts) and yield risk transfer (i.e. insurance with or without public assistance). This paper examines the adoption rates and determinants of farmers' choice of such strategies. We consider insurance contracts, price contracts, off-farm income, other risk reduction measures and other gainful activities, and our analysis is conducted using farm-level data for farms located in eight EU Member States.

Methodology

Econometric model

For farmers, whether or not to adopt a specific risk management tool is often a continuous-choice decision (e.g. to adopt more or less on-farm diversification or rely more or less on off-farm income). Also the decision to insure or hedge follows a (binary) adoption decision and a (continuous) conditional decision about the amount (e.g. proportion of production insured or hedged). In the current approach, the adoption of a specific risk management tool is therefore modelled as a discrete-choice decision (and continuous variables are recoded into binary values). Binary specifications are often used for the evaluation of actual or hypothetical decisions about insurance purchase with numerous explanatory variables (i.e. Ganderton *et al.*, 2000; Sherrick *et al.*, 2004).

Given the hierarchical classification of farms into farming type for all EU Member States, farm data are naturally nested in farming type and Member States. This hierarchical structure gives rise to multi-level mixed-effects modelling by incorporating random effects at the levels of Member States and farming type (Andrews *et al.*, 2006). In this paper, three-level mixed-effects logistic models were used to determine which factors influence the choice to adopt insurance or other risk management strategies. The demand is likely to differ substantially between the relevant farming types as a result of numerous distinct factors such as tilling season, susceptibility of crops and livestock, and possibilities to adopt preventive measures. Moreover, Member States differ in supply conditions (e.g. availability of premium subsidies, price contracts and disaster Member State relief programmes) and differences in demand (e.g. cultural differences). Formally, the econometric model for the probability of adoption is described as follows:

$$Pr(y_{ijk}=1|x_{ijk}, w_j, z_{jk})=H(x_{ijk}\beta+w_j+z_{jk}+\varepsilon_{ijk}) \quad (1)$$

where $Pr(y_{ijk}=1|x_{ijk}, w_j, z_{jk})$ denotes the conditional probability of $y_{ijk}=1$ given a set of variables x_{ijk}, w_j and z_{jk}, y_{ijk} is a binary indicator of a specific risk management tool adoption decision on farm in 2015 (value 1 for adopters and 0 for non-adopters) taken by farmer i in farming system k in Member State j, x_{ijk} is a vector of explanatory variables related to demand factors. In equation (1), $H(\cdot)$ is the logistic cumulative distribution function ($H(\theta)=\frac{\exp(\theta)}{1+\exp(\theta)}$) which maps the linear predictor to the probability of adoption ($y_{ijk}=1$). In this model, the linear combination $x_{ijk}\beta$ represents the fixed effects of the explanatory variables on the likelihood of adoption. The terms w_j and z_{jk} represent random effects at the level of Member States and farming type respectively. ε_{ijk} represents the random error term at farm level. The model is estimated using the melogit procedure of Stata® 14.0 (StataCorp LLC, College Station TX, USA).

The adoption of one strategy can affect (substitute or complement) adoption of another strategy (e.g. impact and thus need for a price contract is less for a well-diversified farm in comparison to a mono-cropping farm). Therefore, regression models for each risk management strategy are estimated in which the explanatory variables comprise the simultaneous adoption decision of other risk management strategies. Similar three-level logistic models are applied as presented in Equation 1 to estimate odds ratios.

Data

In the selection plan the heterogeneity of the farming sector was explicitly considered. In designing the selection plan the same stratification was used as in Farm Accountancy Data Network (FADN) (EC, 2015) which is based on farming type and farm economic size classes. 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 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 farming types in each Member State.

In line with the regular FADN data collection, the data collection was organised in different ways in each of the participating countries in terms of who collected the data and how the data were collected (Vrolijk *et al.*, 2016). Collection processes and strategies were designed and collectors were trained to ensure uniform data gathering with respect to the additional risk management indicators. Data collection was finalised in the spring of 2016 on the calendar year 2015. The risk management data (and other additional indicators collected in the EU Framework 7 FLINT, Farm-Level Indicators for New Topics in Policy Evaluation) were merged with the FADN database. The analysis in this paper is based on data from 821 farmers collected in eight Member States.

Adoption variables

The adoption models focused on the actual participation decision. This information was elicited during the FLINT project. Three complementing or substitute mainstream categories of risk management strategies were identified, namely, insurances, contracts and alternative methods (such as diversification and off-farm income).

Four sub-categories of insurance coverage were included: crop insurance, livestock insurance, property insurance and occupational accident insurance. Insured perils were elicited as well (multiple selections were allowed) for crop insurance and property insurance allowing to distinct hail, storm, excessive rainfall, drought, frost and other perils (e.g. fire). Moreover, a distinction was made between a coverage reimbursing only the direct losses of replacing the damaged goods or a coverage also reimbursing consequential losses due to lost business revenues.

The category of price contracts focused on the most important formal contracts in terms of sales values of a farm. A maximum of four contracts for the main agricultural outputs were considered. Contracts only focused on the marketing of agricultural or horticultural outputs, consequently manure contracts and energy supply contracts were excluded. Six characteristics per contract were derived: contracted output (i.e. 18 classes of crops or livestock); price type of contract (i.e. market price, pool price, minimum price or fixed price); contracted amount (i.e. fixed quantity or supply obligation); duration (one year or less versus multiple years); contracted turnover (i.e. <20 per cent, [20-50 per cent>, [50-79 per cent>, [80-99 per cent>, 100 per cent); and other contract characteristics (e.g. fixed or flexible delivery date, specified quality standards).

The alternative risk mitigation or adaptation strategies included a set of other measures that contribute to risk reduction and a set of other gainful activities. Measures that could contribute to risk reduction included diversification, off-farm employment, off-farm investment, avoiding use of credit, hedging (futures and options) and holding financial reserves. Multiple other gainful activities were included, ranging from farm tourism, processing of agricultural products, child/healthcare, nature management, production of renewable energy and contract work for others.

Explanatory variables

The demand for risk management strategies is often hypothesised to be influenced by numerous explanatory variables (see, for example, Goodwin, 1993). In the multivariate regression analysis, explanatory variables described farm structure, farm income, farm financing and personal characteristics.

The hypothesis is that farm structure influences the adoption of risk management instruments. Two main components of farm structure, namely farming type and farm size, were distinguished. Risks and the rationale of adopting specific risk management strategies differ for obvious reasons between agricultural produce (e.g. losses as a result of adverse weather affecting farms with field crops and the adoption of crop insurance). Therefore, the major segmentation variable used in this research is farming type based on Eurostat's farm typology (FADN code: GENERAL). Eight farming types are listed as dummy variables in the analysis, i.e. farms with mainly field crops, horticulture, wine, other permanent crops, milk, other grazing livestock, granivores or mixed (i.e. crops and livestock). The classification of farms according to type is based on the (relative) mix of their output. The impact of farm size was previously tested by, for example, Goodwin *et al.* (2004) and Sherrick *et al.* (2004), who found a positive relationship between farm size and insurance purchase. Farm economic size is included as a linear variable and expressed in standard output units (FADN code SE005).

Two variables were included as indicators for farm income, namely farm net income (FADN code SE420) and total subsidies received (FADN code SE605). Farm net income is the remuneration to the unpaid factors of farm production (i.e. work, land and capital) and a reward for taking risks. Farms with higher farm income may have less need to adopt risk management strategies because of opportunities for self-financing adverse losses. The reverse situation could be hypothesised for farmers with low income. The total amount of subsidies received on current operations included EU-financed and co-financed decoupled and coupled payments. In the EU, direct payments represent around 30 per cent of farm income (but this differs between farming types). It has been claimed that such payments have an income stabilising role (Cafiero *et al.*, 2007) and the somewhat scant empirical evidence available supports this hypothesis (Agrosynergie 2011; El Benni *et al.* 2012). The fact that direct payments are fixed induces a decrease in the variability of income and creates what is called a 'wealth effect'. This additional stream of income affects preferences for adopting risk management strategies. For this reason, it is not easy to disentangle the risk management component from the support component of many measures (OECD, 2009).

The financial structure of the farm is often tested in explaining adoption of risk management strategies. Farmers with more debt (total liabilities, FADN code SE485) would be expected to adopt more often risk management strategies (Ganderton *et al*., 2000; Mishra and Goodwin, 2003; Mishra *et al*., 2005; Sherrick *et al*., 2004). The reverse situation may be hypothesised for farmers with larger net worth (total assets FADN code SE501). Ultimately, the capacity to bear the risk

Table 1: Percentage adoption by farmers of crop, livestock, building and occupational accident insurance and number of observations per EU Member State.

Member State	Crop		Livestock		Building		Occupational accident	
	Adoption	n	Adoption	n	Adoption	n	Adoption	n
Finland	0	50	90	49	100	50	96	50
Germany	61	52	51	35	88	52	77	52
Greece	90	124	93	30	0	124	100	124
Hungary	34	102	11	64	39	102	13	102
Ireland	0	64	11	64	86	50	56	64
Netherlands	35	155	56	82	95	155	55	155
Poland	41	146	9	87	97	146	82	146
Spain	50	128	95	69	54	128	64	128

Source: own data

will affect the demand for risk management strategies. Therefore, 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, could affect demand (cash flow, FADN code SE526). The previously-described FADN indicators for financial structure are all included as explanatory variables.

Other explanatory variables included were age and training of the farmer. Both personal characteristics are often used in demand studies (Sherrick *et al*., 2004; Ogurtsov *et al*., 2007; Mishra *et al*., 2005). but the direction of the effect is difficult to predict and is often non-significant. From the FLINT survey the use of advisory services in terms of total number of times of personal contact with an advisor was included as an indicator for training.

Results

Adoption of insurance

All farming types in this study cultivated land and hence crop insurance adoption was estimated for all surveyed farms. Adoption of livestock insurance was analysed for the relevant farming types (i.e. grazing livestock, granivores, mixed livestock holdings and mixed crops – livestock holdings). Although elicited separately, it is questionable whether respondents were aware of the distinction between direct and indirect coverages for crop and livestock insurance. Enumerators did not in all cases cross-check policy documents (to confirm either direct, indirect or both). Therefore, adoption rates were aggregated and adopters were those who have subscribed to at least one coverage. Adoption rates for building insurance and occupational accident insurance were aggregated for all farming types in the survey (Table 1).

Adoption of crop insurance varies across Member States, and this can be explained in part in the light of availability of public support. In Ireland, subsidised crop insurance is not available, which may have hampered demand for insurance. In Finland crop insurance is not adopted since the existing Crop Damage Compensation (CDC) scheme was abolished in 2015 as a result of inherent deficiencies in the CDC system (Myyrä and Jauhiainen, 2012). Most analysed Member States with higher adoption rates have opted for public support to promote demand with the exception of Germany. This could be the risk management toolkit under Articles 37-39 of EU (2013b) (e.g. subsidised multi-peril crop insurance in The Netherlands). Other Member States that have chosen not to make use of the toolkit despite the possibility of EU co-financing continued their national subsidised insurance schemes under the state aid rules (e.g. Spain) or deploy other policy instruments to increase uptake (EP, 2014).

Germany has a long tradition of private-based crop insurance with high adoption rates of predominately hail insurance (to a lesser extent this also holds for the Netherlands). Both Member States also have high adoption rates of private-based livestock insurance. In Germany most insurance policies sold are the standard epidemic livestock coverage, while in the Netherlands farmers take out cover protecting their livestock against accidents such ventilation breakdowns and fire. Livestock insurance uptake is highest in Spain, Greece and Finland (note that in Spain livestock insurance is subsidised and in Greece it is mandatory).

Uptake of building insurance and occupational accident insurance is on average high across all Member States with the exception of building insurance in Greece and occupational accident insurance in Hungary.

Adoption of contracts

The level of price protection depends on the type of price contract and contracted turnover. Descriptive statistics show distinct adoption rates of market price, pool price, minimum price or fixed price contracts (Table 2). The contracted amount was in the majority of cases below 50 per cent of the total turnover. Price contracts are less frequently applied in Ireland and Greece. However, the adoption rate is also low in Finland if market price contracts are excluded from the analysis. In a market price contract the price a farmer receives only depends on the market price (i.e. benchmark) at the moment of delivery, which provides no protection and

Table 2: Percentage adoption by farmers of different types of contracts and number of observations per Member State.

Member State	No price contract	Market price	Pool price	Minimum price	Fixed price	n
Finland	34	56	0	0	10	50
Germany	35	27	2	0	37	52
Greece	70	19	2	0	9	124
Hungary	35	36	0	0	28	102
Ireland	100	0	0	0	0	64
Netherlands	28	12	29	9	22	155
Poland	49	29	6	5	12	146
Spain	16	59	9	1	15	128

Source: own data

Table 3: Percentage adoption by farmers of other risk management strategies and number of observations per Member State.

Member State	Diversification	On-farm processing/sales	Off-farm investment	Credit avoidance	Hedging	Financial reserves	Off-farm employment	Other gainful activities	n
Finland	40	18	26	66	4	36	44	32	50
Germany	54	17	19	46	0	64	60	64	52
Greece	90	18	2	69	0	68	23	13	124
Hungary	38	8	6	40	4	38	43	16	102
Ireland	30	0	14	53	3	50	53	2	64
Netherlands	33	10	8	16	2	14	51	46	155
Poland	62	7	2	45	3	40	26	14	146
Spain	28	13	2	59	0	9	23	12	128

Source: own data

can be seen as a delivery contract. Yet in a pool contract a famer receives the average market value of a commodity over a specified period and thus smooths price volatility to a certain extent. Protection increases if the contract guarantees a minimum price. If the market price at the moment of delivery is higher than the specified minimum price, the farmer will benefit from this higher price. Given a fixed price the contract specifies a pre-determined price for which the product is delivered. If the market price is higher than the fixed price the farmer will not benefit from this higher price. Member States with the highest adoption of price contracts (pool, minimum or fixed) are the Netherlands and Germany with adoption rates of 60 and 38 per cent respectively. Contracted activities mainly comprised cereals, industrial crops, potatoes and milk. In three quarters of the contracts the duration was one year or less and quality standards were specified in 50 per cent of the contracts.

Adoption of other risk management strategies or gainful activities

The adoption rates of other risk management strategies or adopting other gainful activities also greatly differ across Member States (Table 3). The highest reported overall adoption rates included the avoidance of credit use to minimising external dependency, diversification to reduce the variability of farm income, holding financial reserves to ride out adverse times and off-farm employment to diversify income streams. Hedging by using futures and options to limit or offset the probability of loss from fluctuations in agricultural commodity prices was least preferred in almost all Member States. The use of specified strategies differed between farming types partly because of how the typology of farms was defined (e.g. mixed farming systems apply diversification by definition) and inherent characteristics of a farming system (e.g. field crop farms, particularly arable farms, apply diversification widely not only as a risk management tool but also for agronomic reasons).

The aforementioned binary elicited FLINT indicators are more subjective indicators that express the importance from a farmer's viewpoint, while some can also be objectively quantified with FADN data directly. The amount of financial reserves and credit avoidance correspond respectively with total farm savings and the opposite of a farm's total liabilities, or a relative measure such as solvency rate. Moreover, quantifying the heterogeneity of diversification can be measured straightforwardly with an index on the basis of the revenue stemming from each activity jointly determining total output.

Determinants of adoption

The determinants of adoption of 12 distinct risk management strategies were estimated. A hedging demand model was not estimated because generating robust estimates was not feasible given the limited uptake. The three-level model with two random-effects equations comprises 39 farming type levels from eight Member States levels in the upper two levels. Estimated fixed effects of the explanatory variables and the random effects at the level of Member States and farming type are presented in Table 4. Likelihood-ratio tests comparing each model to its ordinary logistic regression approach showed that all were highly significant for these data. Reversing the order of the upper two levels did not affect the main findings.

The larger farms adopted crop insurance, occupational accident insurance, contracts and diversification more often but were less likely to adopt credit avoidance and off-farm employment (at a significance level of 1 per cent). Although the latter strategies are considered very effective, they may affect the efficiency of scale (and thus limits prospects of higher average incomes). Note that the perceived adoption of applying financial strategies (i.e. credit avoidance or holding financial reserves) was indeed objectively confirmed by lower liabilities and higher assets as recorded in FADN. With respect to random effects, it can be concluded that the adoption of risk management strategies was significantly affected by farming type while the Member State effect was not significant.

The relationship between adoptions of different strategies was also analysed with a three-level mixed-effects logistic regression model to determine whether they are substitutes (OR < 1) or complements (OR > 1) (Table 5). The main findings are described within and between the three mainstream categories of risk management strategies (i.e. insurances, contracts and alternative methods). Within-category odds ratios revealed that uptake is positively associated (OR > 1). For example, adopters of occupational health insurance were statistically significantly two or three times more likely to adopt other insurance coverages as well. Significant ORs within the category of alternative methods revealed that most strategies complemented each other. For example, farmers opting for credit avoidance were three times more likely also to hold financial reserves. Between the categories of alternative risk management strategies significant results on complementing or substituting choices are more mixed. For example, farmers opting for crop insurance were 2.5 times more likely to use price contracts as well, but half as likely to have off-farm employment.

Table 4: Estimates of the adoption models (parameters are odds ratios) and standard errors for insurance and other risk management strategies.

Variables	Crop insurance	Livestock insurance	Building insurance	Occupational accident insurance	Price contract	Diversification	On-farm processing/sales	Off-farm investment	Credit avoidance	Financial reserves	Off-farm employment	Other gainful activities
Fixed effects												
Size class	1.548***	1.289	0.973	1.388***	1.737***	1.470***	0.995	1.057	0.779***	1.081	0.712***	0.910
	(0.160)	(0.202)	(0.121)	(0.114)	(0.192)	(0.133)	(0.116)	(0.145)	(0.0594)	(0.0868)	(0.0493)	(0.0801)
Total farm output‡	0.992	1.010	0.992	1.003	0.983**	0.986**	0.992	0.997	1.010	0.999	1.006	0.996
	(0.00716)	(0.00920)	(0.00997)	(0.00504)	(0.00712)	(0.00719)	(0.0102)	(0.00819)	(0.00609)	(0.00681)	(0.00429)	(0.00466)
Farm net income‡	1.003	0.997	0.995	0.984	0.981	0.994	1.001	1.005	0.992	0.987	0.994	1.017
	(0.0178)	(0.0247)	(0.0302)	(0.0143)	(0.0182)	(0.0175)	(0.0272)	(0.0264)	(0.0164)	(0.0165)	(0.0132)	(0.0147)
Total subsidies‡	0.944	1.104	1.035	0.943	0.925	1.007	1.061*	1.061*	0.952	0.996	1.025	1.056*
	(0.0389)	(0.0669)	(0.0684)	(0.0342)	(0.0438)	(0.0321)	(0.0362)	(0.0354)	(0.0312)	(0.0312)	(0.0282)	(0.0319)
Total liabilities‡	1.000	1.000	1.004	1.001	0.994*	0.995	0.999	1.000	0.988***	0.992**	0.999	0.999
	(0.00278)	(0.00303)	(0.00637)	(0.00189)	(0.00319)	(0.00330)	(0.00431)	(0.00347)	(0.00372)	(0.00339)	(0.00189)	(0.00252)
Total assets‡	1.001	0.999	1.003	0.999	1.005***	1.002	1.000	1.002	1.002*	1.002**	1.001	1.002**
	(0.00134)	(0.00119)	(0.00271)	(0.000837)	(0.00180)	(0.00135)	(0.00155)	(0.00118)	(0.00105)	(0.00110)	(0.000774)	(0.00111)
Cash flow‡	1.009	0.988	1.008	1.000	1.017**	1.009	0.997	0.992	0.994	1.004	0.998	1.007
	(0.00685)	(0.00983)	(0.00982)	(0.00461)	(0.00734)	(0.00682)	(0.00982)	(0.00940)	(0.00593)	(0.00604)	(0.00406)	(0.00471)
Age	1.002	0.984	0.988	0.985	0.999	0.990	0.996	1.011	1.004	0.991	0.963***	0.975***
	(0.0107)	(0.0140)	(0.0128)	(0.00950)	(0.0107)	(0.00887)	(0.0119)	(0.0144)	(0.00803)	(0.00845)	(0.00777)	(0.00934)
Advisory	1.008	1.023	0.996	0.986	0.990	1.025*	0.965*	1.022	0.995	0.994	1.003	0.986
	(0.0125)	(0.0211)	(0.0188)	(0.0128)	(0.0133)	(0.0134)	(0.0200)	(0.0205)	(0.0104)	(0.0114)	(0.0109)	(0.0144)
Constant	0.0268***	0.00829***	6.179	1.012	0.00563***	0.123**	0.179*	0.0167***	5.074**	0.510	40.93***	1.230
	(0.0339)	(0.0128)	(10.11)	(1.170)	(0.00579)	(0.115)	(0.178)	(0.0221)	(3.555)	(0.415)	(29.74)	(1.065)
Random effects												
Member State	189.1	1.000	251,882	414.0	1.623	6.470	1	2.015	1.464	2.905	2.102*	3.501
	(717.2)	(0.0493)	(2.193e+06)	(1,529)	(1.350)	(8.404)	(0)	(1.201)	(0.466)	(1.973)	(0.903)	(2.701)
Farming type	30.45**	1.565e+06**	3.034**	1.190	14.93**	4.958**	2.453**	1.512	1.408**	1.795*	1.065	1.016
	(41.09)	(1.087e+07)	(1.612)	(0.173)	(16.37)	(3.194)	(1.046)	(0.672)	(0.228)	(0.537)	(0.101)	(0.107)

Number of observations = 782; number of groups = 8; standard errors in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1; ‡ EUR 10,000
Source: own data

Table 5: Estimates of the adoption models (parameters are odds ratios) and standard errors between risk management strategies.

Variables	Crop insurance	Livestock insurance	Building insurance	Occupational accident insurance	Price contract	Diversification	On-farm processing/sales	Off-farm investment	Credit avoidance	Financial reserves	Off-farm employment	Other gainful activities
Fixed effects												
Crop insurance		1.596	1.314	2.223***	2.572***	1.577*	0.599*	1.517	0.685*	0.908	0.526***	1.926***
		(0.586)	(0.493)	(0.571)	(0.671)	(0.385)	(0.183)	(0.581)	(0.152)	(0.216)	(0.106)	(0.430)
Livestock insurance	1.326		6.679***	2.772***	1.365	1.919**	1.523	0.664	0.667	0.751	0.835	1.001
	(0.491)		(3.734)	(0.784)	(0.445)	(0.629)	(0.553)	(0.287)	(0.182)	(0.226)	(0.191)	(0.248)
Building insurance	1.673	4.904***		1.823**	1.727	0.860	0.924	1.097	1.546	1.145	1.032	1.650
	(0.656)	(2.620)		(0.551)	(0.606)	(0.257)	(0.359)	(0.584)	(0.436)	(0.360)	(0.249)	(0.547)
Occupational accident insurance	2.361***	2.572***	1.636		1.489	1.420	0.655	1.172	1.020	1.560*	1.197	0.752
	(0.696)	(0.817)	(0.511)		(0.399)	(0.330)	(0.206)	(0.447)	(0.217)	(0.379)	(0.235)	(0.178)
Price contract	2.530***	1.612	1.999**	1.410		1.640**	1.206	0.616	1.310	1.083	1.016	1.262
	(0.665)	(0.556)	(0.704)	(0.357)		(0.405)	(0.358)	(0.264)	(0.291)	(0.276)	(0.206)	(0.280)
Diversification	1.495	2.425**	0.879	1.333	1.644**		2.891***	1.272	1.248	1.813***	0.874	1.185
	(0.377)	(0.866)	(0.267)	(0.299)	(0.416)		(0.888)	(0.426)	(0.241)	(0.369)	(0.157)	(0.260)
On-farm processing/sales	0.547*	1.008	1.769	0.633	1.074	3.155***		1.309	1.417	0.879	0.762	3.529***
	(0.194)	(0.437)	(0.892)	(0.207)	(0.338)	(1.040)		(0.585)	(0.379)	(0.272)	(0.203)	(0.976)
Off-farm investment	1.680	0.414*	0.810	1.246	0.507	1.430	1.178		1.128	3.301***	2.275***	2.964***
	(0.720)	(0.202)	(0.419)	(0.479)	(0.235)	(0.499)	(0.540)		(0.375)	(1.144)	(0.701)	(1.024)
Credit avoidance	0.662*	0.658	1.602	0.957	1.427	1.195	1.463	1.098		3.237***	0.964	0.755
	(0.155)	(0.203)	(0.473)	(0.204)	(0.327)	(0.235)	(0.385)	(0.363)		(0.628)	(0.167)	(0.164)
Financial reserves	0.850	0.968	1.341	1.592*	0.978	1.875***	0.923	3.356***	3.164***		1.001	1.187
	(0.215)	(0.334)	(0.437)	(0.389)	(0.260)	(0.393)	(0.277)	(1.163)	(0.606)		(0.186)	(0.282)
Off-farm employment	0.468***	0.897	0.846	1.208	0.939	0.838	0.772	2.102**	0.973	0.984		1.627**
	(0.110)	(0.251)	(0.238)	(0.243)	(0.209)	(0.161)	(0.212)	(0.663)	(0.174)	(0.191)		(0.327)
Other gainful activities	1.843**	1.049	1.638	0.751	1.165	1.188	3.639***	3.325***	0.788	1.129	1.754***	
	(0.487)	(0.343)	(0.626)	(0.185)	(0.296)	(0.286)	(1.027)	(1.163)	(0.178)	(0.277)	(0.353)	
Constant	0.259	0.00832***	0.884	0.920	0.0404***	0.392**	0.0517***	0.0126***	0.502	0.144***	0.664	0.0875***
	(0.232)	(0.00768)	(1.199)	(0.713)	(0.0276)	(0.185)	(0.0235)	(0.00842)	(0.216)	(0.0708)	(0.191)	(0.0422)
Random effects												
Member State	63.72	2.202	1.890e+06	41.62	5.549	1.801	1	2.279	1.978	2.311	1.155	2.474
	(208.1)	(3.822)	(1.885e+07)	(99.85)	(7.855)	(1.088)	(0)	(1.643)	(0.923)	(1.322)	(0.142)	(1.422)
Farming type	38.87***	14,617**	1.625	1.258	8.240**	4.257**	1.890*	1.174	1.605**	1.916**	1.105	1
	(53.29)	(65,172)	(0.591)	(0.239)	(7.139)	(2.498)	(0.620)	(0.455)	(0.343)	(0.616)	(0.108)	(0)

Number of observations = 819; number of groups = 8; standard errors in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1
Source: own data

Discussion

We quantified the adoption rates of different risk management tools and determinants of farmers' choice. In the scope of the FLINT project several indicators for risk management strategies were added to the regular FADN data collection to allow for an extended set of analyses. The availability of information on insurances and other risk management tools is very limited or too much aggregated in the current FADN (EC, 2015). The FLINT indicators revealed that adoption rates of instruments such as insurance contracts, price contracts, off-farm income, other risk reduction measures and other gainful activities vary significantly across EU Member States and farming types. Bielza *et al.*, (2008) also report that insurance uptake in agriculture is heterogeneous across Member States. Moreover, current results are in line with past results with respect to hedging against price risks which is adopted by only 2-3 per cent of European farmers (Szekely and Pálinkás, 2009). The econometric analysis indicates that larger farms more often adopted crop insurance, occupational accident insurance, price contracts and diversification but were less likely to adopt credit avoidance and off-farm employment (at a significance level of 1 per cent). The positive relationship between farm size and insurance purchase was also shown in other studies (Goodwin *et al.,* 2004; Sherrick *et al*., 2004). Previous studies mostly focused on insurance adoption while our work focused on a broader set of risk management strategies. Also Huirne *et al.* (2007) emphasised that whole-farm risk management approaches, i.e. approaches in which multiple risks and farm activities are considered simultaneously, are essential in understanding adoption levels and determinants of adoption at farm level.

Monitoring and evaluating the adoption rates, and determinants of adoption, of the aforementioned strategies is important when evaluating policies where targeting is relevant and where linkages or trade-offs between policy objectives exist. For example, the existing CAP direct payments stabilise farm incomes potentially, reducing the demand for risk management strategies (OECD, 2009). Recent CAP reforms (2014-2020) encourage the adoption of agricultural insurance by providing premium subsidies. At the same time the reduced level of market management brought about through recent and ongoing CAP reforms has significantly reduced the CAP's price supporting effects. Despite the potential positive benefits of contracts, no specific measures were included in the 2013 reform, thereby leaving it up to the market to establish contracts. Given the continuous evolution of the CAP and the expectation that risk management will continue to grow in importance, it is now both timely and relevant to take stock of current evaluation practices and specifically focus on which risk management indicators could help to evaluate and develop future polices.

Most elicited new indicators focus on the adoption of risk management strategies and are therefore binary. Yet, farmers' decisions to adopt a specific risk management tool are often continuous-choice decisions. For example, decisions to insure or contract follows a (binary) adoption decision and subsequently a (continuous) conditional decision about the amount (e.g. proportion of production insured or contracted). This simplification holds for all insurance adoption indicators, as well as indicators capturing on-farm processing and the use of other gainful activities. In the current approach, the decision is being modelled as a discrete-choice decision. Eliciting continuous farm level indicators would enable the use of double-hurdle models distinguishing the determinants of the adoption decision from those of the uptake amount. In the first stage of the double-hurdle model, a Probit regression model is estimated where a decision is transformed into a binary variable. The second-stage model is a truncation estimation procedure (Heckit model) whereby only observations of farmers who adopted are included (Heckman, 1979). Refined model estimates could be applied for the FLINT indicators capturing contract use (i.e. proportion of turnover contracted) and off-farm employment (i.e. hours worked).

In addition to analysing adoption rates, there is a strong policy and research interest in the impact of risk management strategies. The impacts of risk management strategies are difficult to assess with performance indicators obtained from a cross-sectional design as is the case in this pilot study. Given this lack of information, studies based on FADN have focused on income volatility, down-side risk, and price and yield volatility (Vrolijk and Poppe, 2008; Kimura *et al.*, 2010). FADN is generally also used to analyse differences in risks between farming systems. For example, Berentsen *et al.* (2012) show that gross margin volatility is significantly higher in organic than conventional dairy farming in the Netherlands (coefficient of variation of 30 vs. 45 per cent) caused by both higher price and production risks. Similarly, organic arable farms were higher with respect to yields, output prices and variable input costs (Berentsen and Van Asseldonk, 2016). These studies are however not able to relate the risks at farm level to the risk management instruments applied on the farm due to current lack of data. With the FLINT indicators the adoption rates can be analysed and future research allows analysing the link with the economic and sustainability performance of farms. Decisions on adopting risk management strategies depend on the associated cost (e.g. insurance premium) relative to the benefit perceived from the reduction in risk (e.g. indemnities in adverse years). Analysing these within farm trade-offs requires mean profits and loss distributions obtained from multiple years. This downside-risk reduction and thus impact can only be estimated if the FLINT data collection will be continued to build up a panel data set.

In summary, if data collection would be continued for several years, the trends in adoption rates can be analysed and 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. The impact of social indicators on the adoption rates can be analysed and the impact of risk management instruments on the environmental performance can be established (e.g. is there a trade-off between crop insurance and use of pesticides). For policy analyses these indicators are a step forward for the determination of the net impacts and establishment of counterfactuals in the long term with FADN (i.e. time series encompassing also adverse years) for measuring the impact of the CAP at farm level.

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Farm economic sustainability in the European Union: A pilot study

The measurement of farm economic sustainability has received intermittent academic interest in recent times, while the conceptual discussions are often quite limited. Moreover, this concept receives more attention at periods of difficulty for the sector. The measurement of farm viability is an important precondition to enrich these discussions. Therefore, it is necessary to develop more comprehensive and detailed measurement techniques to provide more clarity on viability and vulnerability levels in the sector. This paper refocuses attention on this issue, using a pilot dataset collected at farm level across a range of EU Member States which facilitates the assessment of an additional category of viability, namely that of economically sustainable farms, i.e. farms that are economically vulnerable but which are deemed sustainable by the presence of off-farm income. Differences in viability and economic sustainability across the eight surveyed Member States are shown. The analysis is sensitive to the factors included in the measurement of viability as well as to the threshold income used to define viability. Although this is a pilot study, it enhances our understanding of the factors affecting cross-country evaluation of viability and sustainability, and the policy instruments that could improve viability levels.

Keywords: farm viability, FADN, farm income, opportunity costs

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Introduction

Family farming is the dominant form of farming globally. FAO (2014) estimates that 500 million farms in the world can be classified as family farms, defining family farming based on ownership by an individual, small group or household. These family farms are highly important for a variety of reasons including food security: they supply 80 per cent of the world's food (FAO, 2014) and contribute to the sustainability of rural areas (Brouwer, 2004; Hennessy *et al.*, 2008). Supporting farm viability in 'ensuring a fair standard of living for the agricultural community' is one of the key objectives of the European Union's (EU) Common Agricultural Policy (CAP). Measurement of farm viability, in terms of the achievement of a specific income objective, would appear to be the simple option for determining the effectiveness of this objective. However, with the changing and restructured agricultural sector, the surge in pluriactivity and the growing contribution of other income sources in the EU (EC, 2008), the measurement of farm household income is complex and data demanding.

Family farm viability has been documented globally over several decades (e.g. Commins, 1985; Frawley and Commins, 1996; Argilés, 2001; Slavickienė and Savickienė, 2014). Aggelopoulos *et al.* (2007) modelled the financial viability of farms and discussed the difficulties in the Greek agricultural sector and the necessity to measure farm viability in order to avail of financial aid. Hennessy *et al.* (2008) looked at quantifying the viability of farming in Ireland in the context of the persistence of the small farm problem and the idea that the "most economically and physically disadvantaged farming regions tend to rely most on agriculture as a provider of employment" (p.30). Vrolijk *et al.* (2010) examined farm viability across Europe in the context of the impacts that changes in subsidy payments would have on viability rates. Barnes *et al.* (2014) discussed farm viability as a concept which attempts to understand the criteria for "failure at the farm level and to identify factors which determine a switch from viable to non-viable and the consequences of consistent under-performance in the sector" (p.4).

Viability measurement has received attention at different periods in different areas, often at periods of difficulty within the sector, for example in the recent Greek economic context (Aggelopoulos *et al.*, 2007), and in the Irish context in the 1990s when concern was raised about the impacts of free trade on the sector, to the present day where an economic recession and a consequent loss of off-farm employment has an impact on the viability of farm households.

A key finding of the European Court of Auditors' report on the measurement of farm incomes (ECA, 2003) was that "At the present time the community's statistical instruments do not provide sufficient information on the disposable income of agricultural households to allow an evaluation of the agricultural sectors standard of living" (p.18). Other research has stressed the importance of farm household income (Hill 1999a; OECD 1995, OECD 2003) and this has led to several initiatives to evaluate the feasibility of farm household income statistics. Owing to political resistance and fear of farmer refusal, no systematic collection of farm household income has been achieved, although at national level some countries have been able to monitor household incomes in a more systematic way.

This paper reviews the measurement of farm economic viability internationally and assesses critically the methodologies used. Within the context of the long-term sustainability of agricultural production which encompasses the three pillars of economic, environmental and social sustainability, it particularly addresses the economic sustainability of a sample of farms across the EU. It does this by contributing to the development of a methodology to gain a more detailed understanding of the economic viability of the farm enterprise, while acknowledging the restrictions of available data

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to assess farm household income. The impact of off-farm employment is of particular interest in the context of recent economic turbulence. Indeed, off-farm sources of income can reduce annual variations in farm household income (OECD, 2003). The lack of comparable data to assess the economic viability and sustainability of EU farms is addressed by the utilisation of an international pilot data collection conducted as part of the EU FP7 research project FLINT (Farm-Level Indicators on New Topics in policy evaluation).

Theoretical foundations of farm economic viability

Several different definitions of economic viability are used in the literature. In general, the importance of making a living is the key priority, while some studies also require that returns from on-farm investment should also be evident. Among the factors influencing the definition of farm viability, the key difference, apart from the differing elements included, is the varying emphasis on viability as an opportunity cost measure or as a household welfare measure (Table 1). Researchers in the USA and Canada define viability in terms of meeting the income needs of the farm family (Smale *et al.*, 1986; Scott, 2001; Adelaja, 2004) while European definitions focus on viability as an opportunity cost measure (Frawley and Commins, 1996; Argilés, 2001; Aggelopoulos *et al.* 2007; Hennessy *et al.*, 2008; Vrolijk *et al.*, 2010; Berkum *et al.*, 2016). It may be the case that the availability of household data has facilitated this, with data within Europe being much more widely available at the farm enterprise level as opposed to the household level.

Models that utilise different opportunity costs

As a welfare measure, viability measurement has a parallel in concepts used in the more general welfare, poverty and inequality literature. The welfare measurement literature primarily uses the household as the unit of analysis, defining welfare at this level, often assuming equal welfare for members of the household. Farm viability differs however in that it is primarily a farm income-related concept, rather than a household income concept. The concept of viability is related to the contribution of the farm to the achievement of a particular standard of living. Alternatively, the objective could be regarded in achieving a wider, more general objective such as remunerating farm labour and resources in terms of the minimum wage, an agricultural contracting wage or an average wage. The latter view is chosen by many of the researchers listed in Table 1.

Table 1: Definitions of farm economic viability from the literature.

Location	Reference	Definition of viability
USA	Smale *et al*. (1986) (p.14)	A level of annual cash income sufficient to cover farm operating costs, meet the households minimum consumption needs, replace capital items at a rate that ensures constant serviceability of the capital stock, and finance loan retirement as scheduled.
Ireland	Frawley and Commins (1996) (p.21)	A viable farm (is described) as one having (a) the capacity to remunerate family labour at the average agricultural wage, and (b) the capability to give an additional 5 per cent return on non-land assets.
Canada	Scott (2001) (p.17)	Broad goals are basic livelihood security for farmers, and a return on investment sufficient to encourage investments in quality food production and responsible land stewardship.
Spain	Argilés (2001) (p.96)	Farm viability defined as its ability to remunerate working time put in by family members over a long period at a comparable wage to that available from alternative work, and the contrary for non-viability.
USA	Adelaja *et al*. (2004)	A farm is defined as economically viable when it generates enough revenue from its operations to cover all variable and fixed costs of production, all appropriate family living expenses, and capital replacement costs.
Greece	Aggelopoulos *et al*. (2007) (p.896)	Viable farms are farms which render family farm income per used family human labour unit (HLU) higher than the reference income (the Ministry of Agriculture Development annually determines the reference income as equal to approximately 80 per cent of the comparable income) and use at least 1 HLU.
Ireland	Hennessy *et al*. (2008) (p.17)	An economically viable farm is defined as one having (a) the capacity to remunerate unpaid family labour at the average agricultural wage, and (b) the capacity to provide an additional 5 per cent return on non-land assets – these include the capital value of machinery, livestock and production quotas.
Europe	Vrolijk *et al*. (2010) (p.20)	Financial Viability Categories (in the context of reduced subsidy payments in Europe): Category 1: farming provides a positive income higher than opportunity costs. Category 2: farming provides a positive income, but the rewards for the farmers input of labour and capital is less than he/she could earn in other economic activities. Category 3: farming provides no positive income, but it still provides a positive cash flow. Category 4: farming provides no positive income and no positive cash flow. Category 5: farm income has been negative during the reference period before the reduction of payments.
Lithuania	Savickienė *et al*. (2015) (p.413)	Economic viability of a farm is its capability to survive, live and develop by using the available resources.
Scotland/ Sweden	Barnes *et al*. (2014)	Do not define farm economic viability, however, state: "Whilst Viability must include the ability of business entities to meet their operating expenses and financial obligations, there must be some accommodation for future growth. Ultimately, studies on agricultural viability attempted to understand the criteria for failure at the farm level and identify factors which determine a switch from viable to non-viable and the consequences of consistent under-performance in the sector" (p.4).

Source: own compilation

The most common viability assessment is the comparison of Family Farm Income (FFI) per Family Work Unit with a reference income. There can be large differences between the definition of FFI and the reference income and there is a lack of uniformity in the literature as to the objective of the studies (Table 1). Further examination of this in relation to the viability measurement literature shows the challenge in defining a relevant income threshold. Aggelopoulos *et al.* (2007) points out that the Greek Department of Agriculture sets a threshold every year which is 80 per cent of the comparable income. In Ireland, the Labour Court defined the minimum hourly agricultural wage at EUR 9.33[6].

In Ireland, two variants of the farm viability measure have been used. Frawley and Commins (1996) regard farm viability as a 'multidimensional concept', simplified to be the definition of "(i) economic/income factors and (ii) demographic factors, or more accurately, the age composition of the household" (p.21). This definition is then further distilled to an operational definition of "a viable farm (is described) as one having (a) the capacity to remunerate family labour at the average agricultural wage, and (b) the capability to give an additional 5 per cent return on non-land assets" (p.21). The idea of non-land based assets is quite context-specific in this case as land assets are reluctantly sold in Ireland (Hennessy and Rehman, 2008; Hennessy *et al.*, 2008): less than 0.1 per cent of land is sold on the open market each year. This condition on return on capital occurs in several papers (Frawley and Commins, 1996; Scott, 2001; Hennessy *et al.,* 2008; Vrolijk *et al.,* 2010; Berkum *et al*., 2016). Scott (2001) and Hennessy *et al.* (2008) claim that this condition ensures long-term viability. As long as the return on investment is greater than other investment opportunities (such as bank interest or mutual funds), farmers will continue to invest in farming operations.

Assessments of farm viability

The most common assessment of farm viability is a comparison between the income earned by the family farm and a reference income. Most studies use an income definition similar to the FFI of the Farm Accountancy Data Network (FADN), that is to say 'remuneration to fixed factors of production of the farm (work, land and capital) and remuneration to the entrepreneurs' risks (loss/profit) in the accounting year'. This income represents a return to family labour, management and investment in the farm business. However, some authors use a cash income which can be seen as the approximate cash element of FFI. This definition of income does not take into account depreciation and inventory changes. For example, Smale *et al.* (1986) use this definition "because the household's minimum financial obligations […] must be met with cash expenditures" (p.13). Argilés (2001), in the Spanish context, defines viability as the ability to provide family income and concludes that this should be the case over a long time period. It is argued that the lack of specified income levels throughout the literature is reflective of the necessity to allow for annual fluctuations in comparable income. The addition of a time period attempts to account for yearly fluctuations. Scott (2001) and Hennessy *et al.* (2008) add a condition on return on capital in order to ensure that investments will continue in the farming activity. Several researchers also use a three-year average for the farm income, reducing the income variability and thus assess long-term viability. Barnes *et al.* (2014) use two measures of income: cash income, to assess short-term viability, and net farm income to assess long-term viability. Some authors add conditions on other ratios, such as a dependency ratio (Scott, 2001; Aggelopoulos *et al.*, 2007) of the dependence of farms on subsidies. When analysing the impact of subsidy changes in the EU, Vrolijk *et al.* (2010) strongly link to the ideas of opportunity cost and in their category 1, or optimal level viability, the farm provides a positive income level above the defined opportunity cost.

The income earned by the family differs depending on whether depreciation, taxes and inventory changes are taken into account, and whether off-farm income is taken into account. A challenge in many studies of farm viability is to utilise a broader definition of income, as data with detailed information on farm incomes may not necessarily incorporate other sources of income (Hill, 1999b; ECA, 2003; Hill, 2008).

Some of the reviewed studies suggest that a benchmark of living expenses should be the defined viability threshold. This may be a minimum wage in the agricultural sector, an average of non-agricultural workers' wages, or the value of paid labour. Argiles (2001) uses the average of non-agricultural workers' wages as reference income so as to define a long-term viability threshold. In the Irish definition of farm economic viability (Frawley and Commins, 1996; Hennessy *et al.*, 2008) the average agricultural wage is discussed as part of the viability threshold.

Farm viability and off-farm employment

Off-farm employment is a very important income source for most farm households in the EU (Fuller, 1990; Moxnes Jervell, 1999; Hennessy and Rehman, 2008). Off-farm employment interacts with the notion of farm viability in two ways. The first interaction occurs when a resource unit definition of opportunity cost is utilised. In this case, off-farm employment may reduce on-farm hours and so may affect the denominator often used in the viability metric. The second interaction relates to the impact of non-viability (vulnerability). The presence of off-farm income or other non-farming income sources may provide a mitigating measure from a household welfare point of view. According to Hill (1999b), farm households typically have a range of sources of income, and hence farm income on its own is not an appropriate measure of farm household welfare. Farm households with access to off-farm employment may also have greater resilience against farm income fluctuations. However, while both the presence and level of off-farm income are important, data issues restrict their measurement. As reported by EC (2008) and Hill and Bradley (2015), owing to the sensitive nature of data on total household income, these data are not available at EU level despite several attempts to generate statistics concerning other sources of income in agricultural households. This sensitivity also applied to data collection within the FLINT project, thus we do not have data for total

[6] S.I. No. 164 of 2010, Employment Regulation Order (Agricultural Workers Joint Labour Committee) 2010. Dublin Stationery Office.

household income. Instead, we use a combination of farm income plus the presence of off-farm employment as a proxy for total household income.

Farm viability, sustainability and vulnerability classifications

In Ireland, Commins (1985) noted that by 1978, "approximately one quarter of landowners with holdings of over 5 acres had other jobs besides farming" (p.257), this figure has since increased: DAFM (2012) estimated up to 50 per cent of farms have off-farm income from the holder or spouse. Hennessy *et al.* (2008) noted that loss-making farms may be sustained by off-farm employment and thus classify farms where off-farm employment is present as 'sustainable'. Those that are neither economically viable nor sustainable are classified as economically 'vulnerable'. At EU level, EC (2008) noted that there was an increase in pluriactivity in farming in the past few years. More than one third of EU-27 family farmers were pluriactive farmers in 2008. Pluriactivity was already well developed at the end of the 20th century, as Bryden (1993) already revealed high levels of off-farm work.

While the overarching contextual framework of this analysis is the notion of farm viability, this paper focuses on comparative measures of the economic sustainability classification within the overall farm viability context. The analysis employs a novel approach to overcome the data difficulties associated with comparing farm economic sustainability across the EU by using the pilot FLINT variables which are integrated with the wider FADN dataset for the FLINT pilot farms. This approach provides additional information on the comparative sustainability of a sample of farms across the EU. To the best of our knowledge, the lack of appropriate data has to date precluded such a comparative pilot study.

Methodology

Assessment of farm income

In order to develop a common metric that is comparable across EU Member States, the FADN definition of FFI is utilised in this analysis, i.e. the "remuneration to fixed factors of production of the farm (work, land and capital) and remuneration to the entrepreneur's risks (loss/profit) in the accounting year" (EC, 2015, p.15) and is defined as:

FFI = Total output − Total intermediate consumption +
Balance current subsidies & taxes – Depreciation +
Balance subsidies & taxes on investment – Total external factors

Total intermediate consumption represents total specific costs (including inputs produced on the holding) and overheads arising from production in the accounting year. Total external factors cover remuneration of inputs (work, land and capital) which are not the property of the holder (wages, rent and interest paid). As discussed above, this income does not take into account off-farm income, as the relevant data are not collected in FADN.

Choice of farm viability threshold

As already discussed, the viability threshold is one of the key issues in viability analysis. Hennessy *et al.* (2008) used the minimum agricultural wage defined by the Irish Labour Court. However, this wage level is not defined for all EU Member States, therefore cannot be used in a comparative study. The same problem arises for a minimum wage in the wider economy (for example, Finland has no minimum industrial wage). On this basis we have utilised the average wage of full-time employees in the total economy based on OECD data in order to facilitate cross-country comparison of farm incomes to those in other sectors. However, these industrial wages are quite high: for example, the average annual wage in Ireland in 2015 was EUR 47,366, whereas the Irish minimum agricultural wage used by Hennessy and Moran (2015) was EUR 19,167. This is likely to have a big impact on viability results. In order to compare the farm income to an average agricultural income, we employ the wages paid by the farms in the sample. We approximate the annual FADN hourly wage by country as:

$$Annual\ hourly\ paid\ wage = \frac{Paid\ wage}{Paid\ labour\ unit\ (in\ h)}$$

These wages are close to the minimum wages defined nationally and are therefore considered plausible for this analysis.

Measures of farm viability

This section describes the range of viability measures used in this analysis. Hennessy *et al.* (2008) and Hanrahan *et al.* (2014) use three viability classifications: viable, sustainable and vulnerable farms. A farm is classified as viable if the FFI is higher than the average agricultural wage and provides a 5 per cent return on the capital invested in non-land assets, i.e. machinery and livestock. Farms are economically sustainable if they are not viable but either the farmer or the spouse has off-farm employment. Finally, vulnerable farms are neither viable nor sustainable. They do not produce enough profit to be viable and there is no other income.

The broad model of viability is:

$$\frac{Family\ farm\ income - Cost\ of\ own\ capital}{Hours\ worked\ on\ the\ farm} > Threshold\ wage$$

Although the condition on 5 per cent return on non-land assets is relevant in Ireland because of the specific land market, it is not relevant in all countries. Based on Vrolijk *et al.* (2010), we apply a condition on all own assets (total assets – total liabilities): the cost of own capital is defined as a fixed percentage of all own assets (based on long-term ECB interest rates[7]). It is noticeable that farms with a relatively modest income can be viable if they have a small labour input and a low capital investment. On the contrary, farms with a large income may be vulnerable if they have high labour inputs and a significant cost of own capital. Based on the different definitions of farm viability described in previous sections, we apply eight different models of viability (Table 2) which are distinguished on three criteria:

[7] http://sdw.ecb.europa.eu/browseTable.do?node=bbn4864

- *Opportunity cost or farm-level approach*. This approach enables us to see if the farmer would be better off financially to spend an hour working off the farm. The farm-level approach focuses on the farming activity as a whole. If the farm is not viable at the farm level, the farmer would better spend his or her time in another activity (not on their own farm) and invest their capital elsewhere.
- *Condition on cost of own capital (COC)*. The ability to cover the COC enables us to ensure that farmers will be in a position to continue to invest in farming operations. The absence of this condition can be interpreted as farming as a way of life rather than an activity which has to make money.
- *Viability threshold*: Two kinds of thresholds are used here: average wage in the economy or paid wages as observed in FADN. The differences between them are discussed below.

Taking off-farm employment into account in measuring farm economic sustainability

Using the FLINT indicators, it is possible to consider the presence of off-farm employment on the farm, i.e. whether the owner or spouse has an off-farm job. This enables us to distinguish between economically sustainable and vulnerable farms. Here, only data regarding the presence and not the level of contribution of off-farm employment are available.

Data

The FADN dataset is the 'gold standard' of micro-economic data in EU agriculture. However, it includes only information which is directly related to the farm business and this leads to some notable omissions from the farm household's perspective, including education, gender, marital status, household debt (FADN records farm business debts only), number of household members, number of children, whether the farmer has a successor and, critically, off-farm employment. In the context of evaluating CAP objectives (such as farm viability) across the EU, the FLINT project commissioned a pilot survey on a sample of 1,000 farms that are currently within the FADN sample. This survey contains supplementary qualitative and quantitative questions to provide new data for new policy topics (Vrolijk *et al*., 2016).

Some adjustments have been made to account for outliers in the data. We exclude the largest farms with asset values of over EUR 10 m and outliers with very negative asset to income ratios, focusing on farms with moderate loss to capital ratios. The Greek data do not include liability information, so cannot be used to assess the return to capital, which depends upon net asset information in the other countries. About 5 per cent of cases are dropped as a result of these exclusions.

Although the small sample size does not enable us to draw conclusions at a larger scale, the relative values of the components of economic sustainability of farms in eight EU Member States can be compared (Table 3). There are large variations in FFI between farms and also between the countries. The highest average income is achieved in the Netherlands. This is mainly due to high total output. That is also the case in Germany. Ireland shows the second highest average income, because of relatively low intermediate consumption, external factors and depreciation. Spain and Greece have the lowest average incomes. This is due to low output and, in Spain, also because of a high ratio of total intermediate consumption to output. There is a strong variation in COC

Table 2: Models of farm viability.

Model no.	Definition	Opportunity cost or farm level	Presence of cost of own capital	Threshold
1	$(FFI-COC)/Nbhours \geq Avg\ wage\ (h)$	Opportunity cost	COC	Average wage
2	$(FFI-COC)/FWU \geq Avg\ annual\ wage$	Farm level	COC	Average wage
3	$FFI/Nbhours \geq Avg\ wage\ (h)$	Opportunity cost	No COC	Average wage
4	$FFI/FWU \geq Avg\ wage$	Farm level	No COC	Average wage
5	$(FFI-COC)/Nbhours \geq Paid\ wages\ (h)$	Opportunity cost	COC	Paid wage
6	$(FFI-COC)/FWU \geq Paid\ wages$	Farm level	COC	Paid wage
7	$FFI/Nbhours \geq Paid\ wages\ (h)$	Opportunity cost	No COC	Paid wage
8	$FFI/FWU \geq Paid\ wages$	Farm level	No COC	Paid wage

COC: Cost of Own Capital; FFI: Family Farm Income; FWU: Family Work Unit; Nb hours: number of hours worked by unpaid labour units
Source: own compilation

Table 3: Average values of the components of economic sustainability of farms in eight EU Member States.

Component	Member State							
	DE	EL	ES	FI	HU	IE	NL	PL
Number of farms	51	123	127	49	92	59	153	144
FFI (EUR)	27,893	8,452	6,264	24,800	11,222	34,542	60,747	14,746
COC (EUR)	2,664	13,469	4,383	2,490	7,144	10,159	12,070	9,042
Unpaid labour input (h)	2,772	1,574	2,072	2,910	1,463	2,412	3,094	4,456
Unpaid labour input (FWU)	1.17	0.68	1.13	1.32	0.66	1.13	1.33	1.87
Paid labour input (h)	1,485	224	629	538	4,490	154	1,753	910
Paid labour input (AWU)	0.73	0.09	0.31	0.25	2.04	0.08	0.79	0.38
Off-farm employment rate (per cent)	0.63	0.34	0.44	0.43	0.61	0.47	0.58	0.26
Annual paid wage (EUR)	35,360	10,491	18,770	27,786	7,733	21,633	50,786	6,298
Hourly paid wage (EUR)	16.77	4.28	8.12	12.77	3.51	10.23	23.15	2.67
Annual average wage (EUR)	37,613	17,642	27,479	40,893	9,609	47,366	46,384	11,046
Hourly average wage (EUR)	23.69	8.09	14.86	22.85	5.36	22.73	22.20	5.40

Data sources: FADN, FLINT and OECD

between farms and also between countries. For example, the Netherlands has one of the highest COC, due to high investment in machinery assets on these farms.

Regarding the number of worked hours, strong variations are evident between farms and between countries. Polish farms have the highest average number of hours worked by family labour, whereas Hungarian farms have the highest number of hours worked by hired workers. Germany and Hungary have the highest incidence of off-farm and Polish farms have the lowest. Finally, in relation to wages, in most of the countries (except in the Netherlands) the paid wages are lower than the average industrial wages.

Results and discussion

Proportion of economically-viable farms across Member States

Each of the eight farm viability models listed in Table 2 was run on the combined FADN and FLINT dataset to identify the percentages of viable farms (Table 4), represented in Figure 1. It should be kept in mind that these results are only indicative due to the small sample size.

In general, Hungary has the highest farm viability rate, while Spain has one of the lowest viability rates. The former is partially due to the nature of the Hungarian sample, which contains a higher share of large cooperative farms. Greek data are only reported for models excluding the return on capital, due to the fact that liabilities are not reported in the data, so that return on capital reflects gross, not net, capital.

There are particularly strong variations in Greece, Ireland, Finland and Poland, meaning that, for many farms in the sample, the high average wage in the economy compared to paid wages prevents them from being viable. When paid wages are used instead of average wages, the increase in viability rate is higher between the opportunity cost models than between the farm-level models. That is the case in Germany and Spain. This can be explained by a higher difference between hourly and annual wages. Thus, from an opportunity cost perspective, for a farmer who earns more than the paid wages but less than the average, it is preferable to work off-farm and achieve the average wage per hour.

Across models, poorer countries such as Greece, Hungary and Poland have the highest farm viability rates, reflecting lower minimum wage rates. In Hungary, the low labour input and the low average wages in the economy explain the high viability rates. In Poland, they are mainly due to the low average wages in the economy. Western European countries such as Germany, Finland, the Netherlands and Spain have lower viability rates due to the higher benchmark thresholds as a result of higher minimum agricultural and average wages.

This point highlights one of the challenges in making cross-country farm viability comparisons as the paid wages threshold used to calculate viability differs across countries. This is to be expected as the latter are often lower than the average wages. The viability rate is lower in the Netherlands because of a higher threshold of paid wages. Thus, countries with higher farm viability rates are not necessarily those with higher farm incomes, but rather lower opportunity costs of labour.

The level and ranking of viability vary with the choice of definition. For example, Germany has one of the lowest viability levels if one looks at the opportunity cost or rate per hour, but has one of the highest when one looks at the farm level. Most of the time the farms are more viable at farm level than from the opportunity cost perspective. This means that this category of farms is only viable because of the number of hours worked. A high labour input enables them to achieve a high FFI, but they are not viable when examined on a per-hour basis. This is particularly true in Germany, meaning that hours worked is a key element in the viability of these farms.

The viability level is higher for models 5-8 than for 1-4. This is because the benchmark for viability, the average wage paid for agricultural labour, is lower than the average wage in the economy. There is some mobility, due to the relative differences in wage rate, found across countries. Ireland, for example, is ranked second and third lowest for models 2-4 for the average wage, but is ranked among the highest for models 5-7. The Netherlands moves in the opposite direction, as it is ranked higher for average wage and lower ranked for the agricultural wage.

There is less variability between models when the return on capital is considered. The proportion of viable farms is higher in models without a condition on COC. Clearly, it is easier for a farm to be viable if this condition is not taken into account. In Poland, the highest increase is often reached

Table 4: Percentage of viable farms in eight EU Member States according to eight models.

EU Member State	Model number							
	1	2	3	4	5	6	7	8
DE	0.09	0.28	0.10	0.31	0.23	0.31	0.29	0.37
EL			0.31	0.31			0.57	0.56
ES	0.11	0.11	0.18	0.18	0.19	0.18	0.25	0.19
FI	0.05	0.15	0.07	0.15	0.24	0.23	0.26	0.27
HU	0.28	0.45	0.47	0.52	0.50	0.50	0.52	0.52
IE	0.12	0.13	0.16	0.18	0.33	0.33	0.40	0.37
NL	0.19	0.21	0.25	0.25	0.19	0.17	0.24	0.25
PL	0.15	0.15	0.22	0.26	0.26	0.26	0.48	0.46

For details of models see Table 2
Source: own data

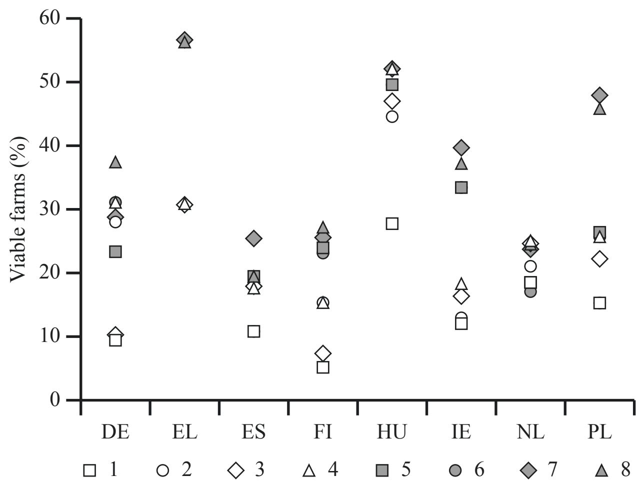

Figure 1: Percentage of viable farms in eight EU Member States according to eight models.

For details of models see Table 2
Source: own data

between models with paid wages, meaning that the condition on the COC plays an important role here. For example, in Poland the difference is about 20 per cent, which means that for 20 per cent of the farms the farmer would be better off to spend an hour working off the farm where his or her wages would not include a condition on COC.

Proportion of economically-sustainable farms across Member States

A similar procedure was undertaken to examine the economic sustainability of farms across the eight Member States (Table 5), represented in Figure 2. There is no strong variation in the rankings of the countries between the different models, so the rankings are firstly described in the context of country differences in the results for model 1, then compared across all models.

In model 1, the share of sustainable farms ranges from 26 (Poland) to 57 per cent (Germany). The countries with the lowest economic sustainability rates are Poland and Greece. This is because these countries have the lowest incidence of off-farm employment. As a corollary to this, Germany, the Netherlands and Hungary have the highest rates of sustainable farms and also have the highest incidence of off-farm employment, with the order changing relatively little if conditioned on being non-viable. Moreover, the difference between the incidence of off-farm employment and the proportion of sustainable farms is less than 13 per cent in these countries. Thus it is evident that many farms would be economically vulnerable without supplementary income from off-farm employment.

Compared to the significant change in the relative rankings in relation to farm viability, there is no strong variation in the proportion of sustainable farms and their ranks between the different models. This can be explained by the fact that off-farm employment is the main variable impacting economic sustainability. The only noticeable difference between models is in terms of thresholds. The proportion of sustainable farms is smaller in models using paid wages, particularly in Ireland. This means that the farms which are no longer viable if we apply paid wages, have an income between the average wage and the paid wage, but also have off-farm income. This may indicate that the paid wage is not sufficient to cover their needs.

Proportion of economically-vulnerable farms across Member States

The final component of the analysis examines those farms that are economically vulnerable as defined above. Again, there are substantial differences across countries and between models (Table 6), represented in Figure 3. The vulnerable

Table 5: Percentage of sustainable farms in eight EU Member States according to eight models.

EU Member State	Model number							
	1	2	3	4	5	6	7	8
DE	0.57	0.49	0.56	0.45	0.53	0.45	0.48	0.41
EL			0.29	0.29			0.23	0.24
ES	0.43	0.43	0.41	0.41	0.41	0.41	0.40	0.41
FI	0.41	0.39	0.41	0.39	0.32	0.32	0.32	0.30
HU	0.49	0.43	0.42	0.40	0.41	0.41	0.40	0.40
IE	0.40	0.39	0.38	0.37	0.27	0.27	0.23	0.26
NL	0.44	0.41	0.41	0.41	0.44	0.45	0.42	0.41
PL	0.26	0.26	0.24	0.22	0.22	0.22	0.17	0.17

For details of models see Table 2
Source: own data

Table 6: Percentage of vulnerable farms in eight EU Member States according to eight models.

EU Member State	Model number							
	1	2	3	4	5	6	7	8
DE	0.33	0.23	0.33	0.23	0.23	0.23	0.23	0.22
EL			0.40	0.40			0.20	0.20
ES	0.46	0.46	0.41	0.41	0.40	0.41	0.35	0.40
FI	0.54	0.46	0.52	0.46	0.44	0.44	0.43	0.43
HU	0.23	0.12	0.11	0.08	0.09	0.09	0.08	0.08
IE	0.48	0.48	0.46	0.45	0.40	0.40	0.37	0.37
NL	0.38	0.38	0.34	0.34	0.38	0.38	0.34	0.35
PL	0.59	0.59	0.54	0.52	0.51	0.52	0.35	0.37

For details of models see Table 2
Source: own data

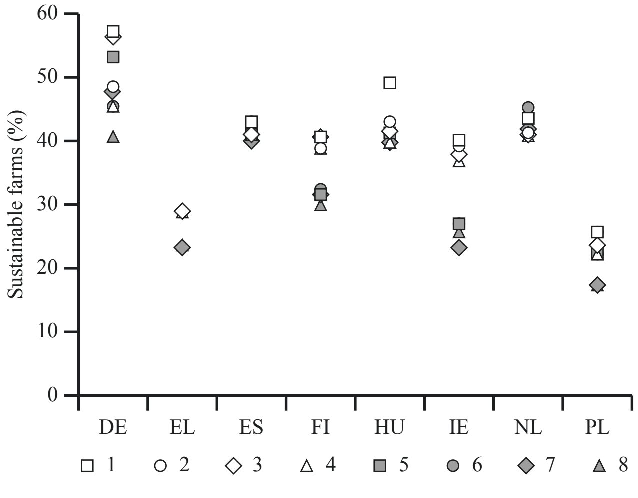

Figure 2: Percentage of sustainable farms in eight EU Member States according to eight models.

For details of models see Table 2
Source: own data

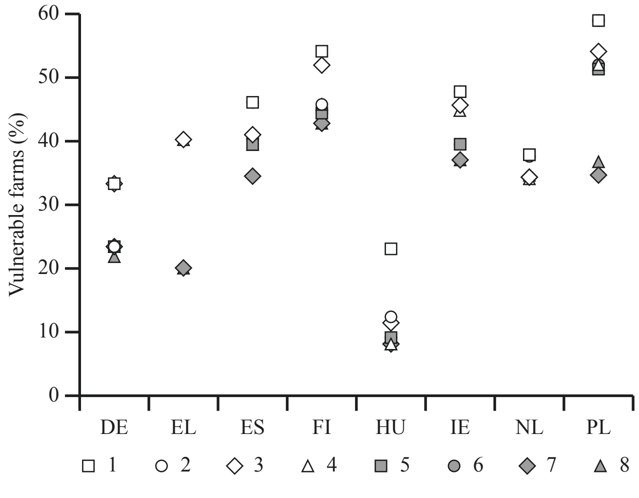

Figure 3: Percentage of vulnerable farms in eight EU Member States according to eight models.

For details of models see Table 2
Source: own data

cohort is the complementary proportion of the previous results. Poland has the highest proportion of vulnerable farms (59 per cent in model 1). Moreover, the low off-farm employment rate explains why most of the farms are not economically sustainable. At the opposite end of the scale, Germany and Hungary have the smallest proportions of vulnerable farms, due to the high proportions of farms classified as sustainable.

Unlike sustainability, vulnerability is affected by changes in the models. A comparison between thresholds shows that there are fewer vulnerable farms with paid wages. The difference in the vulnerability rates assessed with average wage and those assessed with paid wage represents the farms which become viable when the threshold is changed. These farms generate an income between the two wages, but do not have an off-farm job. It can be surmised that either such an income is sufficient for these farmers or they do not want to work off the farm.

In many cases, there is a higher proportion of vulnerable farms when using opportunity cost rather than the farm-level approach. This is the opposite for viability, and sustainability is not impacted. This corroborates our hypothesis that this may represent farms which have a large labour input, preventing the farmers from having an off-farm job. In these cases, the farms generate a sufficient annual income but not a sufficient hourly income.

Conclusions

The measurement of farm economic viability becomes relevant and receives academic interest at different time periods in different areas. During periods of failure or difficulty in the agricultural sector, attention turns toward the measurement of viability with a view to improving the situation given improved methods of measurement. In addition, there is an ongoing and growing need to evaluate CAP and EU Rural Development Programme objectives such as the improvement of farm viability. These needs present challenges to researchers and analysts to develop a farm household income measurement which provides details of the income levels of farm households which could then be analysed relative to other sectors within society. However, a lack of comparable data across EU Member States poses difficulties for meaningful evaluation.

While the comparative cross-country analysis undertaken in this paper is a pilot study, limited by the small sample size, it nonetheless presents a template for future work. The analysis highlights the following factors:

There are substantial differences in viability rates between countries. Some of these are related to national policies. There are a number of different definitional choices that can be used when viability is measured as discussed in this paper. These include the comparator wage which determines the threshold at which viability is determined. Similarly, we can choose whether to incorporate a return on capital, which also affects the viability rate. Lastly, we compare the choice of measuring viability in terms of the opportunity cost of farm resources or as an income measure, comparing farm incomes with an income from another source of employment. With respect to cross-country comparison, we note the importance of the change in both the levels and the rankings of viability between countries, depending upon the measurement choice. It is important therefore in comparing viability across countries to test the sensitivity of results to different measures.

Measuring viability using the current viability definition provides a head count analysis of viability in the country. While the head count measure of viability detailed in this paper is useful in many regards, it lacks detailed results of the issues affecting the non-viable group. More detailed analysis is required to identify different improvement instruments for farms which are in states of chronic vulnerability as opposed to farms which experience less severe vulnerability over a shorter time period.

The results demonstrate the sensitivity of the measures to the use of particular thresholds in the measurement of the viability head counts. In particular, the farm viability rate is sensitive to the threshold or benchmark wage employed. Further work is required at national level to define a comparable threshold metric across the EU. As in the poverty literature, there may be merit in developing measures that are based upon the gap or distance from the threshold as compared to a simple binary measure of being above or below the threshold.

The capacity to evaluate the economic sustainability of farms on the basis of off-farm income, conferred by the use of the FLINT data in this analysis, opens up an important new economic viability classification, by distinguishing between the three categories studied (i.e. economically viable, sustainable and vulnerable farms).

The extension of the FLINT data collection pilot to the wider FADN sample would enable more robust nationally-representative analyses to be undertaken. In addition, the development of additional statistics on other sources of income would present an opportunity to refine the three economic viability categories. Further information on household income would also enable analysis of the relative impact of farm total other incomes on the economic viability categories. Additionally, if data collection was to be undertaken at three- or five-year intervals, a time-series FADN dataset would allow for volatility assessment and the illustration of trends over time, as well as providing an early warning of potential future economic, social or environmental threats. Data collection at a larger scale would also enable the impact of agricultural structures and characteristics of the area on economic sustainability to be studied.

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Short communication

Harold VAN DER MEULEN*[1], Marcel VAN ASSELDONK* and Lan GE*[2]

The state of innovation in European agriculture: Innovators are few and far between

Innovation and adoption of innovation are considered key indicators of competitiveness and sustainability. Analysing data from 821 farms from eight Member States of the European Union in the frame of the EU Framework 7 project FLINT, this study provides an insight into the different adoption rates of five types of innovation in agriculture across Europe and suggests the potential effects of different factors, including farm type and farm size, subsidies and age, on farmers' decision to innovate.

Keywords: farm-level, FADN, EU Member States

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Introduction

Innovation is seen as one of the key drivers for a competitive and sustainable agriculture. It is often hypothesised 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 to the structural characteristics traditionally used in decision-theoretic 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 contrast to farm competitiveness, we are not aware of any in-depth study on the impact of innovation on the sustainability of farming in European Union (EU) Member States. The lack of data on the state of innovation hampers such studies. Against this background, the EU Framework 7 project FLINT[3] collected farm-level indicators on innovation and related aspects in nine EU Member States. In this paper, in combination with data collected by the Farm Accountancy Data Network (FADN)[4], the FLINT data are used to obtain insight into different adoption rates and determinants of adoption of five types of innovation in agriculture across Europe.

Methodology

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 innovations, we examined the level of innovation across different farm size classes. With regard to the type of farming, the hypothesis is that farmers that produce 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 those in dairy and meat.

The analysis in this paper is based on data from 821 farmers collected in eight EU Member States. The FADN and FLINT data relate to accountancy year 2015, except for France and Germany for which it is 2014. Adoption of different types of innovation is analysed as a discrete choice problem. Considering the nested nature of farm data within farming types and Member States, 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)[5] with Member State and farming type as the two levels with random intercepts. The five types of innovation indicators and one aggregated indicator distinguished in the dataset are:

- Product innovation that is new for the company within the last three years, but not new to the market (*product not new*);
- Product that is new to the market (*product new*);
- Process innovation that is new for the company within the last three years, but not new for the market (*process not new*);
- Process innovation that is new for the company and new for the market (*process new*);
- Market and organisational innovation (*organisational*);
- Having one or more of the above-mentioned types of innovation (*farms with innovations*).

Results

The general state 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 per cent of the farms have innovated in one or more of the five 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. 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.

1 http://orcid.org/0000-0002-8246-0224
2 http://orcid.org/0000-0003-3692-7476
3 http://www.flint-fp7.eu
4 http://ec.europa.eu/agriculture/fadn_en
5 http://www.stata.com/manuals13/memeprobit.pdf

Table 1: Adoption by type of innovation and number of observations per Member State.

Member State	Product new	Product not new	Process new	Process not new	Organisational	Farms with innovation	Number of observations
	Per cent of all farms						
Finland	2	12	8	32	36	56	50
Germany	6	17	2	31	31	52	52
Greece	1	16	0	44	7	50	124
Hungary	3	17	1	41	20	52	102
Ireland	0	0	0	2	0	2	65
Netherlands	2	5	4	17	16	32	155
Poland	0	24	0	40	10	52	146
Spain	3	12	2	25	9	33	128
Total sample	2	13	2	30	14	41	821

Source: own data

Table 2: Adoption by type of innovation and number of observations per farm size class.

Farm economic size class	Product new	Product not new	Process new	Process not new	Organisational	Farms with innovation	Number of observations
	Per cent of all farms						
3	0	0	0	22	6	22	18
4	0	15	0	24	4	29	55
5	0	15	0	29	6	37	65
6	4	18	2	36	11	46	143
7	3	18	1	31	16	46	159
8	1	10	1	24	16	37	185
9	1	10	2	33	13	44	87
10	0	15	0	44	24	56	34
11	0	0	0	33	22	44	18
12	9	5	9	18	9	23	22
13	8	19	12	31	27	50	26
14	0	17	0	50	33	67	6
Total sample	2	13	2	30	14	41	819

Source: own data

Table 3: Adoption by type of innovation and number of observations per type of farming.

Type of farming	Product new	Product not new	Process new	Process not new	Organisational	Farms with innovation	Number of observations
	Per cent of all farms						
Specialist field crops	2	20	1	36	15	48	179
Specialist horticulture	8	19	6	11	17	36	36
Specialist permanent crops	0	23	0	47	16	58	104
Specialist grazing livestock	2	8	3	21	13	33	313
Specialist granivores	0	12	1	25	10	36	77
Mixed cropping	5	14	0	18	14	32	22
Mixed livestock holdings	0	0	0	44	11	44	9
Mixed crop – livestock	3	10	0	43	14	48	79
Total sample	2	13	2	30	14	41	819

Source: own data

Innovators are few and far between compared to early and late adopters. The percentage of innovators on product and process is overall around 2 per cent, which is much lower than the early and late adopters.

Innovation and structural characteristics of farms

A higher percentage of larger farms (size classes 12 and 13; Standard Output between EUR 1,000,000 – 3,000,000 per year) innovated in new products and new processes (Table 2). Organisational and market innovations are also more frequently adopted on the largest farms (size classes 13 and 14; Standard Output EUR 1,500,000 and higher). Adoption of innovations in product and process that are not new to the market seems to be less dependent on farm size.

Specialist farms in permanent and field crops and mixed farms (crops and livestock) have the highest percentage of innovation. Organisational and market innovations are quite homogeneous between the different farm types (Table 3). In horticulture, most innovations took place for new products and processes.

Determinants of innovation based on multi-level mixed effect logistic regression

The estimated coefficients of the explanatory variables of the regression analysis suggest that farm type and farm size are likely to be the main determinants of process and organisational innovation (Table 4). Subsidies appear to have a significantly positive effect on the adoption of process innovation. Other explanatory variables included are farmer age and the number of advisory contacts by the farmer in a year. This latter information is derived from the FLINT database. 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 appear to have 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.

Table 4: Estimates of the adoption models (parameters are odds ratios and standard errors) for innovations.

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

Number of observations = 782; number of groups = 8; standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Source: own data

Discussion

Owing to the lack of empirical studies in other countries, the results of this study should be interpreted as indicative and with caution. 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).

For the Netherlands, a comparison can be made between our results and those of the farm-level innovation monitor. This panel data set covers the period from 2005 onwards. In 2014 about 2 per cent of Dutch farmers (including horticulture) were innovators and 16 per cent could be seen as early or late adopters. The proportion of innovators in agriculture has been fluctuating for several years around 2 per cent. 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 these results. Relatively 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.

Our finding that the age of the farmer is a determinant of innovation may be linked to the fact that older farmers have, on average, a lower level of education, which may be correlated with the ability to judge opportunities to innovate. They may also 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).

Continuing data collection on innovation for several years will enable to determine the trends in adoption rates. The integrated character of the FLINT+FADN database allows economic, social and environmental aspects of farming to be combined. For policy analyses, time-series of innovation indicators are a step forward for estimating the net impacts and establishment of counterfactuals on the long term.

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