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The determinants of wheat yields: The role of sustainable innovation, policies and risks in France and Hungary

Mauro Vigani
Emilio Rodríguez Cerezo
Manuel Gómez Barbero

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Abstract

This report presents the results of a survey conducted on 700 wheat farmers in France and Hungary. The survey aimed to single out the most critical elements at the base of wheat productivity, collecting information for the growing seasons 2010/2011, 2011/2012 and 2012/2013. Two types of data were obtained: farmers' opinions on the determinants of wheat productivity; quantitative data on wheat output, production factors, marketing strategies, damages, and field and risk management practices. Through descriptive statistics, the report revealed important and significant differences between the studied countries. According to French farmers' opinion, the most important wheat yield determinants at national level are seasonal weather and soil quality; while Hungarians pointed climate change and seasonal weather. At the farm level, the high prices of inputs and the low wheat market prices are considered the most constraining factors in both countries. Wheat yields are positively correlated to higher agro-chemicals use in Hungary and to additional days of labour in France. The adoption of precision farming provides 7-12% higher yields in both countries, while yield gains from conservation agriculture and IPM are found in partial adopters. In both countries, the most frequently adopted innovation to increase wheat yields and grains' quality are new wheat varieties. However farmers' willingness to adopt genetically modified wheat varieties positive in France and negative in Hungary. Finally, both farmers perceive market risks as more detrimental than natural disasters. While crop insurance is the most adopted tool to deal with natural risks in both countries, French farmers adopt diversification strategies more frequently than Hungarians to deal with market risks.

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Mauro Vigani

Emilio Rodríguez Cerezo

Manuel Gómez Barbero

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1 The views expressed are purely those of the author and may not in any circumstances be regarded as stating an official position of the European Commission.

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Contents

LIST OF ACRONYMS

CAP	Common Agricultural Policy
CUMA	Coopérative d'Utilisation de Matériel Agricole
CV	Coefficient of variation
DG	Directorate General
EARL	Exploitation Agricole à Responsabilité Limitée
EC	European Commission
EU	European Union
EUROSTAT	European Union Statistical Office
FAOSTAT	Food and Agriculture Organization of the United Nations statistical database
GAEC	Groupements d'Exploitation en Commun
GPS	Global positioning system
GM	Genetically modified
GMO	Genetically modified organism
IFPRI	International Food Policy Research Institute
IPM	Integrated pest management
IPTS	Institute for Prospective Technological Studies
IRIWI	International Research Initiative for Wheat Improvement
JRC	Joint Research Centre
MS	Member State
NUTS	Nomenclature of Territorial Units for Statistics
R&D	Research and Development
TAA	Total agricultural area
TUA	Total utilised area
UK	United Kingdom
USA	United States of America

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Executive summary

Wheat is currently a key staple cereal for millions of people worldwide, and demand for wheat is expected to increase strongly in the near future as a result of global population growth and dietary changes. Hence, how to increase wheat production is one of the major challenges that agriculture now faces, especially as there has been a global decline in the growth of wheat yields since the mid-1990s, potentially threatening global food security.

The European Union (EU) has a key role in this context, as it is the main wheat producer and supplier worldwide, with wheat yields above the world average. However, in many Member States (MSs), wheat yields are plateauing, and this lack of yield improvements may put future wheat consumption at risk.

In 2012, the Institute for Prospective Technological Studies (IPTS) of the European Commission's Joint Research Centre (JRC) launched a project which aims to identify the most critical elements at the basis of wheat productivity. The project started with the organisation of an international workshop, followed, in 2013, by a large survey of EU wheat farmers to collect primary data on the factors affecting wheat productivity.

The survey collected information from a sample of 700 farms located in two representative MSs for three growing seasons, namely 2010/2011, 2011/2012 and 2012/2013. Two types of data were obtained: farmers' perceptions of the drivers of and constraints on wheat farming as well as quantitative data on wheat output, income, marketing strategies, production factors, damages, and field and risk management practices.

The selection of the two representative MSs was based on three criteria: (i) the relative importance of the MS with regard to international wheat production; (ii) its pattern of yield development in recent decades; and (iii) the structure of the MS's farming sector and whether or not it provides a representative model for the EU. Based on these criteria, France and Hungary were selected as case studies. In each MS, the most important wheat-growing regions were selected: Centre, Bourgogne, Champagne-Ardenne and Picardie in France and Central Transdanubia, Western Transdanubia, Southern Transdanubia, the Northern Great Plain and the Southern Great Plain in Hungary.

The current report presents the main results of the survey, in the form of descriptive statistics on farmers' perceptions and quantitative data collected. Moreover, this report provides definitions, mechanisms of action and discussions of five of the main factors influencing wheat productivity identified at the above-mentioned international workshop and from a literature review: (i) farm and farmer characteristics; (ii) innovation and changes in input use and management practices; (iii) climate change; (iv) policy reforms and market signals; and (v) risks related to farming activity.

The survey revealed important differences between the two MSs. These differences are relate mainly to farmers' opinions and perceptions of wheat production drivers and constraints, which, in turn, seem to be influenced by structural differences in the farming sectors and local conditions, as confirmed by the quantitative data.

The differences in the characteristics of the surveyed farmers from these two MSs are primarily related to their level of education, which is, on average, higher in Hungary than in France. In both countries, the most common type of wheat farms are arable farms, especially individual/family farms in Hungary and private companies in France (Groupement Agricole d'Exploitation en Commun (GAEC) and Groupement Agricole d'Exploitation en Commun (EARL)). Hungarian farms are, on average, larger (total utilised area -TUA- of 194.5 ha) than French ones (TUA 162.3 ha), but there is a greater variability in the size of Hungarian farms, suggesting that, in Hungary, small wheat producers coexist with large corporate wheat producers.

The main type of wheat produced in both MSs is high-protein winter wheat, and only about 1 % of the farmers produce organic wheat, suggesting that this is still a niche product. The wheat produced is mainly destined for the market, and wheat prices are, on average, 23 % higher in France than in Hungary. In both countries, more than 30 % of the surveyed farm income comes from wheat production. In Hungary, 69.1 % of this income is reinvested in farming activities, compared with only 15 % in France.

On average, yields are about 2.5 tonnes/ha higher in France than in Hungary. In both MSs, temporal yield variability is lower than spatial variability, suggesting a high degree of yield stability, especially in France. The regions with lower

spatial variability are Centre and Champagne-Ardenne in France, and Western and Southern Transdanubia in Hungary.

In the opinion of French farmers, the most important determinants of wheat yield at the national level are seasonal weather conditions and soil quality, while Hungarians cited climate change and, again, seasonal weather conditions. At the farm level, the high price of inputs and the low market price for wheat are considered the most constraining factors with regard to increasing wheat production in both MSs.

The use of fertilisers and crop protection products is much higher in France but expenditure on agri-chemicals is not reflected in higher wheat yields. In contrast, in Hungary higher intensity of agro-chemical use is positively correlated with wheat yields. When we consider the intensity of labour use; in Hungary, additional days of labour are negatively correlated with wheat yields, while in France, additional days of labour are positively correlated with wheat yields.

Soil fertility and pest control can be maintained, and even improved, by appropriate crop rotation schemes. In France, wheat is most frequently preceded by rapeseed, maize and wheat whereas in Hungary the crops that most frequently precede wheat are maize, sunflower and rapeseed. In France, significantly higher wheat yields are obtained by rotation schemes involving three preceding crops (+0.89 tons/ha) and, in the case of single preceding crop schemes, when sugar beet is the preceding crop (+0.87 tons/ha). By contrast, in Hungary, higher wheat yields are found in farms adopting single preceding crop schemes with rapeseed as the preceding crop (+1.1 tons/ha).

The adoption of sustainable agricultural practices also varies. Conservation tillage is not widely used in Hungary (only 8 % of farms), while, in France, 17.7 % of farms adopt minimum tillage and 42 % adopt a mix of traditional and conservation tillage. Moreover, integrated pest management (IPM) is more widely used in France (40 % of farms) than in Hungary (14 % of farms), while, interestingly, precision farming is similarly adopted in France (25.4 % of farms) and Hungary (23.4 % of farms).

Precision farming contributes significantly to yield increases in both MSs (about 7–12% higher yields). As regards conservation agriculture and IPM, the highest yield gains come from partial adopters, suggesting that the best practice is to adopt a combination of traditional and conservation/IPM practices, depending on plot-specific soil and pest conditions.

New varieties are the innovation most frequently adopted to increase wheat yields and grain quality, both in France and in Hungary. Pest resistance is the most important characteristic for French farmers, whereas, for Hungarian farmers, it is abiotic stress resistance, especially drought resistance. Farmers' acceptance of the use of genetically modified (GM) wheat varieties differs. The majority of French farmers would be willing to adopt new GM wheat varieties, while the majority of Hungarian farmers would not cultivate them.

With respect to policies, farmers in both MSs perceive the 2003 Common Agricultural Policy (CAP) reform as a potential source of price volatility, but this is not surprising given that a reduction in the market protection of farms was actually one of the objectives of the reform. Moreover, there is a differing perception of the capacity of CAP payments to increase wheat farming competitiveness. In Hungary, 53.1 % of farmers agreed that the CAP contributed to competitiveness, while 59 % of French farmers did not agree.

As regards the potential risks affecting wheat farming, both French and Hungarian farmers perceive market risks (a drop in wheat prices) as more detrimental than natural disasters. Indeed, in the three growing seasons considered, there was a higher incidence of damages related to market conditions than to natural disasters. To deal with natural risks, crop insurance is the most adopted tool in both countries. To deal with market risks, French farmers adopt diversification strategies more frequently than Hungarians, especially diversification of sales channels, choosing the time to sell and adopting other income-generating activities.

To conclude, the differences in farming systems and local characteristics across the two MSs suggest that there is no single solution to the improvement of wheat production and productivity that can be applied to all situations in the EU. On the contrary, because of the differences in the approaches to wheat farming across MSs, and also sometimes within national territories, measures tailored at the local level are required.

1. Introduction

The ability to increase wheat production has been one of the major challenges faced by agriculture over the last 20 years not only because wheat is currently a key staple cereal for millions of people worldwide, but also because wheat demand is expected to dramatically increase in the near future as a result of the foreseen increase in the global population and dietary changes (CENEB and CIMMYT, 2012). According to the Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT)[2], worldwide production of wheat was 713 million tons in 2013, making it the third most-produced cereal after maize (1 016 million tons) and rice (745 million tons). In addition, it is the fourth most-produced commodity in the world.

Wheat yields showed constant growth during the 20th century, this enabled the development of the sector and was sufficient for the level of consumption. However, since the mid-1990s, there has been a decline in the growth of wheat yields at a global level, affecting, in particular, the most important wheat-producing countries, such as the USA, Canada and the Member States of the European Union (EU) (Brisson et al., 2010).

In order to meet the current and future demands for wheat, and to reduce the potential for food insecurity, important international initiatives were recently instituted. In fact, the G20 Agriculture Ministers, in their 2011 action plan, endorsed the International Research Initiative for Wheat Improvement (IRIWI), which aims to provide a coordination platform for international research programmes and to define research and investment priorities for wheat development[3]. In 2012, Rothamsted Research launched a programme called "20:20 Wheat" with the aim of increasing wheat yield potential to 20 tonnes per hectare within 20 years. Other research programmes on wheat are active in several countries[4].

Europe has a key position in this context, given that it is the main wheat producer and supplier worldwide, with wheat yields well above the world average (about 24 % higher according to FAOSTAT). However, many EU Member States (MSs) are experiencing wheat yield growth stagnation that could put future wheat consumption levels at risk (Brisson et al., 2010). In 2012, the Institute for Prospective Technological Studies (IPTS) of the European Commission's Joint Research Centre (JRC) launched a project which aims to identify the most critical factors determining wheat productivity[5].

In 2012, the first step taken by the JRC IPTS was to organise an international workshop entitled "Wheat Productivity in the EU: Determinants and Challenges for Food Security and for Climate Change" (proceedings available in Vigani et al., 2013). This workshop brought together wheat researchers and experts from leading universities and international organisations. The workshop's main conclusions were that yield stagnation in Europe is attributable to four main factors: changes in agricultural input use and management practices; climate change; policy reforms and market signals; and risks related to farming activity.

The current literature on the above-mentioned factors, which affect wheat yields in particular and productivity in general, is highly fragmented. In some cases, scientists and agronomists have carefully studied the role of specific factors, such as the genetic potential of wheat varieties (Peltonen-Sainio et al., 2009; Brisson et al., 2010; Oury et al., 2012), the efficiency of input use, such as water, fertilisers and crop protection products (Olesen et al., 2003; Jørgensen et al., 2008; Petersen et al., 2010), and the role of field and soil management practices (Rieger et al., 2008; Brennan et al., 2014). Overall, they found that genetic progress has not declined but that it might have been influenced by agronomic factors, such as the reduction in the use of legumes in rotations and changes in input use.

An exception to these studies of very specific factors is provided by a report by Petersen *et al.* (2010), which considered that many factors combined may contribute to the stagnation of wheat yield growth (soil type, climate and external factors, breeding and genetics, fertilisation, crop protection, crop rotation, and farm management and technology). This report concluded that breeding and genetics have contributed to increased wheat yields, while the reduction in the general use of fungicides and

2 Food and Agriculture Organization of the United Nations, FAOSTAT database, available at http://faostat.fao.org/site/362/DesktopDefault.aspx?PageID=362

3 The official web-site of the IRIWI: http://www.wheatinitiative.org

4 For a detailed list of wheat research programmes at country level consult the following web-page: http://www.wheatinitiative.org/research/funding/projects

5 In this report, we refer to land productivity, which is the quantity of wheat produced from each hectare of wheat crop.

nitrogen fertilisation, and the more widespread adoption of monoculture and conservation practices, have had a negative impact. However, these results are based on winter wheat in Denmark and do not necessarily apply to other EU countries or regions.

In the economic literature, studies attempting to explain the effects of the four above-mentioned factors on wheat productivity and yields are not only few in number, but were also carried out at quite different times, and, again, they mainly studied only single factors. Moreover, the majority of these studies do not address the EU situation, but, rather, are based on yields in other countries or regions of the world (Choi, 1993; Smale et al., 1998; Yao and Liu, 1998; Ahmad et al., 2002). A recent economic study on the productivity of the wheat sector in Europe (Di Falco and Chavas, 2006) provided results on the impact of genetic diversity. This study showed that genetic diversity can increase farm productivity; however, the study was confined to a single Italian region and, therefore, the results cannot be applied at the EU level.

Overall, the existing scientific literature on the determinants of wheat productivity focuses on single factors and/or on small case studies, and therefore this literature does not provide a comprehensive analysis of the different elements affecting the EU wheat sector.

Given the conclusions of the JRC IPTS workshop and the above-mentioned gaps in the literature, in 2013 the JRC IPTS decided to launch a large survey among EU wheat farmers in order to collect farm-level primary data on the majority of factors that affect wheat production and productivity. For this purpose, two representative MSs were selected as case studies: France and Hungary (see Section 3). The survey collected information from a sample of 700 individuals, obtaining information on their perception of the drivers of and constraints on wheat farming, as well as quantitative data on wheat output, income, marketing and sales strategies, production factors/inputs, field management practices, and damages and compensation.

The aim of the current report is to present the main descriptive results of this survey. It presents both farmers' perceptions of and quantitative data on wheat production, making use of descriptive statistics, differences in means and tests of significance, correlation and linear prediction. Further empirical analyses disentangling the role of each factor in wheat production and productivity are currently ongoing at the JRC IPTS.

The report comprises several sections. Section 2 is based on a review of the literature and provides definitions, mechanisms of action and discussions of each of the main factors influencing wheat yields, as determined in the 2012 workshop, namely farm and farmer's characteristics; innovation and changes in input use and management practices; climate change; policy reforms and market signals; and risks related to farming activity. Section 3 presents the methodology used to select the case study MSs and design the survey; it also provides the description of the sample. Section 4 presents the descriptive results of the survey. Finally, Section 5 concludes by summarising and discussing these results.

2. What drives agricultural productivity? Existing evidence

Productivity is a measure of farm performance, which is defined as the amount of output obtained given a certain amount of production factors. Productivity can involve all the production factors (total factor productivity) or only some of them (partial productivity, such as labour or land productivity) (Coelli et al., 2005). In this respect, we refer here to land productivity or yields (production per hectare).

The level of agricultural productivity is driven by several factors. These factors are related not only to inputs, crop biology and environmental conditions, but also to the behaviour of agricultural markets and agricultural policies. Hence, the determinants of crop productivity at the farm level can be clustered into the following groups (Vigani et al., 2013):

- farmer and farm characteristics;
- innovation and changes in input use and management practices;
- climate change;
- policy reforms and market signals;
- risks related to farming activity.

In this section, we provide literature-based definitions of each of the above factors and of their elements, describing the mechanisms of action in enhancing or constraining the land productivity (yields) of wheat.

2.1 Farmer and farm characteristics

Individual characteristics of farmers can play an important role in the productivity level of a farm, especially age and education. Older farmers are, in general, more conservative in their practices and less technology oriented than younger farmers. Younger farmers can be more productive, thanks to a higher rate of adoption of innovative practices and technologies; however, the greater experience of older farmers can compensate for their less common use of technologies (Ray, 2004).

As regards the level of farmer education, higher education, especially with a specialisation in agriculture, can result in higher expertise and a propensity towards innovations and, as a consequence, the adoption of technologies and/or practices that enhance productivity (Ray, 2004).

The decision of a farmer to join agricultural associations, cooperatives or unions can also affect farm productivity. These organised groups can transfer technical knowledge to farmers by organising specialised training sessions and courses, teaching farmers how to use new equipment and informing them about innovative practices or services. Moreover, farmers' cooperatives create partnerships for buying inputs and selling products and have higher contract power than individual farms, allowing lower input costs and higher revenue prices (Di Falco et al., 2008).

Not only can a farmer's characteristics influence the level of productivity, but the characteristics of the farm itself can also have an effect; this is especially notable when comparing private corporate and family/individual farms. Family or individual farms have some peculiar characteristics that contribute to shaping the wheat production system (Hennessy, 2014). A family farm is, by definition, owned and operated by a family, and ownership usually passes to the next generation by inheritance. The new generation of younger owners is, in general, more inclined to introduce innovative practices or technologies. Moreover, family farms face some important constraints (Hennessy, 2014). Given their limited dimensions, family or individual farms cannot exploit economies of scale; they are strictly price takers, subject to seasonal fluctuations in petrol and input prices. The small scale of family/individual farms can also affect credit and financial access. By contrast, large corporate farms can exploit the economy of scale and can benefit from greater market power within the production chain. Moreover, financial institutes are more inclined to provide credit lines for large companies than for small ones. However, corporate farms can have higher management costs (Nix, 2015).

Moreover, farms can produce different types of the same crop, which can account for differences in levels of productivity. In the case of wheat, the primitive species (*Triticum vulgaris*) has diverged into different species, classes and varieties, mostly selected for and bred by humans (Heyne, 1987). The most important way of classifying wheat is based on its utilisation, distinguishing soft from durum wheat. Soft wheat is a category including species (the common wheat *Triticum aestivum* and the spelt wheat *Triticum spelta*) and varieties mainly destined for bread production. By contrast, durum wheat (*Triticum durum*) is mainly destined for the production of pasta and semolina. In terms of yield, durum wheat is less productive than soft wheat. For example, the average yield of durum wheat in Spain, since 2005, is 2.2 tons/ha, whereas the average yield of soft wheat is 3.2 tons/ha (European Union Statistical Office (EUROSTAT)).

A second important way of classifying wheat is based on the planting season. Winter wheat is planted in autumn and harvested at the beginning of summer, and it is cultivated mainly in regions with temperate climates; spring wheat is planted in spring and harvested in late summer in cooler regions (Heyne, 1987). A third way of classifying wheat relates to the quality of the resulting wheat flour, as measured by the protein content of the grains, and distinguishes high- and low-protein wheat. In terms of productivity, winter wheat varieties have higher yields than spring wheat varieties, and low-protein-content wheat varieties have higher yields than high-protein-content wheat varieties (Nix, 2015).

A farmer's decision on which quality of wheat to grow is mainly driven by market conditions. The greater global demand for high-protein wheat attracts a market premium and, therefore, productivity is not necessarily a driver for its cultivation. However, the demand for high-protein wheat can vary from year to year, depending on the market's stocks, which induces price volatility (Wilson et al., 2009).

2.2 Innovation and changes in input use and management practices

The growth in agricultural productivity that has occurred in the last century is strongly associated with the invention and commercialisation of new technologies and inputs for crop cultivation (Pardey et al., 2012). Currently, an increase in productivity, especially in the presence of natural resource constraints, is likely to be achieved by targeting input efficiency by means of innovations in fertilisers, plant protection products (i.e. pesticides, fungicides and herbicides) and mechanisation (e.g. precision seeding machines, tractors with global positioning system –GPS- guidance, etc.) (Petersen et al., 2010). Yield increases may also result from improved varieties with traits for biotic and abiotic resistance, and traits that promote nutrient use efficiency and yield stability (Peltonen-Sainio et al., 2009).

The availability of new or improved inputs is directly related to the level of research and development (R&D) investment, both from the public sector and from the private sector. The average rate of growth of public agricultural R&D spending has been decreasing in developed countries, from 9 % in the period 1960–1970 to 1 % in 2000–2009 (Pardey et al., 2012). It is likely that the result will be a slow-down in gains in agricultural productivity and crop yields as a result of a failure to develop innovative tools against emerging problems (e.g. innovative pesticides against new pests or diseases).

The agro-chemical inputs most used in agriculture are inorganic fertilisers and plant protection products. The quantities used by farms are driven by the need not only to maximise agronomic outputs, but also to optimise the cost–benefit relationship. Farmers adjust the rate of input use according to, among other things, the expected harvest price at the end of the season (Vigani et al., 2013). A similar type of adjustment is also made to the type of crop variety used, with higher-quality, lower-yielding varieties that obtain higher market prices being preferred over higher-yielding varieties of a lower quality (Evenson and Gollin, 2003).

The rate of adoption of agro-chemical inputs is also driven by a growing tendency to adopt environmentally friendly and sustainable agricultural practices. In its "Europe 2020 Strategy", the European Commission promotes the increase of agricultural productivity in a sustainable and resource-efficient way (European Commission, 2012). Sustainable production involves ensuring the fulfilment of current (or increasing) levels of demand for agricultural products, while reducing the degradation of production factors, such as soil and water (European Commission, 2010).

Sustainable productivity growth is based on farming systems that exploit conservation practices and low-input innovations adapted to the local conditions, and non-technological innovations such as marketing or organisational innovations. Technical tools for increasing sustainable productivity consist in the optimised use of rotations, nutrients, pesticides, energy, water and genetic resources, lowering the dependence on external inputs (Mexican G20 Presidency, 2012).

The most traditional sustainable practice for maintaining soil fertility is crop rotation. Rotations can be of two or more crops and farmers can decide to adopt more than one rotation system simultaneously. While monoculture can provoke a reduction in crop yields because of the excessive exploitation of soil nutrients and the transfer and development of pathogens from one cropping season to the other, rotation can interrupt or slow down the development of pests or diseases across cropping seasons, and can restore soil fertility as residual of the preceding crop increases the organic matter content of the soil (Hennessy, 2006).

Innovation systems have also responded to the increasing demand for sustainable developments in the areas of insect-resistant crops, water management systems, conservation agriculture practices, integrated pest management (IPM) and precision farming (IFPRI, 2014). The last three are not mutually exclusive and are the most widely used with regard to EU wheat production.

Conservation agriculture includes no-tillage (direct sowing) and minimum tillage (soil cultivation is kept to the minimum necessary for crop establishment and growth, thereby reducing labour and fuel costs) cultivation[6]. The aim of these practices is to minimise soil disturbance in order to preserve soil structure, soil fauna and organic matter. These tillage methods leave most crop residues on the soil surface, which may also be covered by spontaneously growing vegetation or by appropriate sown species. This permanent soil cover enhances the protection of the soil and contributes to the suppression of weeds and pests (Hobbs et al., 2008). Current evidence shows that the effect of conservation agriculture on yields depends on the soil quality and seasonal rainfall (De Vita et al., 2007).

IPM involves integrating different practices for the efficient economic control of pests below the economic injury level[7]. IPM relies on up-to-date information on the life cycles of pests and on their interaction with the crop and the environment, and uses the available and most economical pest control methods (including agro-chemicals) to manage targeted pests in a timely manner. This type of pest management enhances the programmed use of agro-chemicals, allowing lower production costs and the lowest possible hazard to people and the environment, while maintaining the same level of crop productivity (Lima et al., 2014).

Finally, precision farming can be used in either traditional or conservation agriculture and relates to a wide range of technologies intended to improve production efficiency and reduce input use, allowing more sustainable agricultural production (Zarco-Tejada et al., 2014).

2.3 Climate change

Changes in the climatic conditions are an exogenous and long-term factor potentially affecting crop productivity (Challinor et al., 2014). The climate has been changing since the early 1900s, resulting in changes in precipitation, temperature, carbon dioxide (CO_2), fertilisation, climate variability and surface water runoff (Calzadilla et al., 2013). All of these changes can have direct effects on yields, as crop production is directly influenced by precipitation and temperature, and these factors can also have indirect effects through changes in water availability and soil moisture, which are critical determinants of crop growth (Nelson et al., 2009).

The effects of rising temperatures are particularly relevant in some areas of the world (the EU, China, India and Russia) and, in particular, effects on crop yields have been documented (Nelson et al., 2009). As all of these countries/regions are important agricultural producers, a change in climate could represent a major threat to global food security.

At the EU level, not all the climatic changes are necessarily negative, but they can be antagonistic. In northern regions, the increase in temperatures can shorten the frost period and extend the growing season, promoting agriculture in cool-climate marginal croplands (Vigani et al., 2013). However, in southern arid and semi-arid areas, higher temperatures could shorten the crop cycle and reduce crop yields (Calzadilla et al., 2013). Moreover, in southern-central EU regions, higher CO_2 concentrations could enhance plant growth (particularly of C_4 plants) by increasing the efficiency of water use.

The literature on the impact of climate change on crop yields is extensive, and it covers a variety of crops. An exhaustive review of this literature is beyond the scope of this section, but such a review can be found in a report published by Challinor et al. (2014), who carried out a meta-analysis of 1 700 published articles. This paper concluded that, without adaptation, losses in aggregate production of wheat (and other commodity crops) are expected in both temperate and tropical regions as a result of an increase in average temperatures of 2 °C. A recent study by Moore and Lobel (2015) estimated that long-term (since 1989) temperature and precipitation trends have reduced wheat yields in the European continent by about 2.5 %, while maize and sugar beet yields have increased by 0.2 % and 0.3 %, respectively. A similar average reduction of 2.5 % in EU wheat yields was also reported by Vigani et al. (2013).

Farmers can adopt different strategies to mitigate the effects of changes in climatic conditions: using new cultivars; modifying field management practices, such as rotation or seeding dates; applying innovative water-saving strategies; buying targeted crop insurances compensating for natural shocks; and using new crop protection products against emerging pests or diseases resulting from the new climatic conditions (Smith et al., 2008).

2.4 Policy reforms and market signals

The roles of agricultural policies in promoting productivity and competitiveness are somewhat controversial (Mary, 2013; Michalek et al., 2014). For example, subsidies may either increase or decrease productivity, and thus the net effect may be either positive (because of investment-induced productivity gains) or negative (because of allocative and technical efficiency losses) (Rizov et al., 2013).

6 For a comprehensive description of conservation agriculture, see: http://eusoils.jrc.ec.europa.eu/projects/SOCO/FactSheets/ENFactSheet-05.pdf

7 A more comprehensive description of IPM is available at http://ec.europa.eu/environment/archives/ppps/pdf/final_report_ipm.pdf

The 2003 reform of the Common Agricultural Policy (CAP) shifted the payment of farms' subsidies from direct payments for the production of specific crops to single decoupled payments to support farmers' incomes and to remunerate them for their production of public goods[8]. In particular, this single payment scheme addressed the positive externalities of agricultural activity (e.g. environmental protection, landscape preservation and rural employment) (Jaraitė and Kažukauskas, 2012). Moreover, in pursuit of its goal, the 2003 reform reduced internal EU commodity prices, aligning them with global prices. This aspect of the reform promoted the link between agricultural activity and market signals; this can enhance farms' competitiveness (Olper, 2008), but higher exposure to market volatility can have indirect negative effects on technology adoption and farm productivity (Rakotoarisoa, 2011; Rizov et al., 2013).

The 2003 CAP reform also produced heterogeneity in the level of subsidies per hectare received by farms among old (EU-15) and new MSs. Under the new regime, in the MSs implementing the historical payments system, the level of single decoupled payments per hectare is proportional to the support that farms received during the 2000–2002 reference period, which was, by design, highest in the most productive regions. The decoupled payments of MSs which joined the EU after 2004 (after the 2003 CAP reform was introduced) cannot be calculated on the basis of previous payments because these countries were not entitled to receive them, but instead are calculated by taking into account the average national productivity; subsidies are then uniformly distributed among farmers in the different regions[9]. This mechanism for calculating the CAP subsidies resulted in differences in payments per hectare, both within the group of new MSs and between new and old MSs, and in higher payments per hectare to the old MSs (Michalek et al., 2014).

The fact that, by design, there is a link between the level of payments per hectare and the regional or national productivity makes it difficult to estimate the impact of the CAP on farm productivity. It is an endogeneity problem that can be expressed as follows: are farms more productive because of the higher subsidies that they received, or is that higher subsidies are given to the most productive farms a priori?

Among the different agricultural regulations, some are more relevant to crop productivity than others. The Water Framework Directive (Dir. 2000/60/EC), which includes the former Nitrates Directive (Dir. 91/676/EEC), aims to improve quality of all ground and surface water, but, indirectly, can lead to a restriction on water and nitrogen use for agriculture, affecting the level of irrigation and fertilisation.

The Pesticides Framework Directive (Dir. 2009/128/EC) introduces thresholds on the number of pesticide applications, imposing fixed dates for phyto-sanitary treatments. In some cases, the use of some active ingredients for crop protection can be restricted on the basis that they are suspected of being harmful to humans or the environment. Regulation (EC) No 485/2013[10] restricts the use of some active ingredients of the neonicotinoids family in soil or seed treatments against a wide range of insects. The value of neonicotinoid insecticides is mainly due to their positive impact on yield, and a restriction on their use could have an impact on productivity (AgInformatics, 2014).

A different mechanism concerns the regulations on the use of genetically modified organisms (GMOs) (Dir. 2001/18/EC, Reg. 1829/2003 and Reg. 1830/2003[11]). The regulatory costs associated with genetically modified (GM) crops are much higher than those associated with conventional varieties. The approval process for new GM crop varieties is also considerably longer and more expensive, potentially affecting the rate of transfer of the innovation from the laboratory to the field (Kalaitzandonakes et al., 2007). The burdens related to these regulatory restrictions, in addition to perceived market resistance, may reduce the benefits of yield gains provided by GM crops (Beckmann et al., 2010).

8 Further details on the types of payments over the different CAP reforms are available at: http://ec.europa.eu/agriculture/glossary/index_en.htm#direct-payments

9 A more detailed description of how CAP payments are calculated can be found at: http://europa.eu/rapid/press-release_MEMO-13-631_en.htm

10 Commission Implementing Regulation (EU) No 485/2013 amending Implementing Regulation (EU) No 540/2011, as regards the conditions of approval of the active substances clothianidin, thiamethoxam and imidacloprid, and prohibiting the use and sale of seeds treated with plant protection products containing these active substances.

11 Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC; Regulation (EC) No 1829/2003 of the European Parliament and of the Council of 22 September 2003 on genetically modified food and feed; Regulation (EC) No 1830/2003 of the European Parliament and of the Council of 22 September 2003 concerning the traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms and amending Directive 2001/18/EC.

2.5 Risks of farming activity

As described in the previous sections, farming activity has to deal with a number of diversified risks that can cause loss of productivity and/or income fluctuation. These risks can be clustered into three groups (Berg and Kramer, 2008; Kimura et al., 2010):

- production risks from the natural environment and growth process of crops, including weather, disease, pests and other factors that can affect both the quantity and quality of production;
- price, market and financial risks, such as uncertainty or volatility of input and output market prices, changes in the interest rates of loans and restrictions on access to credit;
- institutional risks and uncertainties surrounding government actions, such as regulations on input use, policies on pricing, and income support and tax laws.

But how can risks affect crop productivity? Perceived risks can affect productivity indirectly by having a negative impact on farmers' propensity to invest in new and productive technologies. More specifically, farmers base their investment and planning on expected outputs and on the market price they expect to obtain, but uncertainties regarding future production and income can discourage farmers from investing in productive assets and technologies (Rakotoarisoa, 2011). Hence, despite the development of technologies that can improve production efficiency and competitiveness, risks can affect the demand for such technologies, leading to a misallocation of resources and, ultimately, to inefficiencies (Meuwissen et al., 2008). In order to cope with production and market risks, farmers have incentives to adopt strategies to mitigate risks (Kimura et al., 2010). These strategies can, therefore, improve the confidence of farmers regarding the future and lead to productive investments.

The most common risk management tools are varietal diversity, insurance, timing of selling, production/marketing contracts, production diversification, vertical integration and off-farm employment (Berg and Kramer, 2008; Bielza Diaz-Caneja et al., 2009; Tangermann, 2011). The first two risk management tools are usually adopted to deal with production risks, while the remainder are used to mitigate market risks.

Varietal diversity involves exploiting the genetic diversity of different varieties in order to reduce yield variability and increase average farm yields (Smale et al., 1998; Di Falco and Chavas, 2006). Higher genetic diversity provides a wider range of characteristics, boosting crop resilience in the event of environmental shocks (e.g. drought, excessive heat or pathogens) and lowering the vulnerability of the crop.

The second tool used to reduce production risks is agricultural insurance. In the EU, agricultural insurance covers mainly damage to crops resulting from natural disasters (crop insurance), while in other countries, such as the USA, revenue or income insurance is also available. The latter type of insurance is paid if the total production value falls below a certain threshold (Bielza Diaz-Caneja et al., 2009), hence alleviating the effects of a severe drop in production prices or an increase in production costs. Crop insurance pays indemnities to producers when a damage occurs, repaying the farm the anticipated investment, and acting as an income stabilisation tool. Farms with more stable incomes are expected to be less risk averse and more likely to make productive investments (Rakotoarisoa, 2011).

The timing of selling can be strategically used to stabilise income by avoiding periods of low prices and by holding the wheat in stock until market prices are more advantageous (Tangermann, 2011). Farmers can decide to sell their products at different times throughout the year: before harvesting, immediately after harvesting or later in the year/season.

Production/marketing contracts are contracts between farms and purchasers (e.g. agribusiness firms, government agencies or cooperatives) that are risk-sharing tools. They can reduce market risks for farmers by setting the purchase price in advance, and/or by guaranteeing the ability too sell products on the markets (i.e. ensuring market access) (Palinkas and Székely, 2008). Moreover, contract farming can introduce new technologies or innovative practices by means of transferring information between the agribusiness sector and farmers (Eaton and Shepherd, 2001).

Special types of contracts are those provided by the agricultural financial market. A derivative is a financial contract linked to the future value of the product and which establishes, in advance ("today"), the quantity, quality and prices of the product that will be delivered in the future ("tomorrow") (Hull, 2009).

Production diversification consists in engaging in a range of diverse activities which generate income so that, in the event of an adverse event affecting one activity, the resulting low revenues are likely to be offset by higher revenues from other activities, thus stabilising overall income (Meuwissen et al., 2008). Vertical integration is a type of production diversification in which farms retaining ownership or control of two or more phases of the production and/or marketing chain are less dependent on other market actors. Examples of such activities include selling agricultural inputs, processing, providing storage for other farmers (e.g. elevators), distribution (e.g. providing transport) and providing other agricultural services. The economic literature shows that variations in annual income decrease with an increasing number of different activities engaged in by the farm; however, this occurs at a progressively diminishing rate (Berg and Kramer, 2008). While agricultural diversification has a positive impact on farm income, its effect on yields is controversial, as it can reduce farming specialisation and the benefits from economies of scale, and it can induce higher production costs and production fragmentation (e.g. the need for additional equipment and more complex farm management) (Bielza Diaz-Caneja et al., 2009).

As shown by Mishra and Goodwin (1997), off-farm labour can also be used by farmers to reduce income variability, especially when output prices drop and, therefore, the income derived from the farming business decreases. Hence, off-farm employment can supplement overall income by providing revenue from other (non-farming-related) employment. Given that low farm prices and low expected revenues can reduce farmers' investments in innovation (Rakotoarisoa, 2011), a compensation effect of off-farm revenues may contribute to farm productivity. However, off-farm labour could also have the opposite effect on efficiency, because of a lower level of specialisation of the operators and lower labour intensity.

It is important to note that not all the risk management practices described above necessarily have a positive effect on farm productivity. Risk management practices can require resources (financial or organisational) that must be subtracted from the resources available for the production activity. Hence, income stabilisation does not always coincide with productivity improvement (Kim et al., 2012).

3. Survey design and sample description: France and Hungary

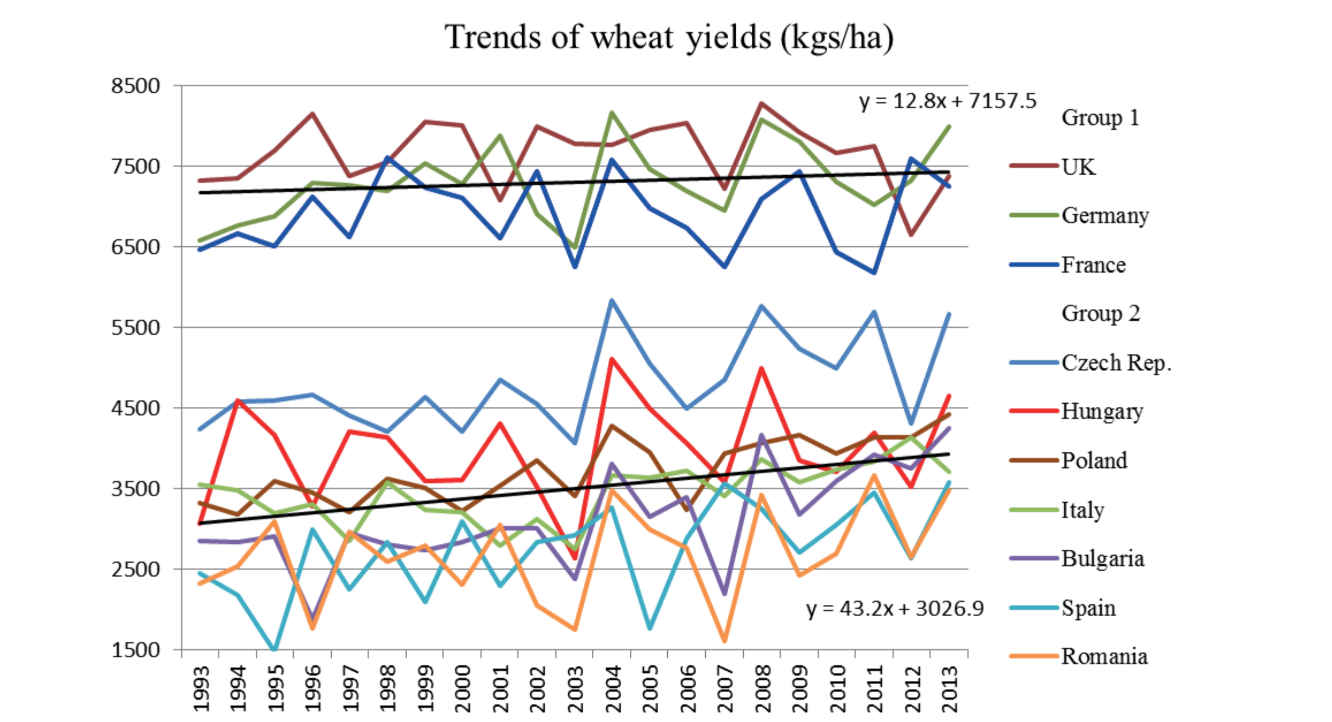
In order to analyse the determinants of wheat yields in the EU, two representative countries were selected as case studies, France and Hungary. This selection was based on the following criteria: (i) the relative importance of the country with regard to international wheat production; (ii) the patterns of yield development in recent decades; and (iii) the structure of the MS's farming sector and whether or not it provides a representative model for the EU.

According to FAOSTAT data, in the last 20 years, EU wheat production represented 20–25 % of global production (about 130 million tons), followed by China (17 %), India (11 %), the USA (10 %) and Russia (7 %). The world average yield, in the same period, was about 2.8 tons/ha (FAOSTAT). The lowest yields are in South America (2.1 tons/ha), while yields in Asia and North America are almost the same as the world average.

In the last 20 years, France accounted on average for almost 20 % of the total wheat in the EU (about 30 million tons), followed by Germany (11 %), the UK (7 %), Poland (4.5 %), Italy (3.8 %), Spain and Romania (3 % each), Hungary (2.2 %, about 3 million tons), Bulgaria and the Czech Republic (these being the top 10 producers of wheat in the EU, each accounting for at least 2 % of total wheat production).

In terms of wheat yields, the above-mentioned EU MSs are clustered into two main groups (see Figure 1). The first group includes France, Germany and the UK. This group is characterised by very high yields (7–8 tons/ha),but yield improvements have been largely unchanged since 1993.

Figure 1 Evolution of wheat yields, from 1993 to 2013, of the 10 most important EU wheat producers



Source: author's elaboration on FAOSTAT data.

In the second group of countries, Poland, Spain, Romania, Italy, Bulgaria, Hungary and the Czech Republic, yields are lower (3–4 tons/ha). However, wheat yield improvements have been greater in this group, as shown by the steeper slope of the trend line. Figure 1 demonstrates that France and Hungary are highly representative of the first and second groups, respectively.

France is the EU MS with the biggest agriculture sector, with about 40 % of the total national territory being agricultural land and with the highest number of agricultural holdings (EUROSTAT, Agricultural census 2010). In the last decade, the average size of farms increased significantly, from 42 ha to 55 ha, while agricultural employment significantly diminished (about 27 % of the labour force migrated towards other economic sectors). These changes suggest that a strong transformation is occurring in the French agricultural sector, most likely in the direction of higher concentration. France is highly specialised in the production of cereals, oilseed and protein crops and, as mentioned above, it is the most important wheat producer in the EU, with a yearly average of 37 million tons produced since 2000 (FAOSTAT). Sixty per cent of the French cereal-growing area is used for growing wheat, applying the most advanced technologies for wheat farming (Vigani et al., 2013).

Within the second group, Hungary has the second highest wheat yield after the Czech Republic, but has a significantly higher production share, in both world (0.7 % in 2013) and EU terms (2.3 % in 2013). The wheat sector in Hungary is very different from that in France, reflecting the heterogeneity of agriculture across the EU MSs. Hungary is a relatively small country, but has produced, on average, 13.3 million tons of wheat annually since 2000 (FAOSTAT). Hungary has a highly competitive agricultural sector, mainly as a result of the quality of the soil, and agricultural value added is growing. The transition of Hungary from a planned economy to the free market severely affected the structure of its agricultural sector, creating a high degree of heterogeneity in farm structures: from small-sized family farms mainly located in the Transdanubian regions, to very large-sized corporate farms in Northern Great Plain. This heterogeneity reflects a great diversity in wheat farm management that is not observable in other countries of the same group (for example, the great majority of Polish farms are family-run farms, while in the Czech Republic the majority are corporate farms) (EUROSTAT, Agricultural census 2010).

For the above-mentioned reasons, France and Hungary were selected as case studies. Given that the objective of the present report is to analyse wheat yields and their determinants, it is important to examine the most relevant wheat areas in the two countries; hence, the following regions have been selected:

- in France, Centre, Bourgogne, Champagne-Ardenne and Picardie, all of which are in the Basin Parisien macro-region;

- in Hungary, three Transdanubian regions, Central Transdanubia (*Közép Dunántúl*), Western Transdanubia (*Nyugat Dunántúl*) and Southern Transdanubia (*Dél Dunántúl*), and the Northern Great Plain (*Észak Alföld*) and the Southern Great Plain (*Dél Alföld*).

Table 1 shows the percentage of agricultural holdings producing wheat and the wheat-growing area for each of the target regions, using the latest available agricultural census data from EUROSTAT, dated 2010. The regions selected in France represent 23.3 % of the total farms producing wheat and 39.1 % of the total wheat-growing area of the country, while the regions selected in Hungary represent 72.9 % of the total farms producing wheat and 82.8 % of the total wheat-growing area of the country.

Table 1 Percentage of farms and area in the selected regions

Region	Farms		Area	
	Farms in the region/Farms in the country	Wheat farms in the region/Wheat farms in the country	Regional TAA/National TAA	Regional wheat area/National wheat area
France				
Champagne-Ardenne	4.8%	4.6%	5.5%	8.3%
Picardie	2.7%	4.7%	4.8%	10.6%
Centre	4.9%	9.8%	8.3%	13.6%
Bourgogne	4.0%	4.1%	6.3%	6.5%
Hungary				
Central Transdanubia	8.0%	5.8%	11.3%	12.4%
Western Transdanubia	11.0%	16.1%	11.2%	13.1%
Southern Transdanubia	13.3%	11.7%	14.7%	14.4%
Northern Great Plain	24.7%	19.6%	22.4%	20.2%
Southern Great Plain	22.4%	19.8%	23.6%	22.6%

Source: EUROSTAT Agricultural census 2010. TAA, total agricultural area.

The target population for our study was farmers growing wheat in France or Hungary during the 2012/2013 agricultural season. The sample comprised 700 farms (350 per country) which are representative of the national wheat sectors in terms of type (e.g. family farms, corporate farms, etc.) and agricultural diversity (e.g. farm size, agricultural practices, etc.). Given that our focus concerns the productivity of market-oriented agricultural activities and not hobby or marginal activities, farms smaller than 2 ha were excluded from the sample.

In order to ensure sample representativeness, the sampling procedure consisted of a stratified multi-stage sampling approach with random selection of the final sample units (farms). The first stage was based on the identification of the wheat-growing area at NUTS 2 level[12]; the second stage was based on the wheat-growing area at local administrative unit level. Local administrations were the first institutional contact points, through which the final contact points (which could be markets, cooperatives, input sellers, etc.) used to reach the wheat growers were identified. The random selection of farms was then guaranteed by rotating between the different local contact points. The sampling error for data collected from France has a confidence interval of ±8.7 %, while the confidence interval for data from Hungary is ±7.9 %. These values are both within the commonly accepted error limits of 10 % for a significance level of 95.5 %.

Data collection was achieved through face-to-face interviews with farmers conducted between 25 November 2013 and 20 January 2014 using a questionnaire which took, on average, about 1 hour to complete. Farmers were asked to provide information for three consecutive growing seasons: the target one (2012/2013) and the two previous ones (2011/2012 and 2010/2011). The final sample distribution is shown in Table 2.

Table 2 Number of farms in the sample per country and region

France	N. farms	Total
Champagne-Ardenne	69	
Picardie	75	
Centre	146	
Bourgogne	60	350
Hungary		
Central Transdanubia	25	
Western Transdanubia	70	
Southern Transdanubia	51	
Northern Great Plain	86	
Southern Great Plain	118	350
Total sample		700

Source: EUROSTAT Agricultural census 2010. TAA, total agricultural area.

12 For a definition of NUTS regions, see: http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction

The data collected during the survey are both qualitative and quantitative. More specifically, the questionnaire consisted of 120 questions of three main types. The first type of questions asked for general information about the head of the farm and the type of farm. The second type of questions were aimed at obtaining qualitative data in the form of farmers' opinions and perceptions with regard to yield determinants, innovations, policies and risks. Finally, the third type of questions aimed to elicit detailed quantitative information on:

- total wheat output and area;
- assets (number and value of machineries and buildings);
- use of and expenditure for agro-chemicals, seeds and labour;
- field management practices (rotation, soil and pest management);
- marketing and sales strategies (price, time of selling, contracts and derivatives);
- income decomposition (different agricultural activities, subsides and reinvestments);
- production and market risks, damages and compensations.

4. Results of the survey on wheat producers in France and Hungary

The aim of this section is to communicate the main results of the survey, presenting the both the qualitative data (farmers' opinions) and the quantitative data in the form of descriptive statistics. Section 4.1 describes the main differences between French and Hungarian farmers and farms, while Section 4.2 compares wheat yields by country and by region. Section 4.3 presents farmers' opinions on the determinants of wheat yields at country and farm level. Subsequently, Section 4.4 describes the use of inputs and sustainable practices and their potential relationship to wheat yields. Section 4.5 describes the innovations adopted by French and Hungarian farmers for wheat production and the reasons for their adoption. Section 4.6 presents farmers' perceptions of the role of EU policies and regulation in the production of wheat and the competitiveness of this production. Finally, Section 4.7 details farmers' opinions regarding the risks associated with wheat farming and describes the disasters and damages suffered by the farms, as well as the strategies adopted to reduce their negative effects.

4.1 Farm and farmer characteristics and wheat production

The differences between the French and Hungarian farmers surveyed, in terms of age and years of working experience in the agricultural sector, are small but statistically significant (Table 3). Hungarian farmers in the sample are almost two years older, on average, than French farmers, but have about two years less agricultural experience.

Table 3 Age and agricultural experience of the head of the farm for the year 2013

	Total	France	Hungary	Significance (t-test)
Age (average)	50.8 (n=694)	49.6 (n=349)	51.9 (n=345)	**
Years in agriculture (average)	26.1 (n=686)	27 (n=337)	25.2 (n=346)	*

*Note: the last column shows the level of statistical significance of the difference between the two countries (**5 % and *1 %). n, number of observations.*

In both countries, the majority of farm heads are married males (Table 4). The differences among farmer characteristics are related primarily to their level of education; in France, farm heads are, on average, less educated (42 % finished secondary education and 26 % completed university) than those in Hungary (67 % finished secondary education and 28 % completed university).

In both countries, 80–82 % of farmers have been specifically educated at agricultural schools. It is also worth noting that only 3 % of the French farmers work off-farm; in Hungary, this proportion is higher (15 %) but is still a minority.

Table 4 Percentage of farmers per groups of characteristics for the year 2013

	Total	France	Hungary	Significance ($\chi 2$)
Gender				
Man	92% (n=643)	95% (n=334)	88% (n=309)	***
Woman	8% (n=57)	5% (n=16)	12% (n=41)	
Marital status				
Single and never married	13% (n=90)	20% (n=69)	6% (n=21)	
Married	77% (n=537)	67% (n=236)	86% (n=301)	
Separated	1% (n=7)	1% (n=4)	1% (n=3)	
Divorced	3% (n=19)	3% (n=10)	3% (n=9)	***
Widowed	2% (n=13)	1% (n=4)	3% (n=9)	
In a registered civil partnership	2% (n=16)	3% (n=9)	2% (n=7)	
Cohabitation	1% (n=8)	2% (n=8)	0% (n=0)	
Education				
Primary	18% (n=127)	31% (n=109)	5% (n=18)	
Secondary	54% (n=380)	42% (n=146)	67% (n=234)	***
University	27% (n=189)	26% (n=91)	28% (n=98)	
Agricultural education				
Yes	81% (n=567)	82% (n=288)	80% (n=279)	***
No	18% (n=126)	15% (n=53)	20% (n=70)	
Working exclusively on-farm				
Yes	91% (n=637)	97% (n=340)	85% (n=298)	***
No	9% (n=63)	3% (n=10)	15% (n=52)	

*Note: the last column shows the level of statistical significance of the distribution of farmers between the two countries (*10 %, **5 % and ***1 %) . A chi-squared test was used to compare categorical and mutually exclusive farmer characteristics between the two countries. Totals of less than 100 % are due to missing values/replies. n, number of farms.*

Table 5 shows statistically significant differences in both the juridical status and the types of farms in the studied countries. In France, more farms are owned by private companies (59 %). However, this figure is somewhat misleading because in France there exist particular types of partnership, such as the Groupement Agricole d'Exploitation en Commun (GAEC) or, for single-person companies, the Exploitation Agricole à Responsabilité Limitée (EARL), that are legally similar to private companies, but are often contracted between family members because they provide more advantageous tax regimes. In GAEC/EARL farms, the working and management conditions are almost or exactly equal to those in family/individual farms.

Table 5 Farms' juridical status, type of farm and membership (percentage of farms)

Juridical status	Total	France	Hungary	Significance ($\chi 2$)
Individual/Family farm	64%	39%	89%	***
Private corporation	34%	59%	8%	
Public company	0%	0%	0%	
Cooperative	1%	0%	3%	
Type of farm				
Arable farm	73%	65%	81%	***
Livestock producer	4%	3%	5%	
Vegetable farmer	1%	0%	1%	
Mixed farm	22%	31%	13%	
Membership				
Cooperative	52%	83%	21%	na
Farmers association	22%	35%	9%	
Union	20%	36%	4%	
Chamber of agriculture	9%	1%	18%	
CUMA	5%	9%	0%	
Other	17%	13%	21%	

*Note: that last column shows the level of statistical significance of the distribution of farmers between the two countries (*10 %, **5 % and ***1 %). na, not applicable (because the categories are not mutually exclusive).*

Most of the surveyed farms in both countries are arable farms (65 % in France, 81 % in Hungary). However, the number of mixed farms is significantly higher in France than in Hungary. These farms, in parallel with the production of cereals, also engage in other activities.

Another important aspect that distinguishes French and Hungarian farms is that French farmers are, in general, more likely to be part of cooperatives (83 %), associations (35 %) or unions (36 %). This may reflect the maturity of the wheat sector in France. France has a long tradition of wheat production, and, consequently, over the years there has developed a large network of cooperatives for buying inputs and selling products, giving farmers greater contract power,; in addition, farmer associations provide training and facilitate knowledge diffusion. A special form of partnership in France is the Coopérative d'Utilisation de Matériel Agricole (CUMA), which allows the sharing of agricultural materials and machineries among members, permitting a reduction in individual farm expenditure for machineries and utilisation costs.

With regard to farm areas (Table 6), the three-year average total utilised area (TUA) of Hungarian farms is larger (194.5 ha) than the TUA of French farms (162.3 ha), while, on average, the wheat-growing area is only 3 ha larger for Hungarian farms than for French farms. However, the variability of the farms' wheat-growing areas in Hungary is very high (with a standard deviation of about 150 ha), suggesting that, in our sample, we have very small family/individual Hungarian wheat-producing farms coexisting with very large corporate wheat-producing farms.

Table 6 Farms' total utilised areas (ha) and wheat surface (ha) by country and per year

	Farm TUA		Wheat ha per Farm				
France	Mean	Obs.	Mean	S.D.	Min	Max	Obs.
2012/2013	162.77	350	55.75	37.05	2	208	350
2011/2012	162.25	350	55.59	37.48	2	217	350
2010/2011	161.81	350	55.41	37.87	0	230	350
Hungary							
2012/2013	194.80	350	52.08	150.02	2	1758	350
2011/2012	194.32	350	52.36	149.00	0	1711	335
2010/2011	194.49	350	53.47	159.54	0	1730	333

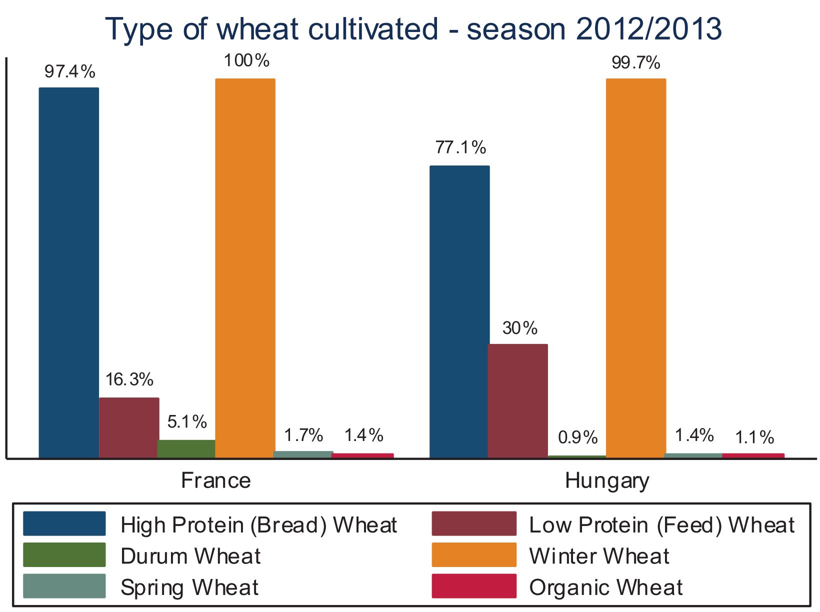
At the regional level (Table 7), Champaign-Ardenne and Central Transdanubia are the regions with the largest average TUAs in France and Hungary, respectively (173 ha and 355 ha). At the same time, Centre in France and Southern Great Plain in Hungary are the regions with the highest share of wheat hectares per farm TUA (36.2 % and 33.8 %, respectively). On average, the wheat-growing areas of all the surveyed farms represent more than 21.9 % of their TUAs, confirming that the regions selected are highly specialised for the production of wheat in France and Hungary (see Table 1 for comparison).

The types of wheat cultivated in the two countries are shown in Figure 2. This figure presents data from only the 2012/2013 season, given that there is no great difference between the types of wheat cultivated from one season to the next (maximum deviation: 7 % of farms).

Table 7 Farms' total utilised areas (ha), wheat surface (ha) and percentage of wheat on TUA by region

Region	Farm TUA		Wheat Ha		Wheat Ha/TUA
	3 years average	Obs.	3 years average	Obs.	%
France					
Champagne-Ardenne	172.97	207	51.29	207	29.7%
Picardie	149.26	225	37.75	225	25.3%
Centre	160.40	438	58.13	438	36.2%
Bourgogne	170.82	180	47.59	180	27.9%
Hungary					
Central Transdanubia	354.91	75	82.08	75	23.1%
Western Transdanubia	203.30	210	52.05	209	25.6%
Southern Transdanubia	221.24	153	48.41	148	21.9%
Northern Great Plain	172.26	258	44.66	249	25.9%
Southern Great Plain	160.05	354	54.17	337	33.8%

Figure 2 Number of farms per type of wheat by country



Note: Farmers can grow more than one wheat type in the same season and not all wheat types are mutually exclusive.

In France, all the farmers surveyed produce winter wheat, and 97.4 % of the winter wheat types grown are high-protein varieties. This type of wheat is also the most cultivated in Hungary (77.1 %), but here 30 % of farmers also produce low-protein wheat. As explained in Section 2.1, high-protein wheat varieties provide lower yields than low-protein wheat varieties. Only about 1 % of farmers produce organic wheat in both countries, suggesting that organic wheat is still a niche product mainly intended for domestic consumption rather than for the international market.

Only a small amount, about 10 % in Hungary and 3.5 % in France, of wheat is produced for a farm's self-consumption or for storage for the next year (Table 8). In fact, the majority of the wheat produced is destined for the market. In the three growing seasons considered, the French farmers in the sample sold wheat at prices, on average, 23 % higher than the prices achieved by Hungarian farmers. This is because the majority of French farms produce higher-quality wheat (see Figure 2).

In our sample, wheat production is not always the agricultural activity generating the highest share of farm income (Table 9). In fact, wheat is the main source of agricultural income for only 28.6 % of farmers in France and only 6.6 % in Hungary. In both countries, other cereals are the main source of income for the majority of farmers.

Table 8 Average percentage of wheat produced sold on the market and average prices received

	Farm TUA		Wheat ha per Farm				
France	Mean	Obs.	Mean	S.D.	Min	Max	Obs.
2012/2013	162.77	350	55.75	37.05	2	208	350
2011/2012	162.25	350	55.59	37.48	2	217	350
2010/2011	161.81	350	55.41	37.87	0	230	350
Hungary							
2012/2013	194.80	350	52.08	150.02	2	1758	350
2011/2012	194.32	350	52.36	149.00	0	1711	335
2010/2011	194.49	350	53.47	159.54	0	1730	333

Table 9 Agricultural activities generating the highest income (percentage of farms)

Activity	France	Hungary
Wheat production	28.6%	6.6%
Cultivation of other cereals	34.6%	60.6%
Cultivation of fruit orchards	0.3%	0.3%
Production of vegetables	0.6%	1.1%
Cultivation of other crops (no cereals)	11.1%	13.4%
Vineyards	2.3%	1.4%
Wine production	0.3%	0.0%
Livestock for meat production	10.9%	10.3%
Livestock for milk production	9.4%	1.1%
Cheese production	0.3%	0.0%
Rural tourism	0.3%	0.0%
Agricultural services (e.g. transport, harvesting, etc.)	1.1%	3.4%
Other	0.3%	1.7%
Total	**100%**	**100%**

Table 10 provides indices of farms' economic dimensions. As regards the distribution of the income level, the majority of French farms are in the middle-income groups, while Hungarian farms are mainly in the low-income groups. In both countries, more than 30 % of farm income comes from producing and selling wheat. In Hungary, 69.1 % of this income is reinvested in farming activities, compared with only 15 % in France.

Finally, Table 10 shows that the level of agricultural hired labour is higher in Hungary than in France. This may be due to the hiring strategies of big corporate farms, especially in the Northern Great Plain region, where the average number of hired workers per farm is 6.95.

Table 10 Economic dimensions of farms: farm income, reinvestment and labour for the year 2013

	France	Hungary
Income level (% of farms)		
Below 15,000 €	0.3%	21.7%
15,001 to 25,000	1.7%	13.7%
25,001 to 50,000	2.9%	13.4%
50,001 to 75,000	3.1%	10.9%
75,001 to 100,000	7.4%	2.3%
100,001 to 150,000	7.7%	3.1%
150,001 to 200,000	14.6%	3.4%
200,001 to 300,000	17.7%	3.4%
300,001 to 400,000	12.9%	2.9%
400,001 to 500,000	4.9%	1.1%
More than 500,000	4.6%	6.9%
No reply	22.3%	17.1%
% of income from wheat (average)	35.4%	31.5%
% of income reinvested in the farm (averag	14.9%	69.1%
N. of hired employees (average)	0.63	4.27

4.2 Wheat yields and yield variability

The survey presented in this report provides information about wheat yields at farm level in the two countries under study for the seasons 2010/2011, 2011/2012 and 2012/2013. Table 11 reports the average yields by country and region for each crop season. In France, the average wheat yield over the three seasons was about 7.044 tons/ha, with the highest average yields occurring in the season 2011/2012 (7.104 tons/ha). In Hungary, the average wheat yield over the three seasons was about 4.545 tons/ha and the highest average yields occurred in 2012/2013 (4.65 tons/ha). On average, yields are about 2.5 tons/ha higher in France than in Hungary.

In France, the yield variability among farms (i.e. spatial variability) is lowest in the Centre region, where the coefficients of variation (CVs) range from 21.6 to 24.5 % depending on the season. This means that wheat yields are more homogeneous in this region than in, for example, Bourgogne (CV 30–33 %). In Hungary, the lowest spatial variability occurs in Western Transdanubia (CV 22–23 %) and the highest spatial variability occurs in Central Transdanubia (CV 36–40 %).

The fact that these regions, Bourgogne (CV = 33 %) and Central Transdanubia (CV = 37.2 %), with the highest spatial variability in the 2012/2013 season are among those with the lowest percentage of wheat hectares per total farm area (see Table 7), this suggests that they have a lower degree of specialisation in wheat farming than the others. Moreover, Central Transdanubia is one of the regions in which the dual system (of large corporate farms and small family farms) is most pronounced.

Table 11 also shows the temporal yield variability across the three crop seasons. At a glance, and according to the CV values, France reports a slightly lower temporal variability and, therefore, a higher yield stability. This fact could be explained by the higher number of agricultural damages and negative weather events reported by farmers in Hungary (see Section 4.7). At the regional level, Champagne-Ardenne and Southern Transdanubia were the regions with the lowest temporal variability (9.5 % and 9.4 %, respectively), while, by contrast, Bourgogne and the Northern Great Plain are the regions with the highest temporal variability (11.2 % and 14 %, respectively).

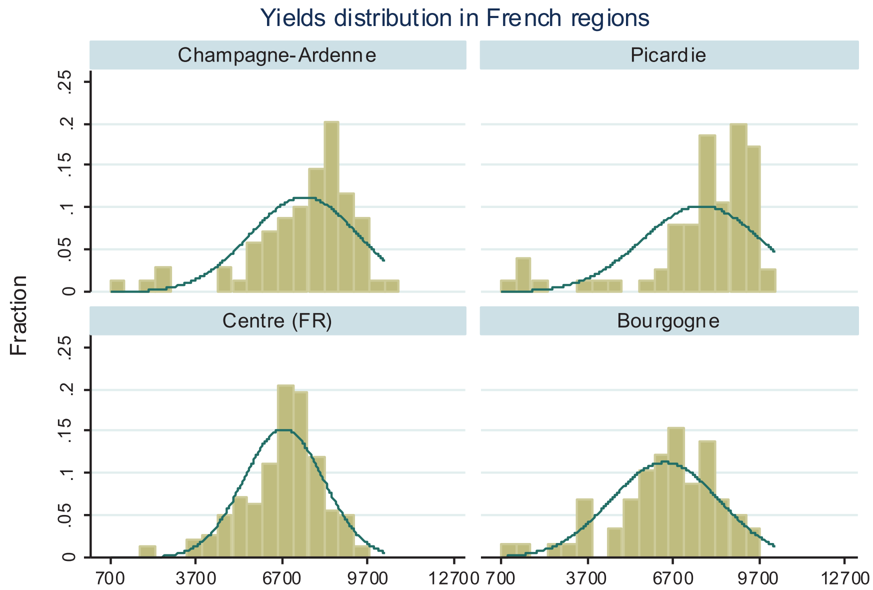
Table 11 Yield averages, standard deviations (s.d.) and coefficients of variation (CV) by year, country and region

Region	Season 2010-2011				Season 2011-2012				Season 2012-2013				Temporal variation 2010-2013	
	Average (tons/ha)	n.	S.d. (tons/ha)	CV	Average (tons/ha)	n.	S.d. (tons/ha)	CV	Average (tons/ha)	n.	S.d. (tons/ha)	CV	CV	n.
France	6.960	335	1.891	27.2%	7.104	339	1.871	26.3%	7.068	343	2.010	28.4%	10.0%	1017
Champagne-Ardenne	7.310	63	2.074	28.4%	7.360	64	1.859	25.3%	7.615	69	1.965	25.8%	9.5%	196
Picardie	7.661	74	2.117	27.6%	7.583	75	2.276	30.0%	7.918	75	2.230	28.2%	9.7%	224
Centre	6.614	140	1.459	22.1%	6.994	142	1.511	21.6%	6.662	141	1.630	24.5%	9.9%	423
Bourgogne	6.518	58	2.023	31.0%	6.469	58	1.934	29.9%	6.306	58	2.081	33.0%	11.2%	174
Hungary	4.489	312	1.505	33.5%	4.496	316	1.635	36.4%	4.650	341	1.529	32.9%	11.8%	969
Central Transdanubia	5.179	23	1.879	36.3%	4.904	23	1.964	40.0%	5.171	24	1.926	37.2%	13.1%	70
Western Transdanubia	4.624	65	1.371	29.6%	4.524	66	1.289	28.5%	4.615	67	1.177	25.5%	12.4%	198
Southern Transdanubia	5.534	47	1.257	22.7%	5.814	45	1.667	28.7%	5.836	51	1.345	23.0%	9.4%	143
Northern Great Plain	3.826	77	1.143	29.9%	3.993	77	1.798	45.0%	3.925	84	1.177	30.0%	14.0%	238
Southern Great Plain	4.261	100	1.531	35.9%	4.192	105	1.420	33.9%	4.566	115	1.594	34.9%	10.8%	320

Note: The coefficient of variation is calculated as (s.d./average) x 100. The variation within years (or intra-farm variability) relies on time observations, comparing the temporal yield standard deviation for each farm within the three years with the overall yield average. n. number of observations

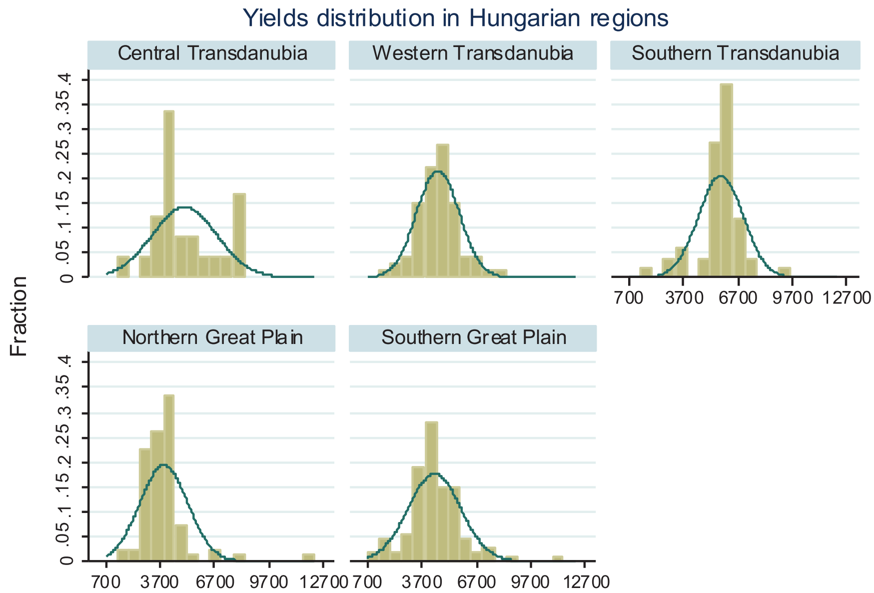
Figures 3 and 4 provide the distributions of the three seasons' average yields for each region of France and Hungary.

Figure 3 Distribution of the three seasons' average yields in French regions (kg/ha)



Note: Farmers can grow more than one wheat type in the same season and not all wheat types are mutually exclusive.

Figure 4 Distribution of the three seasons' average yields in Hungarian regions (kg/ha)



Note: Farmers can grow more than one wheat type in the same season and not all wheat types are mutually exclusive.

Overall, the normal distribution in French regions is right truncated and left skewed, while in Hungarian regions it is left truncated and right skewed, suggesting that in France yields are less dispersed in the farms with the highest yields, i.e., in the groups of most productive farms, yields are more homogeneous. By contrast, in Hungary there is less yield dispersion in the lower part of the distribution, suggesting that yields are more homogeneous among less productive rather than more productive farms.

In addition, to provide quantitative data on yields, farmers also gave their opinion on the performances of the three growing seasons, ranking yields as “below normal”, “normal” or “above normal” (Table 12). The great majority of Hungarian farmers (about 80 %) judged the seasons 2010/2011, 2011/2012 and 2012/2013 as normal in terms of yields. According to the 21.5 % of farmers in the Northern Great Plain, yields in the 2010/2011 season were below normal, while, for the 19.6 % of farmers in the Southern Great Plain, yields in 2012/2013 were above normal. These perceptions of farmers are confirmed by the quantitative data in Table 11 which show that season 2010/2011 was the worst performing in the Northern Great Plain and that season 2012/2013 was the best performing in the Southern Great Plain.

With regard to French farmers’ perceptions, about 37.5 % consider that the last three seasons have produced above normal yields. In particular, season 2012/2013 seemed to be particularly good in Champagne-Ardenne and Picardie, and 2011/2012 was a particularly good season in Centre. Again, these perceptions are confirmed by the average yield data presented in Table 11, which demonstrate that yields were, indeed, highest for those regions in those seasons.

Are wheat yields related to farm structure? In order to verify if such a link exists, Table 13 provides the correlation coefficients of the most relevant economic indices for farm structure (the percentage of farm income from wheat, the level of farm income reinvestment and the number of hired employees) with wheat yields. In France, wheat yields are positively correlated with the share of the total farm income coming from wheat and the percentage of farm income reinvested in the farm. In Hungary, wheat yields are negatively correlated with the percentage of income coming from wheat and the number of hired employees, as well as positively correlated with the percentage of farm income that is reinvested.

Table 12 Farmers’ opinions on yield performance by country and region (percentage of farmers)

Region	Season 2010-2011			Season 2011-2012			Season 2012-2013		
	Above normal	Normal	Below normal	Above normal	Normal	Below normal	Above normal	Normal	Below normal
France	30.5%	52.3%	17.2%	42.9%	44.0%	13.1%	39.4%	40.9%	19.7%
Champagne-Ardenne	31.9%	46.4%	21.7%	29.0%	46.4%	24.6%	53.6%	30.4%	15.9%
Picardie	35.1%	50.0%	14.9%	42.7%	45.3%	12.0%	56.0%	34.7%	9.3%
Centre	26.9%	55.9%	17.2%	54.8%	35.6%	9.6%	31.5%	45.2%	23.3%
Bourgogne	31.7%	53.3%	15.0%	30.0%	60.0%	10.0%	21.7%	50.0%	28.3%
Hungary	7.1%	80.5%	12.4%	10.7%	75.8%	13.5%	10.3%	80.3%	9.4%
Central Transdanubia	0.0%	83.3%	16.7%	0.0%	83.3%	16.7%	8.0%	84.0%	8.0%
Western Transdanubia	10.1%	84.1%	5.8%	11.4%	81.4%	7.1%	14.3%	74.3%	11.4%
Southern Transdanubia	12.8%	85.1%	2.1%	17.8%	75.6%	6.7%	19.6%	70.6%	9.8%
Northern Great Plain	8.9%	69.6%	21.5%	15.2%	70.9%	13.9%	5.8%	86.1%	8.1%
Southern Great Plain	2.9%	83.7%	13.5%	6.5%	74.1%	19.4%	7.6%	83.1%	9.3%

Table 13 Correlation between wheat yields and indices of farm's economic dimension (period 2011–2013)

Region	Season 2010-2011			Season 2011-2012			Season 2012-2013		
	Above normal	Normal	Below normal	Above normal	Normal	Below normal	Above normal	Normal	Below normal
France	30.5%	52.3%	17.2%	42.9%	44.0%	13.1%	39.4%	40.9%	19.7%
Champagne-Ardenne	31.9%	46.4%	21.7%	29.0%	46.4%	24.6%	53.6%	30.4%	15.9%
Picardie	35.1%	50.0%	14.9%	42.7%	45.3%	12.0%	56.0%	34.7%	9.3%
Centre	26.9%	55.9%	17.2%	54.8%	35.6%	9.6%	31.5%	45.2%	23.3%
Bourgogne	31.7%	53.3%	15.0%	30.0%	60.0%	10.0%	21.7%	50.0%	28.3%
Hungary	7.1%	80.5%	12.4%	10.7%	75.8%	13.5%	10.3%	80.3%	9.4%
Central Transdanubia	0.0%	83.3%	16.7%	0.0%	83.3%	16.7%	8.0%	84.0%	8.0%
Western Transdanubia	10.1%	84.1%	5.8%	11.4%	81.4%	7.1%	14.3%	74.3%	11.4%
Southern Transdanubia	12.8%	85.1%	2.1%	17.8%	75.6%	6.7%	19.6%	70.6%	9.8%
Northern Great Plain	8.9%	69.6%	21.5%	15.2%	70.9%	13.9%	5.8%	86.1%	8.1%
Southern Great Plain	2.9%	83.7%	13.5%	6.5%	74.1%	19.4%	7.6%	83.1%	9.3%

**p < 0.05. n, number of observations.*

4.3 Farmers' opinions on the determinants of wheat yields

This section presents the results of the survey on the farmers' opinions about the determinants of wheat yields at country and at farm levels.

As regards the country level, farmers provided their overall opinions on 10 factors potentially affecting wheat yields in their country:

1. soil quality;
2. use of irrigation;
3. use of fertilisers;
4. type of rotation;
5. use of pesticides;
6. seasonal weather conditions;
7. regulations on fertilisers;
8. regulations on pesticides;
9. seeds quality;
10. climate change.

Farmers assigned a score to each factor based on the importance they attribute to that particular factor. Scores ranged from 1 ("not important at all") to 5 ("extremely important") and the threshold for a factor to be considered important is 3. The results are shown in Figure 5.

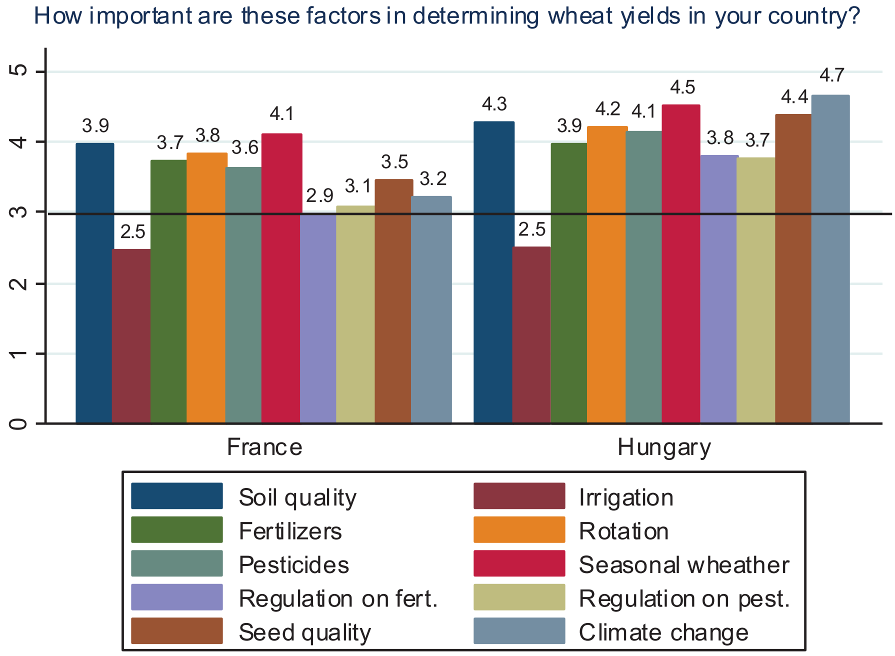
According to French farmers', seasonal weather conditions are the most important factor affecting yields, with this factor being assigned an average score of 4.1 (i.e. ranking above "very important"). Soil quality is the second most important factor in France (average score 3.9), followed by type of rotation (average score 3.8), use of fertilisers (average score 3.7) and use of pesticides (average score 3.6).

Lower scores, but still above the threshold of 3 ("important" factor), were assigned to seed quality (average score 3.5), climate change (average score 3.2) and regulations on pesticides (average score 3.1). The factors that are considered not important in France for determining wheat yields are regulations on fertilisers (average score 2.9) and use of irrigation (average score 2.5).

With regard to Hungary, farmers' opinions coincide with those of French farmers in that use of irrigation is not considered an important factor for determining wheat yields, with an average score of 2.5 (below the threshold of 3 that defines a minimum level of importance). However, with the exception of this opinion that Hungarian and French farmers have in common, Hungarian farmers, overall, assign higher degrees of importance to almost all the factors that determine wheat yields than French farmers do.

In Hungary, farmers consider that the most important determinants of wheat yields are climate change (average score 4.7) and seasonal weather conditions (average score 4.5), which reach a level close to "extremely important". Moreover, a number of factors are considered above the "very important" level: seed quality (average score 4.4), soil quality (average score 4.3), type of rotation (average score 4.2) and use of pesticides (average score 4.1). Finally, there are factors with average scores above the threshold level of 3, but which are considered of less importance than the previous ones, namely the use of fertilisers (average score 3.9), the regulations on fertilisers (average score 3.8) and the regulations on pesticides (average score 3.7).

Figure 5 Farmers' opinions on the importance of factors affecting wheat yields in their country



Note: Level of importance: 1, "not important at all"; 2, "somewhat important"; 3, "important"; 4, "very important"; 5, "extremely important". The threshold for one factor to be considered important is 3. All the values are significantly different from 3 (threshold) with p-values < 10 %.

With respect to determinants of wheat yields at the farm level, farmers provided their opinions on the importance of nine factors potentially constraining the production of wheat. The factors considered are the following:

1. land availability;
2. land prices;
3. labour availability;
4. credit availability;
5. low market prices of wheat;
6. high market prices of inputs for wheat production;
7. difficulties in selling the wheat (as a proxy for market access);
8. storage capacity;
9. climate change.

As for the country-level determinants, farmers assigned a score to each of these farm-level factors from 1 ("not important at all") to 5 ("extremely important") and the threshold for a factor to be considered important is 3. The results are shown in Figure 6.

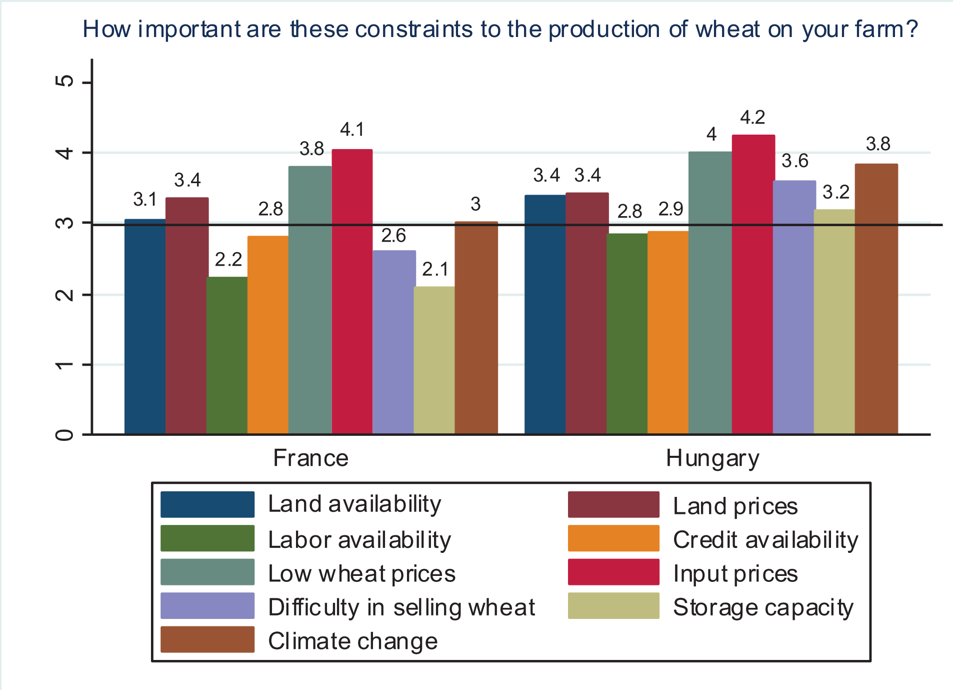
In both countries, farmers assigned the highest scores to input and output prices, suggesting that market signals have a key role in wheat production.

In France, input prices were given an average score of 4.1 ("very important") and wheat prices were assigned an average score of 3.9; however, problems are also attributed to land prices (average score 3.4) and to the availability of land (average score 3.1). By contrast, the low level of importance assigned to storage capacity (average score 2.1), availability of labour (average score 2.2), market access (average score 2.6) and availability of credit (average score 2.8) suggest that these factors are not considered constraints for the production of wheat in France.

In Hungary, in farmers' opinion, more of these potentially constraining factors are above the threshold of importance. Input prices were given an average score of 4.2 and wheat prices were given an average score of 4 ("very important"); however, interestingly, climate change also had an average score above the threshold (of 3.8), confirming the critical role that climate change is considered to play in Hungary at both country and farm levels.

Hungarian farmers also highlighted the importance of difficulties in selling the wheat produced (average score 3.6). As shown in Section 4.1, Hungarian farmers are less likely to be involved with organised cooperatives or farmers associations that could improve market access and price bargaining power. Hungarian farmers consider that the availability and price of land are important constraining factors (average score 3.4), as is storage capacity (average

Figure 6 Farmers' opinions on the importance of constraints affecting wheat production at the farm level



Note: Level of importance: 1 "not important at all"; 2 "somewhat important"; 3 "important"; 4 "very important"; 5 "extremely important". The threshold for one factor to be considered important is 3. All the values are significantly different from 3 (threshold) with p-values < 10 %.

score 3.2); however, credit and labour availability were given scores below the threshold (average scores 2.9 and 2.8, respectively), as in France.

4.4 The role of inputs and sustainable practices for wheat

This section aims to describe the use of inputs and sustainable field management practices in the sample of French and Hungarian farms. Moreover, this section also aims to provide a preliminary indication of whether or not, in our sample, the use of inputs, rotation systems and sustainable practices is linked to wheat yields. Consequently, the section is structured into three parts: input use, rotation schemes and sustainable practices.

4.4.1 The use of agro-chemicals and labour intensity

Wheat farming in France and Hungary is rather input intensive, especially with regard to agro-chemical products. In our sample, almost 96 % of farms make use of inorganic nitrogen, 76 % use phosphorus and 69 % use potassium. The proportion of farmers using manure is much lower (about 33 %), and the large majority of them have in-house availability from livestock. There are almost no farmers not using any kind of fertilisers, only four in the whole sample.

The most important agro-chemicals used for crop protection, in terms of the number of users, are herbicides, fungicides and insecticides. Herbicides and fungicides are used by 90–95 % of farmers in both France and Hungary. There are fewer users of insecticides; about 55 % of the sample use insecticides in France and 82 % in Hungary. However, farmers not using any kind of crop protection agro-chemical are very few, only 2.5 % of the sample.

Despite the similarity in the numbers of users of these agro-chemicals in the two countries, expenditure is different, suggesting different levels of intensity of use. Table 14 shows the average chemical expenditure by year in the two countries. Because higher expenditure could be caused not only by more intensive use, but also by higher prices in one country than the other, the expenditure values have been deflated using EUROSTAT price indices for fertilisers and plant protection products (deflated index, 2010 = 100). In this way, the bias provoked by differences in agro-chemical prices is reduced and the expenditures become comparable.

Table 14 Farms' expenditure for agro-chemical products at deflated prices (2010 = 100)

	Average fertilizer expenditure (€/ha)		Average crop protection expenditure (€/ha)	
	France	Hungary	France	Hungary
2012/2013	222.51	145.28	189.47	90.69
2011/1012	203.66	133.54	192.37	91.40
2010/2011	208.02	142.61	175.08	91.39
Three-year average	211.40	140.48	185.64	91.16

In the three years considered, fertilisers and crop protection expenditures were, on average, 66.5 % and 49.1 % higher in France than in Hungary, suggesting a greater intensity of use of these products in France. However, is higher fertiliser and crop protection product use related to wheat yields? Figures 7 and 8 plot yields against fertiliser or crop protection product expenditure, providing a line of fitted values obtained by linear prediction[13] for each.

The variations in yield with respect to higher fertiliser or crop protection expenditure are very different for the two countries. Additional fertiliser expenditure is not significantly correlated with higher yields in France (*p*-value > 67 %), but is positively correlated with yields in Hungary (slope 3.6, *p*-value < 1 %). Moreover, additional crop protection expenditure is not significantly correlated with higher yields in France (*p*-value>83 %), while it is positively correlated with yields in Hungary (slope 4.3, *p*-value < 1 %).

The situation is the opposite when labour productivity is considered. Again, using linear prediction, Figure 9 shows that, in France, farms with high yields tend to devote more working days to wheat farming than low-yielding farms do (slope 44.1, *p*-value < 10 %). By contrast, Hungarian wheat farming is highly labour intensive and uses a large number of hired workers; in this case, additional days of labour are negatively correlated with wheat yields (slope –10.3, *p*-value < 5 %).

Figure 7 Linear prediction of yields and fertiliser expenditure for the seasons 2010/2011, 2011/2012 and 2012/2013

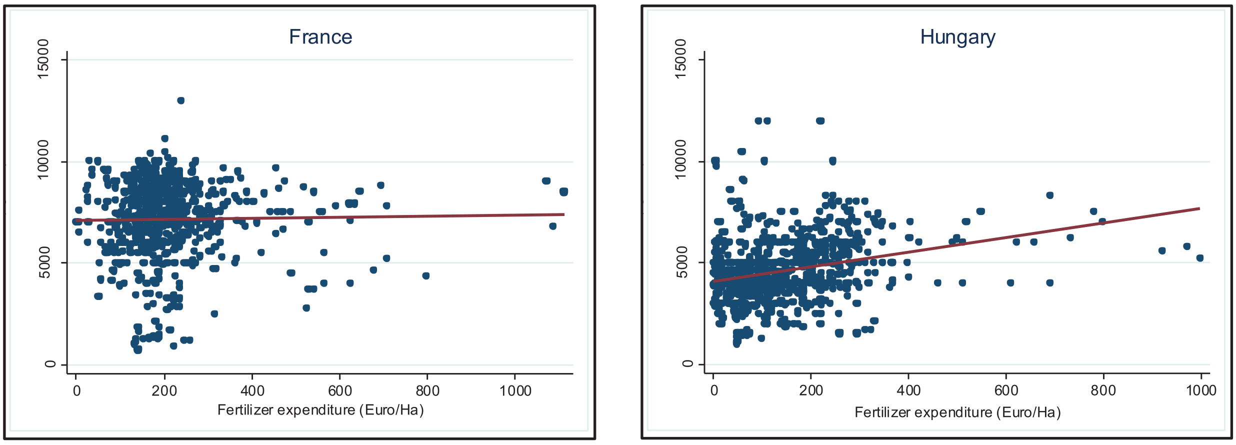
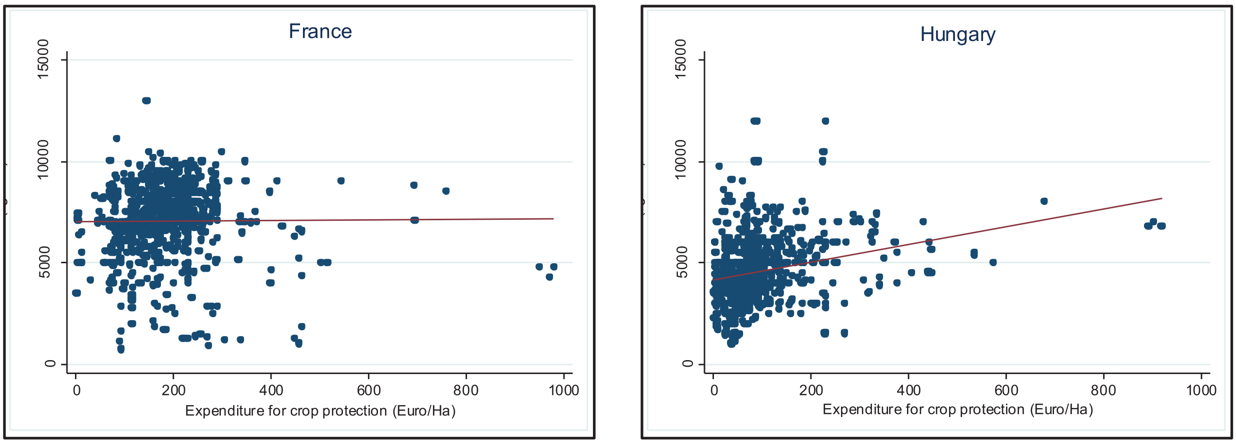
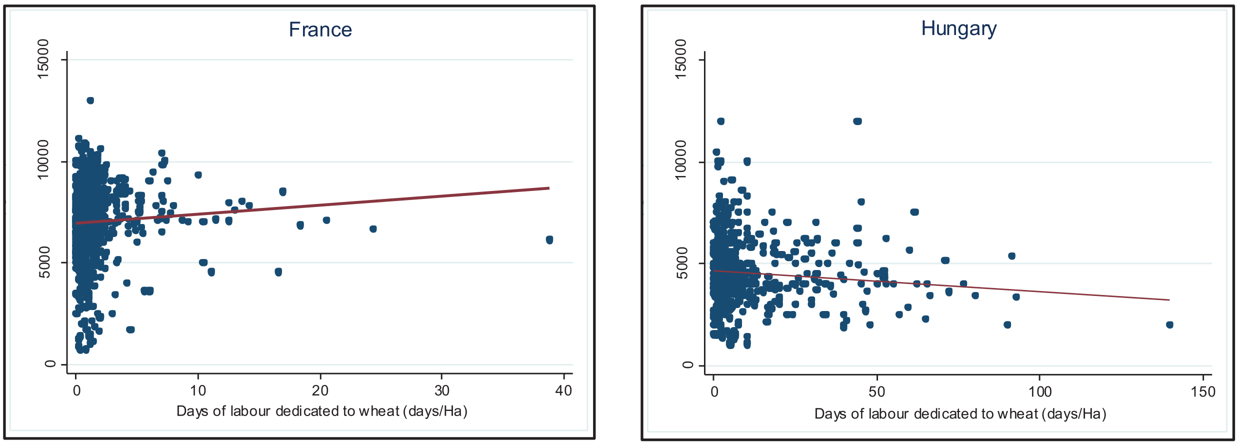


Figure 8 Linear prediction of yields and crop protection expenditure for the seasons 2010/2011, 2011/2012 and 2012/2013



13 The linear prediction is obtained by simple linear regression (estimated through ordinary least squares (OLS)) between two variables, where yields are always the dependent variable while the covariates change in each figure and are specified in the figure title. The linear prediction allows graphical information to be obtained on how yields vary at increasing levels of the independent variable.

Figure 9 Linear prediction of yields and days of labour on wheat hectares for the seasons 2010/2011, 2011/2012 and 2012/2013



4.4.2 Crop rotation schemes

Soil fertility and pest control can be maintained and even improved by proper rotation schemes. In our sample, wheat is mainly preceded by rapeseed in all types of rotation schemes used in France. The use of rapeseed as a rotation crop helps to avoid the development of grassy weeds because of a good covering of the soil surface by its broadleaf. Moreover, after harvesting, its residual primary deep root increases the organic matter content of the soil and softens the soil structure. The second and third most important preceding crops in France are maize and wheat. As regards Hungary, maize is the most commonly used preceding crop, followed by sunflower and rapeseed.

Although rapeseed is the most commonly used preceding crop in France, the farms with significantly higher wheat yields are those that use three preceding crops for rotations (+0.89 tons/ha) (Table 15). Moreover, in France, adopters of sugar beet as a single preceding crop show significantly higher yields (+0.87 tons/ha).

By contrast, in Hungary, higher wheat yields are found in farms that adopt rapeseed as a single preceding crop (+1.1 tons/ha).

However, it is worth noting that the selection of rotation crops is not only driven by wheat yield-maximising reasons. In fact, other factors can strongly influence the choice of the rotation, such as the need for diverse equipment for the cultivation and harvesting of different crops, the productivity level of the other rotation crops and the revenues obtainable. For example, wheat and maize are the two major field crops in the Hungarian agricultural system and maize is a key element of feed mixes for livestock; hence, it is cultivated mainly for this purpose.

Table 15 Differences in average yields (kg/ha) between adopters and non-adopters of different rotation schemes

N. of preceding crops	France			Hungary		
	Adopters	Non-adopt.	Yield difference (kg/ha)	Adopters	Non-adopt.	Yield difference (kg/ha)
One crop:						
Wheat	6248 (n=14)	6833 (n=202)	-585	n.a.	n.a.	n.a.
Corn	6412 (n=54)	6923 (n=162)	-511*	4242 (n=249)	4829 (n=96)	-587**
Sunflower	n.a.	n.a.	n.a.	4747 (n=63)	4329 (n=282)	418*
Rapeseed	7150 (n=113)	6406 (n=103)	744**	5449 (n=21)	4337 (n=324)	1112**
Sugar Beet	7596 (n=17)	6726 (n=199)	870*	n.a.	n.a.	n.a.
Two crops	6855 (n=393)	7163 (n=624)	-308**	4597 (n=374)	4517 (n=595)	80
Three crops	7609 (n=366)	6727 (n=651)	882***	4746 (n=224)	4488 (n=745)	258**

*Note: Statistical differences in average yields were evaluated by t-test. Levels of significance are indicated by asterisks (*10 %, **5 % and ***1 %) . n, number of observations; n.a., not applicable.*

4.4.3 Sustainable practices: conservation tillage, precision farming and integrated pest management

In the sample studied here, the adoption of sustainable agricultural practices varies depending on the country. Conservation tillage is not widely used in Hungary. In fact, the great majority of wheat producers adopt traditional tillage, with only 8 % using minimum tillage and no Hungarian farms using no-tillage practices. By contrast, French farmers' adoption of conservation tillage is more widespread: 38.3 % adopt traditional tillage, 17.7 % adopt minimum tillage and 42 % adopt a mix of traditional and conservation soil management practices. Notably, very few farmers in the sample use no-tillage practices exclusively (only 2 % of French farmers).

With regard to precision farming, farmers were asked if they use machineries with GPS and it emerged that this technology is quite widely used, both in France and in Hungary: 25.4 % and 23.4 % of the farmers surveyed, respectively.

IPM is, however, more widely used in France than in Hungary. Almost 40 % of French farmers interviewed adopt IPM programmes, either on the whole farm's surface or on part of it, whereas only 14 % of Hungarian farmers use IPM.

The statistical differences in yields among the adopters and non-adopters of conservation agriculture, precision farming and IPM are reported in Table 16.

If the entire sample of farms is considered, yields achieved by adopters of traditional soil management practices are about 32.2 % lower (–1667 kg/ha) than those of adopters of sustainable practices, while adopters of traditional pest management report yields about 28.2 % lower (–1459 kg/ha) than those of adopters of IPM.

Table 16 Differences in average yields (kg/ha) between adopters and non-adopters of conservation agriculture, precision farming (GPS) and integrated pest management

	All			France			Hungary		
	Adopters	Non-adopt.	Yields Diff.	Adopters	Non-adopt.	Yields Diff.	Adopters	Non-adopt.	Yields Diff.
Soil management:									
Traditional	5197 (n=1236)	6864 (n=750)	-1667***	6622 (n=390)	7307 (n=627)	-686***	4540 (n=846)	4602 (n=123)	-62
Conservation	6225 (n=274)	5763 (n=1712)	463***	6963 (n=199)	7064 (n=818)	-101	4268 (n=75)	4571 (n=894)	-304
Partial adopters	7231 (n=476)	5383 (n=1510)	1848***	7467 (n=428)	6737 (n=589)	730***	5125 (n=48)	4518 (n=921)	607*
Precision farming	6286 (n=491)	5675 (n=1495)	610***	7425 (n=263)	6911 (n=754)	514***	4971 (n=228)	4418 (n=741)	554***
Pest management:									
Traditional	5179 (n=1104)	6637 (n=882)	-1459***	6907 (n=295)	7100 (n=722)	-193	4548 (n=809)	4547 (n=160)	1
IPM	6620 (n=550)	5522 (n=1436)	1097***	7453 (n=393)	6787 (n=624)	665***	4534 (n=157)	4551 (n=812)	-16
Partial adopters	7246 (n=35)	5658 (n=1654)	1588***	7246 (n=35)	7219 (n=688)	27	n.a. (n=0)	n.a. (n=0)	n.a.

*Note: Data are for the three consecutive agricultural seasons 2010/2011, 2011/2012, 2012/2013. Statistical differences in average yields were evaluated by t-test. Levels of significance are indicated by asterisks (*10 %, **5 % and ***1 %). n, number of observations; n.a., not applicable.*

The highest yield gains come from partial adopters of conservation soil management and IPM practices rather than full adopters. This suggests that the best management practice is to adopt a combination of traditional and sustainable practices, using the most appropriate combination for the specific soil and pest conditions, taking into account the differences among plots and exploiting the local conditions.

However, this should not be generalised to all situations. In fact, farmers in France who apply IPM on the whole farm area are those with the highest yield gains, while differences among adopters and non-adopters of IPM in Hungary are not statistically significant. Moreover, there are no partial adopters of pest management practices in Hungary.

Furthermore, the effect of conservation tillage on yields is not straightforward, as it is positive and significant on only the entire sample and not at country level.

Finally, Table 16 provides an indication that precision farming significantly contributes to increasing yields, by about 7–12 %. The adoption of precision farming is expanding and it is promoted at policy level as one of the key strategies of sustainable productivity (Zarco-Tejada et al., 2014). Our results suggest that the use of precision farming can help to increase the productivity of wheat farming.

4.5 Technology adoption in wheat farming and its drivers

During the interviews, farmers were asked to indicate which innovations had been adopted in the last five years (never used before) and to explain the reasons for these adoptions. The innovations included in the questionnaire were:

a) new type of machinery;

b) new seed varieties;

c) new fertilisers, pesticides and herbicides;

d) new crop rotation;

e) new soil management (tillage);

f) new irrigation.

Farmers could specify one or more of the following reasons for adopting a particular innovation:

a) yields increasing;

b) obtaining higher final prices for wheat;

c) reducing production costs;

d) improving wheat grain quality;

e) reducing production risks;

f) obtaining environmental benefits;

g) other.

Table 17 provides the matrices with the responses to this part of the questionnaire by country. It shows the percentage of farmers adopting a specific innovation and the reasons behind the adoption. Each farmer could indicate more than one innovation adopted in the last five years and could also give more than one reason for his/her choice. Percentages can, therefore, sum up to more than 100 %. Finally, Table 17 also shows the total percentage of adopters of each innovation.

In both countries, the cultivation (adoption) of new varieties was the most frequent response as regards the adoption of innovations in the farms sampled. Seventy-nine per cent of French wheat producers and 43.4 % of the Hungarian ones in the sample confirm this fact. The main reasons given for the adoption of new wheat varieties were increasing yields, followed by improving grain quality.

In France, the second most adopted innovation was the use of new pesticides (20.3 % of responding farmers), followed by the use of new fertilisers (20.3 %) and new herbicides (16.6 %). Again, increasing yields was reported to be the main driver for these choices. In Hungary, the second most adopted innovation was the use of new fertilisers (32.9 %), followed, in this case, by new types of machinery.

Table 17 Percentage and number of farmers by innovation adopted in the last five years and reasons for adoption

		Type of innovation															
		Machinery		Seed variety		Fertilizer		Pesticide		Herbicide		Crop rotation		Tillage		Irrigation	
	FRANCE	%	N.	%	N.	%	N.	%	N.	%	N.	%	N.	%	N.	%	N.
Reason for adoption	Yields increasing	4.3%	15	63.7%	223	8.9%	31	9.7%	34	8.6%	30	6.6%	23	4.3%	15	0.3%	1
	Obtaining higher prices	0.6%	2	10%	35	2.3%	8	2.3%	8	1.4%	5	0%	0	0.3%	1	0%	0
	Reducing production costs	6.6%	23	20.9%	73	7.1%	25	8.9%	31	4.9%	17	4.6%	16	10%	35	0%	0
	Improving grain quality	1.1%	4	39.7%	139	7.1%	25	7.7%	27	4.9%	17	3.1%	11	0.6%	2	0%	0
	Reducing production risks	1.1%	4	26.9%	94	3.1%	11	8%	28	5.1%	18	4.6%	16	3.4%	12	0%	0
	Environmental benefit	3.4%	12	6.9%	24	7.1%	25	7.4%	26	7.1%	25	4%	14	6.9%	24	0%	0
	Other	3.4%	12	9.1%	32	2.9%	10	1.4%	5	2%	7	5.1%	18	3.1%	11	0.3%	1
Total Adopters		13.1%	72	79.7%	620	17.7%	135	20.3%	159	16.6%	119	14%	98	16.9%	100	0.6%	2
	HUNGARY																
Reason for adoption	Yields increasing	20%	70	35.1%	123	18.6%	65	17.4%	61	14%	49	15.1%	53	9.1%	32	0.6%	2
	Obtaining higher prices	5.1%	18	10.6%	37	4.9%	17	4.6%	16	3.7%	13	3.4%	12	1.4%	5	0.3%	1
	Reducing production costs	17.1%	60	7.4%	26	10.6%	37	7.4%	26	6%	21	6.3%	22	5.7%	20	0%	0
	Improving grain quality	3.1%	11	20.3%	71	12%	42	13.7%	48	8.3%	29	5.1%	18	1.4%	5	0%	0
	Reducing production risks	5.1%	18	5.7%	20	7.1%	25	8.6%	30	9.4%	33	5.1%	18	1.4%	5	0.3%	1
	Environmental benefit	1.4%	5	2.3%	8	3.4%	12	4.6%	16	2.9%	10	2.6%	9	3.4%	12	0%	0
	Other	0.9%	3	0.3%	1	0.6%	2	0.9%	3	0.9%	3	0%	0	0.6%	2	0%	0
Total Adopters		30.6%	185	43.4%	286	32.9%	200	29.1%	200	25.7%	158	24%	132	14.6%	81	0.6%	4

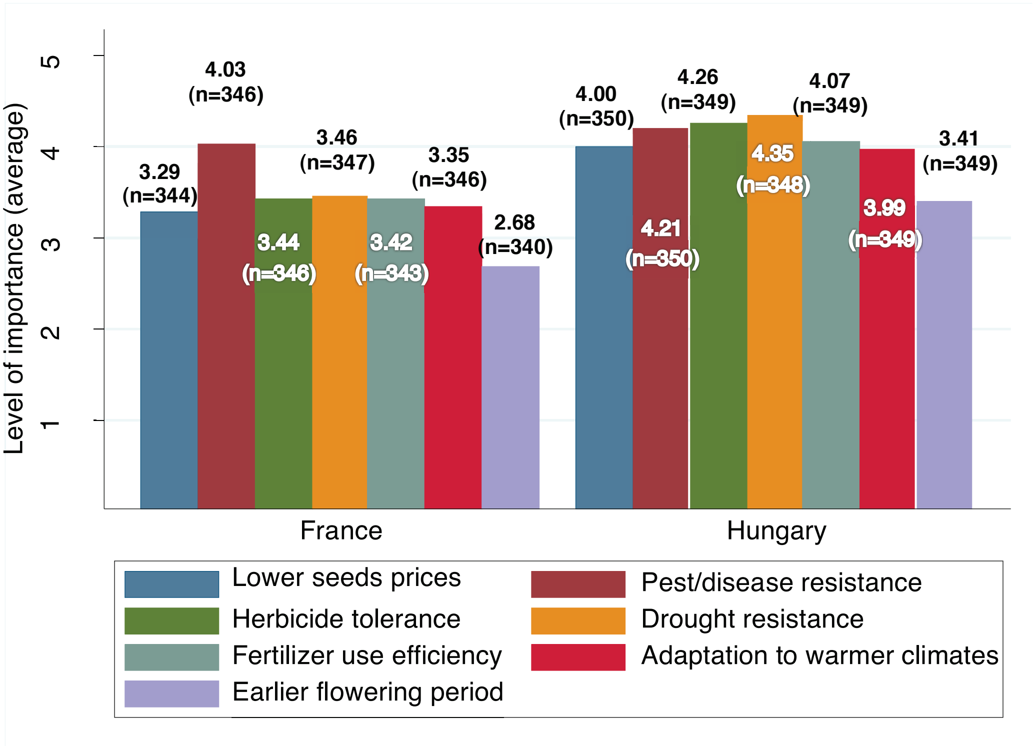
The proportion of Hungarian farmers who reported using new machinery in the last five years was , 30.5 %, compared with 13.1 % of French farmers. The higher level of income reinvestment in farming activities (see Table 10), and the fact that higher labour intensity is negatively associated with wheat yields (see Figure 9), may explain this increase in the use new machinery for wheat production in Hungary. Indeed, 20 % of Hungarian farmers reported that they adopted new machinery as a means to increase yields, and 17.1 % reported adopting new machinery to reduce production costs.

About 16.9 % of French and 14.6 % of Hungarian farmers adopted new tillage practices, but indicated different reasons for doing so. In France, 10 % of new tillage adopters indicated a reduction in production costs and 6.9 % the achievement of environmental benefits as the driver for doing so, while 9.1 % of Hungarian farmers reported that they did this to obtain higher yields. This suggests that new forms of tillage in France are likely to be conservation agriculture, with lower expenditure for field operations and inputs, while in Hungary tillage is likely to be higher intensity.

As seen in Table 17, using new varieties of seed is the key innovation adopted in order to increase wheat yields. In order to establish further details about the use of new varieties, farmers were also asked to indicate which characteristics would be desirable in new and improved wheat varieties (Figure 10). Farmers were presented with a list of characteristics and were asked to assign each a score from 1 to 5, where higher scores indicate a higher level of importance and 3 is the threshold.

As Figure 10 shows, there is a clear indication that pest/disease resistance is considered a very important factor in new and improved wheat varieties (average score 4.03) in France. By contrast, French farmers do not consider that an earlier flowering period (which would permit earlier harvests) is an important characteristic (average score 2.68).

Figure 10 Farmers' opinions of the importance of characteristics of new and improved wheat varieties



Note: Level of importance: 1, "not important at all"; 2, "somewhat important"; 3, "important"; 4, "very important"; 5, "extremely important". The threshold for one factor to be considered important is 3. All the values are significantly different from 3 (threshold) with p-values < 10 %. n, number of observations.

In Hungary, almost all new variety characteristics seem attractive to farmers; however, Hungarian farmers do assign a very high importance (average score 4.35) to drought resistance. This is in line with the fact that Hungarians consider that weather and climate are the most important determinants of yield at the country level (see Section 4.3). The second and third most desired characteristics, in the opinion of Hungarian farmers, are resistance to biotic stresses, namely weeds (average score 4.26) and to pests/diseases (average score 4.21).

Farmers were also asked if they would have still been interested in new varieties with these desired characteristics if the improvements had been achieved through genetic modification. Interestingly, in the two countries, farmers have markedly different levels of willingness to adopt GM varieties. Almost 59 % of French farmers replied "Yes", they would be interested in GM varieties, while 77 % of Hungarian farmers replied "No".

4.6 The role of EU policies and regulations in wheat productivity

In order to understand the role of EU agricultural policies and regulations in wheat production, farmers were presented with a set of statements and asked to indicate their level of agreement/disagreement. For each statement, they could choose from "strongly disagree" (score 1), "slightly disagree" (score 2), "neither agree nor disagree" (score 3), "slightly agree" (score 4) and "strongly agree" (score 5). Table 18 provides the results of farmers' opinions in this regard by country and by farm size.

With regard to the CAP, there is a strong consensus among countries and among small, medium and large farms that the 2003 reform exposed wheat producers to price volatility (statement 3). This is not surprising, because one of the objectives of the reform was actually to reduce the market protection of farms. Moreover, because of the drop in wheat prices during the global economic crisis of 2008, farmers are even more conscious of market fluctuations.

Table 18 Level of agreement/disagreement of farmers on statements regarding agricultural policies/regulations

Statement	By country			By farm size		
	All	France	Hungary	Small	Medium	Large
	Average (S.D.)	Average (S.D.)	Average (S.D.)	Average (S.D.)	Average (S.D.)	Average (S.D.)
1 *The competitiveness of my wheat farming activity is increased thanks to the CAP payments*	2.99* (1.44)	2.40* (1.38)	3.49* (1.28)	3.25* (1.28)	2.82* (1.52)	2.71* (1.47)
2 *Because of the 2003 CAP payments reform, my wheat farming activity is now more risky than ten years ago*	3.21* (1.35)	3.25* (1.33)	3.16* (1.37)	3.27* (1.32)	3.21* (1.32)	3.13* (1.42)
3 *Because of the 2003 CAP payments reform, the price of wheat strongly changes from one year to the other compared to ten years ago*	3.93* (1.20)	4.12* (1.11)	3.73* (1.26)	3.77* (1.18)	4.02* (1.13)	4.01* (1.27)
4 *In the last ten years the use of nitrigen fertilizers for wheat was lower because of the regulation*	3.21* (1.32)	3.33* (1.31)	3.09* (1.32)	3.13* (1.29)	3.18* (1.34)	3.33* (1.33)
5 *In the last five years the use of pesticides in wheat protection was lower because of the regulation (Pesticide Directive)*	3.06* (1.32)	2.93* (1.33)	3.19* (1.30)	3.24* (1.23)	2.96 (1.33)	2.95 (1.39)
6 *The products to protect wheat against diseases (fungicides/insecticides) that I can currently find on the market are less than two years ago*	3.15* (1.37)	3.40* (1.33)	2.91* (1.37)	3.11* (1.31)	3.09 (1.35)	3.23* (1.45)

*Notes: Level of agreement: 1, "strongly disagree"; 2, "slightly disagree"; 3, "neither agree nor disagree"; 4, "slightly agree"; 5, "strongly agree". *Statistically different from 3 with p-value < 10 %; standard deviation in parentheses. Farm size (TUA): small farms < 20 ha; medium farms 20–50 ha; large farms > 50 ha.*

As regards the capacity of CAP payments to increase wheat farming competitiveness (statement 1), French and Hungarian farmers have opposite perceptions. Fifty-nine per cent of the French farmers surveyed do not agree that the CAP has contributed to farm competitiveness, while 53.1 % of Hungarians do agree. Among the different farm size groups, farmers from small farms are the only ones to agree that the CAP contributes to wheat competitiveness (i.e. have an average level of agreement above 3).

The level of agreement on the possibility that the 2003 CAP reform could indirectly induce risks is rather low, but is statistically significant (statement 2). Approximately one-third of French farmers (33.7 %) slightly agree that wheat production has become more risky since the reform, perhaps because the reform introduced a series of environmentally friendly measures not familiar to producers. This opinion is shared by Hungarian farmers, but with a lower level of agreement (average score 3.16). Among the different farm size groups, farmers from small farms have the highest level of agreement with this statement (average score 3.27).

With regard to the impact of regulations on nitrogen use (statement 4), the level of agreement, in general, is rather low, but French farmers and farmers from large farms have the highest level of agreement with this statement (both with an average score of 3.33). The EU regulation that most affects nitrogen use is the Water Framework Directive (Dir. 2000/60/EC), which aims to prevent nitrate pollution of surface and ground water, which affects the use of mineral fertilisers and manure.

The majority of French farmers and farmers from medium and large farms do not agree that the Pesticides Framework Directive (Dir. 2009/128/EC) is affecting the use of pesticides (statement 5). However, this opinion is not shared by farmers from small farms (average score 3.24) or farmers in Hungary (average score 3.19). The latter seem to feel affected by the constraints on pesticide applications (fixing dates and the number of phyto-sanitary treatments).

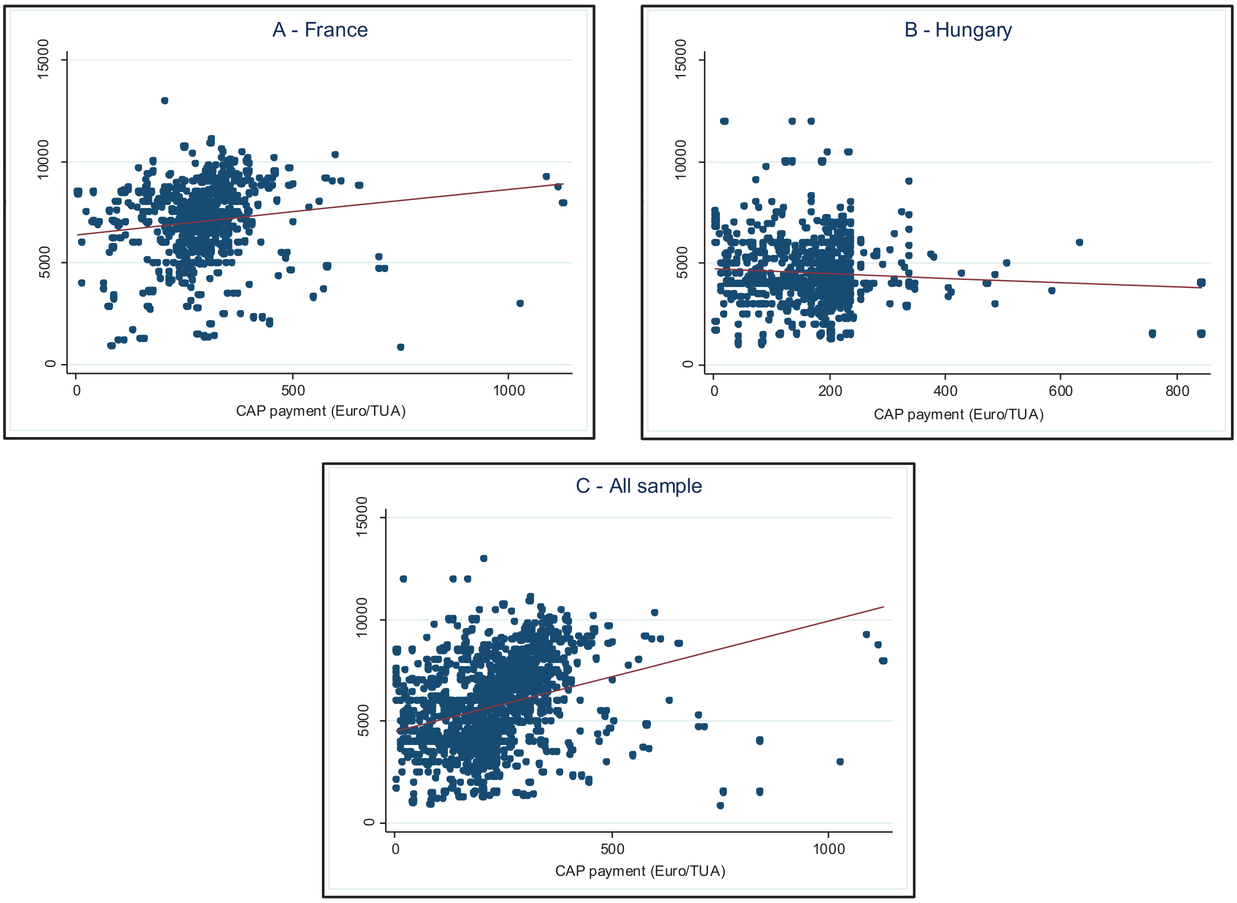
Finally, it is worth noting that in France there is a perception that there are fewer crop protection products are available now than in the past (average score 3.40) (statement 6). This could be because some active ingredients, such as azoles, are suspected to have hormonal effects on humans and, consequently, the approval process for such new products can be delayed to allow more accurate safety assessment. This affects small (average score 3.11) and large (average score 3.23) farm categories. However, Hungarian farmers disagree that there are fewer products nowadays (average score 2.91).

As regards CAP subsidies, the average amount received by the farmers surveyed is higher in France, at EUR 306.46 per hectare, than in n Hungary (EUR 189.48 per hectare). These payments consists of direct payments to farmers under the Single Payment Scheme. The higher amount received by French farmers is not surprising, given that France is one of the EU MSs that historically received large amounts of CAP support.

In order to verify if there is a relationship between the level of CAP subsidies and wheat yields, Figure 11 provides the linear prediction of yields with regard to the level of CAP payments per hectare[14]. Overall, higher CAP payments per hectare correspond to higher wheat yields (slope 5.5, p-value < 1 %, Figure 11C). The additional income provided by CAP subsidies can be used by farmers to acquire new equipment and to experiment with new practices.

However, this overall effect of CAP subsidies on wheat yields is distorted by the French data (slope 2.2, p-value < 1 %, Figure 11A), with French farmers actually receiving 62 % higher payments than Hungarian farmers, In fact, the yield improvement obtained by additional support in Hungary is negative (slope –1.1, p-value < 5 %, Figure 11B).

Figure 11 Linear prediction of yields and CAP payments for the seasons 2010/2011, 2011/2012 and 2012/2013



14 Please note that the linear prediction does not control for the potential endogeneity bias described in Section 2.4, and that it does not control for additional factors potentially affecting yields (e.g. credit constraints).

4.7 Risks and risk management practices

Section 2.5 explained the role of risks in agricultural activity and the channels through which risks can affect productivity. This section first presents farmers' perceptions of the most important risks for wheat production. Second, the disasters that have occurred in the last three seasons, with regard to our sample, are reported. Finally, the type and frequency of risk management practices adopted by the interviewed farmers are presented.

4.7.1 Farmers' perceptions of risks

During the survey, farmers were asked to indicate their perception of a series of potential production and market risk factors. The following risk factors were addressed:

1. hail, drought, floods and other natural disasters;
2. severe drop in wheat market prices;
3. uncertainty about the relation with purchasers of wheat;
4. fluctuation of input prices from one year to the other (seeds, fertilisers, pesticides, etc.);
5. uncertainty about the relation with providers of inputs (seeds, fertilisers, pesticides, etc.);
6. uncertainty about finding qualified labour force;
7. changes in regulations ruling wheat production (e.g. water and pesticides regulations);
8. changes in CAP payments.

Farmers were asked to assign, to each of the above factors, a score to indicate their level of importance (1 = not at all important; 2 = somewhat important; 3 = important; 4 = very important; 5 = extremely important). The results are shown in Table 19.

A severe drop in wheat market prices (risk 2) is the most important risk perceived both in France (average score 4.10) and in Hungary (average score 3.96) and by medium (average score 4.17) and large farms (average score 4.26).

Production risks due to natural disasters (risk 1) are considered, on average, important/very important both in France (average score 3.79) and in Hungary (average score 4.8) and by small (average score 3.73) and large farms (average score 3.81); moreover, this risk was considered slightly above the "very important" threshold of 4 for medium farms.

Uncertainties about the relationship with wheat purchasers (risk 3) is considered important in Hungary (average score 3.45) and by farmers of small farms (average score 3.13), but it is not considered important for French farmers and for the other farm size categories. Interestingly, the level of importance attributed to this particular risk (risk 3) decreases with increasing farm size (from 3.13, for large farms, to 2.74 and 2.67 for medium and small farms, respectively), as does the level of importance attributed to uncertainties regarding relationships with suppliers of inputs (risk 5; 3.06, 2.64 and 2.53 for large, medium and small farms, respectively).

Table 19 Level of importance of production and market risks by country and farm size

Type of risk	By country			By farm size		
	All	France	Hungary	Small	Medium	Large
	Average (S.D.)	Average (S.D.)	Average (S.D.)	Average (S.D.)	Average (S.D.)	Average (S.D.)
1 *Hail, drought, floods and other natural disasters*	3.85* (1.01)	3.79* (0.99)	3.8* (1.02)	3.73* (1.11)	4.03* (0.96)	3.81* (0.91)
2 *Severe drop in wheat market prices*	4.03* (0.94)	4.10* (0.94)	3.96* (0.94)	3.71* (1.04)	4.17* (0.91)	4.26* (0.75)
3 *Uncertainty about the relation with purchasers of wheat*	2.86* (1.26)	2.24* (1.03)	3.45* (1.18)	3.13* (1.27)	2.74* (1.25)	2.67* (1.23)
4 *Fluctuation of input prices from one year to the other*	3.87* (0.88)	3.83* (0.85)	3.91* (0.91)	3.77* (0.99)	3.92* (0.83)	3.97* (0.74)
5 *Uncertainty about the relation with providers of inputs*	2.76* (1.21)	2.23* (0.95)	3.28* (1.22)	3.06 (1.22)	2.64* (1.24)	2.53* (1.10)
6 *Uncertainty about finding qualified labor force*	2.30* (1.23)	1.92* (0.96)	2.67* (1.34)	2.42* (1.29)	2.16* (1.25)	2.32* (1.13)
7 *Changes in regulations ruling wheat production*	3.48* (1.03)	3.42* (1.02)	3.54* (1.04)	3.39* (1.07)	3.52* (0.99)	3.56* (1.00)
8 *Changes in CAP payments*	3.80* (1.04)	3.89* (1.05)	3.72* (1.03)	3.57* (1.05)	3.87* (1.04)	4.01* (0.94)

*Notes: Level of importance: 1, "not at all important"; 2, "somewhat important"; 3, "important"; 4, "very important"; 5, "extremely important". *Statistically different from 3 with p-value < 10 %; standard deviations in parenthesis. Farm size (TUA): small farms < 20 ha; medium farms 20–50 ha; large farms > 50 ha.*

In addition, the volatility of input prices (risk 4) is ranked quite high in terms of important risk factors perceived by farmers. It is the second most important factor for Hungarian farmers (average score 3.91) and it has the highest score among farmers from small farms (average score 3.77).

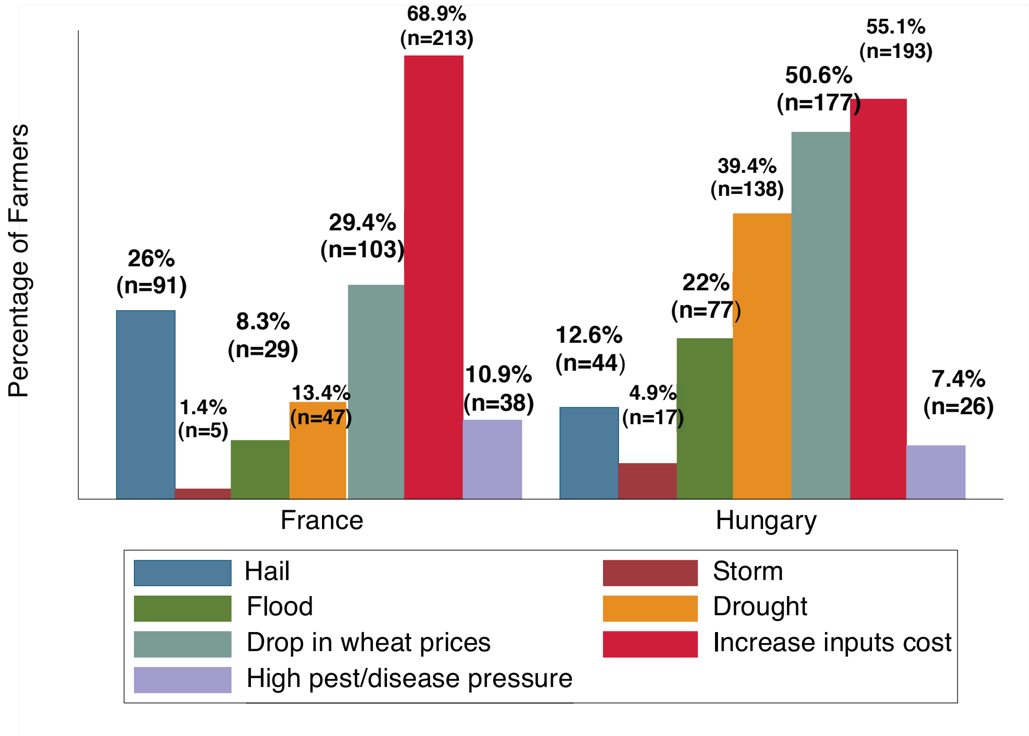
It is worth noting that uncertainties regarding the availability of a labour force (risk 6) is not considered an important factor in France (average score 1.92) or in Hungary (average score 2.67), or by the different farm size groups.

By contrast, changes in regulations and policies are perceived as important/very important risk factors (risks 7 and 8). In particular, on average, changes in CAP payments (risk 8) are accorded a higher level of importance than other agricultural regulations (risk 7, e.g. the water and pesticide regulations) in Hungary and among all the farm size categories. Moreover, risk 8 is the second risk factor to which French farmers have assigned the highest score (average score 3.89). Common to both CAP payments and other regulations is the fact that the level of importance increases with the farm's size: from 3.39, for large farms, to 3.52 and 3.56 for medium and small farms, respectively, in the case of agricultural regulations, and from 3.57 to 3.87 and 4.01 in the case of CAP payments.

4.7.2 Disasters and damages that have occurred to surveyed farmers

Wheat farmers were asked about the disasters or damages that they suffered in the 2010/2011, 2011/2012 and 2012/2013 seasons and the results are presented in Figure 12. The figure indicates the percentage of farmers who have suffered from damages related to weather (hail, storm, flood drought), the market (drop of wheat prices and increase of input cost) and biotic factors (high pest or disease pressure) during these seasons.

Figure 12 Disasters and damages that occurred in the seasons 2010/2011, 2011/2012 and 2012/2013



n, number of observations.

Market damages have the highest incidence, especially the increase of input costs, occurred to 68.9 % of French and to 55.1 % of Hungarian farmers. The proportion of farmers reporting having experienced a severe drop in wheat prices is 50.6 % in Hungary, but is lower in France (29.4 %).

The most frequent weather shocks that occurred in France were hail storms (26 %), followed by drought (13.4 %), while in Hungary drought (39.4 %) and floods (22 %) caused the most damage. With regard to biotic factors, damages occurring as a result of pests or diseases were reported by 10.9 % of French and 7.4 % of Hungarian farmers.

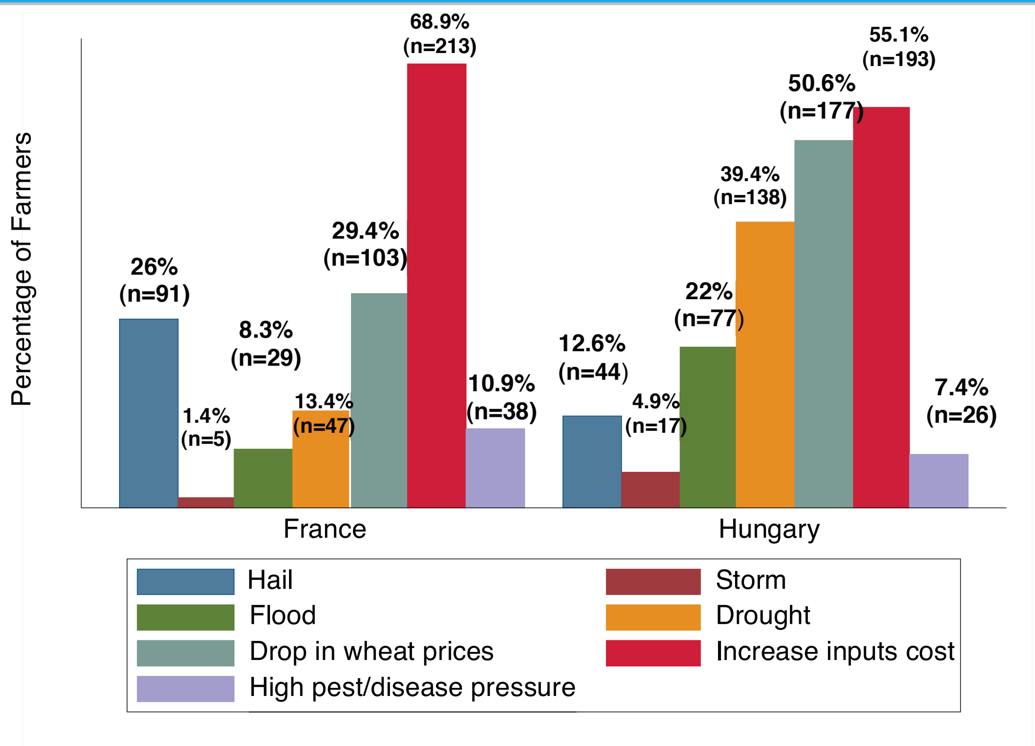
4.7.3 The risk management practices adopted on farms

The risk management practices adopted by the interviewed farmers can be divided into those aimed at reducing production risks and those aimed at reducing market/financial risks. In order to cope with production risks, the surveyed farmers adopted varietal diversity and insurance, while to cope with market/financial risks, they varied the timing of selling their wheat, they diversified sales channels, they made use of off-farm labour and they diversified their income-generating activities.

With regard to production risk practices, French farms adopt more wheat varieties, using, on average, four varieties per farm, whereas in Hungary, on average, 1.5 varieties are used per farm. However, agricultural insurance is the most common form of production risk management. In France, there are three types of agricultural insurance for farmers: private single-risk insurance (usually against hail), private combined insurance (e.g. hail and fire) and partially subsidised yield insurance against all the main climatic hazards. In Hungary, only private single and combined insurances are available (Bielza Diaz-Caneja et al., 2009). Almost half of the farmers interviewed in both countries have crop insurance: 51.4 % in France and 47.7 % in Hungary.

As regards the adoption of market risk management practices, Figure 13 shows the differences in the timing of selling wheat, by percentage of farmers, in the two countries. Figures refer only to season 2012/2013, as the maximum deviation of the number of farmers in the different categories with respect to the other seasons is very low (about 4 %). The timing of selling wheat is different depending on the country.

Figure 13 Different timings of selling wheat



n, number of observations.

About 48.3 % of French farmers sell wheat at different times throughout the year. The great majority of Hungarian farmers sell their grain at a single time of the year, and for almost 60 % of them, this is immediately after the harvest. This is not surprising given that a large portion of Hungarian farms are small family/individual farms which are likely to have a low stock capacity.

Figure 14 shows the distribution of farmers according to the sale channel they use. In France, the majority of farms diversify sales channels by using a variety of different channels (52.6 %); furthermore, selling wheat through cooperatives is common practice, adopted by almost one-third of the French farmers interviewed (29.9 %).

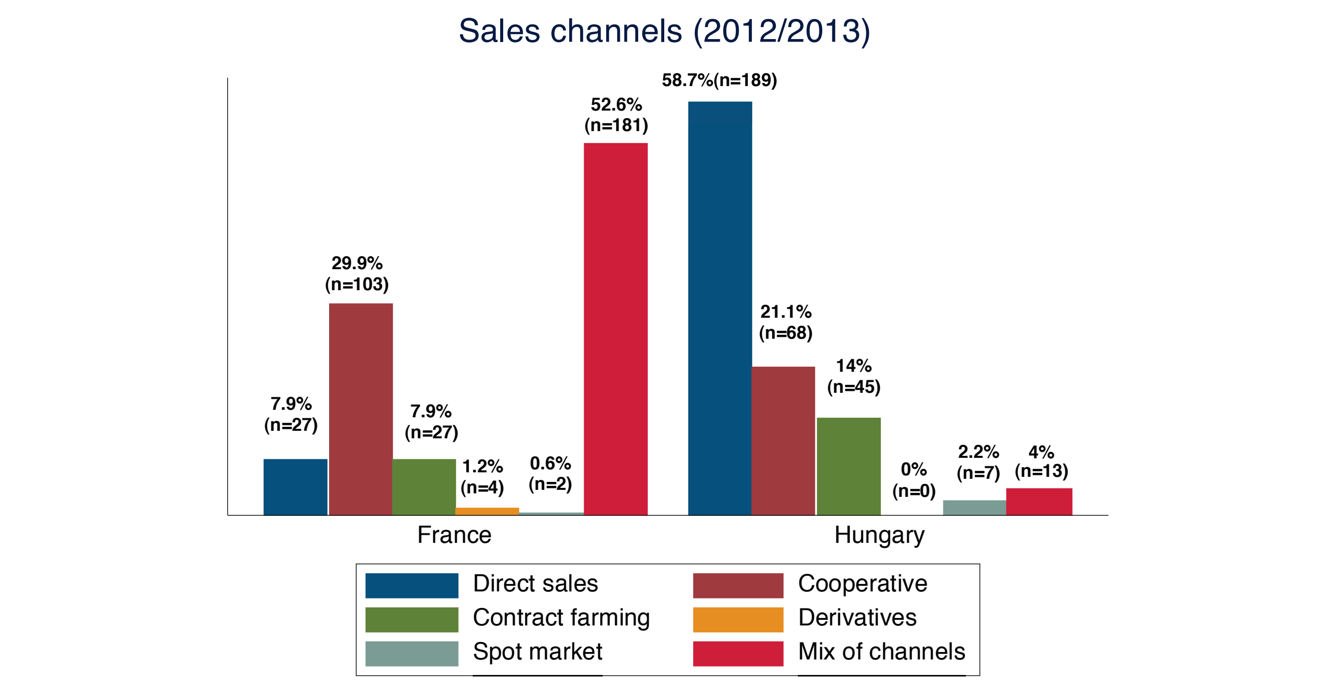
In Hungary, the great majority of farms use a single sales channel, principally direct sales (58.7 %), followed by sales to cooperatives (21.1 %) and contract farming (14 %).

In our sample, the use of financial markets is very low. Only 7.9 % of French farmers use derivatives and no Hungarian farmers use derivatives. Among the derivative products, the most widely used are exchange-traded futures. Only a few farmers use the spot market.

Off-farm labour is also not very widely used as a risk management strategy. As already shown in Table 4, only 3 % of French and 14.5 % of Hungarian farmers work off-farm.

Finally, diversification of agricultural activities has been adopted by the majority of the French farmers (67.8 %) and by 40.1 % of the Hungarian farmers in the sample. Of these, 8.4 % of activities in France and 23 % in Hungary are diversification activities in the form of vertical integration, meaning that farmers diversify their activities by, for example, selling inputs (e.g. fertilisers and pesticides), processing wheat (e.g. milling and baking) and/or providing agricultural services (e.g. act as contractors of agricultural practices).

Figure 14 Farmers by sales channels



n, number of observations.

5. Conclusions and discussion

Wheat is one of the most important cereals for human consumption worldwide. The assurance of adequate levels of wheat production is essential to guarantee current and future food security for a large part of the world's population. Increasing wheat productivity is one of the main challenges currently faced by global agriculture, particularly considering the reduction in the rate of wheat yield gains over the last 20 years.

Europe plays a major role in the context of global wheat demands, as it is the principal supplier for many importing countries; however, it is also one of the regions most affected by wheat yield stagnation. In order to face the current challenges, having a detailed knowledge of the current European wheat sector, and of the drivers and constraints of its productivity, is of the utmost importance.

This report contributes to building such knowledge by providing literature-based evidence of the determinants of agricultural productivity (farm and farmer characteristics, changes in input use, sustainable management practices, innovations, climate change, policy reforms, market signals and agricultural risks) and by presenting the main results of a survey of EU wheat producers.

The survey was conducted in two representative MSs, France and Hungary, selected for their relative importance in the international wheat market, their patterns of wheat yield development in the last decades, and the structure of their farming sectors as representative models of EU wheat farming. The results are based on qualitative data (farmers' perceptions) and on quantitative statistics aimed at verifying whether or not there is a significant relationship between economic/production factors and wheat yields.

Important differences emerged between the two MSs. These differences are highlighted primarily by farmers' opinions and perceptions of drivers and constraints with regard to wheat production, which, in turn, are motivated by structural differences in the farming sectors and local conditions, as confirmed by the quantitative data.

In the opinion of farmers, the most important determinants of wheat yield at the national level in France are seasonal weather conditions and soil quality, and, in Hungary, climate change and, again, seasonal weather conditions . At the farm level, high prices of inputs and low wheat market prices are considered the most constraining factors with regard to increasing wheat production in both MSs. This confirms that market signals play a key role in farm activities.

The use of production factors is heterogeneous among the two MSs. In France, expenditure on fertilisers and crop protection products is much higher than in Hungary, but expenditure is not significantly correlated with wheat yields. In contrast, in Hungary, a higher intensity of agro-chemical use is positively correlated with wheat yields. The opposite is true when we consider the intensity of labour use: in Hungary, additional days of labour are negatively correlated with wheat yields, while, in France, farms with higher yields tend to be more labour intensive.

Sustainable production practices are quite widely used in both France and Hungary. Among the different sustainable practices, precision farming contributes significantly to yield in both MSs (about 7–12 %). As regards conservation agriculture and IPM, the highest yield gains come from partial adopters, suggesting that the best practice is to adopt a combination of traditional and conservation/IPM practices, and to use the most appropriate practice for plot-specific soil and pest conditions within a farm's area.

Innovation also plays a key role in the EU wheat sector, and new varieties are the innovation most frequently adopted in order to increase wheat yields and grain quality, both in France and in Hungary. In the opinion of French farmers, pest resistance is the most important characteristic that new and improved wheat varieties should have, while Hungarian farmers would like to have wheat varieties that are resistant to abiotic stresses, especially drought, confirming that, in Hungary, climate issues are a great source of concern.

Despite the fact that new and improved wheat varieties are highly desirable in both countries to increase yields, farmers' acceptance of the use of GM varieties differs. The majority of French farmers would be willing to adopt new GM varieties, while the majority of Hungarians would not cultivate them. This polarisation in the willingness to use GM crops reflects the fragmented position of the EU MSs on GMOs.

With respect to the role of policies and regulations in influencing wheat production, farmers in both MSs have a negative perception of the 2003 CAP reform, perceiving it as a source of price volatility.

As regards the potential risks of wheat farming, farmers perceive market risks (drop in wheat prices) as more threatening than production risks (natural disasters). This is also confirmed by the observations of disasters and damages that have occurred in the three growing seasons considered, during which time there was a higher incidence of market-related damages than natural disasters. To deal with natural risks, crop insurance is the most adopted tool in both countries. To mitigate the effects of market-related damages, French farmers adopt diversification strategies more frequently than Hungarian farmers, especially by diversifying their income-generating activities, their sales channels and the timing of when they sell their product.

To conclude, the structural differences in farming systems and local characteristics across the two MSs, which are reflected in different farmers' opinions on the determinants of wheat productivity, suggest that there is no single solution to the improvement of wheat production and productivity that can be applied to all situations in the EU. On the contrary, because of the differences in wheat farming across MSs, and also sometimes within national territories, measures tailored at the local level are required.

Solutions to specific problems regarding wheat productivity, such as pests or market failures, should be based on local (national or regional) conditions, production systems and potential risks. This approach is in line with recent strategies aimed at increasing agricultural productivity in a sustainable and resource efficient way, as promoted by the EC in its "Europe 2020 Strategy".

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