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Editorial

Agriculture, food and global value chains: issues, methods and challenges

Margherita Scoppola

Università di Macerata

About one-third of trade in food and agriculture takes place within global value chains (GVC). Coffee, palm oil or biofuels production are examples of the modern organization of agri-food production through GVC (de Becker, Miroudot, 2014; Greenville et al., 2016; Baliè et al., 2019). Agricultural raw materials nowadays may cross borders many times before reaching the final consumers, as they are embedded in intermediate and processed goods which are produced in different countries. Agri-food GVC are typically characterized by a strong coordination between farmers, food processors or traders, and between processors and retailers. Value chain coordination can be initiated by downstream buyers, such as supermarkets and food processors, or by upstream suppliers including farmers or farmer cooperatives (Swinnen and Maertens, 2007; Reardon et al 2007). In a number of cases, a group of "lead firms" plays a critical role by defining the terms of supply chain membership and whom the value is added (Scoppola, 2021).

The growth of the agri-food GVC raises new issues for the agricultural and food sectors. Participating to the GVC is expected to have several positive effects, both for countries and farmers, in terms of technology and knowledge spillovers, increased productivity, growth, employment opportunities, and ultimately increase of farmers' income. On the other hand, market concentration in agri-food GVC raises concerns related to the emergence of market power (Swinnen, Vandeplas, 2014). Further, there are concerns that producing for agri-food GVC may result in the intensification of agricultural production, with negative environmental effects in terms of deployment of natural resources and water stress.

Sound knowledge and evidence about the nature and implications of modern agri-food GVC are relevant for policymaker, firms and civil society. The economic analysis of agri-food GVC challenges agricultural and food economists in several respects. The complex nature of GVC and of the issues they raise makes it essential the use of new and multiple lens of analysis (World Bank, 2020). Country-level (macro) approaches to GVC are needed to investigate the drivers of the world-wide fragmentation of agri-food production and the welfare implications of countries participating to GVC. Recent progresses in the empirical trade analysis of GVC are certainly fundamental to the understanding of agri-food GVC. Industry level (meso) approaches are needed to investigate the relationship among the various stages of the GVC. Analytical tools and approaches from the industrial organization literature are to be used to investigate issues such the price transmission along the agri-food GVC, the drivers of vertical coordination or the distributions of benefits along the GVC. A firm level approach (micro) is needed to investigate the implications of the participation to GVC for farmers.

The 10th AIEAA Annual Conference contributes to this debate, by putting together different disciplines and approaches to the analysis of agri-food GVC and of their implications in terms of economic, social, and environmental sustainability. Three keynotes explore these issues from different perspectives.

The keynotes by Silvia Nenci Ilaria Fusacchia, Anna Giunta, Pierluigi Montalbano and Carlo Pietrobelli entitled *Mapping global value chain participation and positioning in agriculture and food* (Nenci et al., 2022) reviews key methods and data issues arising in country-level analyses of GVC. They overall conclude that improvements in GVC measurements and mapping are currently still severely limited by data availability. Empirical literature to date mostly uses global Input-Output matrices and aggregate trade data to map and measure GVCs; however, sectoral and country coverage remains rather weak. They further review recent

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evidence about trends of GVC, by using the GVC participation indicator and the upstreamness positioning indicator (measuring the distance of the sector from final demand in terms of the number of production stages) for two sectors, that is "Agriculture" and "Food and Beverages". They show that at the country level, GVC participation is globally around 30-35 percent for both agriculture and food and beverages; while GVC linkages in agriculture are mostly forward linked, food and beverages are much more in the middle and at the end of a value chain. Furthermore, they show that, unsurprisingly, agriculture has a higher score on upstreamness with respect to the food and beverages sector. They conclude by discussing some critical issues faced by agriculture and food GVC concerning trade policies, technological innovation and the COVID crises.

The keynote by Tim Lloyd entitled "*Price transmission and imperfect competition in the food industry*" [1] aims at providing insights on how information is conveyed by means of prices between food consumers and agricultural producers along the agri-food value chains. After presenting some basic insights from theory, the keynote addresses the issue of how to detect the degree of market power by reviewing theory-consistent empirical models as well as the approaches developed in the New Empirical Industrial Organisation literature. The increased use of highly detailed retail ('scanner') data reveals that the food industry (retailing, manufacturing, and processing) is a major source of the price changes and that it also mediates price signals originating in other parts of the food chain in increasingly nuanced ways; the author concludes that agricultural and food economists should be wary of inferring too much about the competitive setting based on prices alone.

The keynote by Miet Maertens entitled "*A review of global and local food value chains in Africa: Supply chain linkages and sustainability*" highlights the expansion of agri-food GVC in low- and middle-income countries and how GVC are modernizing rapidly through institutional, technical, and commercial innovations. While a large body of literature focusses on the development implications of participation in GVC, the development of local food supply chains in low- and middle-income countries has received less attention. The review assesses potential linkages between global and local value chains in African countries, and the sustainability outcomes of supply chain innovations. The keynotes emphasizes that market competition as well competition for land, labour, water, and other resources may create negative linkages between the development of global and local food value chains. Spill-over effects, such as investment, technical or institutional spillovers, may create positive linkages and complementarities in the process of supply chain development. The existence of such linkages importantly depends on the type of crop and the structure and organisation of supply chains and entail important consequences towards socio-economic and environmental sustainability.

[1] Slides of the keynotes are downloadable at https://www.aieaa.org/aieaa-conference2021.

REFERENCES

Balié, J., Del Prete, D., Magrini, E., Montalbano P., Nenci S. (2019) Does Trade Policy Impact food and agricultural Global Value Chain of Sub-Saharian African Countries? *American Journal of Agricultural Economics*, 101 (3), 773–789.

de Becker, K., Miroudot, S. (2014) *Mapping Global Value Chain*, Working paper Series 1677, May, European Central Bank.

Greenville, J., Beaujeu, R., Kawasaki, K. (2016) *GVC participation in the agriculture and food sectors,* OECD Trade and Agriculture Directorate Working Paper.

Nenci, S., Fusacchia, I., Giunta, A., Montalbano, P., Pietrobelli, C. (2022) Mapping global value chain participation and positioning in agriculture and food: stylised facts, empirical evidence and critical issues. *Bio-based and Applied Economics, 11(2)*, 5-33. doi: 10.36253/bae-12558

Reardon, T., Henson, S., Berdegué, J. (2007) Proactive fast-tracking' diffusion of supermarkets in developing countries: Implications for market institutions and trade. *Journal of Economic Geography*, 7(4), 399–431.

Scoppola, M. (2021) Globalisation in agriculture and food: the role of multinational enterprises. *European Review of Agricultural Economics*, 48(4), 741-784.

Swinnen, J., Maertens, M. (2007) Globalization, privatization, and vertical coordination in food value *Agricultural Economics* 37(2), 89–102.

Swinnen, J., Vandeplas, A. (2015) *Price transmission in modern agricultural value chains: some conceptual issues* in Steve Mc Corriston (ed) Food Price Dynamics and Price Adjustment in the EU, Oxford Academic: Oxford, UK; Pages 147–166.

World Bank (2020) *World Development Report 2020. Trading for Development in the Age of Global Value Chain*, World Bank, Washington D.C., USA.

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Keynote speech of the 10th AIEAA Conference

Mapping global value chain participation and positioning in agriculture and food: stylised facts, empirical evidence and critical issues

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Abstract. This paper aims to overview the recent body of empirical work on the importance of Global Value Chains (GVCs) in international production and trade. We begin by reviewing different approaches and levels of GVC analysis. We then consider developments in methods and data. Focusing on the agriculture and food sector, we present a map of GVC measures - at the country and sectoral level - computed using trade in value added data to allow researchers to better assess the countries' engagement in GVCs. We also apply this data to show some stylized facts on GVC participation and positioning in agriculture and food and provide empirical evidence of the economic impact of the GVCs on these sectors. We conclude with some critical issues and speculative thoughts regarding the future of GVCs.

Keywords: global value chains, participation and positioning, trade in value added, agricultural and food sectors, survey.
JEL codes: F14, O50, Q17.

1. THE IMPORTANCE OF GLOBAL VALUE CHAINS: PAST AND PRESENT

Over the past twenty years, the term "global value chains" (GVCs) has become increasingly popular among economists, particularly those in the area of international trade. GVCs can be defined as the full range of activities – dispersed across different countries – that firms and workers engage in to bring a product from its conception to its end use (see Gereffi and Fernandez-Stark, 2011). Starting from the early 1990s, the world-wide economy experienced a radical transformation through a significant fragmentation in the production of goods and services and a deeper international division of labour, resulting in larger returns from specialization. This new era has been driven by at least two main factors. First, the information and communication technology (ICT) revolution facilitated the global outsourcing and offshoring of manufacturing activities. Second, the sharp drop in effective

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trade costs, which has been driven both by a significant increase in the rate of reduction of man-made trade barriers and faster methods of shipping goods (Antràs and Chor, 2021).

The dramatic fragmentation in the organization of world production raised by the GVCs has also been witnessed by a sharp increase in the trade of intermediate goods, accounting for more than 50 percent of world trade in the last years and increased tenfold in value over the last thirty years (Figure 1), thus justifying the growing interest of trade economists in understanding global production arrangements.

The evolution of GVC is having a deep impact in many sectors such as resource-based commodities, apparel, electronics, tourism and business service outsourcing, with significant implications in terms of global trade, production and employment, for both developed and developing countries. For industrialized economies, GVCs ensure access to lower priced inputs, wider variety and economies of scale. For developing economies, GVCs represent a valid shortcut to industrialization since they allow them to join existing supply chains instead of building them. Moreover, entering in a proven supply chain eliminates the need to acquire a comparative advantage in a broad range of production stages domestically.

The specialized literature analyses the impact of GVCs by distinguishing between *economic upgrading*, usually defined in terms of efficiency of the production process or characteristics of the product or activities performed (Humphrey and Schmitz, 2002), and *social upgrading* often referred to outcomes related to employment and pay, gender and the environment (Milberg and Winkler, 2010). As for the former, the literature has pointed out a positive relationship between GVC participation and productivity both in developed and developing countries (Kummritz, 2016; Montalbano and Nenci, 2018; Constantinescu et al., 2019). Offshoring and GVCs can lead to significant gains in productivity through numerous channels: the availability of broader input varieties (Halpern et al., 2015); finer division of labour across countries, even by inducing firms to specialize in core tasks (Grossman et al., 2008; Criscuolo et al., 2017; Antràs, 2020); greater competition; learning-by-doing externalities and technology spillovers (Baldwin et al., 2014; Piermartini et al., 2014; Benz et al., 2014). Even though some of these channels are related to traditional trade as well, welfare benefits can be larger when considering a multiple-sector framework and the input-output linkages (Caliendo et al., 2015). This evidence shows that GVCs are a key factor in increasing wages and boosting development and long-term growth. However, the relationship between GVC participation and inclusive development does not fall automatically from the premises. As for *social upgrading*, the specialized literature also highlights the positive effects of GVCs on employment. This

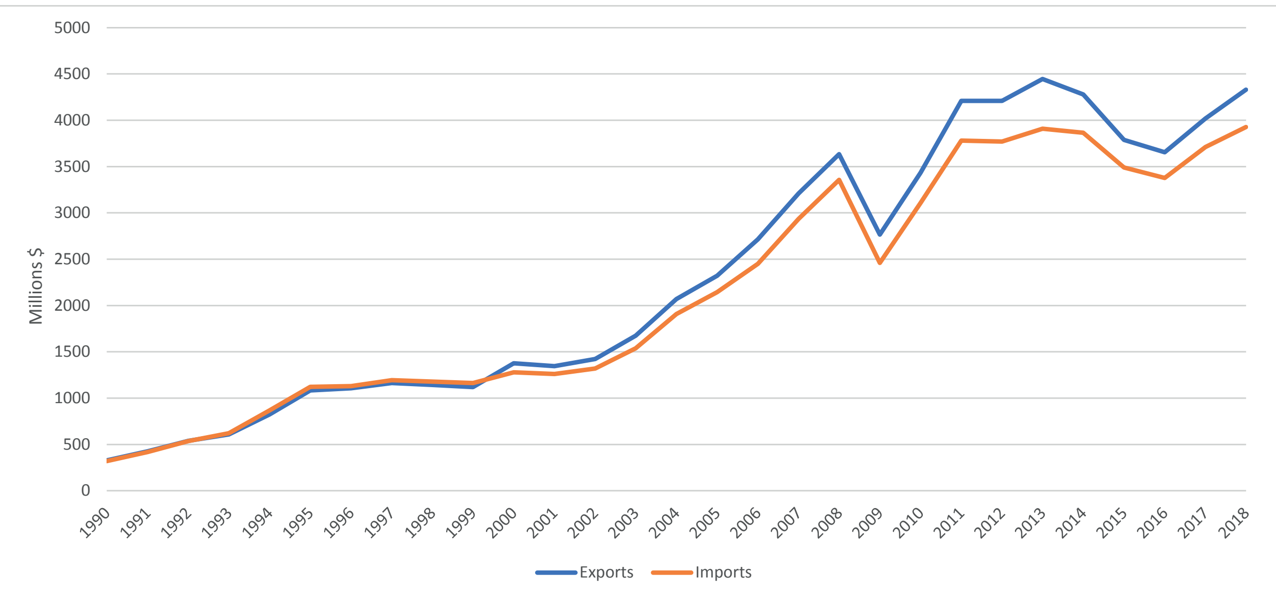

Figure 1. Trend in international trade in intermediate goods (millions of USD). Notes: values of intermediate goods for all the industries included in the BEC - Broad Economic Categories Rev.5 classification. Source: Authors' elaboration on UN-Comtrade data using BEC Classification.

may vary depending on the industry characteristics and the relative engagement in the value chain of the activities that are not outsourced. Relevant employment effects have been observed also in the agro-food sector in Southeast Asia, with countries having the highest shares of workforce associated with agro-food GVCs (Lopez-Gonzalez, 2016). A strand of the literature has also explored the beneficial effects of trade in intermediate inputs on a country's innovation performance, through the transmission of technology and research and development spillovers (Tajoli and Felice, 2018; Fracasso and Marzetti, 2015; Piermartini and Rubinova, 2014).

Turning to sectoral value chains, studies on agri-food chain are not new (Davis and Goldberg, 1957), and the literature embraces some complementary traditions: commodity chain analysis focuses on worldwide temporal and spatial relations (Hopkins and Wallerstein, 1986); *filière* analysis focuses on national political regulation and institutions (Lauret, 1983), whereas value chain analysis focuses on international business organisation and profitability (Porter, 1990). There have also been several applications of industrial organisation to economic and policy issues in the food and agricultural sector as well as analysis of the interaction between industrial organisation and policy in a trade setting: see (among many) Karp and Jeffrey (1993), Scoppola (2007), McCorriston and Sheldon (2011), and Sexton (2012). Much empirical evidence on agri-food GVCs is largely focused on capturing the impact on national economies through an analysis of case studies on the globally integrated value chain at the product level. The increasing importance of global agricultural trade registered during the past three decades comes with changes in the way GVCs are organised, with increasing levels of vertical coordination, upgrading of the supply base and the increased importance of large multinational food companies (Swinnen and Maertens, 2007; McCullough et al., 2008; Scoppola, 2021). A relatively small number of companies now organise the global supply of food and link small producers in developed or developing countries to consumers all over the world (Gereffi and Lee, 2009). This is generally referred to as agro-food GVCs (Humphrey and Memedovic, 2006; Liapis and Tsigas, 2014; Greenville et al., 2016; Balié et al., 2019).

The review of the huge empirical literature on the different dimensions of GVCs is beyond the scope of this article. This survey aims to deepen our understanding of GVCs by measuring and mapping them mainly from a macro perspective, using international trade data, with special attention to the agriculture and food sectors, a subject that, as far as we know, has not yet been summarized.

2. DIFFERENT APPROACHES AND LEVELS OF ANALYSIS OF GVCs

The high complexity and the different scales of analysis make it impossible to define, measure and map GVCs in a single way. This phenomenon of organizationally fragmented international production has been subject to investigation in a wide range of academic disciplines, including economic sociology, international economics, economic geography, international political economy, supply chain management and international business (see Kano et al., 2020). Therefore, the economic literature has evolved along different strands of research, using different approaches and levels of analysis.

2.1 GVCs as a multidisciplinary topic : development, geography, innovation

The development literature, beyond the early discussion on the role of the state in modern capitalism, has been widely influenced by the emergence of GVCs. Specifically, the debate mainly centred on the perspectives that GVCs would open to firms from developing countries to gain access to markets, to access knowledge and technology from abroad, and to "capture value" and part of the rents generated in the process (Davis et al., 2018; Kaplinsky, 2019). The challenge for local firms would be to "upgrade" by innovating to improve their products and processes, but also notably to "functionally upgrade" by entering value chain segments offering larger shares of value added. More generally, local firms' struggle would be to enter value chains niches with a stronger potential for learning and innovation, and for strengthening their technological and innovation capabilities (Morrison et al., 2008).

Sometimes contrary to the interests of local firms, though sometimes fostering them, lead firms often have an interest to protect, appropriate, and create rents in the process of international production (Davis et al., 2018). Pathbreaking research put the concept of value chain *governance* at the core of the analysis and developed a theory that generates five different forms of GVC governance: hierarchy, captive, relational, modular, and market, which range from high to low levels of explicit coordination and power asymmetry (Gereffi et al., 2005). Three variables would determine how GVCs are governed, and these are: the complexity of transactions, the ability to codify transactions, and the capabilities in the supply-base. This theory, which itself draws on other streams of literature, like transaction costs economics, production networks, and technological capability and firm-level learning, has generated an infinite number of studies aiming at measuring and testing it with quantitative and qualitative approaches (e.g. Brancati et al., 2021).

Importantly, from all these approaches it has gradually emerged the idea that GVCs are not only a trade phenomenon. Given the variety of organizational arrangements prevailing in GVCs, and the inherent remarkable power asymmetries between lead firms and their different tiers of suppliers, the "relational dimension" of GVCs has gained utmost importance (World Bank, 2020). Therefore, the focus necessarily shifts away from the mere allocation of value added across countries through anonymous exchanges of goods and services. In contrast, the characteristics of the agents participating in a GVC become crucial, and they necessarily influence the distribution of benefits and rents along the value chain. The introduction of such a relational concept of GVCs, echoed by the World Bank but originally developed by economic sociologists, and international political economists like Gereffi, Sturgeon, Ponte and others, puts on a central stage a variety of themes, like for example the nature of the lead firms, i.e. multinational firms and foreign buyers and traders, and that of their suppliers, the institutional factors shaping the inter-firm relations and the location of global production, as well as the institutions affecting the decisions to invest in learning and innovation and their effectiveness.

Moreover, sometimes this literature has also crossed over a tradition of studies in economic geography that look at how the territorial context may influence enterprise behavior and performance. In many instances, local clusters of firms interact with lead firms and their first-tier suppliers, generating the need to understand how the local and the global dimensions of value chains influence and condition each other. Thus, some authors studied the interface between enterprise clusters and GVCs, discovering their deep and mutually-influencing relationships (Bathelt et al., 2004; De Marchi et al., 2018; Giuliani et al., 2005; Humphrey and Schmitz, 2002; Pietrobelli and Rabellotti, 2007).

More recently, in the effort to understand the evolution and the dynamics of GVCs and foresee the potential they offer to local firms and countries, the issue of innovation in GVCs has also been studied extensively. It has been shown how GVCs may act as conduits of knowledge, channels for technology transfer, and in the end, opportunities to learn and innovate (Lema, Pietrobelli and Rabellotti, 2019). A structured effort to understand the relationship between GVCs and national innovation systems has been attempted with various methods (Fagerberg et al., 2018, Pietrobelli and Rabellotti, 2011). Some authors concluded that a coevolution between GVCs and innovation systems would be constantly at play, though with remarkable sector-specific varieties (Lema et al., 2018, 2019 and 2021).

Finally, the GVC approach is beginning to be employed also for the analysis of natural resource-based sectors, due to the remarkable restructuring and changes that these sectors are undergoing as a result of technological changes and the growing relevance of local communities and environmental considerations (Kaplinsky and Morris, 2016; Pietrobelli et al., 2018; Katz and Pietrobelli, 2018).

2.2 Firms level analysis

Although it is undeniable that, in the real world, it is not countries or industries that participate in GVCs, but rather firms, the analysis of GVC at the firm-level is still at an "infant stage" (Antràs, 2021) and fall well behind the measurements' advances put forward by the literature based on country-sector level data (see Section 3). This is mainly because of the partial lack of good quality firm-level data, not to mention its scarce accessibility and the lack of standardisation of the different (proprietary) firm-level sources. Indeed, to accomplish a fully integrated picture of the back-and-forth features of firms' global linkages, a vast array of countries' harmonized information is needed, which comes from different sources, such as custom-level data together with census-level information. For instance, in order to build up a firm-level counterpart of the country–industry GVC index of backward participation, one has to collect, for the exporting firm, information on: the percentage value of imported intermediate goods on the total value of intermediate goods used in the production; country of imports; the exports' destination. And such a calculation, already difficult to achieve with the available data, will only provide information on a single portion of the trade in value added at the firm level[1]. Going beyond the mere calculation of a backward participation index, census-level information would then be needed to link a firm's trade behaviour to several dimensions of firms' heterogeneity.

Notwithstanding the relative lack of good quality data, in recent years, a few papers, mostly relying on general firm-level surveys, have tried to carry out empirical analyses to investigate the firms' involvement in GVCs and their impact on performance. A list of recent papers and firm-level datasets applied for GVCs empirical analysis is reported in the Appendix.

In order to provide a brief overview of the most recent findings, we will focus here on contributions

[1] On the virtual impossibility of coming up with analogous firm-level measures of forward participation, see Antràs, 2021.

related to the analysis of GVC participation and positioning at the firm level[2] (the analysis at the country-sector level is presented in Section 3). These firms' level analyses still lack a unified framework and unit of analysis. This is due to the fact that, in general, studies rely on different datasets (mainly firms' balance sheets, surveys, etc.), each containing different information. As a result, there are currently several measures of the GVC participation index of firms, without a unified framework. Among the few studies, it is useful to distinguish between the ones ending up with a firm's participation index similar to the one envisaged by the input-output based literature (see Section 3) from those whose indexes rely on firms' internationalization modes. In the first category, Veuglers et al. (2013) use as a proxy of a firm's participation the percentage of imported intermediates over total inputs. The second typology of studies focuses on the firms' internationalization operation modes as a proxy of GVC involvement. Although ending up with different proxies of the GVC participation index, those studies share a certain degree of common ground based on the assumption that a two-way trader firm can be univocally defined as a firm participating in GVCs. Giunta et al. (2021), following on from Veugelers et al. (2013), divide firms' participation in GVCs into two categories: i) single forward mode, when firms are only exporters of intermediates; ii) dual-mode when firms are both importers of materials and services and exporters of intermediates or final goods. Similarly, Agostino et al. (2016) take into account the variety of modes of internationalization associated with the operation of GVCs, such as: exports only, intermediate goods imports only, both exports and imports (two-way trade) and international production. Baldwin and Yan (2014), investigating Canadian manufacturing firms, consider as involved in GVCs those firms which engage simultaneously in importing and exporting activities. Del Prete et al. (2017) analyse a panel of manufacturing firms in Egypt and Morocco. In their empirical investigation, firms involved in GVC activities are international traders that received an internationally recognized quality certification. Brancati et al. (2017) and Agostino et al. (2020), by using a representative sample of Italian industrial firms, investigate the GVC participation index by looking at exporters of semi-finished goods/components and two-way traders. Moreover, they also infer firm GVC participation by using a question in the survey that asks about the existence of "long-lasting and significant relationships with foreign companies" (Brancati et al., 2017). Giovannetti et al. (2015) rely on this same question (i.e., a direct answer from a firm's representative) to proxy the manufacturing firm's participation in GVCs. Likewise, Giovannetti and Marvasi (2016), in their investigation of firms operating in the Italian food industry.

Despite the variety of GVC participation measures adopted in the firm-level applied literature, a striking regularity of results emerges: firms' participation in GVC leads to productivity gains activated by several channels. Exporting allows a firm to exploit scale economies, acquire new technologies abroad and learn by exporting. Furthermore, other benefits may accrue to firms active in GVCs through imports of foreign inputs: cost saving, technology transfer, higher input quality and possible complementarities with domestic inputs. Two-way trading may have the additional advantage of exploiting sunk cost complementarity and other positive interactions between export and import activities. Finally, as is highlighted by the literature on firms' internationalization, productivity gains are ordered: the more advanced the firm's mode of GVC participation, the greater the productivity premium.

The literature on firms' positioning in GVCs distinguishes between final firms - those selling their output on the end market – and supplier firms – those selling their intermediate products to other firms[3] (Accetturo et al., 2011; Agostino et al., 2015, 2016; Veugelers et al., 2013; Giovannetti et al., 2015). Why do these different organizational firms' modes (final and supplier) need to be taken into account? There are at least three important reasons: i) suppliers, mostly small and medium enterprises, constitute the bulk of the productive system in the large majority of countries; ii) the impact of shocks differs according to the firms' positioning in the GVCs (Altomonte di Mauro et al., 2012; Békés et al., 2011; Accetturo and Giunta, 2016); iii) final and supplier firms substantially differ in terms of economic performance as well as the benefits that can be obtained by operating in the GVCs.

Despite its relevance, the latter issue has been brought to the fore by very few papers, mainly because of the relative lack of microdata, making it difficult to carry out a proper investigation. Kimura (2002), Razzolini and Vannoni (2011), Veugelers et al., (2013) document a large profitability and productivity gap between supplier and final firms. Yet, some researchers have highlighted the heterogeneous behaviour and performance of supplier firms (Accetturo et al., 2011). Among

[2] We do not overview here the vast literature based on case studies since their findings are not immediately comparable with the ones based on representative samples (for an overview of the literature based on case studies, see Ponte, 2019).

[3] The exact definition used is: suppliers are firms producing to order for other firms. These firms are positioned in GVCs when they produce to order for other firms located abroad.

these, Agostino et al. (2015), who, based on a representative sample of Italian manufacturing firms, confirm that, on average, GVC supplier firms are less productive than final firms. However, since the "ability" of supplier firms increases, their productivity shortfall diminishes. In fact, for those who succeed in both exporting and innovating, Agostino et al. (2015) prove there is no statistically significant difference in productivity between suppliers and final firms. Finally, a "GVC effect" in terms of superior technical efficiency or productivity can also be traced by comparing suppliers operating on local markets vis a vis with suppliers operating in the GVCs (Agostino et al., 2020; Veugelers et al., 2013).

3. COUNTRY AND SECTORAL GVCs ANALYSIS

Parallel to the firm analysis of GVCs, international economists developed various approaches to map and measure these chains at the country and sectoral level by relying on different methods and data sources. The empirical literature in this field mainly follows three approaches that provide different points of view on the quantification of GVCs and present both strengths and caveats in terms of complexity, accuracy and coverage (Amador and Cabral, 2016).[4] The first one compares international trade statistics of parts and components with trade in final products (see the seminal works of Yeats, 1998; Ng and Yeats, 1999; Athukorala, 2005; and Gaulier et al., 2007, among others). The second approach looks at the customs statistics on processing trade (see the works on the US processing trade by Feenstra et al., 2000; Clark, 2006; and Swenson, 2005; those on EU processing trade by Görg, 2000; Baldone et al., 2001, 2007; Helg and Tajoli, 2005; Egger and Egger, 2005; those on China by Lemoine and Ünal Kesenci, 2004; and Xing, 2012; and recently Kee et al., 2016; Koopman et al., 2012; Jiang, 2021; Luck, 2019). The third method considers classical input-output (I-O) tables, sometimes complemented with import penetration statistics computed from trade data. Using these I-O matrices, Feenstra and Hanson (1996) developed the first measure of foreign content of domestic production (computed as the share of imported inputs in production or total inputs, often used as a measure of outsourcing). This measure has been adopted in many subsequent works, such as Campa and Goldberg (1997), Hijzen (2005), Egger *et al.* (2001), Egger and Egger (2003), and Feenstra and Jensen (2012). Exploiting the same data, Hummels *et al.,* 2001 formulated the second measure of fragmentation, which focuses on the direct and indirect import content of exports, labelled "vertical specialization" that has been applied or updated in other studies (see among others Chen *et al.,* 2005; Zhang and Sun, 2007; Chen and Chang, 2006; Amador and Cabral, 2009). However, traditional I-O tables by themselves are no longer able to capture the complexity of the fragmentation and the mechanism ruling trade in intermediate inputs. With the target of tracing value-added trade flows across countries, a strand of work - which has recently become very popular - has therefore combined information from custom offices with national input-output tables to construct global I-O tables (see the works of Hummels et al., 2001; Johnson and Noguera, 2012; Miroudot and Ragoussis, 2009; Koopman et al., 2010, 2014; Foster Mc Gregor and Stehrer, 2013). Since the tables contain information on supply–use relations between industries and across countries, we can identify the vertical structure of international production sharing and measure cross-border value flows for a country or region.

Since the flows of goods and services within the global production chains are not always reflected in conventional international trade measures, many initiatives and efforts have recently been addressed to measure international fragmentation using trade in value added. The Appendix shows the main available databases.

3.1 Decomposition methodologies and trade in value added components

In parallel, new methodologies have also been developed to exploit data from multi-region input-output (MRIO) tables. These methodologies decompose gross trade flows in different value-added components and allow new GVC indicators to be computed.

One of the most widely used decomposition methodologies is that proposed by Koopman, Wang and Wei (KWW) (2014), who fully decompose gross exports into various sources of value added and connect official gross statistics to value-added measures of trade. Specifically, KWW (2014) break gross exports down into nine different components of domestic value added (domestic value embedded in a country's exports) and foreign value added (foreign value embedded in a country's exports) plus double-counted items (that arise when intermediate goods cross borders multiple times). The result is a complete picture of the value-added generation process in which various preceding formulas for measuring value-added trade are systematically integrated into a single accounting framework.[5] This method encompasses most

[4] For details of the three types of data, see the survey by Amador and Cabral (2016).

[5] For technical details, see Koopman, Wang and Wei (2010 and 2014).

of the methodologies previously proposed in the literature (e.g. Hummels et al., 2001; Daudin et al., 2011; and Johnson and Noguera, 2012).

A second methodology is that developed by Borin and Mancini (BM) (2015, 2019). They extend the KWW (2014) methodology providing exhaustive and rigorous value-added decompositions of exports at the aggregate, bilateral and sectoral levels which are consistent with the KWW framework and overcome shortcomings that affect the KWW decomposition and other previous attempts to obtain a bilateral counterpart (such as Wang et al, 2013).[6]

Using the Koopman et al. (2014) methodology extended by BM (2015, 2019), two key value added components of gross exports are traditionally selected to provide measures of country and sectoral GVC participation:

- The *indirect domestic value added* (DVX), that is, the share of domestic value added in intermediate goods further re-exported by the partner country. It measures the joint participation of the trade partners in a GVC since it contains the exporter's value added of a specific sector that passes through the direct importer for a (or some) stage(s) of production before it reaches third countries. More specifically, it captures the contribution of the domestic country to the exports of other countries;
- The *foreign value added* (FVA) used in the production of a country's exports, that is, the share of value added provided by intermediate inputs imported from abroad and then exported in the form of final or intermediate goods. It measures the contribution of the foreign country to the country's exports.

3.2 GVC participation and positioning indicators[7]

An important question raised in the GVC empirical literature is to what extent single countries and sectors are involved in international production networks.

The Hummels et al. (2001) measure of "vertical specialization" (the VS measure), mentioned above, is probably one of the first and most popular measures of participation of a country in the phases of international production chains. However, this is a partial measure of participation in global value chains since it only considers the backward linkages (i.e. it measures the import content of a country's exports). Therefore, they also suggest considering the exports of intermediate products later processed and re-exported as the VS1 measure.

Following the seminal article of Hummels et al. (2001), various measures of a country's integration in international production networks have been proposed. Using some of the trade in value added components of their decomposition, KWW (2010) propose one of the most widely used indicators of GVC participation in the field literature. They calculate GVC participation by using the trade in value added components mentioned above: the foreign value added (FVA) component and the indirect domestic value added (DVX) component. More specifically, FVA is referred to as a measure of "backward participation", given that it measures imported intermediate inputs that are used to generate output for export. DVX captures the contribution of the domestic sector to the exports of other countries and indicates the extent of involvement in GVC for relatively upstream industries. Therefore, it can be considered as a measure of "forward GVC participation".

By expressing both measures as a percentage of exports, the formula for GVC participation is as follows:

$$GVC\ Participation = \frac{FVA + DVX}{Gross\ Exports}$$

The larger the ratio, the greater the intensity of involvement of a particular country (or sector) in GVCs.

Other studies have measured a country's forward GVC participation by identifying the export components that are later re-exported by the direct importer (see, among others, Rahman and Zhao, 2013; and Ahmed et al., 2017). However, these contributions rely on the KWW decomposition of gross exports. As discussed, this methodology does not properly allocate countries' exports between the share that is directly absorbed by importers and the one that is re-exported abroad. The resulting measures of GVC participation are thus imprecise.

Borin and Mancini (2019) calculated their measure of overall GVC participation. This is given by the sum of a 'backward' component, corresponding to the VS Index, and a 'forward' component, the VS1 indicator suggested by Hummels et al. (2001):

$$GVC\ overall\ Participation = GVCbackward + GVCforward = VS + VS1$$

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[6] In particular, Borin and Mancini (2015, 2019) provide proper definitions for some components that are incorrectly specified by KWW: i) the domestic value added that is directly (and indirectly) absorbed by the final demand of the importing country; ii) the foreign value added in exports; iii) the double counted items produced abroad. They also overcome the main problems that make imprecise and at least partially incorrect the value added decompositions of bilateral exports previously proposed in the literature.

[7] This paragraph is largely based on Nenci (2020).

In this work, we refer to this indicator to measure and map GVCs in the agriculture and food sectors.

Recently, a strand of the international trade literature has developed measures of the positioning of countries and industries in GVCs (see Fally, 2012; Antràs et al., 2012; Antràs and Chor, 2013; Fally and Hillberry, 2015; Alfaro et al., 2019; Miller and Temurshoev, 2017; Wang et al., 2017). Using the global Input-Output tables, with information on the various entries, it is now possible to compute the upstreamness or downstreamness of specific industries and countries. To do this, a common approach is to consider the extent to which a country-industry pair sells its output for final use to consumers worldwide or sells intermediate inputs to other producing sectors in the world. A sector that sells disproportionately to final consumers would appear to be downstream in value chains, whereas a sector that sells little to final consumers is more likely to be upstream in value chains.

Following this approach, Antràs and Chor (2018) present the two GVC positioning measures most popular in the literature. The first indicator is a measure of distance or upstreamness of a production sector from final demand which was developed by Fally (2012), Antràs et al. (2012) and Antràs and Chor (2013).[8] Fally's model, as well as the variation proposed by Antràs et al. (2012), capture the average number of production stages by pegging the endpoint of the sequence at final consumption, which enables us to measure the *distance to final demand* of a product along the production chains. More specifically, this measure aggregates information on the extent to which "an industry in a given country produces goods that are sold directly to final consumers or that are sold to other sectors that themselves sell disproportionately to final consumers. A relatively upstream sector is thus one that sells a small share of its output to final consumers and sells disproportionately to other sectors that themselves sell relatively little to final consumers" (Antràs and Chor, 2018). The second measure, originally proposed by Fally (2012), is based on a country-industry pair's use of intermediate inputs and primary factors of production. It captures the distance or downstreamness of a given sector from the economy's primary factors of production (or sources of value-added). According to this measure, an industry in each country is downstream if its production process embodies a larger amount of intermediate inputs relative to its use of primary factors of production. Conversely, if an industry relies disproportionately on value-added from primary factors of production, then this industry is relatively upstream.

In this work, we adopt the first measure – the upstreamness indicator (Fally, 2012; Antràs et al., 2012; and Antràs and Chor, 2013) – computed by Nenci (2020) at the country-industry level for the "Agriculture" and "Food & Beverages" sectors to present some stylized facts for the countries in the Eora dataset for the period 1995-2015.

4. MAPPING GVC PARTICIPATION AND POSITIONING IN AGRICULTURE AND FOOD: SOME STYLIZED FACTS

Focusing on the global I-O tables and trade in value added data, this section aims to show some recent facts and trends on GVCs using the GVC participation indicator and the upstreamness positioning indicator for the "Agriculture" and "Food and Beverages" sectors. To do this, we refer to the indicators computed by Nenci (2020) from Eora data at the country-industry level relying on Borin and Mancini (2019)'s extension of the Koopman *et al.* (2014) methodology. These indicators are available for 190 countries in the period 1990-2015.[9]

4.1 Mapping GVC participation

Using Nenci (2020)'s data, Dellink et al. (2020) show how GVC participation between 1995 and 2008 is globally around 30-35 percent for both agriculture and food and beverages (Figure 2), although with significant variations across countries (highlighted by the shaded areas in the figure). However, further integration essentially stalled in the subsequent period. This trend is similar for both sectors. This may be because common factors driving GVC participation dominate sectoral and structural change effects. Hence, although agricultural commodities are perhaps less complex than manufacturing products, fragmentation of the associated value chains has also occurred in the agricultural sectors. This has important implications for developing and less developed countries: although they cannot compete internationally in the manufacturing sectors of final goods, they can still participate in GVCs and increase exports.

The effects of the 2008 crisis are evident in both sectors. These effects were also widespread across regions:

[8] Although the arguments used to develop the index differ in Fally (2012) and Antràs and Chor (2013), Antràs et al. (2012) emphasize that the resulting indexes are equivalent.

[9] Due to some inconsistencies in the EORA data, the Republic of the Sudan and the Republic of Zimbabwe are not included in the empirical analysis. These inconsistences are attributable to missing, incomplete, and conflicting raw data that can lead to distorted (i.e., not consistent and unbalanced) IO tables for a country in a given year.

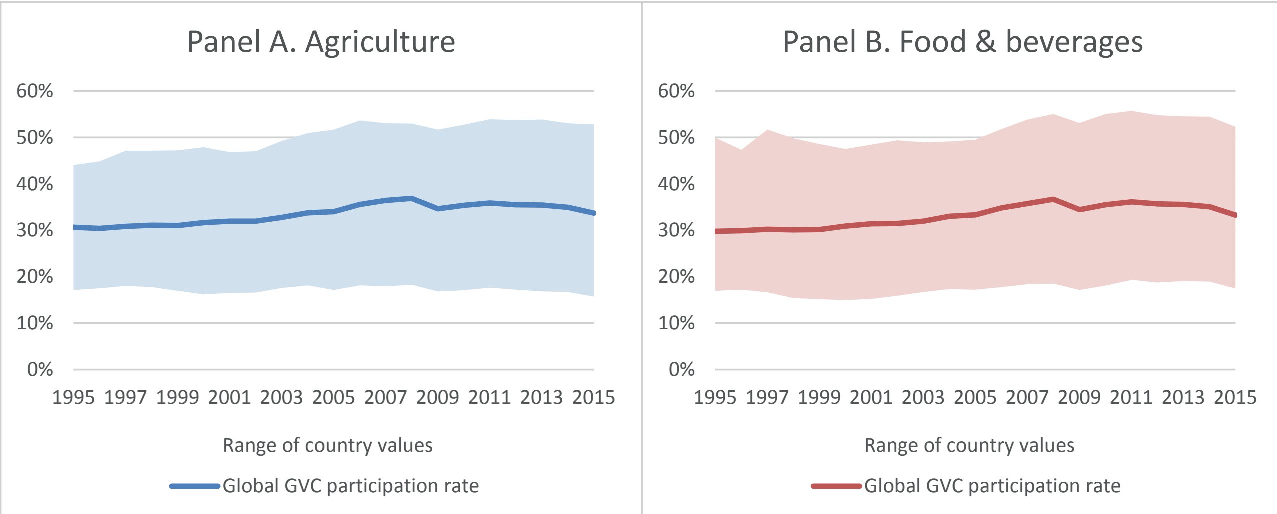

Figure 2. Evolution of global GVC participation rates in Agriculture and Food sectors. Notes: the shaded areas show the range of country values. Source: Dellink, Dervisholli and Nenci (2020) based on Nenci (2020)'s data.

until 2008, about 7 percent of the countries in the database observed a decline in GVC participation. These are primarily economies affected by war, droughts and other major disturbances. After 2008, only 8 percent of the economies – a widely varying group of mostly relatively small countries – further continued their integration in the global economy.

The long-term increase in GVC participation comes with the overall rise of gross exports of agricultural and food commodities. Figure 3 shows the composition of gross exports divided into: backward-linked GVC exports, that is the sum of FVA across countries; forward-linked GVC exports, which are exports that will later be re-exported, aggregated across countries; non-GVC exports, which are exports that do not flow through GVCs but are absorbed in the destination country. The sum of the three components (plus some pure double-counting) equals gross exports. While roughly two-thirds of the export value is not part of a GVC, both backward and forward linkages contribute significantly to the export value. Global exports of food and beverages are roughly twice as large as those of agricultural commodities and, in absolute terms, the rapid increase in food exports after 2002 is remarkable (see Figure 3, Panel B). As expected, GVC linkages in agriculture are mostly forward linked, since agricultural products serve as basic ingredients in other production processes. Food and beverages are much more in the middle and at the end of a value chain and include the processing of agricultural inputs. The backward linkages in food and beverages are mainly imports from agricultural commodities. In contrast, the backward linkages of agriculture refer to imports of inputs for agricultural production and are linked to international trade in fertilizers and seeds as well as to the increased servitization of the economy. The forward linkages in food and beverages are mainly exports by the sector itself – agricultural commodities are lightly processed in one country, then re-exported and further processed and distributed. However, other downstream sectors embed value added created in the food and beverage industry, such as, for example, sugar in pharmaceuticals and cosmetics (Dellink et al., 2020).

Finally, it is important to underline that the exports of agriculture and food sectors can also stimulate value added creation in other sectors, just as agriculture and food value added can be part of the exports of another downstream sector. In both the agriculture and food sectors, the biggest share of sectoral FVA is provided by services (42 percent and 38 percent in 2015, respectively, see Figure 4). This means that any boost to GVC participation in the two sectors leads to increased value-added creation in some foreign services sectors. In agriculture, a significant share of foreign inputs is delivered by chemicals and raw materials – this mainly reflects the globalization of the seeds market. In the food and beverages industry, the second largest FVA input share is agricultural commodities (20 percent). The share of manufacturing in FVA is also sizable in both sectors (this includes machinery). Finally, while foreign inputs from the food sector into agriculture are small, intra-sectoral trade in the food and beverages industry is more substantial (Dellink et al., 2020).

Moving on to GVC analysis at the country level, Figure 5 reports the GVC participation indicators for the

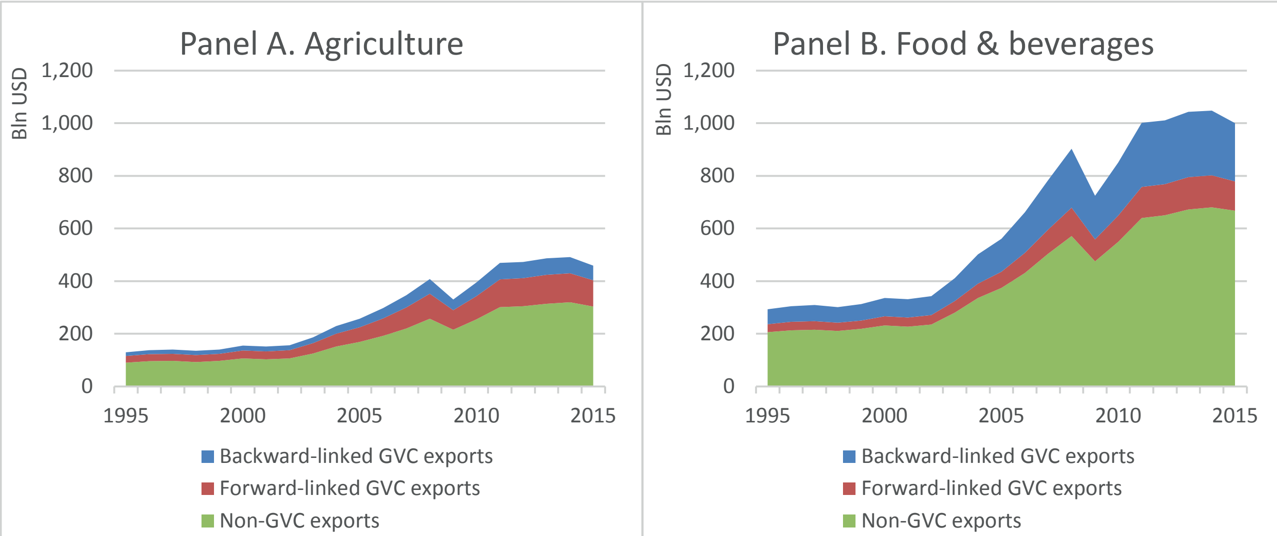

Figure 3. Composition of gross exports in Agriculture and Food sectors. Note: values calculated at the country level and then aggregated. Source: Dellink, Dervisholli and Nenci (2020) based on Nenci (2020)'s data.

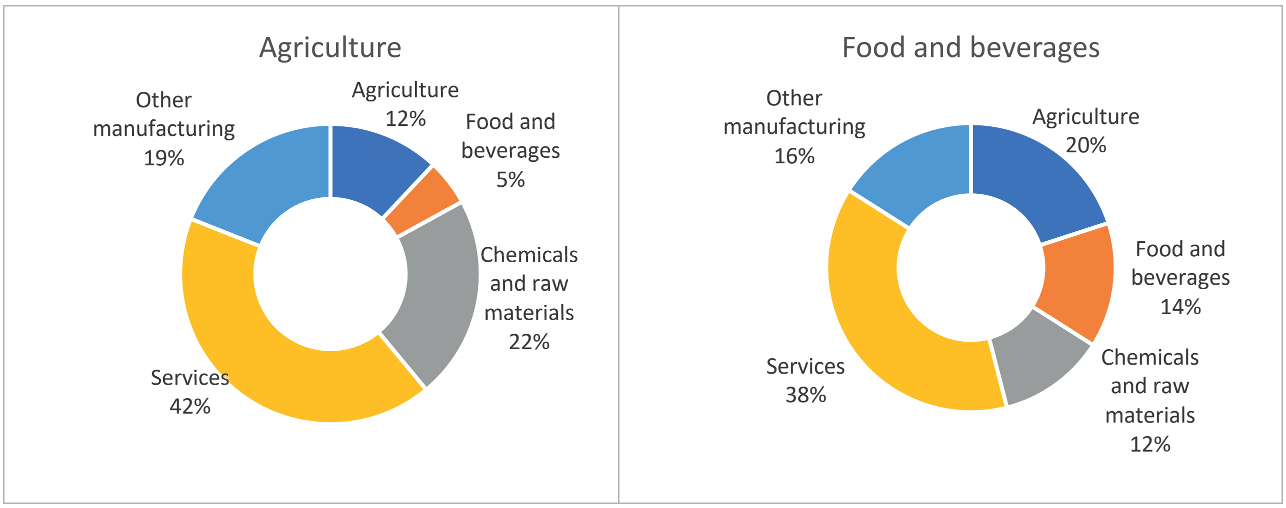

Figure 4. Origin of foreign value added in Agriculture and Food sectors (2015). Source: Authors' elaboration based on Nenci (2020)'s data

agricultural sector for each country in the world in 2015. The European countries present, on average, the highest rate of GVC participation (about 40–45 percent of its total exports, on average, considering both the foreign value added and its domestic value added content embedded in third country exports). Despite low trade shares at the global level, the African region turns out to be deeply involved in agriculture GVC participation too (about 37 percent, on average). This is higher than the average values for America and Asia and is consistent with the relative importance of the African continent in the global agri-food value chains highlighted by the literature in the field. However, we can also detect country heterogeneity in both areas, with Estonia and Latvia showing the highest share of GVC related trade in agriculture in Europe and the Democratic Republic of Congo in Africa. Conversely, the Commonwealth of Independent States (CSI) shows the lowest shares (except for Belarus).

Figure 6 shows a similar picture for the GVC participation indicators for the food and beverages sector. In this case, apart from the usual heterogeneity by country, the African and the European continent share a similar degree of involvement in GVC trade (about 40 percent of their respective total exports).

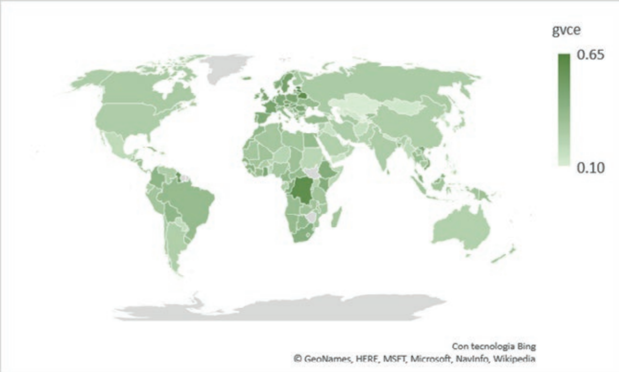

Figure 5. GVC participation for the Agricultural sector by country (2015). Source: Montalbano and Nenci (2022).

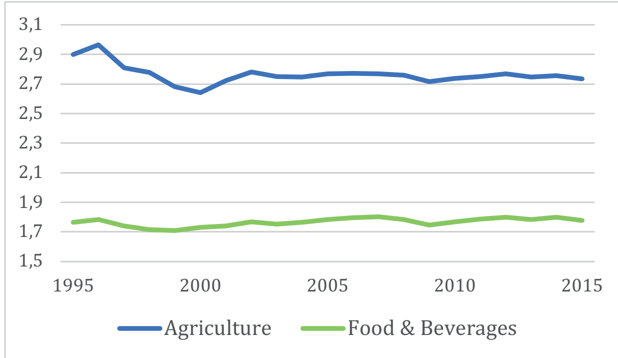

Figure 7. GVC upstreamness at global level. Source: Authors' elaboration based on Nenci (2020)'s data.

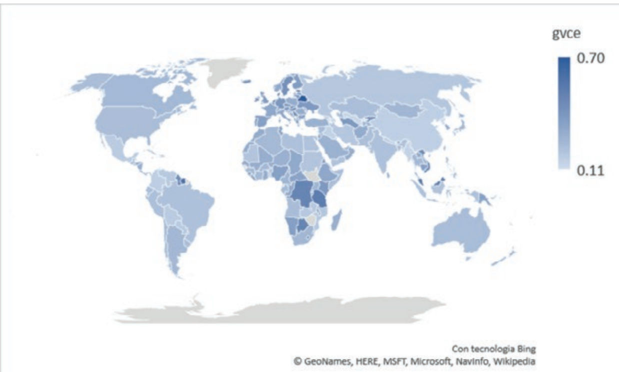

Figure 6. GVC participation for the Food and beverages sector by country (2015). Source: Montalbano and Nenci (2022).

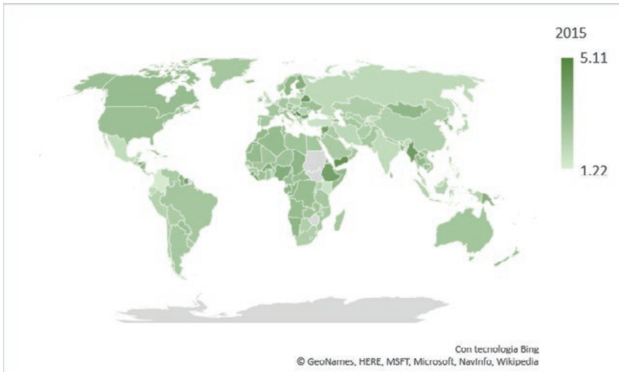

Figure 8. Upstreamness of the agricultural sector by country (2015). Source: Montalbano and Nenci (2022) based on Nenci (2020)'s data.

4.2 Mapping GVC positioning

Another valuable way to analyse and map GVCs is understanding the positioning of countries and/or industries within GVCs. At a descriptive level, these indicators provide information on the specialization of a country in relatively upstream activities or ones that are more proximate to final demand.

Figure 7 shows the evolution of the upstreamness indicator at the sectoral level. Unsurprisingly, agriculture has a higher score on upstreamness (measuring the distance of the sector from final demand in terms of the number of production stages) than the food and beverages sector. While the median for agriculture is positioned more than 2.7 stages upstream of final demand, the one for food and beverages is constantly two stages lower. This positioning indicator closely depends on the length of the chains: between 2000 and 2008, the upstreamness of the two sectors rose modestly but steadily, suggesting an increase in fragmentation in production.

Moving to an analysis by region-country, Figure 8 shows the degree of countries' upstreamness for the agriculture sector in 2015. In this case, Africa, America and Europe share the same average degree of upstreamness (about 3 stages of production from the final consumers), which is above the average world level of 2.25. At the country level, the most upstream countries in Europe are Serbia and Bosnia-Herzegovina (their agriculture production is, on average, concentrated on activities that are up to 5 stages away from the final consumers), whereas in Africa a pick of about 4 stages of production is registered for the agricultural sector in Ethiopia.

Figure 9 shows the degree of countries' upstreamness for the food and beverage sector. As expected, the average degree of upstreamness for Africa and Europe is lower than in the agricultural sector (less than 2 stages of production from final consumers). At the country level, the food and beverage sector also shows a lower degree of heterogeneity. The most upstream country

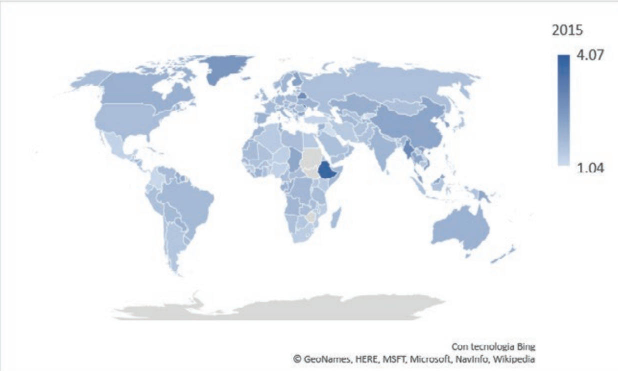

Figure 9. Upstreamness of the Food and Beverages sector by country (2015). Source: Montalbano and Nenci (2022) based on Nenci (2020)'s data.

in Europe is Moldova together with the small European States (about 4 stages away from final consumers), whereas in Africa again, about 4 stages of production away from final consumers are registered in Ethiopia.

5. IMPACTS OF GVCs ON AGRICULTURE AND FOOD PERFORMANCE: EMPIRICAL EVIDENCE

The empirical analyses on the impacts of agricultural and food GVCs have traditionally relied on case studies (Salvatici and Nenci, 2017). Thanks to the availability of MRIO tables and the possibility to compute a new set of GVC indicators based on trade in value added data, scholars have recently acquired the possibility to benefit from true global analyses. These global analyses look at different kinds of effects. A preliminary distinction is between *economic upgrading*, usually defined in terms of efficiency of the production process or characteristics of the product or activities performed (Humphrey and Schmitz, 2002), and *social upgrading* often referred to improvements in the rights and entitlements of workers as social actors, as anchored in the ILO decent work framework, and/or enhancement of outcomes related to employment and pay, gender and the environment (Milberg and Winkler, 2010; Barrientos et al., 2011; Gereffi and Lee, 2016).

As for *economic upgrading*, some studies have analysed the role of intermediate goods in generating a positive impact on the total factor productivity of industries (see, *inter alia*, Bas and Strauss-Kahn, 2014; Halpern *et al*., 2015; Olper *et al*., 2017). Empirical results from Southeast Asia suggest that foreign sourcing in the production of exports is a complement to, rather than a substitute for, the creation of domestic value added in exports (Lopez-Gonzalez, 2016). Other studies confirming the positive relationship between the use of foreign imported inputs and an increase in firm productivity growth in developing countries are: Amiti and Konings (2007) for Indonesia; Kasahara and Rodrigue (2008) for Chilean manufacturing plants; Halpern *et al*. (2011) for Hungary; Topalova and Khandelwal (2011) for India; Montalbano *et al*. (2018a) for Latin America and the Caribbean. Constantinescu et al. (2019) and World Bank (2020) also underline the significance of backward linkages for growth and labour productivity. By focusing on the GVCs' participation in agricultural and food and beverages sectors at the global level for a relatively long time span (1995–2015), Montalbano and Nenci (2022) confirm that, on average and ceteris paribus, there is a positive relationship between changes in agriculture value added per worker and changes in both agriculture and food GVC participation, both backward and forward. These outcomes complement similar established empirical evidence on manufacturing and confirm the positive effect of GVC participation on domestic value added with reference to both backward and forward linkages.

Some scholars have interpreted the notion of economic upgrading as a need for targeting specific production stages and "moving up along the value chain" (Kowalski et al., 2015). This debate has been largely influenced by the "Smiley curve" thesis[10] and has been interpreted as implying that in order to increase the domestic value added share, it may be beneficial to move away from the assembly or manufacturing parts of the chain to be involved in "more sophisticated" downstream stages. This interpretation looks in principle inconsistent with the principle of comparative advantage. This latter argues that the most profitable segments of the value chain should be jointly determined by the characteristics of the production process as well as the relative skills and resource endowments of firms and countries in question. Unfortunately, the empirical analyses on the economic effects of GVC positioning are still rare. Montalbano and Nenci (2022), using global indicators of *upstreamness* for agriculture and food sectors for the usual long time span (1995–2015), highlight a robust negative association cross-country between agriculture value added and the relative distance from final consumers. Although this could be seen as possible confirmation of the fact that moving up the agriculture and food value chains could be seen as a good strategy for participating countries, the authors warn that GVCs are get-

[10] This argument has been made in business management and refers to a graphical depiction similar to a smile where the two ends of the value chain show higher value added than the middle part of the value chain. For a deeper analysis of the "smiley curve", see Elms and Low (2013).

ting longer over time and additional investigations are needed in this field.

As for *social upgrading*, the existing literature on GVCs often implicitly assumes that economic upgrading will automatically translate into social upgrading through better wages and working conditions (Gereffi and Lee, 2016; Knorringa and Pegler 2006; de Oliveira 2008). However, pressures to reduce costs might indeed lead employers to combine economic upgrading with social downgrading (for example, by outsourcing employment to an exploitative labour contractor or delocalizing in countries with lower labour standards, (Barrientos et al., 2011). Preliminary empirical evidence confirms that firm performance is associated with improvements in working conditions (World Bank, 2015). Unfortunately, this strand of the literature, although addressing a key issue in the GVC debate, is still largely based on case studies and anecdotal evidence.

6. CRITICAL ISSUES ON GVCs

There are some critical aspects that are currently affecting the GVCs – global but also agri-food ones - which may affect and shape the future of GVCs. They include: the rise of protectionism, technological development, environmental issues, trends in emerging economies, and recently the Covid-19 pandemic (Antras, 2020; OECD, 2017; Fortunato, 2020). Among the issues identified by scholars, we want to focus on the following: the bidirectional nexus between GVCs and trade policy, the advent of new technologies that have become widespread in recent years and the impact of COVID-19.

6.1 Trade policies and GVCs

A critical and important issue in the analysis of GVCs is that of the relationship with trade policies. Recent developments in international trade literature have attempted to shed light on the interrelation between trade policies and trade patterns within regional and GVCs. GVC-trade policy nexus is bidirectional: the reduction in trade barriers has been identified as one of the determinants of the spread and diffusion of GVCs (Antràs, 2020a) and, conversely, the global fragmentation of production influences trade policy (Goldberg and Pavcnik, 2016; Blanchard et al., 2016).

6.1.1 Impact of trade policy on GVCs

The literature highlighted two main potential effects of trade policy on GVCs: a) a "magnification effects", whereby goods that cross national borders multiple times incur multiple tariff costs. As such, tariffs are applied to gross imports, even though the value added content may be only a fraction of this amount. Different ways of international involvement, notably upstream or downstream participation, shape the extent to which countries are affected by this cost magnification (Yi 2003, 2009; Muradov 2017); b) a "chain effect", which influences all the stages of a GVC and, consequently, a country's backward and forward participation. In terms of forward participation, a depressing impact is expected on the domestic value added content of a country embodied in partner countries' exports. This is because, by reducing the gains for foreign producers of final goods, tariffs also hurt their upstream suppliers. In terms of backward participation, when import-competing sectors use foreign inputs, tariffs allow to pass some protectionist rents from the domestic producers on to upstream foreign input suppliers. This could represent an incentive for foreign suppliers to move to those countries/sectors to get the benefits of the protection (Blanchard et al., 2016; Balié et al., 2019). This may have important policy implications since trade policies no longer exclusively depend on the location of the imported goods but on the nationality of the value added content embodied in traded goods. Consequently, there may be a need to reformulate trade policy priorities, especially in the more downstream food sector (Montalbano and Nenci, 2020a).

Differently from the standard narrative, which focuses mainly on gross exports' performance, trade policy should thus consider that access to imports is an essential component of value-added exports. This implies broadening the scope of tariff and non-tariff trade policies, including softening barriers to imports to facilitate access to world-class inputs (Montalbano et al., 2018b). Moreover, integration into GVCs should be promoted, especially upstream integration that implies producing quality inputs for other countries' productions and exports. OECD (2016) finds that the greatest effects were found to be on trade in intermediates for low and middle-income countries and suggests that protectionist policies, particularly in the form of tariff escalation, are likely to hamper the development of GVCs. Greenville et al. (2017) outline that the levels of tariffs charged and faced, along with sanitary and phytosanitary (SPS) and other technical barriers to trade (TBT) were correlated with lower GVC participation and suggest that higher levels of barriers to the flow of agricultural and food products across borders are associated with lower levels of agricultural and food GVC participation as the cost of being part of GVCs for individual countries increases and thereby decrease their competitiveness.

To quantify the effects of trade policies on countries' economic activity, prices and welfare, computable general equilibrium (CGE) models have been adopted. Some of these models allow for supply chain cross-border linkages, including the GTAP-SC ("Supply-Chains") model (Walmsley et al., 2014) and the IESC model (Minor and Walmsley, 2017) which use a nested Armington demand structure to distinguish between imports for different usages from different source regions. Antimiani et al. (2018b) develop the GTAP-VA ("Value Added") model to account for trade in value added flows when assessing trade policy shocks. In the same vein, the OECD-METRO model includes GVC indicators similar to the approach used in the OECD-WTO TiVA database (OECD, 2018).

A key empirical issue in this literature is that applied tariffs alone are not useful metrics to assess trade protection when intermediate trade is pervasive. Diakantoni et al. (2017) argue that after falling into relative obscurity, at least from a normative perspective, effective protection rates (EPRs) may be back to the central stage as international trade moves from "trade in (final) goods" to "trade in tasks". From a national account perspective, what is internationally traded is the value added (the primary inputs) and the adequate measure of trade distortion is no more the nominal tariff structure on the output, but the effective rate of "protection" on value added. Feenstra (2017) extends the concept of effective protection to reflect the impact of import tariffs on the foreign value added in an industry's exports. More recently, Antimiani et al. (2018a) define in a general equilibrium framework different benchmarks with which to measure restrictiveness, according to where the value added originates: the resulting Value Added Trade Restrictiveness Indexes (VATRIs) are equivalent to the actual protection policies in terms of the impact on domestic or foreign value added embedded in imports. Similarly, Fusacchia et al. (2021) define an index capturing the effects that the tariff structure has on exporting firms that rely on imported intermediate inputs. Rouzet and Miroudot (2013) compute the 'cumulative tariff' (i.e. the accumulated burden of upstream tariffs for a given importer), which quantifies the total cost-push effect of direct and indirect tariffs, taking into account the upstream GVC structure. Muradov (2017) extends the concept to account for indirect bilateral trade flows and proposes two alternative measures to account for related costs, the cumulative tariff at origin and destination.

6.1.2 Effects of GVCs on trade policy

As far as the political economy is concerned, there is growing evidence that GVCs affect trade policy. Antràs and Staiger (2012) make a theoretical contribution by examining trade agreements in the presence of offshoring. Their findings support the view that terms-of-trade motives for cooperation are no longer sufficient when off-shoring is relevant and suggest the need for deep integration, with more individualized agreements that can better reflect member-specific needs (Ruta, 2017). A key issue in this respect is the provision of "rules of origin". These imply that trade agreements can have systemic consequences for the allocation of production across countries. Despite the rules of origin, when the share of intermediate goods increases between a non-member country and a member country, the trade diversion of exports from the non-member country to the member country is largely mitigated. Conversely, the disruption created by trade wars and dismantled agreements may be transmitted to other trading partners and may not be easily avoided by reorganizing buyer–seller relationships (Salvatici, 2020).

Blanchard et al. (2016) develop a value-added approach to modelling tariff setting with GVCs, in which optimal policy depends on the nationality of value-added content embedded in home and foreign final goods. There are two mechanisms in play: the importing country's incentive to manipulate the terms of trade is reduced if foreign producers use inputs from the home country in production, and when domestic producers use foreign inputs in production, some of the protectionist rents from higher tariffs accrue to foreign input suppliers. They find strong empirical support for the predictions of the theory stating that discretionary tariffs decrease in the domestic content of foreign-produced final goods and the foreign content of domestically-produced final goods. Following the predictions of this model and emphasizing political economy considerations, Ludema et al. (2019) and Bown et al. (2020) find similar empirical results using firm-level GVC interlinks and anti-dumping duty and confirm that GVCs matter for trade policy determination.

Lastly, Raimondi et al. (2021) extend the focus on the agricultural and food sectors by assessing how GVC participation affects trade policy. Besides tariffs, they include the bilateral index of non-tariff measures (NTMs) for both SPS requirements and TBT measures which have the greatest impact on trade for most agri-food sectors. They find that a rise in domestic value added (but not the foreign value added) reduces both tariffs and NTM regulatory distance. In their sample of 150 countries for the period 1995-2015, a movement from low to high domestic value added induces a reduction in tariffs/NTMs of about 30%.

International trade of agro-food products is influenced not only by tariff and non-tariff measures, but also by the role played by domestic agricultural policies in determining the competitiveness of the sector. Distortive agricultural policies that promote subsidies for the use of inputs or subsidies outputs addressing directly the producers or the sector as a whole have been found to have a negative effect on GVC participation and on domestic value added creation (Greenville et al., 2017). Along with protectionist policies, agro-food trade faces other economic barriers such as standards and intellectual property rights. Where governments lack the capacity to enforce regulations, MNCs may privately enforce standards necessary both to avoid the risk from media exposure of poor working conditions and to ensure the health and safety of the products all along the GVC. To date, little empirical evidence exists on the relationship between private standards and a country's participation in GVCs. Though some studies have found that compliance with private standards can have positive effects on firms' trade growth and employment (Colen et al., 2012; Otsuki, 2011; Volpe-Martinicus et al., 2010), more recent evidence is mixed (Beghin et al., 2015). In particular, the critique on private standards has concentrated on its developmental implications, arguing that standards are not poor inclusive. Some empirical studies have suggested that the inclusion of smallholders in high-standard trade is only possible with external support from development programmes, public-private partnerships or collective action.

6.2 New technologies and GVCs

The increasing adoption of industrial automation, data exchange, advanced robotics and smart factories (the so called "new technologies") can change the production processes considerably and reshape world production, thus also affecting international trade (Hallward, 2017). These new technologies are also promising in boosting productivity, reducing costs and supporting the speed of catch-up (Dollar, 2019). However, since typically demand for automation arises for labour cost saving reasons and it covers all those tasks that are repetitive and codified, emerging innovations can prove to be quite disruptive and lead to a reduction in the demand for workers (Rodrick, 2018; Acemoglu and Restrepo, 2020, Acemoglu et al., 2020). Consequently, the impact of these technologies on GVCs is twofold. On the one hand, automation represents an alternative to offshoring for those firms in developed countries looking to reduce their labour costs, thus raising the so-called process of "de-globalization" (Antràs, 2020b). However, the degree of substitution between automation and workers is low, especially in the more advanced firms deeply integrated into GVCs. This is because of the demanding precision and quality standards associated with these technologies, which generate a disadvantage, especially for unskilled workers (Rodrik, 2018). On the other hand, new technologies can foster productivity and increase the demand for intermediate inputs. Artuc et al. (2018) show that automation in industrial countries boosted imports from developing countries and a growing literature seems to confirm this trend (see Stapleton and Webb, 2020; and Wang, 2020).

Digital technologies are also useful in enhancing GVC participation by reducing barriers at the entrance. Digital platforms allow the matching of buyers and sellers, fostering verification and monitoring in firm-to-firm relationships and thus lowering the initial fixed costs associated with GVC participation and information frictions (Antràs, 2020a). Furthermore, in these contexts in which language barriers are still prohibitive, the usage of artificial intelligence, big data and machine learning techniques could provide efficient translation services (Brynjolfsson et al., 2019).

Those technological advancements and the associated business and product innovations are also affecting structural and agricultural transformations across the globe (Christiaensen et al., 2021). They hugely reduce transaction costs, change economies of scale and modify the optimal inputs mix in agricultural production, processing and marketing. Since some agricultural tasks are highly automatable, automation could accelerate the exit of workers out of agriculture in developing countries and transform farms and food processing firms in the industrialized world. Robots are beginning to be used in fields and packaging plants, together with tech-savvy agricultural workers, to integrate new technological solutions into specific goods and tasks. Solar-driven water pumps, cold storage and agro-processing equipment are also beginning to spread in developing countries, accelerating the transition away from subsistence production (Banerjee et al., 2017; World Bank, 2020).

Understanding the direction of innovations is particularly important for developing countries and GVCs will play a key role in this process. Extending access to high-speed internet and expanding e-commerce has the potential to greatly facilitate increased GVC participation by relatively small firms and also firms in countries with bad logistical infrastructure (Antràs, 2020a). Since GVCs are a channel through which new technologies are transmitted between developed and developing countries, participation in GVCs could generate spillover effects in terms of learning (Dollar, 2019). Conversely, the reshoring of routine activities induced by technological progress could threaten unskilled workers in developing countries. Since technological progress seems to be skill-biased, the impact of this could be non-trivial. Chang (2016) estimated that almost 80% of Cambodian, Vietnamese, and, to a lower extent, Indonesian workers could face possible replacement by automation. De Vries et al. (2016) highlighted that the biggest impact is on the higher value added and more skill-intensive activities. They found a lower demand for production workers by about 55 million workers in China, but no significant effects on demand for R&D jobs. Bertulfo et al. (2019), using regional input-output tables and a labour force survey for developing Asian economies, found that technology within GVCs is associated with a decrease in employment levels across all sectors.

Technological changes may have a deep impact even on income differentials. A vast strand of literature points out that participation in GVCs increases the skill premium, thus exacerbating wage inequality, especially in developing countries (Chaudhuri et al., 2010; Li et al., 2016; Shen and Zheng, 2020). Chongvilaivan and Thangavelu (2012) show that a 1% rise in GVC participation leads to a rise in skill premium of approximately 2.5% in Thailand. Similarly, Mehta and Hasan (2012) found that GVC participation in services accounted for 30–66% of the increase in return to skills from 1993 to 2004 in India. Based on empirical evidence at manufacturing firm-level data, Wang et al. (2021) argue that the rise of wage inequality in China mainly arises from moving to more upstream sectors rather than changing GVC participation.

6.3 COVID-19 and GVCs

The COVID-19 pandemic has disrupted global economies, with restrictions in the movement leading to large unemployment and GDP downturns across the world. It has also had a significant impact on international trade with a reduction in trade flows induced by government-mandated lockdowns (Baldwin and Freeman, 2020; WTO, 2020; Hayakawa and Mukunoki, 2021): the volume of world merchandise trade contracted by 5.3% in 2020 (a contraction smaller than initially feared). Trade in nominal US dollar terms fell more sharply, 8%, while commercial services exports declined by 20% (source: WTO).

Although the disruptions from COVID-19 are ongoing, there is a growing body of research on the economic impacts of the pandemic. It is worth noting that these works are still in progress and those available are based on anecdotal evidence, estimates, or simulations based on incomplete and imperfect data. Consequently, their results cannot be considered conclusive and much will be learned from more detailed future studies on the topic. That said, a negative impact is what has emerged from initial evidence.

The hot issue is to assess whether or not this negative economic impact of the pandemic turns to be strictly related to the degree of participation of countries in global production networks (Eppinger, 2020). It is undeniable that the Covid-19 pandemic has affected GVCs through several channels (Baldwin and Tomiura, 2020; Baldwin and Freeman, 2020; Miroudot, 2020; Antràs et al., 2020), and the production has been directly cut because of lockdown measures. On the supply side, the lack or scarcity of foreign suppliers due to disruptions in foreign production and transport networks determined a great bottleneck that has affected - and continues to affect - the entire value chain. On the demand side, demand for most products has fallen sharply because of the economic crisis, whereas shocks in consumer markets have affected all foreign upstream suppliers. On the other hand, global demand for certain medical products has increased substantially, even resulting in temporary shortages and export restrictions (for instance, the pandemic led to shortages of medical equipment and pharmaceutical products in many countries as demand spikes exceeded existing supply and production capacity), whereas other sectors and markets significantly expanded because of the pandemic.

Sforza and Steininger (2020) show that the economic effects of the pandemic are heterogeneous across sectors, regions and countries. Di Nino and Veltri (2020) employ international input-output tables to evaluate the transmission via foreign trade of adverse shocks generated by lockdown and containment measures across the euro area. They highlight not only the presence of a large propagation effect in the euro area but also estimate that foreign demand weakness depressed the aggregate activity of the euro area by about one fifth the size of the foreign shock (a quarter of this effect is due to transmission of lower intermediate and final goods demand within the area). Exploring the vulnerability of developing countries to both demand and the supply shock of the pandemic occurring in major economic hubs, Pahl et al. (2021) find that the most integrated economies tend to suffer more through the GVCs.

With specific regard to GVCs in the agriculture and food sectors, since the COVID-19 outbreak, agri-food supply chain disruptions have been widely observed across the world (Christiaensen et al., 2021). The pandemic has imposed shocks on all segments of this supply chain, simultaneously affecting farm production, food processing, transport and logistics, and final demand. In this respect, the non-pharmaceutical interventions imposed by local and/or national authorities to flatten the spread curve of the virus weakened the local food system, thus acting as a real threat to food security, especially for the most vulnerable households (Barrett, 2020; Béné, 2020). However, not all sectors and products have been equally affected and different products have experienced disruptions at different stages of the supply chain (OECD, 2020c). Furthermore, if agri-food supply chains in the developed world have demonstrated remarkable robustness and resilience in the face of COVID-19,[11] in the developing world, the impacts on agri-food-supply chains are expected to be felt widely but unevenly. Farm operations may be spared the worst, while small and medium-sized enterprises in urban areas will face significant problems (Reardon et al., 2020). In terms of actions, local governments have actively strengthened food safety nets and social protection mechanisms to maintain access to food. Specific government measures also addressed the impact of income reductions through subsidies, tax breaks and transfers to those affected. These measures have been indispensable but acted basically as coping strategies. The challenge is to stabilise global supply and consumption, heading the global food system towards a sustainable and resilient path. This revamps the important role of risk exposure and international trade in general, and GVCs' participation in particular, as the key tools for fostering resilience among the poor, and reducing their vulnerability to external shocks (Morton, 2020; Montalbano and Nenci, 2022).

To sum up, some key features of GVCs that matter for efficiency also determine the exposure to shocks and the propagation of these shocks along the chain. A high reliance of sales on foreign demand and high dependence on foreign value-added inputs are associated with high-risk exposure, but not necessarily to higher vulnerability since the latter is mainly related to how people actually manage risks (Montalbano, 2011). In this respect, the COVID-19 pandemic has led firms to a partial diversification of sources of supply whose extent will vary by sector depending on the costs of value chain reorganization. Moreover, according to some scholars, the world economy has already entered an era of de-globalization before the pandemic and the observed slowdown is the consequence of the remarkable and unsustainable period of hyperglobalization experienced in the two decades that preceded the 2008-2009 crisis (Antràs, 2020b). The Covid-19 crisis could have only fortified some of the trends noted above. However, its effects are ambiguous.

7. CONCLUSIONS AND THE FUTURE OF GVCs

This work has analysed a wide range of aspects related to the study of GVCs, mainly using a "macro" lens and an empirical focus. We have first reiterated the economic centrality of GVCs, despite the slowdown recorded after the 2009 crisis and the further disruptions induced by the COVID-19 pandemic. We have then reported the different approaches to the GVC analysis and presented indicators for measuring and mapping GVCs at micro and macro levels. Subsequently, we have shown some stylized facts focusing on GVC participation and the position of the agriculture and food sector, underlining a growing involvement on a global level, although with variation across regions and countries. After, we have summarized the main empirical evidence regarding the impact of value chains on the performance of the sectors under interest, highlighting an improvement in productivity and a supported economic growth. Finally, we have introduced and discussed some of the main critical issues affecting current and future GVCs, such as policy space, new technologies and the effect of Covid-19 pandemic.

As illustrated in this work, we should acknowledge that with respect to GVC measurements and mapping, the literature is still scant. A growing empirical literature emerged by taking advantage of the availability of global I-O matrices and aggregate trade data to map and measure GVCs, whereas sectoral, country coverage and firm-level data remain weak. Mainly, the relative lack of good quality microdata is underwhelming. Researchers struggle to envisage satisfactory proxies for both firms' participation and positioning in the GVCs. Moreover, a lot more is currently left out because it is hard to investigate it. Issues in point are, for instance, the channels of technology transmission in the GVCs; the pros and cons of specific, idiosyncratic investments, in the presence of contractual incompleteness and low quality of institutions; the understanding of the different layers of GVCs and the availability of suppliers according to the tier they operate in.[12] All that remains is to provide

[11] See The Economist, "The World's Food System Has So Far Weathered The Challenge of COVID-19 – But things could still go awry", 9 May 2020.

[12] Antràs (2021:16) advocates "a novel, [..] conceptualization of GVCs in which the focus is shifted away from the mere allocation of value added across countries resulting from anonymous, spot exchanges of goods and services. Instead, a new paradigm emerges in which the identity of the specific agents participating in a GVC is crucial".

more and more data to allow both a more robust understanding of the GVC phenomenon and, consequently, the design of effective policy measures.

The recent slowdown and retrenchment in the global fragmentation of production have induced a growing body of authors to suggest that this trend is the prelude to a new era – the so-called "deglobalization"- whose speed of development may even be powered by the COVID-19 pandemic. Following this track, some trends could arise: first, *reshoring,* resulting in a shorter and less dispersed value chain characterized by a higher geographical concentration of value added (Javorcik, 2020); second, diversification, with a broader distribution of tasks along the GVC, especially for intensive manufacturing industries (Antràs, 2020); third, regionalization, as a consequence of the reduced length of the chains, dominated by three large regions: North America, Europe and a China-centric Asia (Baldwin and Freeman, 2020; Enderwick and Buckley, 2020; Wang and Sun, 2021). Several preliminary analyses seem to deny that *reshoring* and nationalization of production can improve resilience: it would result in lower exposure to foreign shocks, but this comes at the cost of higher exposure to domestic shocks, i.e., value chains are still dependent on single suppliers, which does not protect against disruption in production (Antràs, 2020; Bonadio et al., 2020; OECD, 2020b; Arriola et al., 2020; Espitia et al., 2021). Furthermore, such different kinds of risk exposure are not symmetric, being the foreign markets characterized, on average, by many players and a higher degree of competition. The demand for diversification, on the other hand, seems to find greater consensus: a larger network of diversified suppliers in multiple countries is the better response to avoiding the bottleneck (see Antràs, 2020; Bacchetta et al., 2021; Caselli et al., 2020; Miroudot, 2020). Lastly, the process of regionalization of the GVCs was indeed already in place with hubs in China, the US and Germany (Baldwin and Lopez-Gonzalez, 2015).

Although the undeniable slowdown of recent years and several trends that will limit the expansion of GVCs in the near future, the complexity and high restructuring costs related to GVCs will probably prevent the large-scale dissolution of the existing GVCs (Bonadio et al., 2020; Simola, 2021). The key question then becomes how to consolidate GVCs in the future. In this context, policies can play a critical role. Brancati, Pietrobelli et al. (2021) collect from the field literature four types of policies to build more robust and resilient value chains: i) participation policies aimed at entering in and enhancing the local economy's participation in GVCs. These are market-enabling policies that assist the private sector in restructuring productive activities according to a country's latent comparative advantage and connectedness policies that reduce the costs related to linking domestic firms to foreign value chain partners (e.g. policies that reduce trade costs or information costs); ii) value capture policies intended for strengthening the local economy's value creation and capture within GVCs. Part of the GVC literature suggests supporting product and process upgrading, which implies moving vertically along the value chain to better products or processes as well as the more challenging functional and interchain upgrading, entailing horizontal movement towards new functions or new markets (Gereffi et al., 2005; Humphrey and Schmitz, 2002; Gereffi, 2019). Examples of these policies are: strengthening of local innovation and production ecosystems; building and improving specific types (logistical, digital, and productive) of infrastructures; development of specific skills; establishment of linkages between universities, vocational centers and firms involved in GVCs; provision of advisory services in the areas of standards, metrology, testing, and certifications; iii) GVC inclusiveness policies directed to improve the local social and environmental conditions in GVCs. They concern improvement of labor, social, and environmental regulations and their enforcement, at national and supranational levels; responsible sourcing policies; private standard promotion; involvement of local communities in GVC governance; iv) and finally, resiliency policies designed for strengthening the local economy's resiliency, that is how to ensure that a society's ability to deliver essential goods and services is sufficiently resistant to both local and foreign disruptions. Among these kinds of policies, there are: supply chain and food system stress test; social protection, risk mitigating and risk coping policies; diversification policy; public procurement policy; international cooperation at a bilateral or regional level and to limit export restrictions.

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REFERENCES

Accetturo A., Giunta A., (2016) Global Value Chains and the Great Recession: Evidence from Italian and German Firms. Questioni di Economia e Finanza, n. 304, Banca d'Italia, Rome.

Accetturo A., Giunta A., Rossi S., (2011) The Italian Firms between Crisis and the New Globalization. Occasional Paper, n. 86, Banca d'Italia, Rome.

Acemoglu, D. and Restrepo, P., (2020) Robots and Jobs: Evidence from US Labor Markets. Journal of Political Economy, 128(6): 2188–2244.

Acemoglu, D. and Restrepo, P., (2020) Unpacking Skill Bias: Automation and New Tasks. AEA Papers and Proceedings, 110: 356-61.

Adao, R., Costinot, A., and Donaldson, D., (2017) Nonparametric Counterfactual Predictions in Neoclassical Models of International Trade. American Economic Review, 107(3): 633-689.

Agostino, M., Brancati, E., Giunta, A., Scalera, D., Trivieri, F., (2020) Firm's Efficiency and Global Value Chains: An Empirical Investigation on Italian Industry. *The World Economy*, 43(4): 1000-1033.

Agostino M., Giunta A., Scalera D., Trivieri, F., (2016) Italian Firms in Global Value Chains: Updating our Knowledge. Rivista di Politica Economica, vol. VII-IX: 155-186.

Agostino, M., Giunta A., Nugent J.B., Scalera D., Trivieri F., (2015) The Importance of Being a Capable Supplier. Italian Industrial Firms in Global Value Chains. International Small Business Journal, 33 (7): 708-30.

Aguiar, A., Narayanan, B., and McDougall, R., (2016) An overview of the GTAP 9 data base. Journal of Global Economic Analysis, 1: 181-208.

Ahmed, S., Appendino, M. & Ruta, M., (2017) Global Value Chains and the Exchange Rate Elasticity of Exports, B.E. Journal of Macroeconomics, 17(1): 1-24.

Alfaro, L., Antràs, P., Chor, D. and Conconi, P., (2019) Internalizing Global Value Chains: A Firm-Level Analysis. Journal of Political Economy, 127(2): 509-559.

Altomonte, C., Di Mauro, F., Inferrera, S., (2020) EU Firms participation in GVC: Bliss or curse after COVID?. CompNet, policy brief No. 9.

Altomonte, C., Di Mauro, F., Ottaviano, G., Rungi, A., Vicard, V. (2012) Global Value Chains during the Great Trade Collapse: A Bullwhip effect?. ECB Working Paper No. 1412.

Amador, J. and Cabral, S. (2009) Vertical specialization across the world: a relative measure. The North American Journal of Economics and Finance 20: 267–280.

Amador, J., and Cabral, S. (2016) Global value chains: A survey of drivers and measures. Journal of Economic Surveys, *30*(2): 278-301.

Amin M., Islam A., (2014) Imports of Intermediate Inputs and Country Size. Policy Research Working Paper 6758, The World Bank Development Economics Global Indicators Group.

Amiti, M., and Konings, J., (2007) Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia. American Economic Review 97 (5): 1611–38.

Antimiani, A., Fusacchia, I. and Salvatici, L., (2018a) Value Added Trade Restrictiveness Indexes. Measuring Protection within Global Value Chains. Departmental Working Papers of Economics, University Roma Tre, 238.

Antimiani, A., Fusacchia, I. and Salvatici, L., (2018b) GTAP-VA: An integrated tool for global value chain analysis. Journal of Global Economic Analysis, 3(2): 69–105.

Antonioli, D., Montresor, S., (2021) Innovation persistence in times of crisis: an analysis of Italian firms. Small Bus Econ 56: 1739–1764.

Antràs, P., (2020a) Conceptual Aspects of Global Value Chains. Policy Research Working Paper 9114. World Bank, Washington, DC.

Antràs, P., (2020b) De-Globalisation? Global Value Chains in the Post-COVID-19 Age. NBER Working Paper No. 28115.

Antràs, P. and Chor D., (2021) Global Value Chains, National Bureau of Economic Research, Working Paper 28549, Cambridge, MA.

Antràs, P. and Chor, D., (2013) Organizing the Global Value Chain. Econometrica 81(6): 2127- 2204.

Antràs, P. and D. Chor D., (2018) On the Measurement of Upstreamness and Downstreamness in Global Value Chains. In L. Y. Ing and M. Yu (Eds.), *World Trade Evolution: Growth, Productivity and Employment*, Chapter 5: 126–194. Routledge.

Antras, P., and Staiger, R. W., (2012) Offshoring and the Role of Trade Agreements. American Economic Review, 102 (7): 3140-3183.

Antràs, P., Chor D., Fally T., Hillberry R. , (2012) Measuring the Upstreamness of Production and Trade Flows. American Economic Review Papers and Proceedings 102(3): 412-416.

Antràs, P., Redding, S. J. and Rossi-Hansberg, E., (2020) Globalization and Pandemics. NBER Working Paper No. 27840.

Arriola, C. et al., (2020) Efficiency and risks in global value chains in the context of COVID-19, OECD Economics Department Working Papers, No. 1637, OECD Publishing, Paris.

Artuc, E., Bastos, P., and Rijkers, B., (2018) Robots, Tasks, and Trade. Policy Research Working Paper 8674. World Bank, Washington, DC.

Athukorala, P.C., (2005) Product fragmentation and trade patterns in East Asia. Asian Economic Papers 4: 1–27.

Bacchetta, M., Bekkers, E., Piermartini, R., Rubinova, S., Stolzenburg, V., and Xu, A., (2021) COVID-19 and global value chains: A discussion of arguments on value chain organization and the role of the WTO (No. ERSD-2021-3). WTO Staff Working Paper.

Baldone, S., Sdogati, F. and Tajoli, L., (2001) Patterns and determinants of international fragmentation of production: evidence from outward processing trade between the EU and Central Eastern European countries. Review of World Economics 137: 80–104.

Baldone, S., Sdogati, F. and Tajoli, L., (2007) On some effects of international fragmentation of production on comparative advantages, trade flows and the income of countries. The World Economy 30: 1726–1769.

Balduzzi, P., Brancati, E., Brianti, M. and Schiantarelli, F., (2020) The Economic Effects of COVID-19 and Credit Constraints: Evidence from Italian Firms' Expectations and Plans. IZA Discussion Paper No. 13629.

Baldwin, J., Yan, B., (2014), Global Value Chains and the Productivity of Canadian Manufacturing Firms. Economic Analysis Research Paper Series No. 90

Baldwin, R. and Freeman, R. (2020) Supply chain contagion waves: Thinking ahead on manufacturing contagion and reinfection' from the COVID concussion, VoxEU.org.

Baldwin, R. and Robert-Nicoud, F., (2014) Trade-in-goods and trade-in-tasks: An integrating framework. Journal of International Economics 92(1): 51–62.

Baldwin, R. and Tomiura, E., (2020) Thinking ahead about the trade impact of covid-19. Chapter 5 in Economics in the Time of COVID-19, a VoxEU.org eBook CEPR Press.

Baldwin, R., and Lopez-Gonzalez, J., (2015) Supply-chain Trade: A Portrait of Global Patterns and Several Testable Hypotheses. The World Economy, 38(11): 1682-1721.

Balié, J., Del Prete, D., Magrini, E., Montalbano, P., and and Nenci, S., (2019) Does trade policy impact food and agriculture global value chain participation of sub-Saharan African countries?. American Journal of Agricultural Economics, *101*(3): 773-789.

Banacloche, S., Ángeles Cadarso, M., Monsalve, F., (2020) Implications of measuring value added in exports with a regional input-output table. A case of study in South America. Structural Change and Economic Dynamics, 52: 130-140.

Banerjee, S., Kabir, M., Besnard, J., Nash, J., (2017) Double Dividend: Power and Agriculture Nexus in Sub-Saharan Africa. World Bank Report No. 114112.

Barba Navaretti, G., Bugamelli, M., Schivardi, F., Altomonte, C., Horgos, D., and Maggioni., D., (2011) The global operations of European firms. The second EFIGE policy report. Bruegel Blueprint 12.

Barrett, C. B., (2020) Actions Now Curb Food Systems Fallout from COVID-19. Nature Food, 1(6), 319-320.

Barrientos, S., Gereffi, G., and Rossi, A. (2011) Economic and social upgrading in global production networks: A new paradigm for a changing world. International Labour Review, 150(3-4): 319-340.

Bas, M., and Strauss-Kahn, V., (2014) Does Importing More Inputs Raise Exports? Firm-Level Evidence from France. Review of World Economics, 150(2): 241–475.

Bathelt H., Malmberg M., and Maskell P., (2004) Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. Progress in human geography, 28(1):31-56.

Beghin, J., Maertens, M. and Swinnen, J., (2015) Non-tariff measures and standards in trade and global value chains. Ann. Rev. Resource Econ. 7: 425–450.

Békés, G., Halpern, L., Koren, M., and Muraközy, B. (2011) Still Standing: How European Firms Weathered the Crisis. The third EFIGE policy report, Blueprint 15, Bruegel.

Béné, C., (2020) Resilience of local food systems and links to food security – A review of some important concepts in the context of COVID-19 and other shocks. Food Security 12: 805–822.

Benz, S., M. Larch, and Zimmer, M. (2014) Trade in ideas: Outsourcing and knowledge spillovers. Ifo Working Paper Series 173, Ifo Institute for Economic Research.

Bertulfo, D., Gentile, E., de Vries, G. J., (2019) The Employment Effects of Technological Innovation, Consumption, and Participation in Global Value Chains: Evidence from Developing Asia. ADB Economics Working Paper Series 572, Asian Development Bank.

Blanchard, E. J., C. P. Bown, and Johnson, R. C., (2016) Global supply chains and trade policy. NBER Working Paper 21883.

Bloom, N., Sadun, R. and Van Reenen, J. (2012a) Americans do I.T. better. US multinationals and the productivity miracle. American Economic Review, 102(1): 167–201.

Bloom, N., Genakos, C., Sadun, R. and Van Reenen, J. (2012b) Management practices across firms and countries. Academy of Management Perspectives, 26(1): 12–33.

Bonadio, B., Huo, Z., Levchenko, A., and Pandalai-Nayar, N., (2020) Global Supply Chains in a Pandemic. NBER Working Papers 27224, National Bureau of Economic Research.

Borin, A. and Mancini, M., (2015) Follow the value added: bilateral gross export accounting. Economic Working Papers, No. 1026. Economic Research and International Relations Area. Bank of Italy.

Borin, A. and Mancini, M., (2019) Measuring What Matters in Global Value Chains and Value-Added Trade. World Bank Policy Research Working Paper 8804.

Bown, C.P., Erbahar, A., and Zanardi, M., (2020) Global Value Chains and the Removal of Trade Protection. Working Paper Peterson Institute for International Economics, 20-3.

Brancati E., Brancati, R., Maresca, A., (2017) Global Value Chains, Innovation and Performance: Firm-level Evidence from the Great Recession. Journal of Economic Geography, 17: 1039–1073.

Brancati, E., Pietrobelli, C. and Torres Mazzi, C. (2021) The influence of value-chain governance on innovation performance: A study of Italian suppliers. United Nations University -MERIT Working Papers 2021-017, https://www.merit.unu.edu/publications/working-papers/abstract/?id=8755

Brynjolfsson, E., Xiang, H., and Liu, M., (2019) Does Machine Translation Affect International Trade? Evidence from a Large Digital Platform. Management Science, INFORMS, vol. 65(12): 5449-5460.

Cainelli, G. Ganau, R., Giunta, A., (2018) Spatial agglomeration, Global Value Chains, and productivity. Micro-evidence from Italy and Spain. Economics Letters 169: 43-46.

Caliendo, L., Parro, F., (2015) Estimates of the Trade and Welfare Effects of NAFTA. The Review of Economic Studies, 82(1): 1–44.

Campa, J. and Goldberg, L. S., (1997) The evolving external orientation of manufacturing: a profile of four countries. Federal Reserve Bank of New York Economic Policy Review 3: 53–81.

Caselli, F., Koren, M., Lisicky, M., and Tenreyro, S., (2020) Diversification through trade. The Quarterly Journal of Economics, 135(1): 449-502.

CEPAL, (2016) The South American input-output table: Key assumptions and methodological considerations. Documentos de Proyectos 722, Naciones Unidas Comisión Económica para América Latina y el Caribe.

Chang, J.H., (2016) Asean in Tranformation: the future of job at risk of automation. ILO, Bureau for Employers' Activities, Working Paper No 9.

Chaudhuri, S., Banerjee, D., (2010) FDI in agricultural land, welfare and unemployment in a developing economy. Research in Economics, Elsevier, vol. 64(4): 229-239.

Chen, H., Kondratowicz, M. and Yi, K.-M. (2005) Vertical specialization and three facts about US international trade. The North American Journal of Economics and Finance 16: 35–59.

Chen, H.-Y. and Chang, Y.-M. (2006) Trade verticality and structural change in industries: the cases of Taiwan and South Korea. Open Economies Review 17: 321–340.

Chongvilaivan, A., Thangavelu, S.M., (2012) Does Outsourcing Provision Lead to Wage Inequality? New Evidence from Thailand's Establishment-level Data, Review of International Economics, 20(2): 364-376.

Christiaensen, L., Rutledge, Z., & Taylor, J. E., (2021) The future of work in agri-food. Food Policy, 99, 101963.

Clark, D., (2006) Country and industry-level determinants of vertical specialization-based trade. International Economic Journal 20: 211–225.

Colen, L., Maertens, M. and Swinnen, J. (2012) Private Standards, Trade and Poverty: GlobalGAP and Horticultural Employment in Senegal. The World Economy 35(8):1073–88.

Constantinescu, C., Mattoo, A., and Ruta, M., (2019) Does vertical specialization increase productivity? The World Economy, 42: 2385–2402.

Costinot, A., Rodríguez-Clareb , A., (2014) Trade Theory with Numbers: Quantifying the Consequences of Globalization. Handbook of International Economics, 4: 197-261.

Criscuolo, C. and Timmis, J., (2017) The Relationship Between Global Value Chains and Productivity. International Productivity Monitor, 32: 61–83.

Daudin, G., Rifflart, C., Schweisguth, D., (2011) Who produces for whom in the world economy?. Canadian Journal of Economics, 44, (3): 1403-1437.

Davis, D., Kaplinsky R., and Morris, M., (2018) Rents, Power and Governance in Global Value Chains". Journal of World Systems Research.

Davis, J. H. and Goldberg, (1957) A Concept of Agribusiness. Boston, USA: Division of Research, Graduate School of Business Administration, Harvard University.

De Backer, K. and Miroudot, S., (2013) Mapping global value chains. OECD Trade Policy Papers, No. 159, OECD Publishing.

De Marchi V., Di Maria E., Gereffi, G. (Eds.), 2018, Local

Clusters in Global Value Chains: Linking Actors and Territories, Routledge.
de Oliveira, J. A. P., (Ed.) (2008) Upgrading clusters and small enterprises in developing countries: Environmental, labor, innovation and social issues. Ashgate Publishing, Ltd.
De Vries, G., Chen, Q., Hasan, R., Li, Z., (2016) Skills and Activity Upgrading in Global Value Chains: Trends and Drivers for Asia. Asian Development Bank Economics Working Paper Series No. 496.
De Vries, G., Chen, Q., Hasan, R., Li, Z., (2019) Do Asian Countries Upgrade in Global Value Chains? A Novel Approach and Empirical Evidence. Asian Economic Journal 33(1): 13-37.
Del Prete D., Giovannetti G., Marvasi, E., (2017) Global Value Chain Participation and Productivity Gains for North African Firms. Review of the World Economy, 153: 675-701.
Del Prete, D., Giovannetti, G., Marvasi, E., (2018) Global value chains: New evidence for North Africa. International Economics, 153: 42-54.
Del Prete, D., Rungi, A., (2017) Organizing the global value chain: A firm-level test. Journal of International Economics, 109: 16-30.
Dellink, R., Dervisholli, E. and Nenci, S., (2020) A quantitative analysis of trends in agricultural and food global value chains (GVCs). Background paper for The State of Agricultural Commodity Markets 2020. ISBN 978-92-5-133211-5, Rome, FAO.
Di Nino, V., Veltri, B., (2020) The viral effects of foreign trade and supply networks in the euro area, Economic Bulletin Articles, European Central Bank, vol. 6.
Diakantoni, A., Escaith, H., Roberts, M. and Verbeet, T., (2017) Accumulating Trade Costs and Competitiveness in Global Value Chains. WTO Working Paper, Economic Research and Statistics Division, 02.
Dollar, D., (2019) Technological innovation, supply chain trade, and workers in a globalized world. Global Value Chain Development Report, 1.
Egger, H. and Egger, P., (2001) Cross-border sourcing and outward processing in EU manufacturing. The North American Journal of Economics and Finance 12: 243–256.
Egger, H. and Egger, P., (2003) Outsourcing and skill-specific employment in a small economy: Austria after the fall of the Iron Curtain. Oxford Economic Papers 55: 625–643.
Egger, H. and Egger, P., (2005) The determinants of EU processing trade. The World Economy 28: 147–168.
Elms, D.K., Low, P., (2013) Global Value Chains in a changing World. WTO Publication.
Enderwick, P., and Buckley, P. J., (2020) Rising regionalization: will the post-COVID-19 world see a retreat from globalization?. Transnational Corporations Journal, 27(2).
Eppinger, P., Felbermayr, G. J., Krebs, O. and Kukharskyy, B., (2020) COVID-19 Shocking Global Value Chains. CESifo Working Paper No. 8572.
Espitia, A., Mattoo, A., Rocha, N., Ruta, M. and Winkler, D., (2021) Pandemic trade: COVID-19, Remote Work and Global Value Chains. Policy Research working paper no. WPS 9508, World Bank.
Fagerberg, J., Lundvall, B., and Shrolec, M., (2018) Global value chains, national innovation systems and economic development. The European Journal of Development Research, 30(3): 533–556.
Fajgelbaum, D., Khandelwal, K. A., (2016) Measuring the Unequal Gains from Trade. The Quarterly Journal of Economics, 131(3): 1113-1180.
Fally, T. (2012) Production Staging: Measurement and Facts, mimeo UC Berkeley.
Fally, T. and Hillberry, R., (2015) A coasian model of international production chains. The World Bank.
Feenstra, R.C., (2017) Statistics to Measure Offshoring and its Impact. NBER Working Paper, 23067.
Feenstra, R.C. and Hanson, G.H., (1996) Globalization, outsourcing, and wage inequality. American Economic Review 86: 240–245.
Feenstra, R.C. and Jensen, J.B., (2012) Evaluating estimates of materials offshoring from US manufacturing. Economics Letters 117: 170–173.
Feenstra, R.C., Hanson, G.H. and Swenson, D.L., (2000) Offshore assembly from the United States: production characteristics of the 9802 program, In R. C. Feenstra (ed.). The Impact of International Trade on Wages (chapter 3, pp. 85–125). Chicago, IL: University of Chicago Press.
Fortunato, P., (2020) How COVID-19 is changing global value chains, UNCTAD, September. URL: https://unctad.org/news/how-covid-19-changing-global-valuechains.
Foster-McGregor,N. and Stehrer, R., (2013) Value added content of trade: a comprehensive approach. Economics Letters 120: 354–357.
Fracasso, A., and Vittucci Marzetti, G., (2015) International trade and R&D spillovers. Journal of International Economics, 96(1): 138-149.
Fusacchia, I., Antimiani, A. and Salvatici, L., (2021) An assessment of import tariff costs for Italian exporting firms. Economia Politica, 38: 31-56. [10.1007/s40888-020-00202-8].
Gaulier, G., Lemoine, F. and Unal Kesenci, D., (2007) China's emergence and the reorganization of trade flows in Asia. China Economic Review 18: 209–243.

Gereffi, G. and Lee, J. (2009) A global value chain approach to food safety and quality standards global health diplomacy for chronic disease prevention. Working Paper Series, February.

Gereffi, G., and Lee, J. (2016) Economic and social upgrading in global value chains and industrial clusters: Why governance matters. Journal of business ethics, 133(1): 25-38.

Gereffi, G., Fernandez-Stark, K., (2011) The offshore services value chain: upgrading trajectories in developing countries. International Journal of Technological Learning, Innovation and Development, vol. 4 (1/2/3): 206-234.

Gereffi, G., Humphrey, J., and Sturgeon, T., (2005) The governance of global value chains. Review of International Political Economy, *12*(1), 78–104. https://doi.org/10.1080/09692290500049805

Gereffi, G., Ponte, S., and G. Raj-Reichert (2019) Handbook on Global Value Chains. Edward Elgar Publishing.

Giovannetti, G., Marvasi, E., (2016) Food exporters in Global Value Chains: Evidence from Italy. Food Policy 59: 110–125.

Giovannetti, G., Marvasi, E., Sanfilippo, M., (2015) Supply Chains and the Internationalization of Small Firms. Small Business Economics, 44: 845–865.

Giuliani, E., Pietrobelli, C., and Rabellotti, R., (2005) Upgrading in global value chains: Lessons from Latin American clusters. World Development, *33*(4): 549–573. https://doi.org/10.1016/j.worlddev.2005.01.002

Giunta, A., Montalbano, P., and Nenci, S., (2021) The Micro and the Macro of Global Value Chains: Evidence from selected European countries, mimeo.

Goldberg, P.K. & Pavcnik, N., (2016) The Effects of Trade Policy. In Bagwell K. and Staiger R.W. (eds.) Handbook of Commercial Policy, Vol. 1A: 161-206.

Görg, H., (2000) Fragmentation and trade: US inward processing trade in the EU. Weltwirtschaftliches Archiv 127(3): 403–422.

Greenville, J., Beaujeu, R. and Kawasaki, K., (2016) GVC participation in the agriculture and food sectors: draft report. OECD Trade and Agriculture Directorate Working Paper.

Greenville, J., Kawasaki, K. and Beaujeu, R., (2017) A method for estimating global trade in value added within agriculture and food value chains. OECD Food, Agriculture and Fisheries Papers, 99, OECD Publishing, Paris.

Greenville, J., Kawasaki, K., & Beaujeu, R., (2017) How policies shape global food and agriculture value chains. OECD Food, Agriculture and Fisheries Papers, No. 100, OECD Publishing, Paris.

Grossman, G.M., and Rossi-Hansberg, E., (2008) Trading tasks: A simple theory of offshoring. American Economic Review, 98(5): 1978–97.

Hallward-Driemeier, M., Nayyar, G., (2017) Trouble in the Making? : The Future of Manufacturing-Led Development. Washington, DC: World Bank.

Halpern, L., Koren, M. and Szeidl, A., (2015) Imported inputs and productivity. American Economic Review, 105(12): 3660–3703.

Hayakawa, K and H Mukunoki (2021) Impacts of COVID-19 on International Trade: Evidence from the First Shock. Journal of the Japanese and International Economies 60: 101135.

Helg, R. and Tajoli, L., (2005) Patterns of international fragmentation of production and the relative demand for labor. The North American Journal of Economics and Finance 16: 233–254.

Hijzen, A., (2005) A bird's eye view of international outsourcing: data, measurement and labour demand effects. Economie Internationale 104: 45–63.

Hopkins, T. K. and Wallerstein, I., (1986) Commodity chains in the world-economy prior to 1800. Review 10(1): 157–170.

Hummels, D., Ishii, J. and Yi, K.-M., (2001) The nature and growth of vertical specialization in world trade. Journal of International Economics 54: 75–96.

Humphrey, J. and Memedovic, O., (2006) Global value chains in the agrifood sector. UNIDO Working Papers.

Humphrey, J. and Schmitz, H., (2002) How does insertion in global value chains affect upgrading industrial clusters?. Regional Studies, Vol. 36, No.9.

Inferrera, S., (2021) Globalisation in Europe: Consequences for the business environment and future patterns in light of Covid-19. IWH-CompNet Discussion Papers, No. 2/2021

Javorcik, B., (2020) Global supply chains will not be the same in the post-COVID-19 world. In Baldwin RE, Evenett, S.J. (Eds.), COVID-19 and Trade Policy: Why Turning Inward Won't Work, CEPR Press: 111–116.

Jiang, H., (2021) The role of panel data in organization of global value chain: evidence from a developing country. Applied Economics Letters, 28 (7): 546-550.

Johnson, R.C., (2014) Five Facts about Value-Added Exports and Implications for Macroeconomics and Trade Research. Journal of Economic Perspectives, 28(2): 119-142.

Johnson, R.C., and Noguera, G., (2012) Accounting for intermediates: Production sharing and trade in value added. Journal of International Economics, 86(2): 224-236.

Kano, L., Tsang, E. W., and Yeung, H. W. C., (2020). Global value chains: A review of the multi-disciplinary literature. Journal of International Business Studies: 1-46.
Kaplinsky, R., (2019) Rents and Inequality on Global Value Chains. In S. Ponte, G. Gereffi, & G. Raj-Reichert (Eds.), Handbook on Global Value Chains (370–384). Edward Elgar Publishing.
Kaplinsky, R., and Morris, M., (2016) Thinning and Thickening: Productive Sector Policies in The Era of Global Value Chains. European Journal of Development Research 28: 625–645.
Karp, L. S., and Jeffrey, M. P., (1993) A dynamic model of oligopoly in the coffee export market. American Journal of Agricultural Economics 75: 448–457.
Kasahara, H., and Rodrigue, J., (2008) Does the Use of Imported Intermediates Increase Productivity? Plant-Level Evidence. Journal of Development Economics 87(1): 106–18.
Katz, J., and Pietrobelli, C., (2018) Natural resource-based growth, global value chains and domestic capabilities in the mining industry. Resources Policy, 58: 11-20.
Kee, H. L., and Tang, H., (2016) Domestic Value Added in Exports: Theory and Firm Evidence from China. American Economic Review, 106 (6): 1402-36.
Kimura, F., (2002) Subcontracting and the Performance of Small and Medium firms in Japan. Small Business Economics 18(1): 163–175.
Knorringa, P., Pegler, L., (2006) Globalisation, firm upgrading and impacts on labour. Tijdschrift voor economische en sociale geografie 97(5): 470-479.
Koopman, R., Powers, W., Wang, Z., Wei, S.-J, (2010) Give Credit Where Credit is Due: Tracing Value Added in Global Production Chains. NBER Working Paper No. 16426.
Koopman, R., Wang, Z., and Wei, S., (2012) Estimating domestic content in exports when processing trade is pervasive. Journal of Development Economics.
Koopman, R., Wang, Z., and Wei S.-J., (2014) Tracing Value-Added and Double Counting in Gross Exports. American Economic Review 104 (2), 459–494.
Kowalski, P., et al., (2015) "Participation of Developing Countries in Global Value Chains: Implications for Trade and Trade-Related Policies". OECD Trade Policy Papers, No. 179, OECD Publishing, Paris.
Kummritz, V., (2016) Do Global Value Chains Cause Industrial Development?. Centre for Trade and Economic Integration, The Graduate Institute.
Lauret, F., (1983) Sur les études de filières agroalimentaire. Economie et Sociétés 17: 721–740.
Lema, R., Pietrobelli, C., Rabellotti, R., and Vezzani, A., (2021) Deepening or delinking? Innovative capacity and global value chain participation in the IT industry. Industrial and Corporate Change.
Lema, R., Pietrobelli, C., and Rabellotti, R., (2019) Innovation in global value chains. In S. Ponte, G. Gereffi, & G. Raj-Reichert (Eds.), Handbook on Global Value Chains (370–384). Edward Elgar Publishing.
Lema, R., Rabellotti, R., and Gehl Sampath, P., (2018), Innovation Trajectories in Developing Countries: Co-evolution of Global Value Chains and Innovation Systems. The European Journal of Development Research, 30(3): 345–363.
Lemoine, F. and Unal Kesenci, D., (2004) Assembly trade and technology transfer: the case of China. World Development 32: 829–850.
Lenzen, M., K. Kanemoto, K., Moran, D., Geschke, A., (2012) Mapping the structure of the world economy. Environ. Sci. Technol., 46: 8374-8381.
Lenzen, M., K. Kanemoto, K., Moran, D., Geschke, A., (2013) Building Eora: a global multi-region input–output database at high country and sector resolution. Econ. Syst. Res., 25: 20-49.
Li, S. A., Pan, S. Chi, S. (2016) North-south FDI and directed technological change. Economic Modelling, 59(8): 425-435.
Liapis, P. and Tsigas, M., (2014) Trade in value added of agricultural and food products. Mimeo.
Lopez-Garcia, P., Di Mauro, F., (2015) Assessing European Competitiveness: The New CompNet Microbased Database. ECB Working Paper No. 1764.
Lopez Gonzalez, J., (2016) Using Foreign Factors to Enhance Domestic Export Performance: A Focus on Southeast Asia. OECD Trade Policy Papers, No. 191, OECD Publishing, Paris. http://dx.doi.org/10.1787/5jlpq82v1jxw-en.
Los, B., Timmer, M.P, and De Vries. G. J., (2015) How Global Are Global Value Chains? A New Approach to Measure International Fragmentation. Journal of Regional Science, 55(1): 66–92.
Luck, P., (2019) Global supply chains, firm scope and vertical integration: Evidence from China, Journal of Economic Geography, 19 (1): 173-198.
Ludema, R. D., Mayda, A., Yu, M., Yu, Z., (2019) The political economy of protection in GVCs: Evidence from Chinese micro data. CEPR Discussion Papers 14156.
McCorriston, S. and Sheldon, I. M. (2011) Tariff (De-) escalation with successive oligopoly. Review of Development Economics 15: 587–600.
McCullough, E., Pingali, P. and Stamoulis, K. (eds) (2008). The Transformation of Agri-Food Systems: Globalization, Supply Chains and Smallholder Farmers. London, UK: Earthscan.

Mehta, A. and Hasan, R. (2012) The effects of trade and services liberalization on wage inequality in India. International Review of Economics & Finance. Elsevier, 23(C): 75-90.

Meliciani, V., Tchorek, G., (2019) Internationalization strategy, financial constraints and assets (in)tangibility. A study of euro area countries after the 2008 crisis. Journal of International Trade and Economic Development, 28(2): 161-188.

Milberg, W., Winkler, D., (2010) Trade Crisis and Recovery : Restructuring of Global Value Chains. Policy Research working paper. no. WPS 5294. World Bank.

Miller, R., E. and Temurshoev, U., (2017) Output Upstreamness and Input Downstreamness of Industries/Countries in World Production. International Regional Science Review 40(5): 443-475.

Minor, P., and Walmsley, T., (2017) Reversing NAFTA: A Supply Chain Perspective. Working Paper 007, ImpactEcon. https://impactecon.com/ wp-content/uploads/2017/02/NAFTA-Festschrift-Paper-1.pdf.

Miroudot, S. (2020) Resilience versus robustness in global value chains: Some policy implications. In Baldwin, R. E. and Evenett, S. J. (eds.), COVID-19 and Trade Policy: Why Turning Inward Won't Work, Geneva: VoxEU & CEPR.

Miroudot, S., and Cadestin, C., (2017) Services in Global Value Chains: From Inputs to Value-Creating Activities. OECD Trade Policy Papers, No. 197, OECD Publishing

Miroudot, S., Lanz, R., Ragoussis, A., (2009) Trade in Intermediate Goods and Services. OECD Trade Policy Papers, No. 93, OECD Publishing, Paris.

Montalbano, P., Nenci, S., Pietrobelli, C., (2018b) Opening and Linking up: Firms, GVCs and Productivity in Latin America. Small Business Economics, 50 (4): 917-935.

Montalbano, P., (2011) Trade openness and developing countries' vulnerability: concepts, misconceptions, and directions for research. World Development, 39(9): 1489-1502.

Montalbano, P. and Nenci, S., (2020a) The effects of global value chain (GVC) participation on the economic growth of the agricultural and food sectors. Background paper for The State of Agricultural Commodity Markets 2020. ISBN 978-92-5-133200-9, FAO, Rome.

Montalbano, P. and Nenci, S., (2020b) Countries' participation in agri-food value chains: A global assessment and the implications of the COVID-19 pandemic. Ag4Dev - Agriculture for Development, ISSN 1759-0612, n.41, 2020.

Montalbano, P. and Nenci, S., (2022) Does the participation and positioning of Global Value Chains in the agriculture and food sectors affect economic performance? A global assessment, Food Policy, 108, 102235.

Montalbano, P., Pietrelli, R., and Salvatici, L., (2018a) Participation in the market chain and food security: The case of the Ugandan maize farmers. Food Policy, 76: 81-98.

Morrison, A., Pietrobelli, C., and Rabellotti, R., (2008) Global Value Chains and Technological Capabilities: A Framework to Study Learning and Innovation in Developing Countries. Oxford Development Studies, 36(1),39–58. https://doi.org/10.1080/13600810701848144

Morton, J., (2020) On the Susceptibility and Vulnerability of Agriculture Value Chains to COVID-19. World Development 136(2):105132.

Mukherjee, D., (2018) Services traded for intermediate and final usage: An analysis of the role of services FTAs and restrictions, Journal of Economic Studies.

Muradov, K., (2017) Trade Costs and Borders in Global Value Chains. Review of World Economics (Weltwirtschaftliches Archiv), 153: 487- 509.

Nenci, S., (2020) Mapping global value chain (GVC) participation, positioning and vertical specialization in agriculture and food. Technical note for The State of Agricultural Commodity Markets (SOCO), ISBN 978-92-5-133263-4, FAO, Rome.

Ng, F. and Yeats, A.J., (1999) Production sharing in East Asia: who does what for whom, and why?. Policy Research Working Paper Series 2197. The World Bank.

OECD, (2017) The Future of Global Value Chains: Business as Usual or "A New Normal"?. OECD Science, Technology and Industry Policy Papers, No. 41.

OECD, (2018) METRO Development: The ICIO-TIVA-Module. A Method to Analyse Global Value Chains with METRO. TAD/TC/CA/WP/RD(2018)1.

OECD, (2020a) Coverage and representativeness of Orbis data. OECD Science, Technology and Industry Working Papers 2020/06.

OECD, (2020c) COVID-19 and Global Value Chains: Policy Options to Build More Resilient Production Networks.

OECD, (2016) Evolving Agricultural Policies and Markets: Implications for Multilateral Trade Reform. OECD Publishing, Paris.

OECD, (2020b) Shocks, risks and global value chains: insights from the OECD METRO model. http://www.oecd.org/trade/documents/shocks-risks-gvc-insights-oecd-metro-model.pdf

Olper, A., Curzi, D. and Raimondi, V., (2017) Imported intermediate inputs and firms' productivity growth: Evidence from the food industry. Journal of Agricultural Economics. 68 (1): 280-300.

Otsuki, T., (2011) Effect of International Standards Certification on Firm-Level Exports: An Application of the Control Function Approach. Osaka School of International Public Policy Discussion Paper No. 11E005

Owen, A., Wood, R., Barrett, J., Evans, A., (2016) Explaining value chain differences in MRIO databases through structural path decomposition. Economic Systems Research, 28(2): 243-272.

Pahl, S., Brandi, C., Schwab, J., Stender, F., (2021) Cling Together, Swing Together: The Contagious Effects of COVID-19 on Developing Countries Through Global Value Chains. The World Economy. DOI: 10.1111/twec.13094.

Piermartini, R. and Rubínová. S., (2014) Knowledge spillovers through international supply chains. WTO Working Papers 2014-11. World Trade Organization.

Pietrobelli, C., Marin, A., Olivari, J., (2018) Innovation in mining value chains: New evidence from Latin America. Resources Policy, 58: 1-10,

Pietrobelli, C., and Rabellotti, R., (2007) Upgrading to compete: SMEs, clusters and value chains in Latin America. Harvard University Press, Cambridge, MA.

Pietrobelli, C., and Rabellotti, R., (2011) Global Value Chains Meet Innovation Systems: Are There Learning Opportunities for Developing Countries? World Development, *39*(7): 1261–1269.

Ponte S., Gereffi G, Raj-Reichert G., (2019) Handbook on Global Value Chains, Edward Elgar Publishing, Cheltenham

Porter, M., (1990) The Competitive Advantage of Nations. Boston, MA: Harvard Business School Press.

Rahman, J. and Zhao, T., (2013) Export Performance in Europe: What Do We Know from Supply Links? IMF Working Paper, No. 13/62.

Raimondi, V., Piriu, A., Swinnen, J., and Olper, A., (2021) Global Value Chain and Trade Policy in the Agri food Sector, mimeo.

Razzolini, T. and Vannoni, D., (2011) Export Premia and Subcontracting Discount: Passive Strategies and Performance in Domestic and Foreign Markets. World Economy 34(6): 984–1013.

Reardon, T., and Swinnen, J., (2020) COVID-19 and resilience innovations in food supply chains, in: COVID-19 and global food security, chapter 30: 132-136, International Food Policy Research Institute (IFPRI).

Reardon, T., Bellemare, M. F., and Zilberman, D., (2020) How COVID-19 may disrupt food supply chains in developing countries. *IFPRI book chapters*, 78-80.

Rodrik, D., (2018) New Technologies, Global Value Chains, and Developing Economies, National Bureau of Economic Research Working Paper No. 25164.

Rouzet, D., and Miroudot, S., (2013) The Cumulative Impact of Trade Barriers along the Value Chain: An Empirical Assessment using the OECD Inter-Country Input-Output Model. Paper presented at the 16th Annual Conference on Global Economic Analysis, Shanghai, China. Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP).

Ruta, M., (2017) Preferential trade agreements and global value chains: Theory, evidence, and open questions. World Bank Policy Research Working Paper 8190, Washington DC.

Salvatici, L., (2020) Assessing the impact of trade and other policies on global value chain (GVC) participation, positioning and vertical specialization in agriculture and food. Background paper for The State of Agricultural Commodity Markets (SOCO) 2020.

Salvatici, L. and Nenci, S., (2017) New features, forgotten costs and counterfactual gains of the international trading system, (con L. Salvatici). In European Review of Agricultural Economics, Volume 44, Issue 4, 1 September.

Scoppola, M., (2007) Disciplining exporting state trading enterprises under economies of scale and oligopoly. European Review of Agricultural Economics 34(4): 429–459.

Scoppola, M., (2021) Globalisation in agriculture and food: the role of multinational enterprises. European Review of Agricultural Economics, 48(4), 741-784.

Seker, M., (2011) Trade policies, investment climate and exporters, The World Bank.

Sexton, R. J., (2012) Implications of Modern Agricultural Markets. Seattle, WA: AAEA.

Sforza, A. and Steininger, M., (2020) Globalization in the Time of COVID-19. CESifo Working Paper No. 8184.

Shen, C. and Zheng, J. (2020) Does global value chains participation really promote skill-biased technological change? Theory and evidence from China. Economic Modelling, Elsevier, vol. 86(C).

Simola, H., (2021) The impact of Covid-19 on global value chains. BOFIT Policy Brief No. 2.

Stadler, K., Wood, R., Bulavskaya, T., Södersten, C.-J. , Simas, M., Schmidt, S., (2018) EXIOBASE 3: developing a time series of detailed environmentally extended multi-regional input-output tables. Journal Ind. Ecol., 22: 502-515.

Stapleton, K. and Webb, M., (2020) Automation, Trade and Multinational Activity: Micro Evidence from Spain.

Swenson, D.L. (2005) Overseas assembly and country sourcing choices. Journal of International Economics 66: 107–130.

Swinnen, J. and Maertens, M. (2007) Globalization, privatization, and vertical coordination in food value

chains in developing and transition countries. Agricultural Economics 37(2): 89–102.
Tajoli, L., and Felice, G., (2018) Global Value Chains Participation and Knowledge Spillovers in Developed and Developing Countries: An Empirical Investigation. The European Journal of Development Research, Palgrave Macmillan. European Association of Development Research and Training Institutes (EADI), vol. 30(3): 505-532.
Timmer, M.P, Erumban, A.A., Los, B., Stehrer, R., and De Vries, G.J., (2014) Slicing Up Global Value Chains. Journal of Economic Perspectives, 28(2): 99-118.
Timmer, M.P., Los, B., Stehrer, R. and de Vries, G.J., (2013) Fragmentation, incomes and jobs: an analysis of European competitiveness. Economic Policy 28: 613–661.
Topalova, P. and Khandelwal, A., (2011) Trade Liberalization and Firm Productivity: The Case of India. Review of Economics and Statistics 93(3): 995–1009.
Trefler, D., Zhu, S.C., (2010) The structure of factor content predictions. Journal of International Economics, Elsevier, 82(2): 195-207.
Veugelers, R. , Barbiero, F., Blanga – Gubbay, M., (2013) Meeting the Manufacturing Firms Involved in GVCs, in Veugelers R. (ed.), Manufacturing Europe's Future, Bruegel Blueprint Series, vol. XXI: 108-138
Volpe-Martincus, C., Castresana, S., and Castagnino, T. (2010) ISO Standards: A Certificate to Expand Exports? Firm-Level Evidence from Argentina. Review of International Economics, 18(5): 896-912.
Walmsley, T., Hertel, T.W. and Hummels, D. (2014) Developing a GTAP-based Multi-region, Input–Output Framework for Supply Chain Analysis. In B. Ferrarini and D. Hummels (Eds), Asia and Global Production Networks. Implications for Trade, Incomes and Economic Vulnerability: 16-80. Cheltenham, UK: Edward Elgar and Asian Development Bank.
Wang, J., (2020) Robot adoption, trade, and offshoring: A firm-level analysis. Mimeo Harvard University.
Wang, Z., and Sun, Z., (2021) From globalization to regionalization: The United States, China, and the post-Covid-19 world economic order. Journal of Chinese Political Science, 26(1): 69-87.
Wang, Z., Wei, S., Yu, X. and Zhu, K., (2017) Measures of Participation in Global Value Chains and Global Business Cycles, NBER Working Paper 23222.
Wang, Z., Wei, S.J., Zhu, K., (2013) Quantifying International Production Sharing at the Bilateral and Sector Levels. NBER Working Paper 19677.
World Bank, (2015) Interwoven: How the Better Work Program Improves Job and Life Quality in the Apparel Sector, Washington, DC: The World Bank.
World Bank, (2020) World Development Report: Trading for Development in the Age of Global Value Chains. World Bank Publications, Washington, DC.
WTO, (2020) Trade set to plunge as COVID-19 pandemic upends global economy, Press/855Press Release.
Xing, Y., (2012) Processing trade, exchange rates and China's bilateral trade balances. Journal of Asian Economics 23: 540–547.
Yeats, A.J., (1998) Just How Big is Global Production Sharing?. Policy Research Working Paper, 1871, World Bank, Washington, DC.
Yi, K.-M., (2003) Can Vertical Specialization Explain the Growth of World Trade?. Journal of Political Economy, 111(1): 52-102.
Yi, K-M., (2009) The Collapse of Global Trade: The Role of Vertical Specialisation. In The Collapse of Global Trade, Murky Protectionism, and the Crisis: Recommendations for the G20, Richard Baldwin and Simon Evenett, eds:45-48.
Zhang, X. and Sun, J., (2007) An analysis of China's global industrial competitive strength based on vertical specialization. Frontiers of Economics in China 2: 57–73.

APPENDIX

1A. Firm-level datasets

Examples of firm level datasets include: the CompNet database that collects indicators computed by national data providers using firm-level data, covering variables referred to competitiveness, finance, labour, productivity and trade. It includes firms from 19 European countries and 56 sectors, ranging from 1999 to 2017 (among papers using this dataset, see Inferrera, 2021; Lopez-Garcia and di Mauro, 2015; Altomonte et al., 2020). Similarly, the EFIGE database combines measures of firms' international activities (such as exports, outsourcing, FDI, imports) with quantitative and qualitative information on about 150 items ranging from R&D and innovation, labour organization, financing and organizational activities, and pricing behaviour. Data consists of a representative sample of almost 15,000 surveyed firms (above ten employees) in seven European economies. Data were collected in 2010, covering the years from 2007 to 2009 (see, among others, Barba Navaretti et al., 2011; Accetturo and Giunta, 2011; Cainelli et al., 2018; Meliciani et al., 2019; Giunta et al., 2021).

Additional works focusing on developing countries have used the World Bank Enterprise Survey (WBES). It provides detailed information on the characteristics of firms across several dimensions, including size, owner-

Table 1A. Main datasets for research on GVCs at the firm level.

Firm-level data (used for GVC analyses)						
EFIGE	Bruegel with the support of the European Commission	Survey	2007-2009	15,000 firms	Manufacturing	Barba Navaretti et al., (2011); Accetturo and Giunta, (2011); Cainelli et al., (2018); Meliciani et al. (2019)
CompNet	European Central Bank	Account statistics, Business registry, Surveys, and Balance sheets	1999-2017	19	56	Inferrera, (2021); Lopez-Garcia and di Mauro, (2015); Altomonte et al.(2020)
Dun & Brandstreet's WorldBase	Dun & Bradstreet			190		Alfaro et al., (2019)
Orbis	Bureau van Dijk	Balance sheets		400 million firms		Bloom et al. (2012a), (2012b); Del Prete et al., (2017)
World Bank Enterprise Survey	World Bank	Survey		174,000 firms		Seker (2011); Amin et al. (2014)
MET	Monitoraggio Economia e Territorio (MET)	Survey	2008, 2009, 2011, 2013, 2015, 2017, 2019	25,000 firms per year observed	38	Giovannetti et al. (2015) Balduzzi et al. (2020); Antonioli et al. (2021)

Source: Authors' elaboration.

ship, trading status, and performances for over 135,000 firms belonging to the manufacturing and services sectors interviewed in 139 countries since 2005 under a common global methodology (see, among others, Montalbano et al., 2018b). Some works also took advantage of the Orbis database provided by the Bureau Van Dijk. It contains data for more than 100 countries covering more than 400 million private and public companies worldwide (with about 120 in Europe, 100 in North and South America, and 80 in Asia), and collecting data primarily from balance sheets (see, among others, Del Prete and Rungi, 2017). Although the huge set of information, the main disadvantage is that the firms included in Orbis represent only a fraction of the entire firm population and, most importantly, they do not form a representative sample (OECD, 2020a). Among commercial databases, we also find the Dun & Brandstreet's WorldBase that provides comprehensive coverage of public and private companies and has been used in the empirical literature (Alfaro et al., 2019). Finally, for the Italian case, it is worth mentioning the MET survey. It is carried out every two years. It collects information on a representative sample of around 25,000 Italian manufacturing firms. It also encompasses micro-sized companies (with less than 10 employees). Waves cover the years: 2008, 2009, 2011, 2013, 2015, 2017 and 2019 (see, among others, Brancati et al., 2017; Agostino et al., 2020; Giovannetti et al., 2015; Giovannetti and Marvasi, 2016).

2A. Country and sectoral level datasets

One of the most widely used country-sectoral datasets is the World Input-Output Database (WIOD) which has been developed thanks to a consortium of 11 institutions led by researchers at the University of Groningen. It covers 43 countries (including OECD and emerging countries) and 56 industries from 2000-2014 (Release 2016). Moreover, it is based on official national account statistics and refers to end-use classification to allocate flows across partners and countries. As a result, it has been extensively used in the literature (see, among others, Baldwin and Lopez-Gonzales, 2015; Costinot and Rodrìguez-Clare, 2014; Timmer et al., 2013; Wang et al., 2013; Koopman et al., 2014; Johnson, 2014; Los et al., 2015; Adao et al., 2017; Fajgelbaum et al., 2016; Timmer et al., 2014).

The ADB multi-region I-O database (ADB MRIO) has been developed by the Asian Development Bank and used in the literature (see De Vries et al., 2016; De Vries et al., 2019). It is basically an extension of the WIOD and includes five additional Asian economies – Bangladesh, Malaysia, Philippines, Thailand and Vietnam – for the years 2000 and 2007-2019. Importantly, the data provided for these countries are derived from estimations produced by researchers and do not refer to official statistics.

Another important source of data is the OECD-WTO Trade in Value Added (TiVA) database. It embodies the national I-O tables from 2005 to 2018 for 45 industries and 64 countries, 27 of which are non-OECD member economies (most East and South-east Asian economies and a selection of South American countries). It provides useful indicators on value-added exports and other measures of the global supply chain used in the empirical studies (De Backer and Miroudot, 2013; Miroudot et al., 2017; Mukherjee, 2018).

The data source presenting the broadest coverage in terms of countries is the Eora Global Supply Chain Database, constructed by a team of researchers at the University of Sydney (Lenzen et al, 2012; and Lenzen et

Table 2A. Public Datasets for research on GVCs at the country and sectoral level.

Country and sectoral level						
Project	Institution	Data Sources	Years	Countries	Industries	Related Papers
Wordl Input-Output Database (WIOD)	EU-based consortium	National Supply-Use tables	2000-2014	43	56	Baldwin and Lopez-Gonzales, (2015); Costinot and Rodrìguez-Clare, (2014); Timmer et al., (2013); Wang et al., (2013); Koopman et al., (2014); Johnson, (2014); Los et al., (2015); Adao et al., (2017); Fajgelbaum et al., (2016); Timmer et al., (2014)
Traded In value Added (TiVA) dataset	OECD	National I-O tables	1995-2018	64	45	De Backer and Miroudot, (2013); Miroudot et al. (2017); Muckherjee, D. (2018)
UNCTAD-Eora GVC Database	UNCTAD/Eora	National Supply-Use and I-O tables from Eurostat, OECD, IDE-JETRO	1990-2018	189	26	Lenzen et al., (2012); Lenzen et al., (2013); Del Prete et al., (2018)
ADB Multi-Region Input-Output Database (ADB MRIO)	Asian Development Bank	WIOD exstension	2000, 2007-2019	63	35	De Vries et al., (2016); De Vries et al., (2019)
Global Trade Analysis Project (GTAP)	Purdue University	Individual researchers/institution	2004, 2007, 2011, 2014	141	65	Trefler and Zhu, (2010); Daudin et al., (2011); Johnson and Noguera, (2012); Koopman, Wang and Wei, (2014); Aguiar et al., (2016)
EXIOBASE3	EU-based consortium	National Supply-Use tables	1995-2015	49	163	Stadler et al. (2018); Owen et al. (2016)
South American Input-Output table	ECLAP/IPEA	National I-O tables	2011, 2014	10	40	CEPAL, (2016); Banacloche et al. (2020)

Source: Authors' elaboration.

al, 2013). This database provides a set of both national and global input-output tables, covering 189 countries and 26 sectors for complete time series from 1990 to 2015. Recently, UNCTAD and Eora developed a time-series from 1990 to 2018 of some key GVC indicators, including foreign value added, domestic value added and domestic value added embedded in other countries' exports. Results from 1990 to 2015 are generated from Eora tables, whereas those for 2016-2018 are nowcasted using different data sources. The adopted methodology interpolates the missing points to provide broad, up-to-date coverage.

Along with this, the GTAP is a comprehensive multi-region database developed by the Purdue University which has been increasingly enriched in terms of data thanks to the contributions of individual researchers and organizations. It covers 121 countries plus 20 regions and 65 industries for 2004, 2007, 2011 and 2014. Thanks to its high coverage and relatively sectoral details, it has been intensely exploited by researchers (see, among others, Trefler and Zhu, 2010; Daudin et al., 2011; Johnson and Noguera, 2012; Koopman, Wang and Wei, 2014; Aguiar et al., 2016).

Major regional initiatives - in addition to ADB MRIO – include: the EXIOBASE promoted by the EU-based consortium. This database extracts information from national supply-use and input-output tables extended to environmental indicators. It covers 44 countries plus 5 rest-of-world regions and 163 industries for the period 1995 – 2015; the South-American Input-Output Table from the Economic Commission for Latin America and the Caribbean (ECLAC) covering 10 Latin America countries and 40 sectors for the years 2011 and 2014.

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On the relationships among durum wheat yields and weather conditions: evidence from Apulia region, Southern Italy

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Abstract. The weather index-based insurances may help farmers to cope with climate risks overcoming the most common issues of traditional insurances. However, the weather index-based insurances present the limit of the basis risk: a significant yield loss may occur although the weather index does not trigger the indemnification, or a compensation may be granted even if there has not been a yield loss. Our investigation, conducted on Apulia region (Southern Italy), aimed at deepening the knowledge on the linkages between durum wheat yields and weather events, i.e., the working principles of weather index-based insurances, occurring in susceptible phenological phases. We found several connections among weather and yields and highlight the need to collect more refined data to catch further relationships. We conclude opening a reflection on how the stakeholders may make use of publicly available data to design effective weather crop insurances.

Keywords: climate change, farming system, phenological phase, risk, weather insurance.
JEL codes: G22, Q14, Q18, Q54.

INTRODUCTION

Farming activities are exposed and vulnerable to several risks, among which the weather risks are increasingly frequent and impactful due to climate change (Conradt et al., 2015). Among the several strategies available to reduce the weather impacts on farming systems, e.g., pest control, financial saving, agricultural and structural diversification (Vroege and Finger, 2020), the crop insurance programs can play an important role (Di Falco et al., 2014). In recent years, the attention for the weather index-based insurances (WIBIs) has been growing mainly because these tools may help to overcome some of the challenges associated with traditional indemnity-based insurances, e.g., asymmetric information, high transaction costs, moral hazard, and adverse selection (Norton et al., 2013; Dalhaus and Finger, 2016; Belissa et al., 2019; Ceballos et al., 2019). Differently from the traditional insurances, which provide pay-outs depending on actual yield losses, WIBIs indem-

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nify the farmers when an index, computed on rainfall or temperature and highly correlated with farms performance (e.g., yields), is triggered (Conradt et al., 2015; Dalhaus and Finger, 2016). Therefore, farmers will be indemnified when the index exceeds a pre-determined threshold (Belissa et al., 2019). Moreover, WIBIs can be manipulated neither by the insurers or the insured because they are collected from historical and current dataset provided by recognized bodies (Belissa et al., 2020; Vroege et al., 2021). However, WIBIs present a limit, namely basis risk: a significant yield loss may occur even if the weather index does not trigger the payment (Conradt et al., 2015; Dalhaus et al., 2018) or a compensation may be granted even if there has not been a yield loss (Heimfarth and Musshoff, 2011). The contribution of our study is at least twofold: first, we provide empirical evidence on how yields and weather conditions are correlated, more specifically, we deepen the knowledge on the linkages between durum wheat yields and weather events occurring in susceptible phenological stages; second, we start a reflection on how stakeholders may make use of publicly available data to design an effective crop insurance scheme. We focused on the Apulia region (Southern Italy) which is the main national producer of durum wheat: almost a thousand of tons of production, i.e., accounting for 25% of the Italian durum wheat production, and about 344 thousand cultivated hectares, i.e., accounting for 28% of the Italian area utilized to grow durum wheat (ISMEA, 2020).

THE ITALIAN CROP INSURANCE SYSTEM

The Italy boasts a long tradition of public subsidies for agricultural risk management. The "Fondo di Solidarietà Nazionale" (FSN) was instituted in 1974 to finance both insurance policies and ex-post payments (Enjolras et al., 2012). Moreover, the EU Common Agricultural Policy allocated funds for agricultural insurances (art. 37 of EU Reg. 1305/2013) to cope economic losses due to adverse weather conditions, plant diseases, epizooties, and parasitic infestations (Santeramo et al., 2016; Rogna et al., 2021). Despite the public interventions, the participation level to insurance programs remains low (i.e., around 15 percent) mainly due to high costs of bureaucracy (i.e., complexity of procedures), delays in payments, lack of experience with crop insurance contracts or lack of high-quality information on existing insurance tools (Santeramo, 2019). The role of Defense Consortia, introduced both to facilitate the match of insurers and farmers in the subsidized crop insurance market and to reduce the asymmetric information, is not negligible. It emerges a North-South territorial dualism that affects farmers participation: Defence Consortia are more effective in Northern Italy than in the Southern Italy and, also, the strong presence of producer organizations and cooperatives aggregates the crop insurance's demand in the Northern Italy (Santeramo et al., 2016). Moreover, farmers who trust more in the intermediaries assisting them are inclined to adopt insurance tools to cope the risk of production loss, while risk averse farmers tend to implement other risk management strategies as crop or financial diversification (Trestini et al., 2018). In Italy, only the 9.9 percent of Utilised Agricultural Area is covered by insurance contracts and 20.9 percent of production value is insured (ISMEA, 2021). According to a survey conducted by ISMEA in 2018 on low participation to the subsidized agricultural insurance systems, most Italian farmers renounce to subscribe insurance contracts due to economic reasons, highlighting the high costs of policies. The share of farmers who believe that their farms are not exposed to specific risks or who have had negative experiences when receiving compensation, losing trust on insurance market systems, is also not negligible. Indeed, Giampietri et al., 2020 found that the trust affects the decision-making process: under uncertainty, the trust may substitute the knowledge also overcoming the lack of experience, therefore, strong communication campaigns to improve farmers' participation are recommended. Moreover, focusing on the WIBIs, also subsidized by the Measure 17 of National Rural Development Program 2014-2020, a lack of knowledge emerged among big insured farmers, i.e., WIBIs were unknown to 93 percent of them (ISMEA, 2020). Furthermore, some farmers believe that index-based insurances are inadequate to manage the weather risks due to the distrust of the objectivity of the indexes and parameters used, also showing an aversion to any future subscriptions. Clearly, it is necessary to improve the appeal and communication of these innovative risk management tools, also considering that any intervention aimed at promoting farmer participation should improve the competition among insurance providers, also reducing at the same time the asymmetric information and opportunistic behaviour (Menapace et al., 2016; Rogna et al., 2021; Santeramo and Russo, 2021). In this complex scenario, we estimate the yield response equation to investigate the responsiveness of yield to climate, deepening the working principles of weather index-based insurance, through a case study on durum wheat crop in the Apulia region, also animating the debate on the use of publicly available data to the development of an effective and attractive tool to manage climatic risk in agriculture.

DATA AND RESEARCH METHODOLOGY

An agronomic review on durum wheat allowed us to identify sensitive phenological stages of durum wheat in Apulia region and those critical weather events occurring in certain phenological stages that may cause significant production losses (Table 1).

Cold sensitivity is higher during the germination phase that occurs 10-15 days after sowing in which temperatures of few degrees centigrade below zero may cause considerable damages (Baldoni and Giardini, 2000, Angelini, 2007; Disciplinare di Produzione Integrata della Regione Puglia, 2021). Likewise, temperatures of few degrees centigrade below zero during the stem elongation phase may cause stems death and serious damages to the tissue of the internodes (Baldoni and Giardini, 2000; Angelini, 2007; Disciplinare di Produzione Integrata della Regione Puglia, 2021). Flowering stage occurs in late May and lasts about 10 days in which wheat crop is highly sensitive to cold stress that may cause death of flowers (Angelini, 2007; Baldoni and Giardini, 2000; Disciplinare di Produzione Integrata della Regione Puglia, 2021). Heat and drought stress during susceptible flowering and grain filling stages (i.e., after flowering, until the first decade of July) may cause considerable reductions in wheat yield and quality, leading the acceleration of leaf senescence process, reducing photosynthesis, causing oxidative damage, pollen sterility, also reducing physiological and metabolic imbalances, photosynthesis, grain numbers and weight (Angelini, 2007; Asseng et al., 2011; Li et al., 2013; Farooq et al., 2014; Rezaei et al., 2015; Zampieri et al., 2017; Makinen et al., 2018). Heavy rainfall during the entire crop cycle may cause significant production losses due to the proliferation of pathogens, nutrient leaching, soil erosion, inhibition of oxygen uptake by roots (i.e., hypoxia or anoxia), waterlogging and lodging (Zampieri et al., 2017; Makinen et al., 2018).

Furthermore, we collected yearly total production (tons) and area harvested (hectares) data for durum wheat crop from the National Institute of Statistics (ISTAT), from 2006 to 2019, for each province of Apulia region, also calculating the respective yields (tons/hectare). Then, for the same time-period, we collected 10-days frequency weather data from six synoptic weather stations of the Institute for Environmental Protection and Research (ISPRA), one for each province of Apulia region: Bari (BA), Barletta-Andria-Trani (BT), Brindisi (BR), Foggia (FG), Lecce (LE), Taranto (TA). Weather data include 10-days average minimum temperature (°C), i.e., the average of daily minimum temperatures, 10 days average maximum temperature (°C), i.e., the average of daily maximum temperatures, and 10-days cumulative precipitation (mm), i.e., the average of daily precipitation.

Details on collected variables are shown in Table 2.

Our empirical approach is based on a panel data model that includes fixed effect (i.e., it is a major advantage of the panel rather than cross-sectional regression) both to control for unobservable variables such as seed varieties or soil quality that may vary across the space, i.e., provinces, and to catch the variation across the time within the Apulian provinces (Tack et al., 2015; Blanc and Schlenker, 2017; Kolstad and Moore, 2020).

Table 1. Phenological stages, weather events and critical limits of durum wheat in Apulia region.

Phenological stage	Weather event	Time interval	Critical limit	Reference
Sowing	Cold	From the first decade of November to the first decade of December	Temperature < 0 °C	Baldoni and Giardini, 2000; Angelini, 2007; Disciplinare di produzione integrata della Regione Puglia, 2021
Germination	Cold	From the second decade of November to the second decade of December	Temperature < 0 °C	
Stem elongation	Cold	From the second decade of March to the third decade of April	Temperature < 0 °C	Baldoni and Giardini, 2000; Angelini, 2007
Flowering	Cold	From the second decade of May to the first decade of June	Temperature < 0 °C	Angelini, 2007; Disciplinare di produzione integrata della Regione Puglia, 2021
	Heat, drought		Temperature > 30-31 °C	Angelini, 2007; Rezaei et al., 2015
Grain filling	Heat, drought	From the second decade of June to the first decade of July	Temperature > 34 °C	Angelini, 2007; Asseng et al., 2011; Rezaei et al., 2015; Zampieri et al., 2017; Makinen et al., 2018
All phases	Excessive rainfall	From first decade of November to the first decade of July	Rainfall > 40 mm/day	Makinen et al., 2018

Table 2. Details on collected variables.

Variable (unit)	Frequency	Time-period	Province	Weather station - province (no. of obs, SR in km^2)	Source
durum wheat yield (tons/hectares)	Yearly			-	ISTAT
average minimum temperature (°C) average maximum temperature (°C) cumulative precipitation (mm)	10-days	2006-2019	Bari (BA) Barletta-Andria-Trani (BAT) Brindisi (BR) Foggia (FG) Lecce (LE) Taranto (TA)	Bari - BA (501, 5.138) Trani - BT (144, 1.543) Brindisi - BR (471, 1.839) Monte Sant'Angelo - FG (504, 7.008) Lecce - LE (471, 2.799) Marina di Ginosa – TA (471, 2.437)	ISPRA, UCEA,ARPA

Notes: missing data have been integrated including Research Unit for Climatology and Meteorology (UCEA) and Regional Agency for the Protection of the Environment (ARPA) datasets. Table includes no. of observations and spatial resolution (SR) of weather stations.

The relationship between durum wheat yields and weather events is synthesized as follows:

$$y_{it} = f(w_{it}) + \mu_i + \theta_t + \varepsilon_{it}$$

where y_{it} is the yield over the space ($_i$) and time ($_t$) as function (f) of weather (w_{it}), also including fixed effects over space (μ_i) and time (θ_t), error term and "controls" refers to other relevant exogenous variables (ε_{it}) (Kolstad and Moore, 2020). More specifically, we conducted temporal and spatial autocorrelation identifying those contiguous provinces having a larger shared borders for a twofold check: (i) verify if the weather events occurring in a province may affect durum wheat yields in the contiguous province; (ii) control if the yields may be affected by weather events occurring at time t-1. Undoubtedly, both environmental and agronomic factors may justify the extreme variability of the durum wheat yield across the Apulian provinces: Foggia shows the highest average durum wheat yields while Lecce shows the lowest average yields, although it is characterized by lower yield variability than other provinces as Brindisi that, on the contrary, is more affected by environmental and agronomic factors, reason why it may benefit of crop insurance programs more than other provinces to cope yields fluctuations (Table 3).

Table 3. Durum wheat yields (tons/hectare) among Apulian provinces.

	Average	Minimum	Maximum	Standard deviation
Bari	0.234	0.170	0.306	0.045
BAT	0.224	0.200	0.260	0.020
Brindisi	0.285	0.180	0.420	0.071
Foggia	0.314	0.200	0.420	0.047
Lecce	0.189	0.160	0.220	0.018
Taranto	0.244	0.100	0.350	0.057

Notes: data include yearly durum wheat yield from 2006 to 2020. Source: ISTAT, 2020.

RESULTS

Our results clearly show that a relationship links weather conditions and production yields in the Apulia region. More specifically, precipitation seem to have a negative effect on durum wheat yields (Table 4).

However, controlling by spatial and temporal autocorrelation, the effects of temperatures have been caught. Minimum temperatures negatively affect durum wheat yields, while maximum temperatures positively affect the yields, both in a non-linear way. Indeed, we included the squares of weather variables to catch the nonlinearity, in other terms, the trade-off between weather and yields (Blanc and Schlenker, 2017). Our results clearly highlight that the weather affects the yields in a nonlinear way, therefore, variables have a statistically significant inverted-U shape relationship

Table 4. Effects of weather variables on durum wheat yield.

Variables	Panel prov FE time trend	Panel temporal correlation prov FE time trend	Panel spatial correlation prov FE time trend	Panel temporal correlation spatial correlation prov FE time trend
Temperature (min)	-0.00764 (0.10641)	-0.00124 (0.11715)	-0.46909*** (0.17058)	-0.45553** (0.18731)
Temperature (min) sq.	0.00049 (0.00296)	-0.00023 (0.00320)	0.00892* (0.00490)	0.01384** (0.00544)
Temperature (max)	0.22572 (0.14125)	0.28286* (0.15378)	0.61165** (0.25587)	0.66801** (0.27703)
Temperature (max) sq.	-0.00523* (0.00278)	-0.00612** (0.00299)	-0.01530*** (0.00515)	-0.02022*** (0.00568)
Precipitation	-0.01646** (0.00799)	-0.01625* (0.00844)	-0.03939** (0.01819)	-0.04670** (0.01954)
Precipitation sq.	0.00008 (0.00006)	0.00007 (0.00006)	0.00019 (0.00017)	0.00024 (0.00018)
Yield (lag)	-	0.10464*** (0.02153)	-	-0.09290*** (0.03579)
Temperature (min) contig.	-	-	0.23065*** (0.06565)	0.18642*** (0.07019)
Temperature (max) contig.	-	-	0.00822 (0.10765)	0.04557 (0.11545)
Precipitation contig.	-	-	0.00537 (0.00704)	0.00771 (0.00837)
Observations	1,837	1,638	914	833
Number of id	6	6	4	4

Notes: panel regression model was processed in STATA software. It includes provincial fixed effect, time trend, temporal (i.e., yield lag), and spatial (contiguous weather variables) autocorrelation.
Standard errors in parentheses.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

(Schlenker and Roberts, 2009; Lobell et al., 2011). Last but not least, minimum temperatures may affect the contiguous provinces. According to the scientific literature, any excess (or deficit) of temperature and precipitation (or their combinations) may cause severe yield losses on durum wheat (Baldoni and Giardini, 2000; Angelini, 2007; Asseng et al., 2011; Li et al., 2013; Farooq et al., 2014; Rezaei et al., 2015; Zampieri et al., 2017; Makinen et al., 2018). Furthermore, we estimated the model for each phenological phase of durum wheat to capture the potential heterogeneity in the effect of weather variables, also controlling by spatial and temporal autocorrelation. Our results show that the relationship between weather variables and yields is valid only for some weather variables in certain phenological phases. More specifically, the maximum temperatures and precipitation positively affect durum wheat yield in a nonlinear way when occur in the germination and grain filling stages, respectively (Table 5).

Moreover, minimum temperatures may affect the contiguous provinces. Clearly, ten-days data we have collected does not highlight the dynamics between weather events occurring in certain phenological stages and durum wheat yields mainly because the impacts of daily weather are not captured. Moreover, most variables are not statistically significant: this limit opens a reflection on data disaggregation level and on the need to collect more spatially and temporally refined data, also laying the foundations for the development of an effective index that reflects the responsiveness of the yields to climatic conditions to be implemented in the WIBIs. The evidence resulting from our econometric model on phenological stages is also in contrast with the literature: germination stage is highly sensitive to cold stress (Bal-

Table 5. Effects of weather variables on yield by phase.

Variables	sowing	germination	stem elongation	flowering	grain filling
Yield (lag)	-0.11883	0.05952	0.17798*	-0.04474	0.09403
	(0.20660)	(0.20523)	(0.09219)	(0.18593)	(0.14041)
Temperature (min)	0.95845	-0.00051	0.50020	-1.32087	-0.65587
	(2.53724)	(1.74362)	(1.26379)	(4.06620)	(3.83238)
Temperature (min) sq.	-0.01783	0.01530	-0.01201	0.03550	0.02171
	(0.11363)	(0.08655)	(0.05223)	(0.10882)	(0.08353)
Temperature (max)	3.15220	23.00804**	-2.73726	7.62398	-1.65011
	(12.35641)	(10.88917)	(2.21349)	(8.51643)	(6.74553)
Temperature (max) sq.	-0.15964	-0.76330**	0.06023	-0.15868	0.01396
	(0.35336)	(0.33477)	(0.05582)	(0.15987)	(0.11320)
Precipitation	0.04601	-0.07450	-0.03735	-0.43463	0.42332*
	(0.12015)	(0.11228)	(0.07473)	(0.42173)	(0.24351)
Precipitation sq.	-0.00034	0.00054	0.00049	0.01188	-0.00826*
	(0.00088)	(0.00084)	(0.00101)	(0.01680)	(0.00463)
Temperature (min) contig.	1.05294**	0.86957**	0.62187***	0.52210	0.55304**
	(0.41397)	(0.35021)	(0.17188)	(0.35845)	(0.23765)
Temperature (max) contig.	0.38942	0.17524	-0.06474	0.22627	0.00512
	(1.25128)	(1.33537)	(0.34861)	(0.52741)	(0.37530)
Precipitation contig.	-0.05370	0.01278	-0.01394	-0.10017	-0.05635
	(0.05168)	(0.04199)	(0.03275)	(0.11446)	(0.04998)
Observations	42	44	125	43	67
Number of id	4	4	4	4	4

Notes: panel regression model was processed in STATA software. It includes provincial fixed effect, time trend, temporal (i.e., yield lag), and spatial (contiguous weather variables) autocorrelation.
Notes: standard errors in parentheses
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

doni and Giardini, 2000, Angelini, 2007; Disciplinare di Produzione Integrata della Regione Puglia, 2021), while there are not evidences on heat stress during this stage. However, our study may help the debate suggesting precise directions for the future research.

CONCLUSIONS

Participating in index-based crop insurance schemes is a key challenge to improve the resilience of farming systems and adopting effective subsidies to enhance participation in the schemes is a pressing goal for policymakers. In this complex scenario, we investigated how temperatures and precipitation are correlated with yields data to reflect on potential designs for the index-based insurance schemes. While not novel (e.g., Chen et al., 2014), we found that weather changes affect durum wheat yields in a nonlinear way and some weather events occurring in certain phenological phases may have an impact on the yields. Our results are important to show that even with aggregated data the evidence is striking. However, focusing on phenological stages, our findings are in contrast with the literature highlighting the complexity of the phenomenon and the need to rely on more temporally and spatially disaggregated data. Although we provided clear evidence on the weather-yield relationship, it is impossible to design a WIBI using 10-days weather data. Therefore, our contribution may help the debate suggesting precise directions for the future research: first, a major effort should be devoted to the collection of weekly or daily weather observations, also identifying empirical damage thresholds that can be verified at farm-level, as well as the collection of production area or municipal data; a promising approach could be the Growing Degree Days tool so as to calibrate the more precisely the growing stages in a view to a better explanation of weather risks on crop performances (Conradt et al., 2015; Dalhaus et al., 2018; Lollato et al., 2020); last but not least, the design of the index-based insurance schemes needs of further investigation because establishing a triggering index is a major challenge for the *stakeholders* involved in the implementation of the insurance schemes. The debate on crop insurance schemes is still vivid, and it will be so also in the next decade due to the central role that the risk management (old and novel) tools will have in the new CAP (Meuwissen et al., 2018; Severini et al., 2019; Cordier and Santeramo, 2020).

REFERENCES

Angelini, R. (2007). Coltura & cultura. Il grano. ART SpA - Bologna.

Asseng, S., Foster, I.A.N., and Turner, N.C. (2011). The impact of temperature variability on wheat yields. Global Change Biology, 17(2), 997-1012.

Auffhammer, M., Hsiang, S. M., Schlenker, W., & Sobel, A. (2013). Using weather data and climate model output in economic analyses of climate change. Review of Environmental Economics and Policy, 7(2), 181-198.

Baldoni, R. and Giardini, L. (2000). Coltivazioni erbacee. Cereali e proteaginose. In Toderi, G., and D'Antuono L.F., Frumento (Triticum sp.pl.). Patron Editore.

Belissa, T., Bulte, E., Cecchi, F., Gangopadhyay, S., and Lensink, R. (2019). Liquidity constraints, informal institutions, and the adoption of weather insurance: A randomized controlled Trial in Ethiopia. Journal of Development Economics, 140, 269-278.

Belissa, T., Lensink, R., and Winkel, A. (2020). Effects of Index Insurance on Demand and Supply of Credit: Evidence from Ethiopia. American Journal of Agricultural Economics, 102(5), 1511-1531.

Blanc, E., & Schlenker, W. (2017). The use of panel models in assessments of climate impacts on agriculture. Review of Environmental Economics and Policy, 11(2), 258-279.

Ceballos, F., Kramer, B., and Robles, M. (2019). The feasibility of picture-based insurance (PBI): Smartphone pictures for affordable crop insurance. Development Engineering, 4, 100042.

Chen, C.C., McCarl, B.A., and Schimmelpfennig, D.E. (2004). Yield variability as influenced by climate: A statistical investigation. Climatic Change, 66(1), 239-261.

Conradt, S., Finger, R., and Spörri, M. (2015). Flexible weather index-based insurance design. Climate Risk Management, 10, 106-117.

Conradt, S., Finger, R., and Bokusheva, R. (2015). Tailored to the extremes: Quantile regression for index-based insurance contract design. Agricultural economics, 46(4), 537-547.

Cordier, J. and Santeramo, F. (2020). Mutual funds and the Income Stabilisation Tool in the EU: Retrospect and Prospects. EuroChoices, 19(1), 53-58.

Dalhaus, T. and Finger, R. (2016). Can gridded precipitation data and phenological observations reduce basis risk of weather index–based insurance? Weather, Climate, and Society, 8(4), 409-419.

Dalhaus, T., Musshoff, O., and Finger, R. (2018). Phenology information contributes to reduce temporal basis risk in agricultural weather index insurance. Scientific reports, 8(1), 1-10.

Disciplinare di Produzione Integrata della Regione Puglia (2021). http://burp.regione.puglia.it/documents/10192/56088259/DET_67_2_3_2021.pdf/bb22795d-6335-4498-bc3a-7a13bf8d140d. Accessed 31 August 2021

Di Falco, S.D., Adinolfi, F., Bozzola, M., and Capitanio, F. (2014). Crop insurance as a strategy for adapting to climate change. Journal of Agricultural Economics, 65(2), 485-504.

Enjolras, G., Capitanio, F., and Adinolfi, F. (2012). The demand for crop insurance: Combined approaches for France and Italy. Agricultural economics review, 13(389-2016-23488), 5-22.

Farooq, M., Hussain, M., and Siddique, K. H. (2014). Drought stress in wheat during flowering and grain-filling periods. Critical reviews in plant sciences, 33(4), 331-349.

Giampietri, E., Yu, X., & Trestini, S. (2020). The role of trust and perceived barriers on farmer's intention to adopt risk management tools. Bio-based and Applied Economics Journal, 9(1050-2021-213), 1-24.

Kolstad, C. D., & Moore, F. C. (2020). Estimating the economic impacts of climate change using weather observations. Review of Environmental Economics and Policy, 14(1), 1-24.

Li, Y.F., Wu, Y., Hernandez-Espinosa, N., and Peña, R. J. (2013). Heat and drought stress on durum wheat: Responses of genotypes, yield, and quality parameters. Journal of Cereal Science, 57(3), 398-404.

Lobell, D. B., Bänziger, M., Magorokosho, C., & Vivek, B. (2011). Nonlinear heat effects on African maize as evidenced by historical yield trials. Nature climate change, 1(1), 42-45.

Lollato, R.P., Bavia, G.P., Perin, V., Knapp, M., Santos, E.A., Patrignani, A., and DeWolf, E.D. (2020). Climate-risk assessment for winter wheat using long-term weather data. Agronomy Journal, 112(3), 2132-2151.

Mäkinen, H., Kaseva, J., Trnka, M., Balek, J., Kersebaum, K. C., Nendel, C., Gobin, A., Olesen, J.E., Bindi, M., Ferrise, R., Moriondo, M., Rodrìguez, A., Ruiz-Ramos, M., Takàc, J., Bezàk, P., Ventrella, D., Ruget, F., Capellades, G., and Kahiluoto, H. (2018). Sensitivity of European wheat to extreme weather. Field Crops Research, 222, 209-217.

Menapace, L., Colson, G., and Raffaelli, R. (2016). A comparison of hypothetical risk attitude elicitation instruments for explaining farmer crop insurance purchases. European Review of Agricultural Economics, 43(1), 113-135.

Meuwissen, M. P., de Mey, Y., and van Asseldonk, M. (2018). Prospects for agricultural insurance in Europe. Agricultural Finance Review.

Norton, M.T., Turvey, C., and Osgood, D. (2013). Quantifying spatial basis risk for weather index insurance. The Journal of Risk Finance.

Rezaei, E.E., Webber, H., Gaiser, T., Naab, J., and Ewert, F. (2015). Heat stress in cereals: mechanisms and modelling. European Journal of Agronomy, 64, 98-113.

Rogna, M., Schamel, G., and Weissensteiner, A. (2021). The apple producers' choice between hail insurance and anti-hail nets. Agricultural Finance Review.

Santeramo, F. G., Goodwin, B. K., Adinolfi, F., and Capitanio, F. (2016). Farmer participation, entry and exit decisions in the Italian crop insurance programme. Journal of Agricultural Economics, 67(3), 639-657.

Santeramo, F.G. and Ford Ramsey, A. (2017). Crop Insurance in the EU: Lessons and Caution from the US. EuroChoices, 16(3), 34-39.

Santeramo, F.G. (2018). Imperfect information and participation in insurance markets: evidence from Italy. Agricultural Finance Review, 78(2), 183-194.

Santeramo, F. G. (2019). I learn, you learn, we gain experience in crop insurance markets. Applied Economic Perspectives and Policy, 41(2), 284-304.

Santeramo, F.G. and Russo, I. (2021). Aspetti comportamentali della partecipazione ai programmi di assicurazione agricola agevolata nell'Italia meridionale. Italian Review of Agricultural Economics, 76(2), 73-90.

Schlenker, W., & Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to US crop yields under climate change. Proceedings of the National Academy of sciences, 106(37), 15594-15598.

Severini, S., Biagini, L., and Finger, R. (2019). Modeling agricultural risk management policies–The implementation of the Income Stabilization Tool in Italy. Journal of Policy Modeling, 41(1), 140-155.

Tack, J., Barkley, A., & Nalley, L. L. (2015). Effect of warming temperatures on US wheat yields. Proceedings of the National Academy of Sciences, 112(22), 6931-6936.

Trestini, S., Giampietri, E., & Smiglak-Krajewska, M. (2018). Farmer behaviour towards the agricultural risk management tools provided by the CAP: a comparison between Italy and Poland (No. 2038-2018-2993).

Vroege, W. and Finger, R. (2020). Insuring Weather Risks in European Agriculture. EuroChoices, 19(2), 54-62.

Vroege, W., Bucheli, J., Dalhaus, T., Hirschi, M., and Finger, R. (2021). Insuring crops from space: the potential of satellite-retrieved soil moisture to reduce farmers' drought risk exposure. European Review of Agricultural Economics, 48(2), 266-314.

Woodard, J. D. and Garcia, P. (2008). Weather derivatives, spatial aggregation, and systemic risk: implications for reinsurance hedging. Journal of Agricultural and Resource Economics, 34-51.

Zampieri, M., Ceglar, A., Dentener, F., and Toreti, A. (2017). Wheat yield loss attributable to heat waves, drought and water excess at the global, national and subnational scales. Environmental Research Letters, 12(6), 064008.

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A choice model-based analysis of diversification in organic and conventional farms

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Abstract. Diversification is a polymorphic strategy to increase agricultural income and reduce the risks deriving from the surrounding environment. This strategy can also be successfully adopted in the context of organic farming. However, there is a lack of confirmation in this regard given the scarcity of studies that explicitly focus on diversification in organic farms. The objective of this paper is to analyse the influence of some territorial, socio-economic, and political factors on the probability of diversifying in both organic and conventional farms. To this aim, multinomial and binary logit models are applied to the Italian case. Results suggest that on-farm diversification requires specific competences and adequate organization. However, the reasons for diversifying differ depending on the production model. In conventional farming, farmers diversify to achieve income levels comparable with those of a more competitive agriculture. Conversely, for organic farmers, diversification represents an integrated part of the production model to take advantage of synergies between organic production and diversification. From these results, some policy implications are drawn.

Keywords: on-farm diversification, Common Agricultural Policy, organic farming, conventional farming, multinomial logit model.
JEL Codes: C25, Q12, Q18.

1. INTRODUCTION

Farmers can use different strategies to increase and stabilize income and reduce the risks deriving from external pressures and changes in the socio-economic context. As a prevention strategy, they can diversify their sources of income to spread the risk over more activities (Salvioni *et al.*, 2020). Diversification is a polymorphic strategy that can be expressed both inside and outside the farm through several multifunctional directions which can be broadly classified as deepening, broadening and re-grounding (van der Ploeg and Roep, 2003). It involves that one or more farm inputs are partially diverted from agricultural production: (a) within the same agri-food chain, to expand products range, quality and value or to shorten the length of the supply chain (deepening); (b) to produce other types of goods and services, such as hospitality, restoration, welfare and environmental services (broadening); (c) outside the primary sector, to integrate agricultural income (re-grounding).

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The potential of diversification is recognized both for farms, especially for family ones, and for rural areas, as evidenced by the specific support granted at the European level by the Common Agricultural Policy (CAP), specifically the Rural Development Policy (RDP) (European Parliament, 2016). This strategy not only can be successfully adopted in the context of organic farming but might also provide a comparative advantage over conventional farms that diversify by leveraging the willingness of consumers to pay higher prices for products and services provided by organic farms. However, there is a lack of confirmation in this regard given the scarcity of studies that explicitly focus on diversification in organic farms. This is because, in the wide stream of literature on multifunctionality and diversification, organic farming is commonly considered as a deepening strategy of conventional farms and is analysed as one of the factors explaining diversification (Salvioni *et al.*, 2009; Rivaroli *et al.*, 2017; Dries *et al.*, 2012). Nevertheless, organic farming is a specific farm model, which brings about a rethinking of the management of the whole farm and its relations with the "outside world", inspired by principles of sustainability (Luttikholt, 2007). Chemically synthesised inputs are strictly limited and replaced with inputs of natural origin. Furthermore, techniques that prevent pollution, improve product quality, increase animal welfare standards, and ensure a soil ecology that retains nutrients and biodiversity are introduced. In this way, organic farming carries out a dual and complex function related to both the market and the production of public goods, in accordance with the changing consumers' preferences (Regulation EC No 2018/848). This change is also reflected in the growth and in spread of organic farming. Focusing on the European Union context, according to Eurostat statistics, from 2012 to 2019, organic area, including that under conversion, increased by 46%, reaching a share of around 9% of 2016 total utilised agricultural area. Italy, with 16% of organic area, is among the countries with the highest share of agricultural area devoted to organic production and with the highest growth rate (+70%). For all these reasons, organic farming cannot be considered as a mere option of diversification, but a unique model of production as opposed to the dominant model of conventional agriculture, which is taking increasing importance especially in some European countries such as Italy.

There is a wide literature analysing the determinants and the theoretical foundations of the process of income diversification (Boncinelli *et al.*, 2018). However, to the authors' knowledge, there is no research work that focuses on the differences between organic and conventional farmers concerning the reasons that lead to diversification. The knowledge of factors affecting the choice of diversification in different farm models can be helpful for two main reasons. Firstly, it contributes to verifying the hypothesis that the decision of diversifying is a necessity related to income volatility and lower levels of competitiveness, which push farmers to seek alternative opportunities to traditional activities in order to increase and stabilize income. In this respect, it may help policy makers to better define policy instruments. If the reasons explaining diversification vary according to the type of farms, policies can be usefully differentiated and better targeted, therefore increasing their effectiveness. Secondly, it can contribute to better assessing policy effectiveness. In fact, a certain sensitivity of farmers to policy support can be a signal of effectiveness of policy instruments in favour of diversification. However, if this were confirmed also for organic farms, i.e., organic farms diversify thanks to the support to diversification, there could be indirect implications related to the effectiveness of policy supporting organic farming, which could be further investigated. This policy is aimed at incentivising organic farming by payments that should cover the higher costs that the adoption of organic practices brings about in comparison with conventional farming. In consideration of the higher prices paid by consumers for organic products, hence the potentially higher revenues for organic farms, if farms, which benefit from policy support for adopting organic practices, diversify by using support for diversification, this could mean that the payments aimed at encouraging organic farming are not sufficient to cover the higher costs, thus forcing organic farms to diversify by activating the related policy tools.

The objective of this paper is to assess the differences between organic and conventional farmers in the choice of on-farm diversification. More precisely, the aim is to analyse the influence of territorial, socio-economic, and political factors on the probability of diversifying in these two types of farmers. The main novelty lies in an unconventional approach to diversification where organic farming is not analysed as a mere strategy of diversification but as a distinct entrepreneurial model that may have different motivations leading to a differentiated policy approach.

For the purposes of this study, logit models are adopted. Logistic regression analysis is widely used in several disciplines to investigate the relationship between binary or ordinal response probability and explanatory variables. Multinomial logistic regression generalizes logistic regression to problems with more than two possible discrete outcomes. This kind of models have been already applied to study the phenomenon of diversification in agriculture (i.e., Meraner *et al.*, 2015; Vik and Mcelwee, 2011). A multinomial logit model is first applied to compare organic and conventional farmers who diversify with farmers with no diversification strategies. This model gives the possibility of directly comparing two distinct groups of farmers relative to a base group. A logistic model is then applied only to farmers who diversify, in order to investigate the effects of specific factors affecting diversification, particularly policies in favour of diversification. This analysis is carried out by using the Farm Accountancy Data Network (FADN) sample of Italian farmers for the period 2014-2018.

The remaining of this paper is organized as follows. Section 2 provides an overview of the existing literature on the main determinants of on-farm diversification and on the potential synergies deriving from combining organic production with diversification. Section 3 illustrates the methodology, the variables and the data used. Sections 4 and 5 present and discuss the results of this analysis, respectively. Section 6 provides some concluding remarks and policy implications.

2. ON-FARM DIVERSIFICATION AND ORGANIC FARMING

On-farm income diversification in agriculture roots in the multifunctional role of agriculture (Henke and Vanni, 2017; Meraner *et al.*, 2015; Van Huylenbroeck *et al.*, 2007). Brought in vogue at the time of Agenda 2000 to legitimate the public support to the European model of agriculture, multifunctionality has become the key to a renovated role of agriculture and rural areas in the European and other developed contexts. On-farm diversification is practical application of multifunctionality through which new functions of production in agriculture complement, and sometimes compete with, the main one related to food production, especially in terms of inputs such as land, family labour and capital. Deep and ongoing environmental and economic changes have enhanced the interest in on-farm diversification, by reallocating production factors towards new non-agricultural activities.

The reasons that lead farmers to diversify have been widely investigated in literature. Traditionally, economic survival and occupation strategies have been the main drivers of off-farm diversification. However, in on-farm diversification, several factors play a role in the decision to diversify. Most are related to farmer characteristics, such as level of education (McElwee and Bosworth, 2010; Boncinelli *et al.*, 2017,2018; Khanal, 2020) and age (Barbieri and Mahoney, 2009; Joo *et al.*, 2013; Boncinelli *et al.*, 2018; Meraner *et al.*, 2015); farm characteristics, such as farm size (McNamara and Weiss, 2005; Ilbery, 1991; McNally, 2001; García-Arias *et al.*, 2015; Bartolini *et al.*, 2014; Boncinelli *et al.*, 2018; Dries *et al.*, 2012), productive specialization and location (Dries *et al.*, 2012; Bartolini *et al.*, 2014; Rivaroli *et al.*, 2017); and policy support (Bartolini *et al.*, 2014). However, studies do not always reach unanimous conclusions on the factors that affect farm diversification and how they act. For instance, Joo *et al.* (2013) show that older farmers are more likely to participate in agritourism while Barbieri and Mahoney (2009) suggest that young farmers have a longer-term view that pushes them to diversify. According to Boncinelli *et al.* (2018), younger and older farmers have the same behaviour in relation to diversification. It is also interesting to find different results about policy in literature despite the existence of rural development instruments specifically conceived to support farm diversification. While, for some studies, policy is ineffective or produces weak effects (Boncinelli *et al.*, 2017,2018), for others, both CAP Pillars positively influence farm diversification (Bartolini *et al.*, 2014).

A reason that could explain contrasting results is that research on diversification mostly analyses organic and conventional farms jointly and considers organic farming as a strategy of on-farm diversification. This type of analysis is founded on the idea that organic production is a secondary function that farms introduce to expand their business portfolio, as they do when they decide to process products and sell them directly. This approach can be valid if farms implement the organic method only on a part of total production, but it is less appropriate where this choice, which involves an increasing number of farms, concerns the whole farm.

As a consequence, studies that specifically analyse diversification in organic farms are fewer, even though results highlight the relevance of such a combination. Frederiksen and Langer (2008) show that half of Danish organic farms engage in other farm-based activities, especially direct sales, of which a half is of some or major economic importance. They conclude that on-farm diversification should not be simply considered as a pathway away from agriculture but an integrated part of organic farming strategies. David *et al.* (2010) investigate the adaptive capacity of organic farms that adopt diversification strategies. They analyse the evolution of some organic farms in the southeast of France over a 15-year period, monitoring farm performance and farmers' strategy. Their results show that on and off-farm diversification contribute significantly to farm viability. Aubert and Enjolras (2016), using an econometric model with simultaneous equations based on data from the 2010 census of French farms, demonstrate that farmers specialised in winegrowing and arboriculture who adopt organic farming label are more likely to sell their produce through short food supply chains. As for the Italian context, the choice to diversify appears more relevant in the organic sector than in the entire agricultural sector. For instance, Dries *et al.* (2012), by a multivariate probit model applied to 2006 data from Italian FADN, demonstrate that there is complementarity between agricultural diversification activities, such as organic farming, and the structural ones, such as direct sales or agritourism. Bartolini *et al.* (2014) show a greater probability of diversification for cases of organic management in the Tuscany region, due to the synergies between different diversification strategies. Marongiu and Cesaro (2017), by applying a logistic regression model to the Italian FADN data for the period 2013-2015, reveal the existence of a positive correlation between participation in food quality systems, such as organic farming, and the presence of related activities in farms specialized in permanent crops and dairy production. Khanal *et al.* (2019) confirm the existence of correlations between agritourism and organic diversification strategies for US farmers due to possible synergies between them and warn that the estimates produced by choice models could be biased if these correlations were not taken into account. By analysing the willingness to pay for a designated farm holiday stay in an Italian region of Trentino Alto-Adige, Sidali *et al.*, (2019) show that this complementarity also gives a comparative advantage in that the combination of organic farming and farm stay operations ensures a higher accommodation price than what conventional farms offering only hospitality are able to obtain.

The studies that specifically analyse the determinants of diversification in organic farmers are even fewer. Zander (2008), based on a survey conducted on a sample of successful organic farms in Germany, concludes that an important motivation for organic farmers to opt for the vertical integration is to keep the value added of their products on farm. Moreover, they give evidence that farmers who diversify tend to be larger in order to achieve good market conditions and that the availability of high skills is a precondition for successful diversification. Weltin *et al.* (2017) use a survey of over 2 thousand farms from eleven European regions in order to investigate differences regarding the willingness to diversify in the future. They find that farm households with organic production led by young farmers are most likely to diversify activities, particularly on-farm.

3. MATERIALS AND METHODS

3.1 The model

The model used is a multinomial logit model where a farmer makes a choice among three unordered alternatives: 1) no diversification; 2) conventional production and diversification; 3) organic production and diversification. Farmer *i*'s utility derived from choice alternative *j* is:

$$U_{ij} = \mathbf{x}'_i\boldsymbol{\beta}_j + \varepsilon_{ij} \qquad i = 1,\ldots, N;\ j = 1,\ldots,J \tag{1}$$

where $J = 3$ is the number of possible alternatives, N is the number of farmers, $\mathbf{x}'_i$ is a row vector of case-specific variables that are supposed to influence this utility, $\boldsymbol{\beta}_j$ is a vector of coefficients to be estimated, ε_{ij} are random errors which are assumed to be independent and identically distributed across alternatives. This assumption is plausible since the alternatives analysed are not close substitutes and can therefore be assumed to be distinct (McFadden, 1974). Let Y_{ij} be the dependent variable with J outcomes numbered from 1 to J. After imposing the restriction $\boldsymbol{\beta}_1 = \mathbf{0}$, which allows the model to be identified, the choice probability is defined by the following multinomial logit framework:

$$Pr(Y_i = 1|\mathbf{x}'_i) = \frac{1}{1+\sum_{k=2}^{J}\exp(\mathbf{x}'_i\boldsymbol{\beta}_k)} \tag{2}$$

$$Pr(Y_i = j|\mathbf{x}'_i) = \frac{\exp(\mathbf{x}'_i\boldsymbol{\beta}_j)}{1+\sum_{k=2}^{J}\exp(\mathbf{x}'_i\boldsymbol{\beta}_k)} \quad j = 2,\ldots,J \tag{3}$$

Estimation of the model is obtained by maximising the following log-likelihood function:

$$\ln L = \prod_{i}^{N}\prod_{j}^{J} I(Y_i = j)\ln[Pr(Y_i = j|\mathbf{x}'_i)] \tag{4}$$

where $I(Y_i = j)$ is the indicator function of the farmer's choice, which takes 1 if $Y_i = j$ and 0 otherwise. Choice (1) is used as a base outcome. Therefore, the probability that either an organic or a conventional farmer diversifies is calculated relatively to that of a farmer who does not diversify. In this way, the effects of determinants on the choice of diversification are assessed by keeping organic farmers and conventional farmers separate. In addition, to analyse the different influence of specific characteristics of farmers who diversify (specifically, policy in favour of diversification, which does not concern farmers with no diversification strategies), a logistic model is also applied to a subset composed of farmers with diversification strategies where the binary response is the probability that organic farmers diversify. This allows us to further investigate the differences between the two different types of farmers by assessing the effects of specific factors on organic farmers relative to that produced on conventional farmers.

While in binary models coefficients $\boldsymbol{\beta}_j$ are easily interpretable, in multinomial logit models these coefficients show how predictors relate to the probability of observing a specific category relative to a base category and, therefore, indicate neither the direction nor the size of effects of predictors on the probability that an alternative is chosen (Wulff, 2015). To provide this information, average marginal effects are thus calculated. Marginal effects are the slope of the prediction function at a given value of the explanatory variable and inform about the change in predicted probabilities due to a change in a given predictor. For a continuous independent variable, the marginal effect related to coefficient k, farmer i and choice j is derived as follows:

$$ME_{kij} = \frac{\partial\, Pr(Y_i = j|\mathbf{x}_i')}{\partial\, x_{ik}} = Pr(Y_i = j|\mathbf{x}_i')\left(\beta_{kj} - \overline{\beta}_i\right) \quad (5)$$

where $\overline{\beta}_i = \sum_{j=1}^{J} \beta_{kj} Pr(Y_i = j|\mathbf{x}_i')$ is a probability weighted average of the coefficients for different choice combinations, β_{kj}. The average marginal effect is calculated over all the observations. For dummy variables, the marginal effect is defined by the discrete change in individual probabilities evaluated at the alternative values of the dummy (1 and 0).

3.2 The variables and the dataset used

As already specified, in the multinomial logit model the dependent variable is represented by the following categories: farms with no diversification strategies, which are used a base outcome, and two other options represented by farms that diversify and produce conventionally and farms that diversify and cultivate organically. The latter are used as a dependent variable in the logit model, which implies that organic farmers are compared with conventional farmers, both with diversification strategies. As independent variables, a set of socio-economic and political factors that are supposed to affect the probability of diversification are analysed. The selection of these variables depends on the main determinants of diversification that have been analysed in literature (see section 2) and on data availability. The variables taken into consideration refer to both farmer and farm characteristics as well as policy support. As regards farmer characteristics, education and age are analysed while, with reference to farm features, altitude, geographical localization, economic size and productive specialization are investigated. The level of education is represented by two binary variables. They are one if the farmer has a high level and a medium level of education, respectively. They are zero when the level of education is low. Age is modelled by a dummy indicating if farmers are young according to the threshold set by the CAP for accessing specific measures in favour of farmers with no more than 40 years of age.

Altitude is represented by two binary variables that take unitary value if farms are localized in flat areas and in hills, respectively, while they are zero if farms are located in the mountains. Geographical localization is described by a dummy that takes one if the farm is localized in Central-Northern Italy and zero if it is in Southern Italy. Economic size is represented by a dummy that takes value of one if the farm is large. It is zero in the case of small and medium-sized farms. Following a Eurostat (2016) classification, farms are identified as large if output is equal or higher than €25 thousand. As a measure of output, an average of gross marketable production (GMP) related to crops and livestock is calculated. Productive specialization is measured by four dummies related to arable crops, horticulture, livestock and permanent crops, respectively. Zero values indicate mixed specialization. Finally, policy is analysed by including CAP support per hectare related to the First Pillar and the RDP support in favour of diversification, expressed as a binary variable, which takes one if a farm received support.

The data used come from the Italian FADN. The sample analysed is composed of 51450 observations in the period 2014-2018. In this way, the effects of 2014-2020 CAP policy on the choice of diversification are analysed. 2018 corresponds with the latest year available. Observations are represented by different farms observed in one or more years. Since the farms that are present within FADN are subject to be changed over years, the analysis is conducted on pooled data. To take account of unobserved effects in different periods, dummies for the years 2015 to 2018 are added. If they are all zero, they indicate the year 2014.

The Italian FADN offers several data that can be used to identify farm diversification strategies (Table 1). These data refer to processing, direct farm sales, quality certification, agritourism, supply of mechanical, environmental, recreational and educational services, and other services such as rental of non-agricultural equipment and rooms for courses and seminars, craft and educational activities. Recalling the well-known and commonly used classification described in van der Ploeg and Roep (2003), processing, direct farm sales and quality certification can be included within the multifunctional direction of deepening, while the others are the result of broadening.[1] The presence of at least one

[1] van der Ploeg and Roep (2003) describe three types of multifunctional directions for farms: deepening, broadening and re-grounding. Deepening refers to all agricultural activities that are transformed, expand-

of the possible diversification activities can be inferred from economic information, data on policy support, list of certified products and processes and list of non-agricultural activities. The Italian FADN also allows the distinction between organic and conventional farms, indicating farms that are classified as organic.[2] By combining information on the presence of diversification with that relating to organic certification, it is possible to distinguish farms among organic farms that diversify, conventional farms that diversify and farms of any type without diversification strategies.

Table 2 shows the distribution of organic, conventional and all farms by kind of multifunctional direction. As can be noted, most farms undertake the direction of deepening, specifically processing. A small percentage of farms is oriented to broadening and an even smaller share combines both strategies. The differences between organic and conventional farms are not marked. However, organic farms are more oriented to deepening than broadening. Moreover, among organic farms with deepening, a higher share of farms process and sell products directly in comparison with conventional farms.

Table 3 shows some descriptive statistics of the sample used by logit models. The observations related to organic farms that diversify represent 12% of the entire sample and 74% of those related to all organic farms. Most are in Southern Italy (60%), operate in hills (60%) and have a medium-high level of education (about 70%). Moreover, they are prevalently specialized in permanent crops (54%) and received on average about 470 €/ha from the First Pillar of the CAP. Only 14% of the observations applied for RDP measures in favour of diversification. Compared to organic farms, conventional farms that diversify are relatively lower (58% of observations related to all conventional farms), are mainly localized in Central-Northern Italy (over 60% of observations), do not show a prevalently higher level of education and are less specialized in permanent crops (40%). They received on average 325 €/ha from the First Pillar of the CAP and nearly 30% of observations were supported by the Second Pillar.

4. RESULTS

Table 4 shows the results related to the multinomial logit model which assesses the effects of a selection of explanatory variables on the probability of diversification in organic and conventional farmers compared with farms with no diversification strategies. The significance associated with the likelihood-ratio test indicates that the model can be reasonably used to explain the reasons that lead farmers to diversify. McFadden's pseudo-R^2 can also be considered as acceptable.[3]

The coefficients related to localization show that there is a negative and significant relationship between the localization of organic farmers in Central-Northern Italy and the relative probability of diversifying, On the contrary, this relationship is positive in the case of conventional farmers. This means that organic farmers who diversify are more likely to localise in Southern Italy while it is more probable to find conventional farmers who diversify in Central-Northern Italy than farmers who do not diversify.

In relation to altitude, for both organic and conventional farmers the relationship between localization in flat areas and relative probability is negative while the one related to localization in hills is positive. Therefore, in both cases there is a higher probability that these farms localize in hills and do not localize in flat areas in comparison with farms that do not diversify. However, this probability appears to be slightly higher in organic farms.

As regards age, the coefficient associated with organic farms is positive and significant. This implies that organic farms that diversify are more likely to be younger compared to farms that do not diversify. On the contrary, the coefficient related to conventional farms is non-significant and no conclusion can thus be drawn.

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ed and/or relinked to other players and agencies in order to deliver products that entail more value added per unit precisely because they fit better with the demands in society at large. Broadening refers to the development of non-agricultural activities that enlarge the income flows of the farm enterprise, while they simultaneously imply the delivery of goods and services society is willing to pay for. Re-grounding occurs when the farm enterprise is grounded in a new or different set of resources and/or involved in new patterns of resource use. It refers to two specific fields of activity: pluri-activity and farming economically. Through pluri-activity the farm enterprise is partly built on off-farm income while farming economically is a strategy that raises income at farm enterprise level by reducing the use of external inputs and increasing the efficiency in the use of available internal inputs.

[2] In the Italian FADN, a farm is classified as organic if it is certified organic as a whole, there is at least one organic product or there is one process that is carried out with organic methods. This means that there could be mixed farms that combine organic and conventional farming. In this study, these farms are treated as organic.

[3] McFadden's pseudo-R^2 tends to be considerably lower than the R^2 index and should not be judged by the standards for a "good fit" in ordinary regression analysis. In fact, values of 0.2 to 0.4 represent an excellent fit (McFadden, 1978). Therefore, a value of 0.11 can be considered as acceptable. In any case, it should be stressed that the objective of the paper is to assess the influence of a battery of variables on the decision to diversify, focusing on those which are most analysed in literature and are of particular interest for this study. The search for further variables that can help to increase the goodness-of-fit of the model can be a future research direction.

Table 1. FADN variables used to identify on-farm diversification.

FADN Table	Variable	Direction
Economic accounts	Gross marketable production – Processing	Deepening
Economic accounts	Gross marketable production – Direct sales	Deepening
Policy	Measure 3.1 – New participation in quality schemes	Deepening
Policy	Measure 4.2 – Investments for processing/marketing and development	Deepening
Policy	Measure 4.4 – Non-productive investments	Broadening
Policy	Measure 8.1 – Afforestation/creation of woodland	Broadening
Policy	Measure 8.2 – Establishment and maintenance of agro-forestry systems	Broadening
Policy	Measure 8.6 – Investments in processing and marketing of forest products	Deepening
Policy	Measure 10.1 – Agri-environment-climate commitments	Broadening
Policy	Measure 10.2 – Genetic resources in agriculture	Broadening
Policy	Measure 15.1 – Forest-environmental and climate commitments	Broadening
Policy	Measure 132 – Participation of farmers in food quality schemes	Deepening
Policy	Measure 214 – Agri-environment payments	Broadening
Policy	Measure 221 – First afforestation of agricultural land	Broadening
Policy	Measure 222 – First establishment of agroforestry systems	Broadening
Policy	Measure 223 – First afforestation of non-agricultural land	Broadening
Policy	Measure 225 – Forest-environment payments	Broadening
Related activities	Agritourism	Broadening
Related activities	Craft activities	Broadening
Related activities	Educational activities	Broadening
Related activities	Mechanical services	Broadening
Related activities	Production of renewable energy	Broadening
Related activities	Recreational services	Broadening
Related activities	Rental of non-agricultural equipment	Broadening
Related activities	Rental of rooms for courses and seminars	Broadening
Related activities	Other services	Broadening
Certifications	Community eco-management and audit scheme (EMAS)	Broadening
Certifications	Environmental management system	Broadening
Certifications	Food safety management system	Deepening
Certifications	Integrated certified production	Broadening
Certifications	Intercompany traceability	Deepening
Certifications	Management system for hygienic self-control of products and processes	Deepening
Certifications	National zootechnical quality system	Deepening
Certifications	Protected designations of origin	Deepening
Certifications	Protected geographical Indication	Deepening
Certifications	Quality management system	Deepening
Certifications	Reduced environmental impact	Broadening
Certifications	Superior quality label (i.e. GMO free)	Deepening
Certifications	Traceability of the agri-food chain	Deepening
Certifications	Traditional agri-food product registered	Deepening
Certifications	Traditional specialities guaranteed	Deepening

Note: during the period 2014-2018, there are also payments related to the previous programming period (Measures 132, 214, 221, 222, 223, 225). To avoid the exclusion of farms that diversify and are supported by the past policy, these payments are also used for identifying diversification strategies. Measure 214 also includes payments in favour of organic farming. Since the focus is on policy in favour of diversification and organic farming is not here considered as a result of diversification, this measure was not considered in all cases where farms receiving support were organic farms or farms in conversion.

Table 2. Distribution of farms with diversification strategies by multifunctional direction, Italy, 2014-2018 (in %).

Direction	Organic Farms	Conventional Farms	All farms
Deepening	88.6	87.3	87.6
Processing	*98.2*	*97.0*	*97.2*
Quality certification	*64.5*	*70.8*	*69.4*
Direct sales	*52.0*	*46.7*	*47.9*
Broadening	6.5	8.4	8.0
Deepening & Broadening	4.9	4.3	4.4
Total	100.0	100.0	100.0

Note: the sum of processing, quality and direct sales is not 100 since the same farm can undertake one or more directions.

With reference to the education level, the relevant coefficients are positive and statistically significant indicating that it is more probable to find farmers with high and medium levels of education among farms that diversify in comparison with those with no diversification strategies. The coefficients associated with organic farms are largely higher and this shows the probability that organic farmers who diversify are more educated is higher than the one related to conventional farmers relatively to farms that do not diversify.

As far as economic aspects are concerned, the significant and positive coefficients associated with size demonstrate that there is a higher probability of diversifying in larger farms, and this is more evident for organic farmers.

About specialization, there is a positive and significant relationship between diversification and permanent crops in both types of farms, meaning that farmers who diversify are more likely to be specialised in permanent crops. This relationship is negative in other cases indicating that it is less probable that farms specialized in arable crops, horticulture and livestock diversify. The size of coefficients is larger in the case of organic farmers, therefore showing stronger relationships.

Concerning policy support from the First Pillar of the CAP, coefficients are significant, but the signs are opposed. As for organic farms, the positive coefficient shows that, as policy support increases, the likelihood that farms diversify increases in comparison with farms that do not diversify. Conversely, the negative coefficient associated with conventional farms indicates that farmers with higher support have a lower probability of diversifying.

Finally, dummies related to time show that the probability that farms diversify increased over time reaching the highest value in 2017.

Table 5 presents the marginal effects of explanatory variables calculated at the sample means. As mentioned in section 3.2, in contrast with coefficients, average marginal effects provide information about the relationship between alternatives and predictors independent of the base outcome. They measure the difference in probability of each of the outcome level associated with a change in each predictor variable. Consequently, coefficients and marginal effects have different interpretation and can provide different results. As regards organic farmers, the signs of the coefficients estimated by the multinomial logit model are confirmed, and all average marginal effects are significant. Results indicate that organic farmers localized in Central-Northern Italy and in flat areas have a probability of diversifying that is 7% and 6% lower than those localized in Southern Italy and in the mountains, respectively, as negative average marginal effects demonstrate. On the contrary, farmers operating in hills have a probability of diversifying that is 1% higher. Moreover, the likelihood that organic farms diversify is 3% higher in younger farmers and 6% and 12% higher in farmers with medium and high levels of education, respectively. From an economic point of view, larger farms are those where there is a higher probability of diversifying (+2%). With reference to specialization, the possibility of finding organic farmers who diversify is 3% higher in farms oriented to permanent crops than in mixed farms and is lower in other typologies of farms, especially among farms specialized in horticulture (-12%). The marginal effects associated with policy indicate that if policy support per hectare increases by one thousand units, the probability that an organic farm diversifies increases by 1%.

With regard to conventional farmers, not all marginal effects are consistent with coefficients in terms of direction and significance. Specifically, results show that conventional farmers operating in Central-Northern Italy and in hills have a probability of diversifying that is 7% and 4% higher than those localized in Southern Italy and in the mountains, respectively. Conversely, farmers operating in flat areas have a probability of diversifying that is 12% lower. Moreover, the likelihood that conventional farms diversify is 3% lower in younger farmers. It is also 2% lower in farmers with higher levels of education. These negative and significant relationships concerning age and education contrast with the results related to coefficients.

From an economic standpoint, the average marginal effect associated with size is positive but non-significant. Therefore, no conclusion can be drawn. With reference to specialization, conventional farms oriented to permanent crops have a probability of diversifying that is 6%

Table 3. Descriptive statistics about the sample used, Italy, 2014-2018.

	Mean	Standard deviation	Maximum*
Organic farms with diversification strategies (no. of obs. 6053)			
Located in Central-Northern Italy (dummy)	0.41	0.49	1
Located in flat land (dummy)	0.17	0.38	1
Located in hills (dummy)	0.60	0.49	1
Young farmers (≤ 40 years) (dummy)	0.21	0.41	1
Farmers with high-level education (dummy)	0.15	0.36	1
Farmers with medium-level education (dummy)	0.53	0.50	1
Large (≥ 25 € thousand of avg. GMP) (dummy)	0.70	0.46	1
Specialized in arable (dummy)	0.11	0.31	1
Specialized in horticulture (dummy)	0.03	0.17	1
Specialized in permanent crops (dummy)	0.54	0.50	1
Specialized in livestock (dummy)	0.20	0.40	1
First Pillar CAP payments per hectare (€)	466.56	604.00	10061.95
Supported by the second Pillar CAP for diversification (dummy)	0.14	0.35	1
Conventional farms with diversification strategies (no. of obs. 25088)			
Located in Central-Northern Italy (dummy)	0.63	0.48	1
Located in flat land (dummy)	0.24	0.43	1
Located in hills (dummy)	0.52	0.50	1
Young farmers (≤ 40 years) (dummy)	0.13	0.33	1
Farmers with high-level education (dummy)	0.06	0.23	1
Farmers with medium-level education (dummy)	0.43	0.50	1
Large (≥ 25 € thousand of avg. GMP) (dummy)	0.68	0.47	1
Specialized in arable (dummy)	0.19	0.39	1
Specialized in horticulture (dummy)	0.07	0.25	1
Specialized in permanent crops (dummy)	0.37	0.48	1
Specialized in livestock (dummy)	0.27	0.44	1
First Pillar CAP payments per hectare (€)	325.25	571.11	40618.18
Supported by the second Pillar CAP for diversification (dummy)	0.27	0.44	1
Farms with no diversification strategies (no. of obs. 20309)			
Located in Central-Northern Italy (dummy)	0.65	0.48	1
Located in flat land (dummy)	0.46	0.50	1
Located in hills (dummy)	0.34	0.47	1
Young farmers (≤ 40 years) (dummy)	0.12	0.32	1
Farmers with high-level education (dummy)	0.04	0.20	1
Farmers with medium-level education (dummy)	0.39	0.49	1
Large (≥ 25 € thousand of avg. GMP) (dummy)	0.70	0.46	1
Specialized in arable (dummy)	0.31	0.46	1
Specialized in horticulture (dummy)	0.16	0.37	1
Specialized in permanent crops (dummy)	0.16	0.36	1
Specialized in livestock (dummy)	0.31	0.46	1
First Pillar CAP payments per hectare (€)	395.34	1759.88	121033.9
Supported by the second Pillar CAP for diversification (dummy)	0.00	0.00	0

* Minimum values are always zero.

Table 4. Estimation of the multinomial logit model for organic and conventional farmers with diversification strategies compared with farmers with no diversification strategies.

	Organic farmers		Conventional farmers	
	Coefficients	Standard Deviation	Coefficients	Standard Deviation
Intercept	-1.250*	0.075	0.572*	0.048
Localization				
Central-Northern Italy (dummy)	-0.614*	0.033	0.144*	0.021
Altitude				
Flat land (dummy)	-1.246*	0.049	-0.849*	0.029
Hills (dummy)	0.282*	0.041	0.224*	0.027
Mountains (baseline)				
Age				
Young farmers (≤ 40 years) (dummy)	0.316*	0.044	-0.025	0.032
Education level				
High-level education (dummy)	1.436*	0.060	0.281*	0.049
Medium-level education (dummy)	0.712*	0.036	0.151*	0.022
Low-level education (baseline)				
Economic size				
Large (≥ 25 € thousand) (dummy)	0.275*	0.036	0.096*	0.023
Specialization				
Arable (dummy)	-1.499*	0.064	-0.908*	0.040
Horticulture (dummy)	-2.149*	0.090	-1.340*	0.046
Permanent crops (dummy)	0.610*	0.055	0.421*	0.040
Livestock (dummy)	-1.002*	0.059	-0.648*	0.039
Mixed (baseline)				
Policy				
First Pillar CAP payments per hectare**	0.045*	0.009	-0.127*	0.020
Time				
2014 (baseline)				
2015 (dummy)	0.314*	0.055	0.107*	0.032
2016 (dummy)	0.486*	0.053	0.101*	0.031
2017 (dummy)	0.692*	0.052	0.178*	0.031
2018 (dummy)	0.651*	0.052	0.168*	0.032

Number of observations = 51450

Likelihood-ratio test $\chi^2(32)$ =11045.95

Prob>χ^2=0

McFadden's pseudo R^2=0.111

* Statistically significant at 1%; ** coefficients and standard deviations are multiplied by 1000 for improving reading.

higher than the one of mixed farms. The other types of farms have lower probabilities, which reach the lowest value in farms specialized in horticulture (-18%). The marginal effect related to policy indicates that an increase of one thousand units in policy support per hectare decreases the probability of diversifying in conventional farms by 3%.

Table 6 shows the results related to the logit model, where the explanatory variables are regressed against the binary response probability of diversification in organic

Table 5. Marginal effects of explanatory variables related to the multinomial logit model.

	Organic farmers		Conventional farmers	
	Coefficients	Standard Deviation	Coefficients	Standard Deviation
Localization				
Central-Northern Italy (dummy)	-0.066**	0.003	0.072**	0.004
Altitude				
Flat land (dummy)	-0.063**	0.004	-0.121**	0.006
Hills (dummy)	0.012**	0.003	0.035**	0.006
Mountains (baseline)				
Age				
Young farmers (≤ 40 years) (dummy)	0.031**	0.004	-0.025**	0.007
Education level				
High-level education (dummy)	0.116**	0.005	-0.023*	0.010
Medium-level education (dummy)	0.057**	0.003	-0.009	0.005
Low-level education (baseline)				
Economic size				
Large (≥ 25 € thousand) (dummy)	0.020**	0.003	0.005	0.005
Specialization				
Arable (dummy)	-0.083**	0.005	-0.119**	0.008
Horticulture (dummy)	-0.117**	0.008	-0.179**	0.010
Permanent crops (dummy)	0.031**	0.004	0.060**	0.008
Livestock (dummy)	-0.053**	0.005	-0.089**	0.008
Mixed (baseline)				
Policy				
First Pillar CAP payments per hectare***	0.012**	0.001	-0.032**	0.005

* Statistically significant at 5%; ** Statistically significant at 1%; *** coefficients and standard deviations are multiplied by 1000 for improving reading.

farmers only compared with conventional farms that diversify. The likelihood-ratio test shows that the model as a whole fits significantly better than a model with no predictors. The negative and significant coefficients associated with Central-Northern Italy and flat land indicate that, in comparison with conventional farmers with diversification strategies, organic farmers who diversify have a lower probability to be localized in Central-Northern Italy and in flat areas. The coefficient related to hills is positive but non-significant, meaning that both types of farmers have the same probability of being localized in hills. As regards socio-demographic aspects, the positive and significant coefficients indicate that it is more likely that organic farmers who diversify are younger and have higher levels of education compared to conventional farmers. Organic farms that diversify are also larger than the conventional ones as the coefficient relevant to economic size demonstrates. Regarding specialization, the signs of coefficients, which are all significant, show that there is a higher likelihood that diversification is present in organic farmers specialized in permanent crops as well as a lower probability that organic farmers who diversify are specialized in arable crops, horticulture and livestock.

The positive and significant coefficient related to policy support from the First Pillar of the CAP confirms that organic farmers with higher support have a higher probability of diversifying than diversified conventional farms. On the contrary, the coefficient associated with policy support from RDP in favour of diversification is significant but negative. This means that there is lower probability of diversifying in organic farmers who receive support from the RDP.

Table 6 also provides information about average marginal effects. The effects estimated are consistent in terms of direction with those shown in Table 5 and can

Table 6. Estimation of the logit model for organic farmers compared with conventional farmers with diversification strategies and average marginal effects.

	Organic farmers		Average marginal effects	
	Coefficients	Standard Deviation	Effects	Standard Deviation
Intercept	-1.858*	0.072	-	-
Localization				
Central-Northern Italy (dummy)	-0.676*	0.032	-0.094*	0.004
Altitude				
Flat land (dummy)	-0.506*	0.049	-0.071*	0.007
Hills (dummy)	0.021	0.038	0.003	0.005
Mountains (baseline)				
Age				
Young farmers (≤ 40 years) (dummy)	0.388*	0.040	0.054*	0.006
Education level				
High-level education (dummy)	1.265*	0.053	0.176*	0.007
Medium-level education (dummy)	0.589*	0.034	0.082*	0.005
Low-level education (baseline)				
Economic size				
Large (≥ 25 € thousand) (dummy)	0.206*	0.034	0.029*	0.005
Specialization				
Arable (dummy)	-0.583*	0.061	-0.081*	0.009
Horticulture (dummy)	-0.862*	0.090	-0.120*	0.013
Permanent crops (dummy)	0.186*	0.049	0.026*	0.007
Livestock (dummy)	-0.272*	0.055	-0.038*	0.008
Mixed (baseline)				
Policy				
First Pillar CAP payments per hectare**	0.409*	0.030	0.057*	0.004
Second Pillar CAP support for diversification (dummy)	-0.665*	0.043	-0.093*	0.006
Time				
2014 (baseline)				
2015 (dummy)	0.162*	0.053		
2016 (dummy)	0.385*	0.051		
2017 (dummy)	0.531*	0.050		
2018 (dummy)	0.543*	0.050		

Number of observations = 31141

Likelihood-ratio test $\chi^2(17)$ =3220.12

Prob>χ^2=0

McFadden's pseudo R^2=0.105

* Statistically significant at 1%; ** coefficients and standard deviations are multiplied by 1000 for improving reading.

be interpreted analogously. An additional result is related to the positive and significant effect concerning the Second Pillar of the CAP, which shows that the organic farmers not receiving support from the RDP have a probability of diversifying that is 9% higher than that of farmers who are supported. This implies that among conventional farmers who do not receive support this probability is 9% lower.

5 DISCUSSION

Results indicate that farmers who diversify have different geographical localization. Organic farmers are mainly localized in Southern Italy while conventional farmers can be prevalently found in Central-Northern Italy. This partly contrasts with Dries *et al.* (2012) who find that the likelihood to observe diversification is higher in Southern Italy due to more difficult socio-economic conditions that favour the development of non-traditional activities to complement agricultural income. In our study, a higher probability of diversifying also involves conventional farms located in Central-Northern Italy and is a consequence of the territorial distribution of farmers. In fact, about 60% of organic farmers who diversify are in Southern Italy, against 35% of conventional farmers. A common finding is that that diversification is less widespread among farms operating in flat areas. This is likely due to the fact that the more competitive farms that are localized in flat areas have a lower need to expand their activity and increase their income than farms located in less favoured areas (Dries *et al.*, 2012).

As far as the characteristics of farmers are concerned, results show that education level contributes to explaining diversification strategies. Specifically, farmers with higher levels of education diversify more frequently in accordance with other studies (McElwee and Bosworth, 2010; Boncinelli *et al.*, 2017, 2018). This confirms that the lack of education and skilled labour may represent major barriers to finding opportunities within the new challenges of agricultural business (Khanal, 2020). However, among conventional farmers, those who are most likely to diversify are not farmers with the highest levels of education, although they are more educated than those who do not diversify.

Farmer's age also influences the probability of engaging in diversification activities but with contrasting effects. This might explain why controversial results can be found in literature. In the case of conventional farms, farmers do not exhibit clear differences compared to farmers with no diversification strategies. However, within the group of conventional farms, older farmers seem to be more oriented to diversification as others studies have shown (Joo *et al.*, 2013). Conversely, in organic farms, there is higher propensity of younger farmers to diversify, which is consistent with the findings of Barbieri and Mahoney (2009), who have stressed that longer-term ties would lead younger farmers to strengthen the existing farm business through diversification for future generations.

Looking at economic and structural aspects, it turns out that the economically largest farmers are those who diversify the most, independently of their model of production. The reason could be that the reduction of marginal returns determines that farms' resource allocation is addressed towards more profitable activities (McNamara and Weiss, 2005; Ilbery, 1991; McNally, 2001) or more simply that larger farmers have more resources to bound to other activities than agriculture (García-Arias *et al.*, 2015). Specialization is another factor explaining the choice of diversifying in both organic and conventional farmers. Farmers specialized in permanent crops are found to diversify to a larger extent in line with findings by Dries *et al.* (2012). This higher tendency to diversification may be due different reasons (Salvioni *et al.*, 2020). Firstly, farms that allocate most of the agricultural area to permanent crops may have limitations in managing risks through crop diversification. For this, they may be characterized by lower and more concentrated seasonal harvests than farms specialized in herbaceous crops, which raise a problem of underuse of labour force during the rest of the year. Additionally, products from permanent cropping systems (i.e., olive oil and wine) are better suited to differentiation-based marketing strategies. These factors increase the likelihood for farms to diversify, in particular towards processing and direct sale, which represent widespread diversification strategies in farmers specialized in permanent crops.

As regards policies, both Pillar 1 and 2 payments affect the propensity to diversify production consistently with previous studies (Bartolini *et al.*, 2014). However, the effects on organic and conventional farmers are opposed. In the case of conventional farmers, results indicate that Pillar 1 payments negatively affect the choice of diversifying. The explanation could be that these payments, by producing a wealth effect, reduce the need to increase income by diversification. Conversely, in organic farmers, the effects are positive. Farmers who receive a higher support tend to diversify to a larger extent than the average. In this case, the higher financial resources made available by the CAP are likely to be used to finance diversification. Therefore, for organic farmers, the motivation pushing to diversification does not seem to integrate income but to expand activity by taking advantage of benefits from both organic production in terms of consumers' willingness to purchase at higher prices and diversification in relation to the possibility of obtaining an even higher value added (Zander, 2008; Sidali *et al.*, 2019). With reference to the Second Pillar of the CAP, payments affect positively diversification adoption but only in conventional farmers. Conversely, these payments do not exert any influence on organic farmers. Results even show that organic farmers that diversify apply for policy measures supporting diversification to a lesser extent. This is a further confirmation of different motivations leading conventional and organic farmers to diversify.

In interpreting the results, some possible drawbacks deriving from the approach used here should be taken into consideration.

A first potential drawback comes from the fact that the sampled farms that do not diversify include both organic and conventional farms and that the latter represent the majority (around 90%). Therefore, one of two comparisons is substantially between organic farms that diversify and those conventional which do not diversify. In addition, the fact that organic farms that diversify represent most organic farms (about 70%) implies that this comparison is basically between organic farms and conventional farms, and that the results are therefore affected by the main characteristics and differences of organic farms in comparison with the conventional ones. However, this does not compromise the main findings of this study but, on the contrary, strengthens the conclusion that organic farming and on-farm diversification are strongly connected with each other.

A further and possible drawback deriving from mixing organic and conventional farms that do not diversify is that these two types of farms can exhibit marked differences which can explain why a conventional farm decides to convert to organic farming and would suggest that farms that do not diversify should also be kept separate. For example, marginality conditions and difficulties in reaching the same profitability as that of more competitive conventional farms due to agricultural constraints can be some of these reasons. However, this may be valid for a part of farms, especially for those which decide to convert. In fact, it has been shown that organic farms are mostly present in areas with favourable socio-economic and climatic conditions, both globally but also within countries, and that, within developed countries, the locations of organic crop farmers often do not differ significantly from the locations of conventional crop farmers (Malek *et al.*, 2019). Moreover, for a share of farms, particularly for new entrants, organic farming may represent an effective strategy to capture the economic opportunities provided by the current changes in the market and consumers' preferences regardless of the presence of agricultural constraints. This allows conventional and organic farming to be viewed in the same way as business strategies and is consistent with the main objective of the paper of understanding the reasons why a farm decides to diversify rather than converting to organic farming. From a methodologic point of view, keeping organic and conventional farms that do not diversify also separate means that two distinct logit models should be performed in the place of a single multinomial model. Although this can be a useful exercise for future research, which can provide further information, in this way, the coefficients of the models estimated separately for organic and conventional farms as well as the relevant marginal effects could not be compared directly.

6. CONCLUSIONS AND POLICY IMPLICATIONS

This paper aimed to analyse the possible differences between organic and conventional farms in relation to the reasons that lead farmers to diversify. The focus is on the Italian FADN sample of farms observed in the period 2014-2018. From a methodological standpoint, multinomial and binary logit models, linking the probability that several alternatives are chosen to a few territorial, socio-economic, and political factors, are adopted. The approach used is based on the consideration that organic farming should not be considered as one of the possible options of diversification available to conventional farms but a model of production that may respond to different logics.

Results suggest that, in both organic and conventional farms, diversification might not be necessarily an obliged passage for marginal farms which desire to survive. On the contrary, it can be more assimilated to an entrepreneurial strategy that requires specific competences and adequate organization. However, the reasons for diversifying differ according to the kind of production model. In the case of conventional farming, farmers might decide to diversify because they are not able to reach income levels comparable with those of a more competitive and highly mechanized agriculture due to factors related to localization, specialization, and lower support from the First Pillar of the CAP. Therefore, they diversify to increase their income using policy support from the RDP in favour of diversification. Conversely, in the case of organic farming, diversification seems to be an integrated part of the production model. Organic farmers are likely to implement new activities, particularly processing and direct sales, to take advantage of benefits from both organic production and diversification, regardless of the policy support for diversification. For these farms, localization in less competitive areas and specialization in permanent crops might not be necessarily weakness factors, but rather distinctive characteristics that can be further enhanced by the diversification pattern.

These results highlight some possible policy implications. A first consideration is that the incentives to implement diversification strategies appear to be ineffective in organic farms. A reason can be related to profitability reasons and the existence of synergies between different activities. The benefits, net of costs and administrative burdens, which can be obtained by requesting public support for diversification, may be lower than the benefits deriving from combining organic farming with diversification without asking for support. Therefore, organic farmers can afford not to request support, or they do not express the need to request it at all. This can be positive as it can mean that organic farming, combined with diversification, allows farmers to reach levels of competitiveness that make the request for public support for diversification unnecessary. However, it must be considered that organic farmers, compared to conventional ones, also benefit from specific support for the conversion and maintenance of organic farming and this raises the question of how to better distribute the funds in favour of diversification between different types of farming in order to make policy more targeted and effective. A further consideration is more general and concerns both organic and conventional farms. Results show that diversification strategies are undertaken prevalently by larger farms with higher levels of education. This means that smaller and family farms, which would benefit from on-farm diversification, do not diversify and this might depend on the lack of resources as well as on low skills and entrepreneurial capabilities, which prevent them from accessing policy support. Therefore, administrative simplification as well as training and consultancy services specifically designed for this category of farms should be strengthened to avoid abandonment of agriculture, particularly in marginal areas. In the context of organic farming, this strategy could leverage the greater presence and propensity of young farmers to diversify and would be in line with recent European policy indications aimed at giving a significant acceleration in the growth of the organic sector.

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REFERENCES

Aubert, M. and Enjolras, G. (2016). Do short food supply chains go hand in hand with environment-friendly practices? An analysis of French farms. *International Journal of Agricultural Resources, Governance and Ecology* 12(2): 189–213.

Barbieri, C. and Mahoney, E. (2009). Why is diversification an attractive farm adjustment strategy? Insights from Texas farmers and ranchers. *Journal of Rural Studies* 25(1): 58–66.

Bartolini, F., Andreoli, M. and Brunori, G. (2014). Explaining determinants of the on-farm diversification: Empirical evidence from Tuscany region. *Bio-based and Applied Economics* 3(2): 137–157.

Boncinelli, F., Bartolini, F. and Casini, L. (2018). Structural factors of labour allocation for farm diversification activities. *Land Use Policy* 71: 204–212.

Boncinelli, F., Bartolini, F., Casini, L. and Brunori, G. (2017). On farm non-agricultural activities: geographical determinants of diversification and intensification strategy. *Letters in Spatial and Resource Sciences* 10(1): 17–29.

David, C., Mundler, P., Demarle, O. and Ingrand, S. (2010). Long-term strategies and flexibility of organic farmers in southeastern France. *International Journal of Agricultural Sustainability* 8(4): 305–318.

Dries, L., Pascucci, S. and Gardebroek, C. (2012). Diversification in Italian farm systems. *New Medit* 4: 7–15.

European Parliament (2016). Farm diversification in the EU. Briefing, April 2016 Available at: http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/581978/EPRS_BRI(2016)581978_EN.pdf.

Eurostat (2016). Small and large farms in the EU - statistics from the farm structure survey. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Small_and_large_farms_in_the_EU_-_statistics_from_the_farm_structure_survey.

Frederiksen, P. and Langer, V. (2008). Patterns of resource use on Danish organic farms: Aspects of farm-based rural development. *International Journal of Agricultural Resources, Governance and Ecology* 7(1–2): 96–109.

García-Arias, A.I., Vázquez-González, I., Sineiro-García, F. and Pérez-Fra, M. (2015). Farm diversification strategies in northwestern Spain: Factors affecting transitional pathways. *Land Use Policy* 49: 413–425.

Henke, R. and Vanni, F. (2017). Drivers of on-farm diversification in the Italian peri-urban agriculture. *Italian Review of Agricultural Economics* 72(1): 79–100.

Van Huylenbroeck, G., Vandermeulen, V., Mettepenningen, E. and Verspecht, A. (2007). Multifunctionality of Agriculture: A Review of Definitions, Evidence and Instruments. *Living Reviews in Landscape Research* 1: 1–43.

Ilbery, B.W. (1991). Farm diversification as an adjustment strategy on the urban fringe of the West Midlands. *Journal of Rural Studies* 7(3): 207–218.

Joo, H., Khanal, A.R. and Mishra, A.K. (2013). Farmers' Participation in Agritourism: Does It Affect the Bottom Line? *Agricultural and Resource Economics Review* 42(3): 471–490.

Khanal, A.R. (2020). Interlinked diversification strategies: evidence from the US farm business households. *Journal of Agribusiness in Developing and Emerging Economies* 10(3): 253–268.

Khanal, A.R., Mishra, A.K. and Omobitan, O. (2019). Examining organic, agritourism, and agri-environmental diversification decisions of American farms: are these decisions interlinked? *Review of Agricultural, Food and Environmental Studies* 100(1–4): 27–45.

Luttikholt, L.W.M. (2007). Principles of organic agriculture as formulated by the International Federation of Organic Agriculture Movements. *NJAS - Wageningen Journal of Life Sciences* 54(4): 347–360.

Malek, Ž., Tieskens, K.F. and Verburg, P.H. (2019). Explaining the global spatial distribution of organic crop producers. *Agricultural Systems* 176: 102680.

Marongiu, S. and Cesaro, L. (2017). Determinants of Farmers' participation in Food Quality Schemes in Italy and farm-level performance analysis based on FADN. Paper presented at the XV EAAE Congress, Parma, 28 August – 1 September 2017.

McElwee, G. and Bosworth, G. (2010). Exploring the strategic skills of farmers across a typology of farm diversification approaches. *Journal of Farm Management* 13(12): 819–838.

McFadden, D. (1978). Quantitative Methods for Analyzing Travel Behaviour on Individuals: Some Recent Developments. In Hensher, D. A. and Stopher, P. R. (eds.), *Behavioural Travel Modelling*. London: Crom Helm, 279–317.

McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In Zarembka, P. (ed.), *Frontiers of Econometrics*. New York: Academic Press, 105–142.

McNally, S. (2001). Farm diversification in England and Wales-what can we learn from the farm business survey? *Journal of Rural Studies* 17(2): 247–257.

McNamara, K.T. and Weiss, C. (2005). Farm Household Income and On- and Off-Farm Diversification. *Journal of Agricultural and Applied Economics* 37(1): 37–48.

Meraner, M., Heijman, W., Kuhlman, T. and Finger, R. (2015). Determinants of farm diversification in the Netherlands. *Land Use Policy* 42: 767–780.

van der Ploeg, J.D. and Roep, D. (2003). Multifunctionality and rural development: the actual situation in Europe. In Van Huylenbroeck, G. and Durand, G. (eds.), *Multifunctional Agriculture: A new paradigm for European Agriculture and Rural Development*. Ashgate, Hampshire, England, 37–53.

Rivaroli, S., Ghelfi, R., Bertazzoli, A. and Piorr, A. (2017). Diversification pathways and farming systems: Insights from the Emilia-Romagna region, Italy. *Outlook on Agriculture* 46(4): 239–247.

Salvioni, C., Esposito, L., Henke, R. and Rondinelli, V. (2009). Diversification strategies in small farms in Italy. Paper presented at 111 EAAE-IAAE Seminar Small Farms: decline or persistence, University of Kent, Canterbury, UK, 26th-27th June 2009.

Salvioni, C., Henke, R. and Vanni, F. (2020). The Impact of Non-Agricultural Diversification on Financial Performance: Evidence from Family Farms in Italy. *Sustainability* 12(2): 486.

Sidali, K.L., Spitaler, A. and Schamel, G. (2019). Agritourism: A Hedonic Approach of Quality Tourism Indicators in South Tyrol. *Sustainability* 11(13): 3747.

Vik, J. and Mcelwee, G. (2011). Diversification and the Entrepreneurial Motivations of Farmers in Norway. *Journal of Small Business Management* 49(3): 390–410.

Weltin, M., Zasada, I., Franke, C., Piorr, A., Raggi, M. and Viaggi, D. (2017). Analysing behavioural differences of farm households: An example of income diversification strategies based on European farm survey data. *Land Use Policy* 62: 172–184.

Wulff, J.N. (2015). Interpreting Results From the Multinomial Logit Model: Demonstrated by Foreign Market Entry. *Organizational Research Methods* 18(2): 300–325.

Zander, K. (2008). Diversification and specialisation as development strategies in organic farms. Paper presented at 16th IFOAM Organic World Congress, Modena, Italy, June 16-20, 2008 Available at: http://orgprints.org/id/eprint/13980.

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Financial performance of connected Agribusiness activities in Italian agriculture

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Abstract. The Rural Development Policy combines measures that favour the growth of the productive dimension of farms and their specialization, and measures aimed at supporting diversification paths, with the expansion of the productive functions performed. The evaluation of the economic and financial results of farms engaged in activities of the second type can help to calibrate the intervention between the two options. To this end, we have studied a constant sample of FADN farms in the period 2014-2016, identifying the units engaged in organic farming or other forms of quality production, or engaged in direct sales or processing of their products or, again, in the management of farmhouses. We discuss the condition of financial sustainability of the farms involved in those activities by evaluating their ability to generate cash flows to offset for the depreciation of the farm production system. We used the ratio Free Cash Flow on Equity on Depreciation to compare the results of farms engaged in those activities and farms which are limited to conventional agriculture. The analysis of this comparison and of some structural, technical, and economic characteristics of the farms involved in those types of activities resulted in various considerations on their characteristics and conditions of financial sustainability. Our attention has focused above all on the financial results of farms within the sectors of Italian agriculture in greater financial difficulty. The main objective was, in fact, to verify whether to diversify the farm's commitment with these activities has contributed to improving the financial sustainability in those agricultural sectors. Various considerations have arisen that can help fine-tune policies to support the types of diversification examined in this study.

Keywords: depreciation, Free Cash Flow on Equity, farm financial sustainability, agribusiness, organic farming, agricultural products processing, direct sale of agricultural products, quality agricultural products, farmhouses.
JEL Codes: Q13, Q14.

1. INTRODUCTION

Rural development policy was introduced as the second pillar of the CAP as part of the Agenda 2000 reform. Since then, with the aim of protecting rural heritage and creating new jobs, it has also been dedicated to supporting multifunctionality and the diversification of agricultural activities. The focus on diversification increased in the 2007-2013 period, with Axis 3

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(quality of life in rural areas and diversification of the rural economy), as well as in the 2014-2020 programming period, extended up to 2023 and 2025 for many RDP projects, with priorities 2 (Farm Viability and Competitiveness) and 6 (Social inclusion and economic development).[1] In the latter period, the Italian Regions allocated 624 million euros, 3.2% of the entire RDP budget, for sub-measures 6.2 (Aid for start-up of non-agricultural activities in rural areas) and 6.4 (Investments to create and develop non-agricultural activities). The budget has been reduced in 2020 over the same period in 2018, linked to the COVID-19 crisis, especially for activities such as agritourism, educational farms. Yet, requests for support for operations related to diversification have been substantial, making funding insufficient in many cases (ISMEA, 2020).

In the period 2010-2019 the trend to diversify agricultural activities has notably grown and in 2019 about one fifth of the total value of agricultural production (€ 12.5 billion) came from secondary and support activities. Among others, the first-stage processing of agricultural products increased from 1.5 to 2.4 billion euros in the whole period, while direct selling of farm products grew by 4.3% in 2018-2019 (CREA PB, 2021; ISTAT, 2020). Farms engaged in related or secondary activities are concentrated in the Centre-North of Italy, which indicates an imbalance in the development of these activities but also a great potential for further expansion.

The scientific literature treats the intensification and propagation of these activities as the effect of a change in EU agricultural policies and in the choices of farmers seeking to stabilize and supplement their incomes. In this regard, an important line of analysis examines the factors influencing farmers' decision to diversify or undertake other activities besides conventional agriculture (Mishra et al., 2004; Rivaroli et al, 2017; Barbieri, 2010). A wide debate therefore concerns the influence of the farmer's age and education, the presence of female labour, the degree of production specialization and the operational size of the farm. McNamara and Weiss (2005) and Meraner et al. (2015) claim that larger farms diversify; in contrast, Mishra et al. (2004) claim that larger farms tend to specialize instead. For tourism-related activities, the influence of other factors is also considered, such as public support or the environmental characteristics of the area where the farms are located (De Rooij et al., 2014; Boncinelli et al., 2018; Biczkowski et al., 2021). Proximity to urban areas and consumers is also shown to play a key role, especially in terms of direct selling (Zasada et al., 2015; Pölling and Mergenthaler, 2017). Conversely, it is also highlighted that farms far from urban areas can be pushed to diversify due to the lack of alternatives (Bartolini et al., 2014; Arias et al., 2015). At the same time, the repercussions of these activities on the development and social and environmental well-being of one's own territory are also considered (Arfini et al.,2019a, 2019b; Raimondi et al., 2018; Belletti et al. 2017; Heringa et al., 2012; Lange et al., 2013).

The analysis also concerns the production, economic and financial results obtained by the farms that are dedicated to these activities. Studies have investigated the impact of these activities on farm work (Chaplin et al., 2004; Raimondi et al., 2018), on technical efficiency (Lakner et al., 2018, Arru et al., 2019) and on income (Barbieri, 2013; Barnes et al., 2015; Salvioni and Fontanella, 2013). Khanal and Mishra (2014) study the financial situation of these farms and state that the income of agritourism families is higher than other agricultural households. According to Joo et al. (2013) agritourism has a positive effect on financial sustainability only on small farms. Salvioni et al. (2020) conclude that diversification also has a positive impact on the financial performance of Italian farms.

Below we focus our attention on the financial condition of the farms engaged in these activities. We study their cash flows which, according to Fazzari et al (1988) and Kaplan and Zingales (2000), measure the firm's dependence on internal funds, helping to explain its investment choices, the ability to obtain credit and, hence, to finance investments. Our analysis follows the approach of Dono et al. (2021) which frame financial sustainability in the ability to offset the depreciation of the production system with cash flows. Specifically, these authors evaluate the ratio between Free Cash Flow on Equity (FCFE) and the value of depreciation (F/D index) in a constant sample of FADN farms over the period 2014-2016, and show that F/D is higher than 1 in most types of specialized farms, while it is less than 1 in non-specialized types.

Dono et al. (2021) examine the financial condition of the ensemble of Italian farms, focussing on the different technical-economic orientation sectors. Here we deepen the study of their FADN sample by examining the financial condition in the farms that diversify their activities. In this regard, we focus on *first processing* and *direct selling* of farm products, as well as on *farmhouse*. These activities require more profound changes in entrepreneurial performance, unlike the electricity production, the provision of farm subcontracting services and

[1] Focus Area 2A "Improving the economic performance of all farms and facilitating farm restructuring and modernisation" and 6A "Facilitating diversification, creation and development of small enterprises as well as job creation".

the land leasing, which are excluded from our analysis. We also consider *organic farming* that, while managing typical agricultural practices, modifies the classic profile of the farm and its productions, abandoning the conventional approach. Finally, we include the supply of *quality products* that, with the single farm, often involves other units in areas where productions with typical and homogeneous attributes are made[2].

For convenience we call *Agribusiness* the whole of these activities, considering that they are an attempt to search for market niches by enriching the range of goods and services provided to users of the typical farm products. The analysis compares the financial results of the farms conducting these 5 activities with the results of farms that conduct only conventional farming activities, which we call *simple farming*. We first examine the financial condition of the FADN sample farms involved in at least one of the 5 based on the F/D ratio, named *sustainability index*, as done by Dono et al. (2021).. Structural, commercial, and economic characteristics that can influence the financial results of the farms involved in the 5 *agribusiness* are hence identified. Comparisons are made with the financial results of the farms that are limited to conventional agricultural management. The analysis is exploratory and looks for clues on the contribution of these activities to the financial sustainability of Italian farms, focusing on the agricultural sectors that Dono et al. (2021) indicate as in difficult financial conditions. This study is, therefore, preliminary to a modelling, econometric or mathematical programming, of the contribution of these activities to the financial sustainability of Italian agriculture.

The next paragraph presents the materials and methods, framing the contribution of the financial analysis, the sequence of operations to calculate cash flows and the indicator used to express the financial sustainability of farms. The section on the results reports the general characteristics of the sample of farms, with the representativeness and weight of the 5 agribusiness activities on the total. Subsequently, the levels of FCFE and depreciation are described to compare the condition of the farms that only deal with typical agriculture and those involved in the 5 agribusinesses. This analysis is conducted by single activity, by technical-economic sector and by size class of farms. The discussion and conclusion sections follow.

[2] Dealing with diversification and multifunctionality would require referring to consolidated scientific classifications that generally lead back to the concepts of deepening, expansion and regrounding. (Van der Ploeg et Roep, 2003). Yet, the scientific literature agrees that referring to a unique classification could create confusion and complicate the comparison between results obtained from different studies (Sardone et Monda, 2019; Henke et Salvioni, 2011). Even referring to regulations does not always solve the problem of classification. National accounting divides into *support activities* and *secondary activities* contributing to the agriculture production. Eurostat distinguishes *Processing of agricultural products* and *other production of goods and services*. Italian legislation is based on Article 2135 of the Civil Code (OECD, 2009).

2. MATERIALS AND METHODS.

2.1 General characteristics of the sample of farms

We analyse the financial sustainability of Italian farms based on the constant sample of FADN data used by Dono et al. (2021). The FADN was established by the Reg. 79/65/EEC, updated by Reg. CE 1217/2009, and annually collects technical and economic data of a large farms sample following a similar approach in the European Union countries. The more than 86,000 FADN farms represent nearly 5 million farms in the EU, 90% of the Utilized Agricultural Area (UAA) and 90% of Standard Production. Currently the Italian sample is based on about 11,000 farms and covers 95% of the UAA, 97% of the value of Standard Production, 92% of the Work forces and 91% of the Livestock Units. About 1,000 variables are recorded for each farm in the sample, more than 2,500 for the Italian FADN. The FADN sample only includes professional and market-oriented farms and is stratified by region, size class and technical-economic orientation [OTE as Italian acronym, Type of Farm (TF) according to Reg. CE n. 1242/2008, henceforth TF]. Based on these data, Dono et al. (2021) obtain three years of financial statements (2014-2016) for a constant FADN sample consisting of 4.612 Italian farms, for a total of 13,836 observations.

Here we divide the FADN sample considering the farms involved in the 5 most diffused *agribusiness*: namely *organic farming (thereafter organic)*, *processing*, *direct selling (selling)*, *quality production (quality)*, and *farmhouses*. Of these groupings, the weight on the total sample of some key variables, structural (Gross Capital, UAA, Working Units) and economic [Gross Saleable Production (GSP), Operating Income], as well as their average value is calculated. This provides a representation of the importance and the operational and economic dimension of these activities. The next paragraph illustrates how the cash flows for each farm are calculated in each of the three years considered.

2.2 The calculation of cash flows

Table 1 shows how the cash flow of each farm is computed. The procedure begins by subtracting the tax component from the Operating Result, then adds depre-

Table 1. FCFE Calculation: formulas and FADN Databases (FDB) used.

Income and cash flow items	FDB	Note
Operating income	IS	
- Taxes		
+ Depreciation		
+ Other provisions	BS	Δ (employee leaving indemnity fund + other funds)
± Δ Net working capital	BS	Δ (debts + credits + product stock + raw materials stocks)
- Investments		
Cash Flow From Operations (CAFFO)		
± Principal portion	BS	Δ medium/long term debt
- Interest portion	IS	
+ Public aid		EU second pillar aid and other national aid
+ Other receipts		
Free Cash Flow + Compensation to Farmer resources (CAFFE)		
- Payment to capital	*BS*	% of net capital
- Compensation to managerial work	*IS*	% of gross marketable output
- Compensation to manual labor	*Lab*	hourly wages for hours of family work
Free Cash Flow to Equity (FCFE)		

(IS) = Income Statement; (BS) = Balance Sheet; (Lab) = Labor file; D = variation over the year.

ciation, provisions for severance pay and for risks and other expenses. The *variation of net working capital*, as made up of operating receivables with customers and operating payables with suppliers is hence added, as well as *investments*, obtained as increase of inventories net of their depreciation. This generates the *Cash Flow from Operations*. Once the cash flow of the operating activity has been obtained, the financial balance of relationships with the financiers of the farm is considered: where paying interest and principal on debts falling due in the year reduces liquidity, while obtaining new loans increases it. Public aid from the second pillar of the CAP and other national measures also increase liquidity, as well as revenue from other current accounts or other income, such as financial assets or divestments. Paying fines and repaying other loans reduces liquidity. This sequence generates a monetary liquidity variable that still includes payments to work, and the capital resources provided by the farmer. The final cash flow is obtained by subtracting cash withdrawals to pay for the farmer's resources: Dono et al. (2021) estimated these latter payments at opportunity cost values to obtain the *Free Cash Flow to Equity* (FCFE). We use the same approach, although it is an approximation as the farmer does not necessarily collect the opportunity cost payments for the resources provided as, moreover, as is the case with the distribution of corporate dividends (Chay & Jungwon Suh, 2009).

Financial sustainability is considered as achieved when FCFE is greater than the depreciation of productive capital, even by a margin that can also repay a debt service provided at a subsidized rate. This indicator can be traced back to the financial analysis of the debt of the company that Bonazzi and Iotti apply to the tomato processing industry, aquaculture, and dairy cattle breeding in Italy (Bonazzi and Iotti, 2014a, 2014b, 2015; Iotti and Bonazzi, 2015). These authors calculate the financial sustainability of investment debt by relating its cost to the cash flows generated by various level of the operating activities[3]. Yet, these indicators can be calculated only in relation to specific investment programs that are in place only in a part of the FADN farms. To carry out a financial sustainability analysis in all cases, as in Dono et al. (2021), we assess whether the final monetary liquidity surplus given by FCFE is sufficient to balance the residual implicit costs, i.e., the depreciation of technologies and provisions for risks or other funds. The index does not check whether the farms will reproduce the initial capital or not. Depreciation, in fact, is calculated at historical cost, which in the case of old plants can make the current restoration cost even very different from that associated with depreciation. Furthermore, new market, policy support and production technology conditions may not induce farmers to restore the original system. Thus, the index verifies a minimum sustainability condition, defined as *weak*, which reveals whether farms are generating additional cash flows at the same rate at

[3] Bonazzi and Iotti (2014b) consider, among others, the Operating Cash Flow, and the Unlevered Free Cash Flow, which subtracts the investment and adds the divestment to the former.

which their technological system depreciates. Moreover, unlike the economic valuation indices, the financial components allow this ratio to also embody the investment efforts of farms, as well as their commercial and financial relationships. Dono et al. (2021) calculate the index for the whole sample and for 18 TFs that aggregate the original FADN TFs.

The following analysis compares the economic-financial situation of farms dedicated exclusively to agriculture (*simple farming*), and those involved in at least one of the 5 activities listed above as *agribusiness*. Specifically, the analysis concerns basic structural, commercial, and economic characteristics of the farms in those groups, as well as their values of FCFE, Depreciation and FCFE/Depreciation Ratio (F/D), calculated as in Dono et al. (2021). The comparison is carried out within each Type of Farming (TF), whose index values of *simple farming* are used as reference for assessing the condition of the farms involved in *agribusiness*. After a first general analysis in the whole sample and in each of its TFs, the farms' financial results in each of the 3 years of the sample are examined. This generates three groups of different stability in the financial result: *agribusiness* farms with always better results than *simple farming* (*better*); farms with alternating results (*alternating*); and farms whose results are always worse than *simple farming* (*worse*). This aggregation changes the numbers in *simple farming* and *agribusiness* because includes in the latter also farms engaged in these activities for only one or two of the three years considered, i.e., that are in the start-up or disinvestment phase.

Finally, the results of these three groups are presented by size classes to reduce the influence of the operational scale on the comparison between *agribusiness* and *simple farming*. These classes are obtained by dividing into three equal segments the variation range of the farm's gross saleable agricultural production (GSP) in each TF. Therefore, for instance, expressed in thousands of euros, the small dairy cattle have a GSP of less than € 1.025, the medium between € 1.025 and € 2.044, the large between € 2.044 and € 3.063. Particular attention is paid to the results in the TFs whose F/D value is below the financial sustainability threshold, to assess whether their agribusiness farms show better results or share this difficult situation.

3. RESULTS

Table 2 shows structural and economic features on the constant sample of FADN farms in the period 2014-2016. The two sections of the table distinguish the cases only involved in *simple farming* and the cases also engaged in the 5 *agribusiness*. The latter are shown both for their general aggregate (*agribusiness*), and for each of the 5 activities. The first section of the table reports the percentage of each group for each variable that are Gross Capital, Utilized Agricultural Area (UAA), Family Work Units, Gross Saleable Production (GSP), Operating Income and the number of cases. Note that the sum of *simple farming* and *agribusiness* is 100, while the sum of the 5 activities exceeds the total of *agribusiness*, because of cases engaged at the same time in more of these activities. The second section of the table reports the average value of those variables, and the average value of ROI calculated net of from the first pillar CAP payments.

The two sections of the table show that, despite an average area analogous to *simple farming*, the farms with *agribusiness* operate in average with lower Gross Capital, employ fewer Family Work Units and generate lower Production Values and Operating Income. Differences emerge for *organic*, whose Production Value is higher than in *simple farming*. *Farmhouses* prevails for Gross Capital invested and employed Family Work, although not in terms of Production Value. The ROI values indicate that overall, the efficiency of these farms is relatively lower than in the *simple farming* units. The *farmhouse* is an exception because it obtains its income, albeit lower, with greater efficiency than simple agriculture.

Table 3 presents the results of the FCFE and Depreciation, as well as the F/D sustainability index, calculated for the whole of the three years on the individual observations in each group.[4]

The F/D index of *simple farming* is higher than the sample average (1.84 vs 1.57) and the entire *agribusiness* (1.15). This worse result of *agribusiness* is mainly due to the lower cash flow production (-42.1% compared to *simple farming*) than to a different level of depreciation (-9.5%). *Organic* is the exception given the +0,31% of FCFE and the -13,2% of Depreciation compared to *simple farming*. *Processing* is in a weaker situation but exceeds the financial sustainability threshold of 1.15 used by Dono et al. (2021). The other *agribusinesses* show average unviable conditions depending on low (*selling*) or negative FCFE values (*quality* and *farmhouses*), and on an average high level of Depreciation (*farmhouses*).

[4] The table shows the levels of statistical significance of the differences between FCFE values and between Depreciation values but not between F/D values. This happens because the F/D index in the tables are not the average of the farms' values in the individual groups but the ratios between the sum of the FCFE and Depreciation in each group. This kind of calculation does not change the general relationships among groups but prevents from performing the test of the differences between the values of the different groups.

Table 2a. Structural and economic features of FADN farms - percentage weight on the total.

	Gross Capital	UAA	Working Units	GSP	Operating Income	Number
Simple farming	59.0	48.5	50.8	54.1	60.8	48.9
Agribusiness	41.0	51.5	49.2	45.9	39.2	51.1
Organic	14.1	15.9	13.3	20.0	13.2	15.0
Processing	29.2	38.1	37.6	34.5	27.7	39.2
Selling	14.9	19.5	18.1	14.0	12.4	17.6
Quality	5.1	5.7	4.7	5.2	4.5	5.3
Farmhouses	4.6	3.8	4.9	2.5	3.2	4.0

Table 2b: structural and economic features of FADN farms - average value

	Gross Capital	UAA	Working Units	GSP	Operating Income	ROI
Simple farming	1,032,498	32.2	1.36	117,717	64,829	- 0.040
Agribusiness	703,715	32.7	1.26	95,254	39,931	- 0.056
Organic	832,688	34.4	1.16	141,639	45,878	- 0.060
Processing	659,383	31.5	1.25	93,408	36,805	- 0.059
Selling	750,580	35.9	1.34	84,297	36,625	- 0.039
Quality	844,165	34.5	1.16	103,918	44,375	- 0.055
Farmhouses	1,021,023	30.4	1.61	64,896	41,244	- 0.023
Total sample	885,714	32.4	1.31	106,227	52,094	- 0.047

Source: Our elaboration of FADN data.

Table 3. FCFE, Depreciation and financial sustainability index over the entire three-year constant sample.

	FCFE	Depreciation	F/D
Simple farming	19,643	10,825	1.81
Agribusiness	11,283***	9,792***	1.15
Organic	19,703	9,396***	2.10
Processing	11,312***	8,708***	1.30
Selling	10,231***	10,638*	0.96
Quality	-4,440***	9,494**	-0.47
Farmhouses	-3,238***	19,468***	-0.17
Total sample	15,553	9,897	1.57

Difference with *Simple farming* - statistical significance: *** P = 0.99, ** P = 0.95, * P = 0.90.
Source: Our elaboration of FADN data.

Table 4 shows the number of farms in the sample, the percentage of farms by TF, by *simple farming* and by each of the 5 *agribusiness*, and the value of the financial sustainability index for each group. It is noted that the presence of agribusiness farms in many TFs is appreciable: in order, in *processing*, *organic* and *direct sales*. In various TFs the presence of *quality* (vineyards), of *farmhouse* (mixed crops and livestock, dairy cattle) is also relevant. *Agribusiness* farms have an F / D index value higher than the value in *simple farming* in several TFs (in bold-italics and in larger font in the table). 5 of the 7 TFs that are below the financial sustainability threshold for their farms as a whole, have an F/D index value higher than that threshold for their respective *organic* farms. Important results are also found for *quality* (in 3 out of 7 TFs in financial crisis), *farmhouse* and *selling* (in 2 out of 7) and *processing* (in 1 out of 7). No *agribusiness* exceeds the sustainability threshold in dairy cattle; rather, the F/D of all dairy cattle farms involved in *agribusinesses* are lower than *simple farming*.

3.1 Results by stability of financial conditions and by operational size

Table 5 compares the results of *agribusiness* and *simple farming* based on the stability of the results achieved in the single years of the examined period. As before, the comparison is carried out within the Types of Farming (TF) and considers three groups: *agribusiness* farms that in all three years achieved *better* results than *simple farming*; those with always *worse* outcomes; those with *alternating* results. The asterisks in *worse* and *alternating* indicate the statistical significance of the differences between their FCFE and Depreciation and the corresponding values for *better*; the asterisks in *better* refer to the difference with *simple farming*.

Table 4. Number of farms (sample), percentage of farms (by TF, *simple farming* and *agribusiness*), value of the financial sustainability index (by groupings).

Types of farming (TFs)	number of farms Sample	percentage of farms						F/D						
		SIFA	ORG	PRO	DIS	QUA	FAR	SMP	SIFA	ORG	PRO	DIS	QUA	FAR
Mixed Crops and Livestock	447	49.4	11.9	38.3	16.1	2.0	10.1	-0.08	0.09	***2.75***	-0.02	-0.80	***1.16***	0.02
Extensive Beef Cattle	828	47.9	17.0	40.3	9.4	1.1	4.6	0.10	-0.29	***1.23***	***0.28***	***-0.25***	-1.45	***1.51***
Mixed Crops	840	39.3	16.2	49.6	15.7	2.6	6.8	0.38	0.43	***1.71***	0.00	0.36	***4.04***	-0.50
Mixed Fruits	1.491	53.4	17.2	36.6	9.9	4.4	2.5	0.80	0.49	***3.25***	***2.11***	***1.95***	-1.50	-1.18
Arable Crops	3.039	66.2	7.5	26.1	7.6	1.7	1.9	0.82	0.77	***2.71***	0.08	0.40	***5.63***	0.52
Sheep	720	47.4	23.2	33.3	12.1	0.8	2.1	0.87	0.98	0.94	0.78	***1.12***	***6.35***	***1.23***
Dairy Cattle	1.209	67.0	6.4	22.2	8.1	2.2	8.0	1.15	1.71	-0.11	0.52	0.35	-0.98	-2.19
Vineyards	1.683	45.5	9.4	44.4	14.1	9.5	4.2	1.19	-0.29	***1.46***	***2.08***	***1.25***	-3.08	***0.49***
Mixed Livestock	297	50.5	10.8	39.1	10.1	1.3	4.0	1.42	0.32	***9.28***	***0.37***	***2.41***	***7.32***	-1.26
Greenhouse Vegetables	126	73.8	7.1	14.3	9.5	2.4	0.0	1.44	1.91	1.67	-0.94	-3.50	***2.02***	
Olive Growing	531	5.3	49.9	86.4	17.1	6.8	5.6	2.08	-4.87	***2.49***	***2.84***	***2.16***	***3.35***	***0.32***
Swine	252	77.4	1.2	19.0	5.2	0.0	2.4	2.42	2.54	***5.91***	1.63	2.29		-7.13
Other	849	65.6	5.8	24.3	9.8	1.4	1.4	2.65	3.62	1.81	1.05	0.79	-2.24	***4.90***
Poultry	336	74.7	6.3	19.3	4.2	0.3	0.0	3.90	3.80	0.81	***4.82***	***3.92***		
Citrus Fruits	222	16.2	55.4	61.3	9.9	1.8	0.0	4.12	1.75	***5.24***	***4.94***	***3.22***	0.79	
Open Field Vegetables	624	65.5	9.0	26.3	8.3	1.9	2.4	4.48	5.00	1.72	3.41	***6.96***	2.78	-0.12
Fruits in Shell	114	69.3	20.2	18.4	0.0	0.9	0.0	6.86	4.39	***9.12***	***10.58***		***32.31***	
Intensive Beef Cattle	228	82.9	7.0	10.1	3.1	1.3	3.1	7.08	7.78	-0.47	-2.36	-0.30	-5.77	-0.76
Total	13.836	55.4	13.1	34.5	10.2	3.1	3.6	1.57	1.81	***2.10***	1.30	0.96	-0.47	-0.17

Total sample (SMP), Simple farming (SIFA), organic (ORG), processing (PRO), selling (DIS), quality (QUA), farmhouses (FAR).
Source: our elaboration of FADN data.

The table shows that 32.4% of *organic* farms performs *better* than *simple farming*. The percentage is much lower in other *agribusiness*, 17-22%, where instead 40% of farms always obtain worse results than *simple farming*. The gap between the F/D in the three groups is considerable for all activities, with very high average values for *better*. The average F/D in *alternating* is close to the sustainability threshold (1.15) in *organic* and *processing*. In the other activities F/D is less than 1, close to 0 in *farmhouses*. For each *agribusiness* high CV values for FCFE and low values for depreciation emerge, suggesting that the differences in F/D mainly depend on the different values of the cash flows.

Table 6 reports the F/D values of the three groups with relevant structural and economic variables at farm level. The latter include depreciable capital, which affects both the denominator of the F/D index, increasing the depreciation value, and its numerator, adding liquidity to FCFE. The average value of investments over the three years, which certainly influences the productivity level of other resources in the future, but immediately subtracts liquidity from FCFE. Aid from the CAP II pillar adds liquidity to FCFE and includes public funding to support investments as well as agribusiness management activities. Gross Saleable Production (GSP) reflects the operational size of farms and directly contributes to generating operating income, which adds liquidity to FCFE. The Net change in working capital (*ΔWCC*) adds, or subtracts, liquidity to FCFE as the result of all commercial relationships with customers, suppliers, and banks. Finally, Return on Investments (*ROI*) calculated net of the CAP aid of the first pillar, as an indicator of farm efficiency. The data are reported for *simple farming* and *agribusiness*, and for *better*, *alternating,* and *worse* groups. The asterisks indicate the statistical significance of the differences between *better* and the groups *worse* and *alternating*; between *better* and *simple farming*; finally, between total *agribusiness* and *simple farming*.

The average endowment of depreciable, the value of investments, GSP and ROI of *agribusiness* are significantly lower than *simple farming*. *Agribusiness* activities are instead more supported by CAP II aid. There is no significant difference in Δ WCC.

Differences with *simple farming* emerge for the individual groups. *Better* also displays a significantly lower endowment of *depreciable* in *organic*, *processing* and

Table 5. farms with *better*, *alternating,* or *worse* results – percentage, F/D index, FCFE and Depreciation, coefficient variation (CV). Statistical significance of differences among the various groups (*).

Variables		Better	Alternating	Worse	CV = s/m
Percentage weight	Organic	32.4	37.3	30.3	0.11
	Processing	21.8	35.3	42.9	0.32
	Selling	21.4	35.0	43.6	0.34
	Quality	21.1	37.8	41.1	0.32
	Farmhouses	17.3	41.1	41.6	0.42
F/D index	Organic	*8.54*	1.10	-1.45	1.90
	Processing	*5.98*	1.20	-2.14	2.43
	Selling	*5.89*	0.60	-2.02	2.70
	Quality	*5.76*	0.70	-1.95	2.60
	Farmhouses	*4.51*	0.20	-1.71	3.19
FCFE	Organic	74,933 ***	8,745 ***	-17,859 ***	2.18
	Processing	61,763 ***	10,432 ***	-16,270 ***	2.13
	Selling	64,150 ***	6,577 ***	-19,028 ***	2.47
	Quality	41,972 ***	6,260 ***	-21,997 ***	3.67
	Farmhouses	65,614 ***	3,355 ***	-39,724 ***	5.43
Depreciation	Organic	8,777 ***	8,167	12,343 **	0.23
	Processing	10,325	8,829 **	7,594 ***	0.15
	Selling	10,882	10,763	9,437	0.08
	Quality	7,283 ***	9,255 *	11,259 ***	0.21

Statistical significance of differences: *** P = 0.99, ** P = 0.95, * P = 0.90.
Source: Our elaboration of FADN data.

quality activities, while it is higher in *farmhouse*. The activities in *better* all make less investments than *simple farming*, while they benefit from significantly greater CAP II aid. They also display a higher ROI and, more important, positive even net of CAP I aid. Conversely, these activities show non-statistically significant differences for GSP and Δ WCC, even if with positive values and higher than *simple farming*.

Statistically significant differences emerge among the three groups in *agribusiness*. *Alternating* and *worse* show significantly higher endowments of depreciable than *better*, as well as lower levels of ROI, Δ WCC and GSP[5]. Since the GSP values in *better* are close to *simple farming*, the GSP levels of *worse* and *alternating* are also lower than this group's values. Conversely, *alternating*, and *worse* show significantly higher investments levels compared to *better*; despite this greater commitment, *worse* receives significantly smaller CAP II aid.

An in-depth analysis may concern the position of the *better*, *alternating*, and *worse* groups, in the individual TFs and also by dimensional classes. The next paragraph presents the results of this analysis by focusing on the TFs whose F/D value is below the financial sustainability threshold.

[5] Some variables are distributed in the farms of alternating and worse with a high variability; this makes the differences in their average values compared to *better* statistically insignificant, although appreciable.

3.1.1 Stability of financial conditions by TFs and by operational size

Tables 7 and 7bis report various information relating to the three financial result groups, better (BET), alternating (ALT) and worse (WOR), in each *agribusiness* and for *simple farming* in the TFs whose F/D value is below the financial sustainability threshold.

Table 7 shows, first, the relevance of the three groups with different financial results in terms of percentage of *agribusiness* farms placed in them. The ALT group is on average pre-eminent in all cases, and in most of them it is closely followed by WOR. The percentage of farms in BET is close or above WOR only in *organic*.

The table presents in bold-italics and with a larger font the TFs cases whose F/D *agribusiness* values are greater than *simple farming*. In all cases, the F/D values of *better* are well above the financial sustainability threshold and the value of *simple farming*. *Alternating* also presents many cases above *simple farming*, albeit only a few well above the sustainability threshold (*quality* in sheep and mixed crops - livestock). The F/D values

Table 6. *Simple farming*, total and single agribusinesses in the 3 financial result groups - percentage of farms on total sample, F/D index; per farm 000 € of depreciable, investments, CAP II aid, GSP, DWCC; ROI.

	%	F/D	depreciable (€ 000)	investments (€ 000)	CAP II (€ 000)	GSP (€ 000)	Δ WCC (€ 000)	ROI
Simple farming	*48.9*	*1.84*	*87.0*	*19.4*	*2.9*	*182.5*	*-0.2*	*-0.04*
Agribusiness	51.1	1.24	76.7***	13.7***	5.0***	101.9***	-0.8	-0.06***
Better								
Organic	4.9	8.54	54.8 ***	5.2 ***	10.1 ***	176.3	4.5	0.01 ***
Processing	8.6	5.98	69.9 ***	7.7 ***	6.4 ***	173.7	2.5	0.01 ***
Selling	3.8	5.89	76.5	8.9 ***	6.0 ***	184.1	2.3	0.02 ***
Quality	1.1	5.76	49.4 ***	7.9 ***	5.5 ***	144.9 *	0.4	-0.04
Farmhouses	0.7	4.51	140.4 ***	10.6 ***	8.4 ***	162.5	-1.1	0.01 ***
Alternating								
Organic	5.6	1.07	66.0 *	17.0 **	9.6	102.7 ***	-0.6	-0.04 ***
Processing	13.9	1.18	77.8	15.3 ***	5.6	105.6 ***	-2.1 ***	-0.03 ***
Selling	6.2	0.61	108.5 ***	16.1 ***	6.4	102.9 ***	-1.6	-0.02 ***
Quality	2.0	0.68	87.8 ***	23.5 ***	7.0	104.3 *	-3.5	-0.02 *
Farmhouses	1.6	0.22	202.8 ***	25.4 ***	7.7	97.7 **	-2.4	-0.01 *
Worse								
Organic	4.6	-1.45	114.1 ***	19.8 ***	6.9 ***	64.5 ***	-4.1	-0.15 ***
Processing	16.8	-2.14	72.6	10.3 *	2.8 ***	46.0 ***	-2.1 ***	-0.13 ***
Selling	7.7	-2.02	96.3 *	12.3 ***	3.2 ***	56.0 ***	-3.7 ***	-0.08 ***
Quality	2.2	-1.95	110.8 ***	34.6 ***	5.9	118.2	-7.2 ***	-0.08
Farmhouses	1.7	-1.71	286.2 ***	44.8 ***	5.9 *	69.8 ***	-8.3	-0.06 ***

Statistical significance of differences: *** P = 0.99, ** P = 0.95, * P = 0.90.
Source: Our elaboration of FADN data.

of *worse* are all below the sustainability threshold and below the average result of *simple farming*.

The ability to generate cash flows (FCFE) appears crucial in determining the F/D result, as suggested by the extent of the values in *better*, which in all TFs and *agribusiness* are higher than *simple farming*. Similar evidence is found in *alternating*, notably in sheep and mixed crops - livestock. Conversely, FCFE is always negative and inferior to simple farming in *worse*.

Depreciation contributes to determining the value of F/D by increasing both the denominator and the numerator of the index. This makes his specific discussion less interesting and, given the exploratory nature of this study, it was decided not to include his data in Table 7 and to make them available in the tables in Appendix A.

Table 7bis reports some variables that influence the amount of cash flow. In this case, values of agribusiness that are above *simple farming* are marked with a bold italic font.

The level of gross saleable production (GSP) directly affects operating income, that is one of the main components of FCFE. In this case it is noted that in most cases in *better* GSP is higher in *agribusiness* farms than in *simple farming*, while the opposite happens for all the farms in *worse*. Here too we find very high GSP values in the sheep TF in *alternating*.

Furthermore, the ROI, here taken as an indicator of efficiency, assumes average positive values in *agribusiness* farms, while in simple farming it always assumes average negative values. *Agribusiness* farms have higher ROI also in many TFs in *alternating*. Yet, in these cases the indicator mainly maintains negative values. Even in *worse* there are TFs whose ROI is higher in *agribusiness* than in *simple farming*, even if always with a negative sign.

Finally, the table shows the investments (INV), which subtract liquidity from FCFE, and the II pillar aid of the Common Agricultural Policy (CAP II), which add it often applying measures to support the former. Those data show that the value of the investments in *agribusiness* is lower than in *simple farming* in almost all TFs. The opposite happens for *alternating* and *worse*, where investments of some TFs are even 6-7 higher than in *better*. Above all, it is interesting to note that, despite this investment discrepancy, CAP II aid are mostly greater in *better* than in *alternating* and *worse*.

The last in-depth study of this exploration concerns the distribution of *agribusiness* farms among the three

Table 7. Percentage of farms, F/D, FCFE in each financial result group in each agribusiness by TF; comparison F/D and FCFE in *simple farming.*

Type of farming (TFs)	Farms % Agribusiness					F/D						FCFE (000 €)					
	ORG	PRO	DIS	QUA	FAR	SIF	ORG	PRO	DIS	QUA	FAR	SIF	ORG	PRO	DIS	QUA	FAR
Mixed Crops - Livestock BET	34.0	15.8	16.7		15.6	0.09	***5.32***	***5.83***	***5.01***		***6.53***	0.9	***109.2***	***88.9***	***35.3***		***50.0***
Extensive Beef Cattle	30.5	21.3	15.4	11.1	26.3	-0.29	***4.45***	***3.63***	***6.70***	***2.02***	***5.32***	-2.4	***40.6***	***54.7***	***45.5***	***15.2***	***107.8***
Mixed Crops	21.3	13.2	19.7	18.2	5.3	0.43	***7.14***	***7.66***	***8.05***	***7.04***	***28.12***	2.8	***90.4***	***56.6***	***48.9***	***192.9***	***26.1***
Mixed Fruits	35.9	25.5	23.6	23.1	13.5	0.49	***8.24***	***7.48***	***10.58***	***4.61***	***6.24***	4.2	***55.4***	***54.6***	***99.5***	***48.0***	***38.3***
Arable Crops	31.0	17.9	16.8	37.3	19.3	0.77	***9.36***	***6.50***	***5.47***	***13.9***	***7.79***	6.7	***83.7***	***43.1***	***57.4***	***59.5***	***59.8***
Sheep	26.9	13.3	21.8		40.0	0.98	***6.42***	***5.34***	***4.17***		***4.50***	7.2	***52.5***	***81.6***	***93.2***		***261.7***
Dairy Cattle	13.0	16.4	19.4	3.7	6.2	1.71	***6.41***	***4.98***	***6.39***	***2.32***	***2.48***	38.3	***73.9***	***88.9***	***79.0***	36.1	***50.3***
Mixed Crops - Livestock ALT	50.9	36.3	40.3	33.3	60.0	0.09	***1.18***	***0.12***	***0.24***	***5.66***	***0.13***	0.9	***17.1***	***1.5***	***4.6***	***125.8***	***3.3***
Extensive Beef Cattle	43.3	43.1	47.4	44.4	52.6	-0.29	***0.39***	-0.57	***-0.24***	-1.60	-0.33	-2.4	***3.9***	-6.1	-3.8	-21.6	-5.8
Mixed Crops	52.2	44.1	51.5	50.0	63.2	0.43	***1.15***	***0.56***	0.09	***0.58***	***0.50***	2.8	***7.0***	***2.9***	0.6	***2.9***	***3.8***
Mixed Fruits	37.9	32.8	34.5	41.5	37.8	0.49	***1.02***	***1.29***	-0.42	-1.79	-0.38	4.2	***7.7***	***6.4***	-4.1	-23.7	-10.5
Arable Crops	36.2	30.7	29.7	37.3	33.3	0.77	***1.20***	0.01	0.03	***1.23***	0.71	6.7	5.4	0.0	0.2	5.0	***10.3***
Sheep	40.7	40.0	37.9	100.0	20.0	0.98	***1.06***	***1.10***	***1.09***	***6.35***	***1.69***	7.2	***11.5***	***14.2***	***15.3***	***49.2***	***62.2***
Dairy Cattle	39.0	39.2	32.7	11.1	23.7	1.71	0.79	0.89	0.89	-6.07	-0.74	38.3	15.8	12.4	15.7	-175.2	-15.1
Mixed Crops - Livestock WOR	15.1	48.0	43.1	66.7	24.4	0.09	-4.02	-7.39	-8.29	-5.04	-4.68	0.9	-24.5	-30.8	-38.3	-40.6	-38.3
Extensive Beef Cattle	26.2	35.6	37.2	44.4	21.1	-0.29	-2.69	-4.15	-4.64	-2.99	-6.07	-2.4	-13.8	-17.8	-20.8	-8.8	-11.9
Mixed Crops	26.5	42.7	28.8	31.8	31.6	0.43	-1.82	-2.19	-1.60	-4.04	-0.76	2.8	-25.1	-20.5	-23.3	-9.7	-56.5
Mixed Fruits	26.2	41.7	41.9	35.4	48.6	0.49	-4.46	-3.83	-3.33	-6.52	-2.99	4.2	-12.6	-13.4	-16.7	-48.0	-49.3
Arable Crops	32.8	51.4	53.4	25.5	47.4	0.77	-1.71	-2.30	-2.08	-8.12	-0.39	6.7	-18.9	-14.1	-12.7	-15.2	-10.5
Sheep	32.3	46.7	40.2		40.0	0.98	-0.70	-0.86	-0.66		-0.15	7.2	-16.6	-12.3	-13.5		-21.0
Dairy Cattle	48.1	44.4	48.0	85.2	70.1	1.71	-1.37	-0.85	-0.59	-0.52	-3.17	38.3	-37.7	-21.2	-23.1	-19.0	-59.5

Better (BET, alternating (ALT), worse (WOR), simple farming (SIFA), organic (ORG), processing (PRO), selling (DIS), quality (QUA), farmhouses (FAR).
Source: our elaboration of FADN data.

GSP size classes and the financial result groups. Table 8 allows this assessment for TFs with F/D values below the *financial sustainability threshold (FIST),* and for the group above it.

The first section of the table shows that most of the *agribusiness* farms are in the small dimensional class: 98.2% in the TFs with F/D under FIST, 96.9% in the other TFs. *Agribusiness* farms in BET are always a minority share; in TFs below FIST their percentage is even lower, 20.5%, while the financial result of more than 40% of those farms is worse than *simple farming*.

The second part of the table shows the F/D index values of each group[6]. A gap emerges between the F/D values in *better*, which confirm the figures of the previous tables, and those in *alternating* and *worse*. The prevalence of cases in the latter groups greatly reduces the average values of F/D both for the total *agribusiness* and for the small farms. The impact is greater in TFs in financial difficulty, to the point that their F/D index value is below the FIST both in the general average and in small farms.

[6] In the group *large* the F/D value of *alternating* is lower than in *worse* because the comparison is carried out within each TFs, and given the low number of large farms in *alternating* and *worse*, this implies comparing the results of diverse TFs.

4. DISCUSSION

More than half of our FADN observations manage activities that we have called *agribusiness*. Yet, their weight on the sample's income is much lower, and when compared to *simple farming* the average operating income of *agribusiness* is a lower fraction of both gross invested capital and family work units. We found that these activities are carried out on farms that have smaller GSP, and in large part also worse financial results than *simple farming* in their respective TFs. Yet, a group, albeit a minority, of *agribusiness* farms achieves better financial results than *simple farming*; and it is interesting to note that most of these farms are classified in TFs

Table 7bis. GSP, ROI, Investments and CAP II aid per farm in *simple farming* and in each financial result group of each *agribusiness*.

		GSP (000 €)						ROI						INV (000 €)						CAP II (000 €)					
		SIF	ORG	PRO	DIS	QUA	FAR	SIF	ORG	PRO	DIS	QUA	FAR	SIF	ORG	PRO	DIS	QUA	FAR	SIF	ORG	PRO	DIS	QUA	FAR
Mixed Crops - Livestock	BET	169,8	***313,3***	***224,3***	123,8		107,2	-0,04	***0,04***	***0,04***	***0,00***		***0,04***	23,0	9,6	6,8	0,2		2,8	4,0	***8,6***	***4,7***	3,5		1,4
Extensive Beef Cattle	BET	105,4	***116,4***	***160,3***	98,8	38,6	***378,9***	-0,07	***-0,02***	***0,02***	***0,02***	***-0,03***	***0,02***	11,3	5,5	8,1	5,4	7,6	***16,3***	4,5	***11,1***	***9,4***	4,5	***11,0***	***8,5***
Mixed Crops	BET	89,1	***172,5***	***156,4***	***147,4***	***501,1***	***107,2***	-0,13	***0,06***	***0,05***	***0,04***	***-0,03***	***0,01***	7,3	3,0	1,3	1,0	1,1	1,2	1,8	***7,1***	***3,5***	***4,8***	***8,9***	***7,4***
Mixed Fruits	BET	95,2	***155,1***	***155,3***	***311,8***	***129,2***	66,4	-0,01	***0,03***	***0,03***	***0,03***	***0,01***	***0,04***	18,7	3,3	2,8	5,2	11,4	7,2	1,4	***8,0***	***4,1***	***6,6***	***5,3***	***2,8***
Arable Crops	BET	115,2	***216,6***	***124,3***	***155,8***	***166,2***	93,2	-0,08	***0,04***	***-0,02***	***0,00***	***0,02***	***0,01***	18,4	4,1	4,4	8,8	0,2	15,0	3,8	***12,7***	***7,9***	***7,8***	***6,9***	***14,0***
Sheep	BET	67,8	***118,9***	***205,6***	***241,2***		***662,4***	-0,03	***0,02***	***0,07***	***0,05***		***0,03***	9,4	6,6	***9,6***	8,2		***20,5***	5,5	***19,8***	***10,6***	5,5		***17,0***
Dairy Cattle	BET	269,5	188,5	251,5	203,6	221,4	107,6	0,00	***0,04***	***0,04***	***0,05***	***0,00***	***0,00***	34,2	12,3	17,5	11,8	0,0	17,7	5,3	***10,6***	***8,5***	***12,2***	0,0	***28,3***
Mixed Crops - Livestock	ALT	169,8	86,2	85,5	103,0	118,0	132,6	-0,04	***0,00***	***-0,01***	***0,00***	***0,10***	***0,01***	23,0	15,2	14,5	21,4	8,1	***29,2***	4,0	***10,9***	***7,0***	***8,7***	2,7	***10,6***
Extensive Beef Cattle	ALT	105,4	65,0	79,9	80,2	63,4	103,1	-0,07	***-0,04***	***-0,03***	***-0,03***	***-0,03***	***-0,02***	11,3	***12,7***	***17,1***	***21,5***	0,1	***20,1***	4,5	***12,4***	***5,5***	***9,2***	***19,4***	***12,6***
Mixed Crops	ALT	89,1	***95,3***	68,3	72,5	51,3	40,7	-0,13	***-0,12***	***-0,06***	***-0,01***	***-0,03***	***0,01***	7,3	6,0	***8,4***	***11,1***	4,1	***7,7***	1,8	***8,3***	***4,7***	***6,7***	***9,0***	***5,3***
Mixed Fruits	ALT	95,2	87,4	72,9	78,4	***108,4***	***109,6***	-0,01	-0,03	-0,01	-0,02	-0,03	***0,00***	18,7	14,5	10,7	17,6	***63,3***	***46,4***	1,4	***8,6***	***3,8***	***4,2***	***3,1***	***2,2***
Arable Crops	ALT	115,2	61,2	60,9	67,6	56,4	***118,2***	-0,08	***-0,04***	***-0,05***	***-0,03***	***-0,06***	***-0,03***	18,4	6,2	10,9	7,2	7,0	13,3	3,8	***8,8***	3,1	***5,7***	***4,4***	***11,0***
Sheep	ALT	67,8	***80,9***	***107,7***	***91,1***	***108,0***	67,4	-0,03	***-0,01***	***-0,02***	***-0,02***	-0,03	***0,00***	9,4	***13,4***	***22,1***	***12,6***	1,2	0,1	5,5	***12,4***	***12,8***	***14,0***	***7,3***	***23,3***
Dairy Cattle	ALT	269,5	209,3	143,5	154,1	116,2	127,4	0,00	***0,00***	***0,00***	0,00	-0,02	***0,01***	34,2	***45,1***	25,5	18,6	***210,1***	***63,4***	5,3	***24,6***	***14,2***	***15,8***	***64,7***	***10,5***
Mixed Crops - Livestock	WOR	169,8	60,5	38,0	32,9	45,8	15,4	-0,04	-0,18	-0,12	-0,10	***-0,02***	-0,18	23,0	11,0	13,3	21,3	***26,6***	***28,1***	4,0	3,6	1,4	1,4	2,6	1,5
Extensive Beef Cattle	WOR	105,4	32,4	38,4	40,2	20,1	16,7	-0,07	-0,11	-0,09	-0,10	-0,18	-0,14	11,3	***11,7***	5,5	8,5	1,8	1,7	4,5	***5,5***	1,8	2,8	3,9	3,4
Mixed Crops	WOR	89,1	42,7	30,6	42,9	20,4	80,8	-0,13	-0,24	-0,17	***-0,11***	-0,39	-0,19	7,3	***49,5***	***18,4***	***15,5***	1,0	***59,2***	1,8	***4,2***	1,6	0,8	***1,9***	***4,6***
Mixed Fruits	WOR	95,2	27,8	27,0	32,6	73,0	71,2	-0,01	-0,22	-0,16	-0,11	-0,06	***-0,01***	18,7	2,7	4,2	5,9	***50,7***	***78,4***	1,4	***2,9***	1,0	***1,6***	1,2	0,7
Arable Crops	WOR	115,2	51,1	36,5	43,1	21,2	55,4	-0,08	-0,13	-0,14	***-0,08***	***-0,06***	***-0,07***	18,4	***24,3***	7,4	8,4	3,1	8,2	3,8	***5,5***	1,8	2,2	1,1	3,5
Sheep	WOR	67,8	53,6	41,7	45,6		***151,2***	-0,03	-0,08	-0,09	-0,07		-0,04	9,4	***17,9***	7,9	9,2		***37,9***	5,5	***9,9***	3,4	***6,6***		***18,8***
Dairy Cattle	WOR	269,5	94,9	102,5	159,5	237,5	74,0	0,00	-0,02	-0,03	-0,02	-0,02	-0,01	34,2	***42,5***	22,1	30,6	***67,7***	***76,3***	5,3	***18,1***	***14,3***	***20,3***	***27,0***	***9,7***

Better (BET, alternating (ALT), worse (WOR), simple farming (SIFA), organic (ORG), processing (PRO), selling (DIS), quality (QUA), farmhouses (FAR).
Souce: Our elaboration of FADN data.

Table 8. Percentage distribution of agribusiness farms by financial result groups, size class and by groups of TFs, with relative value of the F/D index.

		% on *agribusiness* farms				F/D value			
		BET	ALT	WOR	TOTAL	BET	ALT	WOR	TOTAL
F/D < FIST	SMALL	19.2	37.6	41.4	98.2	5.68	0.28	-1.76	0.21
	MEDIUM	0.9	0.4	0.0	1.4	8.70	4.81		7.67
	LARGE	0.4	0.02	0.02	0.4	7.83	-5.07	1.12	6.94
	TOTAL	20.5	38.1	41.4	100.0	6.25	0.39	-1.74	0.60
F/D > FIST	SMALL	24.5	37.9	34.6	96.9	3.06	1.31	-0.99	1.00
	MEDIUM	1.3	1.2	0.1	2.6	3.71	-0.24	0.83	2.34
	LARGE	0.4	0.03	0.1	0.5	10.34	1.00	3.18	8.64
	TOTAL	26.2	39.1	34.7	100.0	3.75	1.22	-0.89	1.34

Source: our elaboration of FADN data.

whose average F/D value is below the financial profitability threshold. The ability to produce liquidity is the most important factor in determining the financial sustainability differential between farms in *simple farming* and those engaged in the various types of *agribusiness*. Among the latter, *organic* shows the best situation, with analogous share of the three groups and the lowest percentage of farms in *worse*. *Processing* remains above the sustainability threshold even in *alternating*. *Selling*, *quality* and *farmhouses* do not share this condition and show an average unsustainable condition. Farmhouses shows the largest percentage of cases in *unstable* and *worse*.

The results on the structural and economic variables provided interesting insights into the conditions linked to the different levels of financial sustainability in the various groups.

High values of the F/D index are associated with high levels of GSP and ROI. The group *better* reaches values of 3-4 times higher for these variables than the *unstable* and *worst*. *Better* achieves greater sustainability even than *simple farming*. Its higher level of GSP suggests that the link between the operational dimension and financial difficulties of *agribusiness* farms should be studied. The literature deals extensively with this topic. Meraner et al. (2015) claim that an increase in the economic dimension affects the likelihood of undertaking transformation activities. McNamara and Weiss (2005) also argue that as farm size increases, on-farm income diversification is more likely since the decline of marginal yields favours the allocation of farm resources towards more profitable activities. IIbery (1991) and McNally (2001) reach the same conclusion. According to García-Arias et al. (2015) this happens because larger farms have more resources to devote to non-typical activities. Lakner et al. (2018) note that in Austria and Switzerland, diversification increases farm production, which in turn strengthens the stability of agricultural production. Instead, diversification negatively affects technical efficiency in some territories, while it improves it in others. Clearly, the commitment to new activities other than simple agriculture also involves profound changes in the corporate structure and organization, as indicated by Salvioni et al. (2020). This suggests that many *agribusiness* farms might still be in an evolutionary phase that does not yet allow for significant levels of production, efficiency, and profitability. In our sample the farms engaged in *agribusiness* are mostly small and most of them obtain worse results of the same type in simple farming. This gap is more marked in TFs in financial difficulty, while in other TFs even small farms with *alternating* results are financially sustainable. Large farms are in a clear minority, even if in the group *better* their sustainability is very high. This picture of limited financial sustainability of small farms engaged in *agribusiness* is in partial contrast to the results of the studies cited above.

The greater commitment in *investments* does not correspond to greater public aid. The amount of *CAP II* payments is, in fact, significantly *lower* for *alternating*, *worse*, and *simple farming*, despite the greater investments undertaken. This divergence could be due to the time gap between the time of the investment expenditure and the reimbursement provided for by the *CAP II* aid mechanisms, whose payments are linked on project progress. Still, our analysis is based on a three-year time frame; hence, even in the presence of that time gap, it should capture at least a part of the aid associated with these investments. In any case, the condition of greater financial difficulty of the farms in the stage of investments raises the question of the effectiveness of this support system, which does not appear to contribute to financial sustainability in that specific phase. The issue needs to be investigated also by examining in detail the composition of the *CAP II* aid, which includes support for activities that do not require investing in depreciable capital. In any case, this evidence agrees with the conclusions of Boncinelli et al. (2018) that highlight the absence of any relationship between RDP payments and diversification.

Higher endowments of depreciable are found precisely in the groups *alternating* and *worse* in which the FCFE values are lower or even negative. Instead, for all agribusiness activities, the group *better* shows lower endowment of these capital, along with lower depreciation levels which reduce the denominator of F/D. On the other hand, there is the impact of higher depreciation levels in increasing the numerator of the F/D ratio, favouring greater generation of FCFE. Dono et al. (2021) concluded that in the studied period these capitals show little capacity to increase farms financial sustainability. Our evidence seems to agree with those conclusions, which suggests that in acquiring new capital it will be useful to verify their impact on the productivity. This is mainly true for *organic*, *quality* and *farmhouse* whose endowments of depreciable in *worse* and *alternating* are much higher than in *better*, but negative differences in FCFE are also greater.

The literature also deals with the conditions for the development of commercial relationships with buyers, suppliers, and banks: in the cash flows analysis they also contribute to transforming the value of production into greater liquidity through the *Δ WCC*. In this regard, Pölling and Mergenthaler (2017) claim that in *direct sales* activities an important role is played by proximity to urban centres, although with differences due to the farm size and technical-economic orientation. Besides, the wide variability in the results agrees with the statements of Bauman et al. (2018) on US farms engaged in *direct selling* that show how results vary under different management conditions, types of market and farm location areas. Our study did not consider the location of the farm which, especially in disadvantaged areas, far from the most dynamic agricultural markets, could lead to less intensive activities or activities related to tourism, such as *farmhouses*. In this regard, a third of the farmers interviewed by De Rooij et al. (2014) believes that multifunctionality is best located in areas "without a future for conventional farming".

The literature on farm diversification pays close attention to the performance of the *farmhouses*. Bagi and Reeder (2012), show that the global net income of the average agritourism farm was small relative to all other farms in 2007. Mastronardi, et al., (2011) claim that the profitability of *simple farming*, especially when specialized in tree crops, is more than double than in *farmhouses*. Still, according to Giaccio et al. (2018a; 2018b) *farmhouses* can increase their income also engaging in other activities such as *selling*, *organic* and typical foods production, catering and wine tasting services, access to environmental assets, such as forest areas, and provision of leisure services, such as cultural and sport activities. Dries et al. (2012) and Khanal (2020) also claim that there are synergies between structural and farm diversification activities. On the contrary, Khanal and Mishra (2014) affirm that small farms obtain better results by undertaking both farmhouse and off-farm work[7]. Giaccio et al. (2018a) show that farm income decreases significantly as the number of family members employed on the farm increases. At the same time, according to Lupi et al. (2017) farms that employ more (non-family) work are more likely to invest in agritourism businesses.

We have not explored the links between diverse *agribusiness* activities due to the limited number of observations with more integrated activities in the studies FADN sample. Our evidence agrees with these results as we found the most difficult situations in *farmhouses* and *quality*, which are in less favourable condition even when they get the best results, as in *better*. Moreover, in the latter activity there is a strong push towards technological innovation that requires great changes and investments that put the farms in difficulty at least momentarily. An example is the Parmigiano Reggiano supply chain, cited by Arfini et al. (2019a). We believe that our conclusions are consistent with these considerations, as they depict a very dynamic situation, characterized by investments that have not yet reimbursed the costs incurred and are not yet fully operational.

5. CONCLUSION

We have found that the studied activities in the examined period constitute a dynamic group in which the farms with negative or unsustainable results are not doomed to bankruptcy. In fact, many of the *agribusiness* farms are engaged in major investments which, on the one hand, subtract liquidity from the cash flow and,

[7] Yet, this aspect should be investigated by remembering that the Italian legislation on the subject is very different from that of other countries and the farm is considered an agricultural activity and can only be carried out by a farmer "through the use of his own farm in term of the connection of the farming, forestry and livestock raising activities within the holding "(Law number 96/2006).

on the other, take time to express their potential or even become operational. All this outlines a situation in evolution, perhaps even rapid, therefore, to be verified with further in-depth studies in a short time. In this perspective, it should also be deepened that farms that approached agribusiness in the middle of the last decade, investing or in a growth phase in this period, have had probably a major stop due to the COVID-19 crisis. This could have strongly affected their growth precisely at the moment of entry into operation of many of their investments.

Still, the evidence of financial difficulty faced by *agribusiness* farms that make more investments suggests that it would be useful to modulate financial aid in a different way. This could be partially disbursed at the beginning of the investment process to reduce the financial difficulties associated with its activation. In any case, it is also interesting to explore the perspectives of the group *better* that, at the moment, is investing less than the others. In particular, it can be asked whether these farms will be able to generate sufficient financial resources to renew their technologies when their capital runs out of payback.

The situation of the farms in *agribusiness* deserves further investigation especially about the situation of the mixed and more extensive TFs that appear to be in financial difficulty according to Dono et al. (2021). It is of interest to deepen the investigation on the possible contribution of *agribusiness* in improving the financial condition of these TFs. To investigate these aspects, given the scarcity of observations for activities such as *quality* and *farmhouses*, it would be desirable to increase the FADN sample, especially of *agribusiness* relevance. Another aspect of interest concerns the results deriving from the aggregation of these activities: it leads to investigate the issues of the integration of functions along the value chain by farms.

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REFERENCES

Arfini, F.; Antonioli, F.; Cozzi, E.; Donati, M.; Guareschi, M.; Mancini, M.C.; Veneziani, M. (2019a). Sustainability, Innovation and Rural Development: The Case of Parmigiano-Reggiano PDO. Sustainability 2019, 11, 4978. https://doi.org/10.3390/su11184978

Arfini, F.; Cozzi, E.; Mancini, M.C.; Ferrer-Perez, H.; Gil, J.M. (2019b). Are Geographical Indication Products Fostering Public Goods? Some Evidence from Europe. Sustainability, 11, 272. https://doi.org/10.3390/su11010272

Bagi, F. S., Reeder, R. J. (2012) 'Factors affecting farmer participation in Farmhouses', Agricultural and Resource Economics Review, 41(2), pp. 189–199. doi: 10.1017/S1068280500003348.

Barbieri, C. (2013). Assessing the sustainability of Farmhouses in the US: a comparison between Farmhouses and other farm entrepreneurial ventures. Journal of Sustainable Tourism, 21(2), 252–270. doi:10.1080/09669582.2012.685174

Barbieri, C. (2010). An importance-performance analysis of the motivations behind Farmhouses and other farm enterprise developments in Canada. J. Rural Commun. Dev. 2010, 5, 1–16.

Barnes, A. P., Hansson, H., Manevska-Tasevska, G., Shrestha, S. S., Thomson, S. G. (2015). The influence of diversification on long-term viability of the agricultural sector. Land Use Policy, 49, 404–412. doi:10.1016/j.landusepol.2015.08

Bartolini, F., Andreoli, M., Brunori, G. (2014) Explaining determinants of the on-farm diversification: Empirical evidence from Tuscany region, Bio-based and Applied Economics, 3(2), pp. 137–157. doi: 10.13128/BAE-12994.

Bauman, A., Thilmany McFadden, D., & Jablonski, B. (2018). The Financial Performance Implications of Differential Marketing Strategies: Exploring Farms that Pursue Local Markets as a Core Competitive Advantage. Agricultural and Resource Economics Review, 47(3), 477-504. doi:10.1017/age.2017.34

Belletti, G., Marescotti, A., Touzard, J.-M. (2017). Geographical Indications, Public Goods, and Sustainable Development: The Roles of Actors' Strategies and Public Policies, World Development, 98, issue C, p. 45-57, https://EconPapers.repec.org/RePEc:eee:wdevel:v:98:y:2017:i:c:p:45-57.

Biczkowski, M., Jezierska-thöle, A., Rudnicki, R. (2021) The impact of rdp measures on the diversification of agriculture and rural development—seeking additional livelihoods: The case of Poland, Agriculture (Switzerland), 11(3), pp. 1–26. doi: 10.3390/agriculture11030253.

Bonazzi, G., Iotti, M. (2014a). Agricultural cooperative firms: budgetary adjustments and analysis of credit access applying scoring systems, American Journal of

Applied Sciences, Vol. 11 No. 7, pp. 1181-1192, doi: 10.3844/ajassp.2014.1181.1192.
Bonazzi, G., Iotti, M. (2014b). Interest coverage ratios (ICRs) and financial sustainability: application to firms with Bovine dairy livestock, American Journal of Agricultural and Biological Sciences, Vol. 9 No. 4, pp. 482-489, doi: 10.3844/ajabssp.2014.482.489.
Bonazzi, G. and Iotti, M. (2015), Comparative applications of income and financial analysis for tomato processing firms in Italy, Agroalimentaria, Vol. 21 No. 41, pp. 113-131.
Boncinelli, F., Bartolini, F., Casini, L. (2018) 'Structural factors of labour allocation for farm diversification activities', Land Use Policy, 71(October 2017), pp. 204–212. doi: 10.1016/j.landusepol.2017.11.058.
Chaplin, H., Davidova, S., Gorton, M. (2004). Agricultural adjustment and the diversification of farm households and corporate farms in Central Europe. Journal of Rural Studies, 20(1), 61–77. doi:10.1016/s0743-0167(03)00043-3
Chay, J.B., Suh, J. (2009). Payout policy and cash-flow uncertainty, Journal of Financial Economics, Vol. 93, pp. 88-107.
CREA PB (2021). Annuario dell'agricoltura italiana 2019. Vol. LXXIII.
De Rooij, S., Ventura, F., Milone, P., van der Ploeg, J. D. (2014). Sustaining Food Production through Multifunctionality: The Dynamics of Large Farms in Italy. Sociologia Ruralis, 54(3), 303–320. doi:10.1111/soru.12025
Dono G., Buttinelli R., Cortignani R. (2021), Financial sustainability in Italian farms: an analysis of the FADN sample, *Agricultural Finance Review*.
Dries, L., Pascucci, S., Gardebroek, C. (2012). Diversification in Italian farm systems: Are farmers using interlinked strategies?. New Medit. 11. 7-15.
European Commission (2019). The European Green Deal. Brussels, COM/2019/640 final. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
European Commission (2020). Farm to Fork Strategy-For a Fair, Healthy and Environmentally Friendly Food System, COM/2020/381 final. https://ec.europa.eu/food/farm2fork_en
Fazzari, S., Petersen, B., Hubbard, R.G. (1988). Financing Costraints and Corporate Investment. *Brookings Papers on Economic Activity, 1,* 141-206. https://doi.org/10.2307/2534426
García-Arias, A., Vázquez-González, I., Sineiro-García, F., Pérez-Fra, M. (2015). Farm diversification strategies in northwestern Spain: Factors affecting transitional pathways. Land Use Policy. 49. 413-425. 10.1016/j.landusepol.2015.08.011.
Giaccio, V., Giannelli, A., Mastronardi, L. (2018a) Explaining determinants of Agri-tourism income: evidence from Italy, Tourism Review, 73(2), pp. 216–229. doi: 10.1108/TR-05-2017-0089.
Giaccio, V., Mastronardi, L., Marino, D., Giannelli, A., Scardera, A. (2018b). Do Rural Policies Impact on Tourism Development in Italy? A Case Study of Farmhouses. 10.20944/preprints201807.0316.v1.
Henke R., Salvioni C. (2011). La diversificazione dei redditi nelle aziende agricole italiane. QA – Rivista dell'Associazione Rossi-Doria, 3: 25-56.
Heringa, P., van der Heide, M., Heijman, Wim J.M. (2012). The economic impact of multifunctional agriculture in The Netherlands, 2012 Conference, August 18-24, 2012, Foz do Iguacu, Brazil 125593, International Association of Agricultural Economists.
Iotti, M., Bonazzi, G. (2015), "Profitability and financial sustainability analysis in Italian aquaculture firms by application of economic and financial margins", American Journal of Agricultural and Biological Sciences, Vol. 10 No. 1, pp. 18-34, doi: 10.3844/ajabssp.2015.18.34.
ISMEA (2020). Il PSR come supporto alla diversificazione, creazione, sviluppo di attività extra-agricole e alla valorizzazione delle aree rurali tramite l'attivazione delle sottomisure 6.2 e 6.4 e attraverso la Focus Area 6A.
ISTAT (2020). Andamento dell'economia agricola, anno 2019. 20 maggio 2020.
Joo, H., Khanal, A.R., Mishra, A.K. (2013). Farmers' Participation in Farmhouses: Does It Affect the Bottom Line? Agricultural and Resource Economics Review, 42(03), 471–490. doi:10.1017/s1068280500004949
Kaplan, S., Zingales, L. (2000). Investment Cash Flow Sensitivities are not valid measures of financing constraints, *Quarterly Journal of Economics 115(2),* 707–712. https://doi.org/10.1162/003355300554782
Khanal, A. R. (2020). Interlinked diversification strategies: evidence from the US farm business households. Journal of *Agribusiness* in Developing and Emerging Economies, 10(3), 253–268. doi:10.1108/jadee-10-2018-0144
Khanal, A. R., Mishra, A. K. (2014) Farmhouses and off-farm work: Survival strategies for small farms, Agricultural Economics (United Kingdom), 45(S1), pp. 65–76. doi: 10.1111/agec.12130.
Lakner, S. et al. (2018) The effects of diversification activities on the technical efficiency of organic farms in Switzerland, Austria, and Southern Germany, Sustainability (Switzerland), 10(4). doi: 10.3390/su10041304.
Lange, A., Piorr, A., Siebert, R., Zasada, I. (2013). Spatial differentiation of farm diversification: How

rural attractiveness and vicinity to cities determine farm households' response to the CAP. Land Use Policy, 31, 136–144. doi:10.1016/j.landusepol.2012.02.

Lupi, C., Giaccio, V., Mastronardi, L., Giannelli, A., Scardera, A. (2017). Exploring the features of Farmhouses and its contribution to rural development in Italy. Land Use Policy, 64, 383–390. doi:10.1016/j.landusepol.2017.03.

McNamara, K.T., Weiss, C. (2005). Farm Household Income and On-and-Off Farm Diversification, Journal of Agricultural and Applied Economics, 37, issue 1, number 43711, https://EconPapers.repec.org/RePEc:ags:joaaec:43711.

Meraner, M., Heijman, W., Kuhlman, T., Finger, R. (2015). Determinants of farm diversification in the Netherlands. Land Use Policy, 42, 767–780. doi:10.1016/j.landusepol.2014.10.

Mishra, A.K., El-Osta, H.S., Sandretto, C.L. (2004). Factors affecting farm enterprise diversification. Agricultural Finance Review, 64(2), 151–166. doi:10.1108/00214660480001160

Pölling, Bernd & Mergenthaler, Marcus. (2017). The Location Matters: Determinants for "Deepening" and "Broadening" Diversification Strategies in Ruhr Metropolis' Urban Farming. Sustainability (Switzerland). 9. 10.3390/su9071168.

Raimondi, V., Curzi, D., Arfini, F., Olper, A., Aghabeygi, M. (2018). Evaluating Socio-Economic Impacts of PDO on Rural Areas, 2018 Seventh AIEAA Conference, June 14-15, Conegliano, Italy 275648, Italian Association of Agricultural and Applied Economics (AIEAA). 10.22004/ag.econ.275648

Rivaroli, S., Ghelfi, R., Bertazzoli, A., Piorr, A. (2017). Diversification pathways and farming systems: Insights from the Emilia-Romagna region, Italy. Outlook on Agriculture. 46. 003072701774170. 10.1177/0030727017741701.

Salvioni, C., Ascione, E., Henke, R. (2013) Structural and economic dynamics in diversified Italian farms, Bio-based and Applied Economics, 2(3), pp. 257–275. doi: 10.13128/BAE-13094.

Salvioni, C., Henke, R., Vanni, F. (2020) The impact of non-agricultural diversification on financial performance: Evidence from family farms in Italy, Sustainability (Switzerland), 12(2). doi: 10.3390/su12020486.

Salvioni, C., Fontanella, L. (2013). Diversification strategies and their impact on farm performance. Applied Studies In *Agribusiness* And Commerce. 7. 57-61.

Sardone, R., Monda, M. (2019). La diversificazione dell'agricoltura: tra esigenze conoscitive e lacune informative. Italian Review of Agricultural Economics 74(2): 41-52. doi: 10.13128/rea-10852

Van der Ploeg J.D., Roep D. (2003). Multifunctionality and rural development: the actual situation in Europe, in Van Huylenbroeck G. - Durand G., eds., Multifunctional Agriculture. A new paradigm for European agriculture and Rural Development, Ashgate, Burlington, VT (USA) e Aldershot (UK).

Zasada, I., Reutter, M., Piorr, A., Lefebvre, M., Gomez y Paloma, S. (2015). Between capital investments and capacity building—Development and application of a conceptual framework towards a place-based rural development policy. Land Use Policy. 46. 178-188. 10.1016/j.landusepol.2014.11.023.

APPENDIX A

The following tables report key variables for the three financial result groups (*better*, *alternating*, *worse*) in each *agribusiness*, in each TF. The reported variables are: FCFE, Depreciation (DEPR), F/D, Amortizable Capital (AMOC), Investments (INVES), CAP II aid, Gross saleable production (GSP), Working capital Variation (DWCC), Return on investment (ROI), percentage of farms in the financial result group over the farms of the agribusiness activity in the TF (% N).

Organic *better* than *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock	109,193	20,512	5.32	97,967	9,569	8,579	313,256	36,987	0.04	34.0
Extensive Beef Cattle	40,575	9,127	4.45	17,596	5,544	11,069	116,419	45	-0.02	30.5
Mixed Crops	90,421	12,672	7.14	95,509	2,992	7,090	172,464	553	0.06	21.3
Mixed Fruits	55,440	6,725	8.24	36,501	3,319	7,997	155,074	-380	0.03	35.9
Arable Crops	83,680	8,941	9.36	54,566	4,148	12,742	216,572	4,252	0.04	31.0
Sheep	52,541	8,187	6.42	24,724	6,644	19,846	118,887	977	0.02	26.9
Dairy Cattle	73,903	11,531	6.41	86,511	12,323	10,593	188,461	3,414	0.04	13.0
Vineyards	91,709	11,499	7.98	52,548	8,244	7,651	191,196	3,901	0.04	28.5
Mixed Livestock	261,754	8,091	32.35	84,251	5,194	20,724	333,967	110,174	-0.01	53.1
Greenhouse Vegetables										0.0
Olive Growing	26,066	6,528	3.99	61,104	1,055	8,475	77,641	-182	-0.06	54.3
Swine										0.0
Other	133,535	9,695	13.77	21,941	4,129	2,325	391,676	-23,171	0.05	16.3
Poultry	39,353	0		300	569	2,265	40,998	20,243	0.07	14.3
Citrus Fruits	68,206	6,085	11.21	21,609	1,786	16,400	161,915	66	0.04	34.1
Open Field Vegetables	23,688	2,409	9.83	28,860	576	3,787	99,397	-848	0.05	12.5
Fruits in Shell	172,103	15,461	11.13	123,239	77,055	13,213	277,489	5,340	0.09	39.1
Intensive Beef Cattle										0.0
TOTAL	66,164	8,491	7.79	50,585	5,039	10,724	156,493	5,096	0.03	32.1

Organic *alternating* over *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock	17,108	14,524	1.18	177,659	15,166	10,894	86,153	4,563	0.00	50.9
Extensive Beef Cattle	3,911	10,062	0.39	46,070	12,727	12,435	65,036	514	-0.04	43.3
Mixed Crops	6,956	6,039	1.15	56,972	6,006	8,263	95,321	1,840	-0.12	52.2
Mixed Fruits	7,679	7,539	1.02	62,409	14,549	8,610	87,370	1,661	-0.03	37.9
Arable Crops	5,383	4,480	1.20	63,378	6,181	8,822	61,184	-1,476	-0.04	36.2
Sheep	11,527	10,850	1.06	68,431	13,368	12,379	80,934	-1,659	-0.01	40.7
Dairy Cattle	15,776	19,906	0.79	159,685	45,105	24,557	209,309	10,287	0.00	39.0
Vineyards	25,842	14,839	1.74	141,147	28,124	5,819	193,831	-8,474	0.01	28.5
Mixed Livestock	-68,795	15,394	-4.47	77,632	249,670	36,338	393,577	-2,658	0.00	46.9
Greenhouse Vegetables	122,678	60,799	2.02	419,479	17,667	0	359,083	3,897	0.15	33.3
Olive Growing	-5,363	2,672	-2.01	20,878	9,710	5,419	36,509	-1,268	-0.14	39.2
Swine	34,723	5,878	5.91	29,567	2,053	1,985	167,743	4,831	0.01	100.0
Other	20,961	11,101	1.89	48,417	16,005	5,753	233,513	4,194	0.00	36.7
Poultry	26,326	8,207	3.21	45,290	5,827	2,551	204,896	3,705	0.03	42.9
Citrus Fruits	26,762	5,297	5.05	34,080	3,034	9,998	110,320	-2,812	0.01	33.3
Open Field Vegetables	51,623	8,086	6.38	73,211	10,473	12,217	245,748	-8,365	0.03	33.9
Fruits in Shell	39,010	7,066	5.52	33,545	7,974	6,738	110,803	-432	0.00	39.1
Intensive Beef Cattle	-7,387	0		0	642	15,644	52,139	-3,383	-0.14	12.5
TOTAL	9,528	8,450	1.13	67,821	17,894	9,961	106,017	-260	-0.02	38.9

Organic *worse* than *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock	-24,513	6,102	-4.02	61,924	11,036	3,562	60,453	-7,029	-0.18	*15.1*
Extensive Beef Cattle	-13,761	5,122	-2.69	46,679	*11,651*	*5,525*	32,360	152	-0.11	*26.2*
Mixed Crops	-25,102	*13,788*	-1.82	*138,688*	*49,515*	*4,201*	42,735	*28,541*	-0.24	*26.5*
Mixed Fruits	-12,582	2,821	-4.46	22,869	2,697	*2,878*	27,796	-921	-0.22	*26.2*
Arable Crops	-18,884	*11,045*	-1.71	*102,593*	*24,338*	*5,509*	51,088	*8,300*	-0.13	*32.8*
Sheep	-16,554	*23,816*	-0.70	*111,819*	*17,869*	*9,912*	53,587	-2,268	-0.08	*32.3*
Dairy Cattle	-37,685	*27,452*	-1.37	*474,224*	*42,490*	*18,110*	94,878	-16,880	-0.02	*48.1*
Vineyards	-39,157	*8,966*	-4.37	*96,108*	*30,606*	*3,415*	*64,375*	-12,851	-0.05	*43.0*
Mixed Livestock										0.0
Greenhouse Vegetables	-10,333	220	-46.90	894	258	183	47,574	-19	-0.38	*66.7*
Olive Growing	*-8,468*	374	-22.65	11,419	8,935	*3,535*	9,704	*2,177*	-0.92	*6.4*
Swine										0.0
Other	-20,669	*11,293*	-1.83	*80,328*	*14,388*	*1,848*	90,521	*-1,975*	-0.07	*46.9*
Poultry	-18,823	*17,204*	-1.09	*202,599*	*52,103*	*3,644*	33,280	*378*	0.03	*42.9*
Citrus Fruits	3,003	*7,647*	0.39	*41,900*	1,836	*17,079*	*106,604*	-14,695	-0.40	*32.5*
Open Field Vegetables	2,845	*18,155*	0.16	*138,296*	*18,838*	*19,757*	189,140	-6,639	-0.03	*53.6*
Fruits in Shell	-1,628	928	-1.75	4,789	125	3,000	14,635	-21	-0.11	*21.7*
Intensive Beef Cattle	-5,473	13,965	-0.39	98,120	16,923	*5,106*	112,462	5,760	*-0.02*	*87.5*
TOTAL	-18,154	*11,666*	-1.56	*109,610*	*20,448*	*7,465*	64,853	-1,511	-0.18	*29.0*

Processing *better* than *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock	*88,889*	*15,258*	*5.83*	92,144	6,792	*4,745*	*224,278*	*27,380*	*0.04*	*15.8*
Extensive Beef Cattle	*54,724*	*15,065*	*3.63*	*80,792*	8,082	*9,412*	*160,292*	-2,011	*0.02*	*21.3*
Mixed Crops	*56,630*	*7,389*	*7.66*	*56,618*	1,340	*3,526*	*156,402*	-1,734	*0.05*	*13.2*
Mixed Fruits	*54,591*	7,294	*7.48*	48,466	2,822	*4,134*	*155,289*	112	*0.03*	*25.5*
Arable Crops	*43,136*	6,641	*6.50*	51,009	4,379	*7,940*	*124,253*	885	*-0.02*	*17.9*
Sheep	*81,562*	*15,263*	*5.34*	*63,739*	*9,630*	*10,553*	*205,572*	-1,497	*0.07*	*13.3*
Dairy Cattle	*88,913*	17,848	*4.98*	100,811	17,456	*8,491*	251,492	1,010	*0.04*	*16.4*
Vineyards	*130,368*	*20,798*	*6.27*	*129,997*	*20,506*	*6,817*	*341,806*	*5,144*	*0.05*	*17.6*
Mixed Livestock	*67,981*	5,452	*12.47*	27,026	4,052	*5,068*	135,264	*620*	*-0.01*	*18.1*
Greenhouse Vegetables	*110,337*	13,041	*8.46*	71,338	*206,941*	0	*1,227,583*	*5,195*	*0.11*	*5.6*
Olive Growing	*31,199*	7,360	*4.24*	62,558	2,783	*5,216*	*90,941*	*696*	*-0.04*	*51.6*
Swine	*247,597*	15,465	*16.01*	241,610	19,139	0	529,816	*19,945*	*0.11*	*8.3*
Other	*48,088*	4,520	*10.64*	39,468	3,838	*3,098*	*155,421*	*1,625*	*0.05*	*16.5*
Poultry	*148,415*	6,282	*23.62*	53,552	1,453	231	*235,666*	*14,281*	*0.12*	*26.2*
Citrus Fruits	*91,413*	*7,872*	*11.61*	*25,833*	2,573	*19,427*	*202,941*	*35*	*0.07*	*20.6*
Open Field Vegetables	*174,734*	7,233	*24.16*	27,483	2,742	1,369	*495,664*	*3,379*	*0.09*	*6.7*
Fruits in Shell	*166,380*	*15,417*	*10.79*	*129,450*	*78,364*	*3,473*	*294,791*	*2,920*	*0.14*	*42.9*
Intensive Beef Cattle										0.0
TOTAL	*66,637*	10,455	*6.37*	69,550	7,589	*6,320*	*178,136*	*1,936*	*0.05*	*21.0*

Processing *alternating* over *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock	*1,509*	*12,893*	*0.12*	*160,760*	14,463	*7,049*	85,496	2,624	*-0.01*	*36.3*
Extensive Beef Cattle	-6,135	*10,803*	-0.57	*80,844*	*17,070*	*5,465*	79,945	-1,816	*-0.03*	*43.1*
Mixed Crops	*2,881*	5,140	*0.56*	44,313	*8,425*	*4,711*	68,257	*387*	*-0.06*	*44.1*
Mixed Fruits	*6,407*	4,980	*1.29*	36,882	10,723	*3,819*	72,857	-1,894	-0.01	*32.8*
Arable Crops	42	6,118	0.01	60,493	10,900	3,119	60,893	1,152	*-0.05*	*30.7*

Sheep	*14,242*	*12,995*	*1.10*	*74,768*	*22,056*	*12,770*	*107,724*	-3,697	*-0.02*	*40.0*
Dairy Cattle	12,447	14,022	0.89	89,683	25,468	*14,158*	143,487	-508	*0.00*	*39.2*
Vineyards	*25,015*	*12,530*	*2.00*	*117,510*	*23,602*	*5,170*	*181,251*	-12,605	*0.01*	*42.8*
Mixed Livestock	1,135	8,505	0.13	78,242	2,182	*6,276*	88,829	*-1,986*	*-0.02*	*36.2*
Greenhouse Vegetables	-7,503	5,057	-1.48	85,363	2,561	0	117,605	-7,652	*-0.01*	*66.7*
Olive Growing	*-744*	3,262	*-0.23*	22,515	11,398	*3,499*	52,342	*1,257*	*-0.09*	*38.8*
Swine	49,173	20,570	2.39	276,229	19,019	2,062	242,757	*8,139*	*0.02*	*54.2*
Other	*35,606*	*11,939*	2.98	*82,981*	*12,388*	*6,543*	*172,322*	*5,783*	*0.02*	*27.2*
Poultry	35,497	7,733	*4.59*	98,844	2,797	1,534	80,597	*1,523*	0.00	*32.3*
Citrus Fruits	*27,544*	*5,886*	*4.68*	*65,145*	*6,392*	*4,045*	*114,355*	*9,471*	*-0.01*	*39.0*
Open Field Vegetables	*57,435*	9,656	*5.95*	*109,927*	*22,290*	*8,926*	*221,115*	*8,717*	*0.00*	*34.8*
Fruits in Shell	*28,272*	2,908	*9.72*	3,838	219	*3,750*	58,413	-179	*0.06*	*42.9*
Intensive Beef Cattle										0.0
TOTAL	11,414	8,762	1.30	76,789	15,010	*5,592*	107,373	-1,630	*-0.01*	*37.5*

Processing *worse* than *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock	-30,766	4,162	-7.39	50,886	13,321	1,401	38,041	-759	-0.12	*48.0*
Extensive Beef Cattle	-17,789	4,285	-4.15	32,949	5,524	1,766	38,418	-1,616	-0.09	*35.6*
Mixed Crops	-20,487	*9,369*	-2.19	*91,870*	*18,435*	1,588	30,619	-3,812	-0.17	*42.7*
Mixed Fruits	-13,401	3,499	-3.83	32,768	4,228	989	27,011	-784	-0.16	*41.7*
Arable Crops	-14,127	6,130	-2.30	62,271	7,419	1,776	36,535	-108	-0.14	*51.4*
Sheep	-12,270	*14,348*	-0.86	*85,963*	7,892	3,407	41,673	-1,627	-0.09	*46.7*
Dairy Cattle	-21,153	*24,952*	-0.85	*282,835*	22,067	*14,251*	102,464	-10,187	-0.03	*44.4*
Vineyards	-24,222	*6,449*	-3.76	*51,764*	*15,298*	*2,139*	53,581	-6,794	-0.11	*39.6*
Mixed Livestock	-23,110	3,962	-5.83	47,854	9,918	2,213	26,977	*-1,301*	-0.08	*45.7*
Greenhouse Vegetables	-19,794	1,997	-9.91	8,296	406	0	58,705	569	-0.10	*27.8*
Olive Growing	*-11,929*	1,032	-11.56	13,684	5,385	1,698	12,250	*2,167*	-0.72	*9.6*
Swine	-38,069	20,761	-1.83	230,148	*46,772*	2,109	160,185	*2,501*	-0.06	*37.5*
Other	-17,727	*5,854*	-3.03	*47,832*	*12,962*	*862*	50,489	*-733*	-0.08	*56.3*
Poultry	694	15,298	0.05	*201,017*	*16,952*	*2,256*	36,209	*5,410*	-0.02	*41.5*
Citrus Fruits	-5,130	*4,089*	-1.25	*29,133*	1,843	*973*	48,743	*191*	-0.08	*40.4*
Open Field Vegetables	1,764	9,804	0.18	*75,356*	3,663	*7,373*	96,405	-3,077	-0.10	*58.5*
Fruits in Shell	-1,818	70	-25.98	106	25	0	18,359	0	-0.16	*14.3*
Intensive Beef Cattle	-20,623	8,736	-2.36	74,741	10,050	*3,116*	70,165	-6,733	-0.05	*100.0*
TOTAL	-16,819	7,773	-2.16	73,071	10,756	2,772	46,686	-2,456	-0.13	*41.5*

Selling *better* than *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock	*35,287*	7,037	*5.01*	74,201	156	3,464	123,840	2,181	*0.00*	*16.7*
Extensive Beef Cattle	*45,472*	6,787	*6.70*	23,718	5,356	4,513	98,766	*9,022*	*0.02*	*15.4*
Mixed Crops	*48,920*	6,080	*8.05*	*48,530*	983	*4,791*	*147,406*	-1,565	*0.04*	*19.7*
Mixed Fruits	*99,538*	*9,407*	*10.58*	*67,452*	5,219	*6,639*	*311,843*	-261	*0.03*	*23.6*
Arable Crops	*57,363*	*10,489*	*5.47*	*100,370*	8,764	*7,837*	*155,844*	2,277	*0.00*	*16.8*
Sheep	*93,209*	*22,328*	*4.17*	*116,462*	8,212	5,513	*241,199*	*4,961*	*0.05*	*21.8*
Dairy Cattle	*79,037*	12,365	*6.39*	108,252	11,794	*12,155*	203,553	*6,852*	*0.05*	*19.4*
Vineyards	*102,697*	*18,920*	*5.43*	*103,390*	*25,351*	*5,488*	*278,632*	-1,037	*0.04*	*19.4*
Mixed Livestock	*46,498*	5,996	*7.76*	40,998	3,541	2,829	82,530	*1,758*	*-0.01*	*33.3*
Greenhouse Vegetables										0.0

Olive Growing	42,654	8,014	5.32	83,858	4,107	5,035	74,964	8,167	-0.08	36.3
Swine										0.0
Other	49,953	4,162	12.00	30,663	1,804	4,469	180,961	-1,480	0.05	16.9
Poultry	161,001	24,526	6.56	259,482	20,481	74	678,060	20,830	0.11	21.4
Citrus Fruits										0.0
Open Field Vegetables	194,439	9,224	21.08	24,137	3,369	1,387	352,758	2,538	0.10	13.5
Fruits in Shell										0.0
Intensive Beef Cattle										0.0
TOTAL	74,090	11,319	6.55	81,060	8,886	5,867	200,362	2,534	0.03	13.4

Selling *alternating* over *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock	4,607	19,509	0.24	247,712	21,364	8,659	102,997	5,499	0.00	40.3
Extensive Beef Cattle	-3,772	15,679	-0.24	143,830	21,522	9,174	80,176	1,901	-0.03	47.4
Mixed Crops	627	7,283	0.09	73,373	11,085	6,722	72,529	1,919	-0.01	51.5
Mixed Fruits	-4,144	9,923	-0.42	82,349	17,562	4,156	78,367	1,076	-0.02	34.5
Arable Crops	220	7,754	0.03	92,019	7,242	5,674	67,567	-858	-0.03	29.7
Sheep	15,267	14,061	1.09	83,027	12,610	13,965	91,058	-3,390	-0.02	37.9
Dairy Cattle	15,707	17,615	0.89	115,054	18,623	15,793	154,130	-1,080	0.00	32.7
Vineyards	12,873	14,236	0.90	152,928	25,930	2,989	123,473	-6,559	0.01	42.6
Mixed Livestock	6,127	7,771	0.79	76,646	4,548	5,763	63,373	-689	0.00	46.7
Greenhouse Vegetables	-4,362	10,754	-0.41	187,712	25,215	0	168,187	-16,972	0.01	66.7
Olive Growing	-6,734	3,398	-1.98	30,025	6,773	5,150	28,368	1,733	-0.18	52.7
Swine	121,918	36,840	3.31	445,716	27,693	0	251,157	28,730	0.03	38.5
Other	32,057	6,662	4.81	64,538	12,007	7,889	157,321	26,134	0.02	25.3
Poultry	32,180	8,342	3.86	86,852	5,633	0	85,363	557	0.07	42.9
Citrus Fruits	29,781	5,581	5.34	108,196	5,901	3,713	171,767	2,741	0.02	59.1
Open Field Vegetables	133,639	9,781	13.66	158,482	24,991	19,066	209,821	21,826	-0.01	25.0
Fruits in Shell										0.0
Intensive Beef Cattle										0.0
TOTAL	9,991	11,094	0.90	112,224	15,716	6,768	97,772	913	-0.01	38.9

Selling *worse* than *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock	-38,334	4,625	-8.29	74,060	21,312	1,353	32,919	2,468	-0.10	43.1
Extensive Beef Cattle	-20,787	4,480	-4.64	38,884	8,490	2,845	40,152	-2,870	-0.10	37.2
Mixed Crops	-23,301	14,588	-1.60	143,512	15,459	785	42,938	1,432	-0.11	28.8
Mixed Fruits	-16,718	5,026	-3.33	52,699	5,905	1,581	32,579	-4,254	-0.11	41.9
Arable Crops	-12,714	6,106	-2.08	58,620	8,409	2,195	43,063	1,480	-0.08	53.4
Sheep	-13,503	20,539	-0.66	83,448	9,164	6,633	45,650	-1,265	-0.07	40.2
Dairy Cattle	-23,088	39,004	-0.59	505,291	30,591	20,348	159,536	-17,221	-0.02	48.0
Vineyards	-26,399	6,910	-3.82	63,210	14,062	2,123	71,003	-7,539	-0.06	38.0
Mixed Livestock	-15,415	3,513	-4.39	41,835	3,207	1,080	20,246	-436	-0.07	20.0
Greenhouse Vegetables	-97,845	8,949	-10.93	90,302	86,673	0	52,271	-789	-0.07	33.3
Olive Growing	-12,421	1,736	-7.15	39,410	8,004	2,295	15,975	2,542	-0.23	11.0
Swine	-14,009	4,143	-3.38	53,040	472	0	95,932	-14,341	-0.08	61.5
Other	-21,773	4,463	-4.88	52,850	13,770	637	65,308	-2,486	-0.07	57.8
Poultry	-20,796	4,459	-4.66	62,483	3,657	394	101,142	-6,458	-0.08	35.7
Citrus Fruits	-597	5,124	-0.12	46,463	141	1,358	83,520	81	-0.03	40.9
Open Field Vegetables	-9,758	6,521	-1.50	56,911	3,699	3,409	51,962	-514	-0.11	61.5
Fruits in Shell										0.0

Intensive Beef Cattle	-4,999	16,758	-0.30	166,096	6,388	2,163	126,560	-813	*-0.03*	*100.0*
TOTAL	-19,564	9,891	-1.98	*101,629*	12,343	*3,594*	59,592	-3,133	-0.08	*41.5*

Quality *better* than *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock										0.0
Extensive Beef Cattle	*15,209*	7,518	*2.02*	2,166	7,601	*11,000*	38,631	1,766	*-0.03*	*11.1*
Mixed Crops	*192,871*	*27,399*	*7.04*	*190,015*	1,103	*8,943*	*501,130*	-3,392	*-0.03*	*18.2*
Mixed Fruits	*47,970*	*10,407*	*4.61*	42,141	11,370	*5,263*	*129,228*	*3,026*	*0.01*	*23.1*
Arable Crops	*59,543*	4,271	*13.94*	30,696	166	*6,920*	*166,162*	333	*0.02*	*37.3*
Sheep										0.0
Dairy Cattle	36,092	15,578	*2.32*	36,714	0	0	221,359	*27,069*	*0.00*	*3.7*
Vineyards	*26,027*	*5,422*	*4.80*	26,669	*13,031*	*4,845*	*75,352*	*2,660*	-0.07	*8.1*
Mixed Livestock	*37,945*	5,186	*7.32*	84,275	3,997	*4,880*	*182,175*	*22*	*0.00*	*100.0*
Greenhouse Vegetables										0.0
Olive Growing	*28,106*	4,756	*5.91*	31,899	2,606	*4,326*	*79,933*	*3,562*	*-0.01*	*61.1*
Swine										0.0
Other										0.0
Poultry										0.0
Citrus Fruits	*11,382*	1,126	*10.11*	52	0	*6,000*	52,523	*1,912*	-0.31	*25.0*
Open Field Vegetables	11,133	1,417	*7.86*	19,101	1,545	0	41,033	*29*	*0.09*	*16.7*
Fruits in Shell	*20,227*	626	*32.31*	0	0	0	48,803	-262	*0.06*	0.0
Intensive Beef Cattle										0.0
TOTAL	*46,217*	6,872	*6.73*	41,423	5,199	*5,312*	132,653	*2,189*	*-0.02*	*19.5*

Quality *alternating* over *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock	*125,751*	*22,201*	*5.66*	*240,691*	8,127	2,691	118,021	*63,436*	*0.10*	*33.3*
Extensive Beef Cattle	-21,557	*13,448*	-1.60	41,514	111	*19,373*	63,367	-11,508	*-0.03*	*44.4*
Mixed Crops	*2,914*	5,055	*0.58*	47,622	4,142	*8,960*	51,327	-925	*-0.03*	*50.0*
Mixed Fruits	-23,707	*13,275*	-1.79	*145,448*	*63,341*	*3,119*	*108,437*	*8,922*	-0.03	*41.5*
Arable Crops	4,981	4,064	*1.23*	54,145	7,018	*4,438*	56,443	2,780	*-0.06*	*37.3*
Sheep	*49,173*	*7,746*	*6.35*	49,055	1,221	*7,326*	*107,976*	*9,335*	-0.03	*100.0*
Dairy Cattle	-175,232	*28,851*	-6.07	*280,639*	*210,096*	*64,672*	116,180	-11,380	-0.02	*11.1*
Vineyards	*-914*	*6,345*	*-0.14*	*69,216*	*27,918*	928	*78,265*	-9,769	*0.01*	*45.0*
Mixed Livestock										0.0
Greenhouse Vegetables	*122,678*	*60,799*	*2.02*	*419,479*	*17,667*	0	*359,083*	*3,897*	*0.15*	*100.0*
Olive Growing	*-6,572*	4,817	*-1.36*	21,661	15,822	*6,380*	52,196	*-59*	-0.35	*27.8*
Swine										0.0
Other	*44,401*	*8,571*	*5.18*	8,025	*17,449*	0	*761,955*	*3,593*	*0.08*	*25.0*
Poultry	-1,599	0		0	166	0	*261,351*	*3,218*	-0.02	0.0
Citrus Fruits	5,680	1,755	*3.24*	12,835	0	*1,500*	42,782	-893	*0.00*	*25.0*
Open Field Vegetables	*112,228*	7,696	*14.58*	*65,191*	4,999	*15,734*	*264,272*	*24,885*	*0.04*	*41.7*
Fruits in Shell										0.0
Intensive Beef Cattle										0.0
TOTAL	2,868	8,917	0.32	*85,271*	*28,871*	*4,770*	103,062	-625	*-0.02*	*39.5*

Quality *worse* than *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock	-40,620	8,060	-5.04	*116,804*	*26,607*	2,615	45,815	-1,637	*-0.02*	*66.7*
Extensive Beef Cattle	-8,802	2,948	-2.99	17,765	1,836	3,929	20,100	-665	-0.18	*44.4*

Mixed Crops	-9,655	2,392	-4.04	31,950	1,015	*1,889*	20,353	*-489*	-0.39	*31.8*
Mixed Fruits	-48,012	7,367	-6.52	*68,521*	*50,730*	1,171	72,980	1,249	-0.06	*35.4*
Arable Crops	-15,208	1,874	-8.12	27,857	3,053	1,051	21,169	-4	*-0.06*	*25.5*
Sheep										0.0
Dairy Cattle	-19,023	*36,746*	-0.52	*538,991*	*67,693*	*26,983*	237,489	-12,790	-0.02	*85.2*
Vineyards	-42,756	*5,680*	-7.53	*36,530*	*41,608*	927	*60,935*	-2,871	-0.06	*46.9*
Mixed Livestock										0.0
Greenhouse Vegetables										0.0
Olive Growing	*-9,662*	163	-59.46	676	135	*7,174*	9,261	*-358*	-1.64	*11.1*
Swine										0.0
Other	-79,015	*25,764*	-3.07	*245,432*	*92,080*	*1,777*	*294,073*	-64,573	*-0.01*	*75.0*
Poultry										0.0
Citrus Fruits	-3,535	*4,852*	-0.73	*32,999*	*4,715*	0	*92,400*	*6,772*	*-0.02*	*50.0*
Open Field Vegetables	-4,704	*31,944*	-0.15	*237,877*	*32,417*	*4,251*	*355,549*	-3,144	*-0.01*	*41.7*
Fruits in Shell										0.0
Intensive Beef Cattle	-43,921	7,617	-5.77	36,872	57,418	1,617	165,490	9,123	-0.05	*100.0*
TOTAL	-35,660	*11,303*	-3.16	*124,412*	*41,558*	*4,863*	101,302	-6,058	-0.21	*40.9*

Farmhouse *better* than *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock	*49,983*	7,658	*6.53*	84,241	2,807	1,406	107,202	-499	*0.04*	*15.6*
Extensive Beef Cattle	*107,815*	*20,280*	*5.32*	*107,942*	*16,347*	*8,544*	*378,880*	-7,073	*0.02*	*26.3*
Mixed Crops	*26,066*	927	*28.12*	8,842	1,211	*7,410*	*107,226*	-3,954	*0.01*	*5.3*
Mixed Fruits	*38,252*	6,127	*6.24*	*118,149*	7,232	*2,794*	66,355	-1,215	*0.04*	*13.5*
Arable Crops	*59,830*	7,684	*7.79*	*144,572*	15,041	*13,981*	93,245	-4,904	*0.01*	*19.3*
Sheep	*261,716*	*58,210*	*4.50*	*276,053*	*20,478*	*17,014*	*662,378*	*6,050*	*0.03*	*40.0*
Dairy Cattle	*50,293*	20,315	*2.48*	*188,155*	17,720	*28,265*	107,586	*11,629*	*0.00*	*6.2*
Vineyards	*143,257*	*18,216*	*7.86*	*125,046*	*9,352*	*3,561*	*341,652*	-50,443	*0.07*	*7.0*
Mixed Livestock	*44,940*	9,433	*4.76*	*137,639*	2,510	2,841	44,754	*695*	*0.02*	*50.0*
Greenhouse Vegetables										0.0
Olive Growing	*7,107*	*8,913*	*0.80*	*125,718*	2,291	*6,944*	31,462	*1,726*	*-0.03*	*73.3*
Swine										0.0
Other	*141,020*	*18,546*	*7.60*	*274,564*	*12,067*	170	*245,407*	*15*	*0.08*	*41.7*
Poultry										0.0
Citrus Fruits										0.0
Open Field Vegetables										0.0
Fruits in Shell										0.0
Intensive Beef Cattle										0.0
TOTAL	*70,640*	*14,907*	*4.74*	*142,460*	9,187	*8,668*	171,327	-2,907	*0.03*	*17.2*

Farmhouse *alternating* over *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock	*3,293*	*25,083*	*0.13*	*372,873*	*29,246*	*10,591*	132,646	3,529	*0.01*	*60.0*
Extensive Beef Cattle	-5,787	*17,719*	-0.33	*143,984*	*20,068*	*12,585*	103,071	-3,036	*-0.02*	*52.6*
Mixed Crops	*3,753*	*7,523*	*0.50*	*98,239*	*7,717*	*5,268*	40,742	*5,328*	*0.01*	*63.2*
Mixed Fruits	-10,534	*27,722*	-0.38	*280,899*	*46,421*	*2,188*	*109,643*	*5,422*	*0.00*	*37.8*
Arable Crops	*10,323*	*14,586*	0.71	*168,903*	13,273	*11,008*	*118,242*	2,503	*-0.03*	*33.3*
Sheep	*62,237*	*36,748*	*1.69*	*146,030*	92	*23,333*	67,419	*1,860*	*0.00*	*20.0*
Dairy Cattle	-15,110	20,433	-0.74	*380,562*	*63,411*	*10,528*	*127,419*	*12,472*	*0.01*	*23.7*
Vineyards	*15,204*	*15,159*	*1.00*	*201,807*	*26,725*	*2,057*	*110,558*	-23,815	*0.01*	*62.0*
Mixed Livestock	57	10,535	0.01	97,329	3,796	*7,089*	25,627	*-2,911*	*-0.01*	*41.7*

Greenhouse Vegetables										0.0
Olive Growing	*-8,316*	1,612	-5.16	4,956	276	*2,930*	33,794	*-120*	-0.29	*20.0*
Swine	-8,855	1,853	-4.78	15,738	1,082	357	104,530	*-4,545*	-0.02	*50.0*
Other	*22,456*	1,943	*11.56*	26,156	*9,904*	19	*159,023*	-5,203	*0.08*	*33.3*
Poultry										0.0
Citrus Fruits										0.0
Open Field Vegetables	41,056	7,097	*5.79*	*173,061*	*14,071*	138	55,430	*16,973*	*0.10*	*40.0*
Fruits in Shell										0.0
Intensive Beef Cattle										0.0
TOTAL	9,991	*11,094*	0.90	*112,224*	15,716	*6,768*	97,772	*913*	*-0.01*	*42.1*

Farmhouse *worse* than *simple farming*	FCFE	DEPR	F/D	AMOC	INVES	CAP II	GSP	DWCC	ROI	%N
Mixed Crops and Livestock	-38,318	8,179	-4.68	*144,514*	*28,072*	1,474	15,361	-495	-0.18	*24.4*
Extensive Beef Cattle	-11,946	1,968	-6.07	14,096	1,697	3,379	16,722	-3,706	-0.14	*21.1*
Mixed Crops	-56,520	*74,737*	-0.76	*752,915*	*59,157*	*4,630*	80,847	-96,498	-0.19	*31.6*
Mixed Fruits	-49,275	*16,497*	-2.99	*244,037*	*78,449*	689	71,227	-10,382	*-0.01*	*48.6*
Arable Crops	-10,529	*27,052*	-0.39	*424,340*	8,171	3,452	55,426	-3,555	*-0.07*	*47.4*
Sheep	-20,992	*144,062*	-0.15	*337,282*	*37,894*	*18,848*	*151,222*	-21,282	-0.04	*40.0*
Dairy Cattle	-59,479	18,757	-3.17	*324,263*	*76,349*	*9,700*	73,979	*5,278*	-0.01	*70.1*
Vineyards	-39,324	*14,267*	-2.76	*178,816*	*21,264*	1,334	*135,022*	-8,476	-0.03	*31.0*
Mixed Livestock	-411,154	2,993	-137.37	*443,043*	*396,241*	588	7,831	*3,001*	*-0.03*	*8.3*
Greenhouse Vegetables										0.0
Olive Growing	*-19,688*	1,619	-12.16	71,543	*35,615*	*9,272*	10,903	*11,799*	-0.19	*6.7*
Swine	-17,262	1,811	-9.53	9,367	1	0	5,320	*-736*	-0.27	*50.0*
Other	-23,333	*15,840*	-1.47	*351,705*	*10,590*	0	27,534	-23,596	-0.02	*25.0*
Poultry										0.0
Citrus Fruits										0.0
Open Field Vegetables	-28,544	5,396	-5.29	*90,163*	*20,090*	57	30,692	*913*	*-0.02*	*60.0*
Fruits in Shell										0.0
Intensive Beef Cattle	-6,447	8,521	-0.76	51,330	13,644	*6,124*	126,006	-4,896	-0.04	*100.0*
TOTAL	-42,442	*25,121*	-1.69	*305,184*	*47,696*	*5,402*	72,568	-10,259	-0.09	*40.7*

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Pesticides, crop choices and changes in well-being

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Abstract. This study investigates how Pesticide Risk Indicators (PRIs) can be applied to help develop sound economic policies. We modified one of the numerous PRIs proposed over the years, the Environmental Impact Quotient (EIQ), originally developed for the fruit industry, to consider co-formulants and adjuvants. The new formula includes three components representing the externalities of farm worker risk, consumer risk, and ecological risk. It also considers the potential externalities of the use of pesticides on residents living near the farms where these products are used. We applied the modified EIQ to two areas located in central Italy (the Chiana Valley in Tuscany and the Tiber and Upper Tiber Valleys in Tuscany/Umbria), surveying a sample of farms to determine the quantity and types of pesticides used on five crops: durum wheat, soft wheat, corn, tobacco, and olives. After calculating the impact quotient, we used data from a survey conducted in a different Italian region regarding the willingness to pay (WTP) for a pesticide-free environment and determined the WTP for even minimal changes in that quotient. Using those results, we simulated the changes in welfare (calculated as changes in willingness to pay) that would result from modifying the amount of land used for each crop. Our findings indicate that the proposed WTP indicator may have broad utility and that its application may lead to enhanced awareness of the consequences of pesticide use in farming.

Keywords: pesticides, impact indicators, TEIQ, pesticide externalities.
JEL Codes: Q10, Q15.

1. INTRODUCTION

The agri-food sector is nowadays asked to change approach towards production, taking into account the impact of its activities on the environment. In 2020, as part of the European Green Deal, the From Farm to Fork strategy highlighted the need to transform the European food system into a healthier, fairer and more sustainable system. Among its goals, the strategy aims to reduce by 50% the use of plant protection products. Previously, the Directive 128/2009 already raised the issue of a more sustainable use of plant protection products. However, the lack of knowledge about the overall effects of these products on health and the environment makes it more difficult to reach the goal.

The harmful effects of plant protection products (PPPs), like those of many pollutants, have not been fully established. There are generally significant obstacles to attempting to measure pesticide negative externalities, which in many cases are compounded by the irreversibility of some of those effects (Turner et al., 2003).

Accurate and realistic measurement of the environmental externalities caused using PPPs would require the simultaneous assessment of all their potential harms concerning human health and natural capital (Pretty et al., 2000)[1]. While there is abundant research into consumer health and the protection of farm workers, few studies have investigated the effects of pesticide use on people living near the land where such products are employed. However, the widespread urbanization of rural areas and the proximity of intensive farming to residential areas or other locations where people frequently visit have made this an increasingly important issue (Targetti et al., 2020).

The most common approach to ascertaining the consequences of pesticide use is to determine the relationship between a pollutant's concentration in the environment and its effects, evaluating the risk entails an analysis of the "dose" (pollution level) and "response" (effect). In general, the three factors that must be considered when examining the environmental damage caused by PPPs are hazard (the potential harm caused), exposure, and risk, where risk is the likelihood that the hazardous effect will occur and depends on the interaction between the hazard and exposure. Other factors important for assessing the externalities caused by PPPs are their characteristics of selectivity, the spectrum of action, penetration capacity and systemic action.

By law, plant protection products must be evaluated for potential hazards and, where necessary, classified for their toxicological, ecotoxicological, and physicochemical effects. PPPs are currently classified based on acute and chronic toxicity. According to Directive (EC) 2009/128 of the European Parliament, a National Action Plan for the sustainable use of pesticides must include "indicators to monitor the use of plant protection products containing active substances of particular concern." The standard variable is the amount of pesticide per hectare of farmland. As observed by Devillers et al. (2005) and Ioriatti et al. (2011), it has become evident that simply measuring the quantity of PPPs used is not sufficient to estimate the risk and characteristics of exposure. To address this shortcoming, the scientific community has developed a wide range of tools to estimate the impact of PPPs more accurately. These tools are generally known as pesticide risk indicators (PRIs). Pesticide risk indicators (PRIs) have also been used to assess the environmental impact of certain plant disease control programs over time in different locations, to evaluate the impact of farming and plant protection policies (Gallivan et al., 2001; Greitens and Day, 2007), and to identify changes in environmental risks that require attention (Ioriatti, 2011).

The scientific community has developed several PRIs.[2] For example, Deviller et al. (2005) presented an exhaustive list of dozens of PRIs and a grid describing each one's components, formulation methods, advantages, and limitations.

Generally, it is indeed challenging to find an acceptable balance between the benefits of a simplified system and a more elaborate model which can provide a greater wealth of information but is harder to use. Furthermore, each of the available methods for devising PRIs has strengths and weaknesses that take on different degrees of importance depending on the intended purpose. Finally, regardless of the specified purpose, the methods for formulating PRIs can also simply identify changes in the environment or seek to quantify their extent and meaning (Ioriatti and Martini, 2011).

This article aims to study the possibility of assessing economically the consequences of PPPs reduction in a specific area. In this evaluation also the impact of co-formulants and adjuvants have been considered as well as drift effect for bystanders and locals.

For this purpose, an indicator has been integrated with few components in order to estimate the impact of PPPs used in an area located in the Tuscany Region. Data have been collected among a representative sample of farms. In this way the economic value of the externalities has been assessed. Finally, a simulation was conducted hypnotizing the substitution of high-impact crops with low-impact ones.

[1] Some definitions of technical terms have been provided in the glossary to Appendix 3 to avoid overburdening the paper.

[2] PRIs have been used in various parts of Italy, sometimes on an experimental basis, to evaluate environmental policies and plant protection practices. (Devillers et al., 2005) and the EIQ at the Centro Vitivinicolo Provinciale of Brescia (2008) the Piedmont Region's for rural development plan2000-2006 The EIQ has also been used in international research, (Leach and Mumford, 2008).

2. MATERIALS AND METHODS

Pesticide risk indicators usually combine hazard and exposure information with data on the quantity of the pesticide used and under what conditions. To a large extent, hazard information can be found on the pesticide's Safety Data Sheet (SDS)[3]. In this study, too, SDSs were used as a source of information for the assessment of health and environmental risks. Sections 2 and 3 of an SDS list of all pesticide hazardous ingredients[4], along with their concentrations or ranges of concentration. These sections also contain the hazard statements that are assigned according to their physicochemical, health and environmental risks. To provide consistent estimates, this work follows the methodology recommended, amongst others, by Ioriatti et al. (2011).

For the purposes of this study, where Safety Data Sheets did not provide sufficient hazard information or a detailed breakdown of ingredients (as was sometimes the case of formulations that are no longer registered), the Pesticide Properties Database (PPDB)[5] or the safety data sheets of similar products were used as sources for toxicological information.

Among the possible PRIs which may be considered in this study, we chose to use a modified version of the Environmental Impact Quotient (EIQ), which was originally developed to help consultants, who were promoting integrated fruit production in New York State, select low-impact pest control methods (Ioriatti et al., 2011; Kovach et al., 1992).[6] Like most PRIs, the original EIQ does not consider co-formulants, for which information on identity, chemical properties, and health and environmental impact is rarely available. Surgan et al. (2010) raised some criticisms regarding PRI methodology, demonstrating that, concerning farm workers' health, the inert ingredients of a PPP can sometimes have a higher impact score, as determined from the EIQ, than its active ingredients. This means that relying solely on the active ingredient for measurement purposes may underestimate the potential adverse impact of a certain PPP formulation. In response to this criticism, we developed a modified EIQ for this study that considers all substances in a preparation that pose a risk to human health or the environment, as stated on safety data sheets (available at http://sds-agrofarma.imagelinenetwork.com) in accordance with Directive 91/155/EEC as amended by Directive 2001/58/EC.

As originally formulated, the EIQ is a rating system that evaluates product's active ingredients about their potential adverse impact on farm workers, consumers, and terrestrial and aquatic organisms (Ioriatti et al., 2011). The primary module of the EIQ is a simple algebraic equation that generates a composite index of environmental impacts for each pesticide. A second module produces a field rating by incorporating variables related to the use of the PPP in specific situations (dose per hectare and concentration of active ingredients). The third step of the EIQ method is to estimate the impact of different pest control strategies by combining the EIQ scores of each pesticide treatment deemed necessary for a working farm. The result is the "EIQ field rating," which can be used to compare the environmental impact of alternative strategies for a given farm over a specified period of time.

In the last 15 years, several authors have proposed modifications to the EIQ. Of the various possibilities, for this study, we chose a modified formula that considers the other substances in a product (co-formulants, adjuvants, etc.) in addition to its active ingredients (Ioriatti et al., 2011). In essence, the modified formula (newEIQ) is based on the same principles as the original EIQ (Kovach et al., 1992) but considers the overall impact of a commercial PPP as used in farming. By using the newEIQ it is, therefore, possible to determine the impact of all hazardous active ingredients on the agricultural workers, consumers, and the environment. More in detail, there are three components of the newEIQ. They can be written as follows:

$$newEIQi=(X1 + X2 + X3)/3 \quad (1)$$

with

$$X1=C[(DT*5)+(DT*P)] \quad (2)$$

$$X2=[(C*P*SY)+(L)] \quad (3)$$

$$X3=[(F*P) +(T*P*5)+(Z*P*3)] \quad (4)$$

Therefore:

$$newEIQi=\{C[(DT*5)+(DT*P)]+[(C*P*SY)+(L)]+[(F*P) +(T*P*5)+(Z*P*3)+]\}/3 \quad (5)$$

[3] By the law, the safety data sheet that must be reported on the packaging of any pesticide shall include any health and safety information for the user.

[4] The hazard statements are described in Appendix 1.

[5] See (http://sitem.herts.ac.uk/aeru/ppdb/en/index.htm)) or the safety data sheets of similar products were used as sources for toxicological information.

[6] This type of approach is used not only to compare the impact of different plant production strategies, but also to assess the environmental benefits of integrated fruit production (Agnello et al., 2009), to evaluate the overall impact of plant protection methods on different crops in a certain territory (Ioriatti and Martini, 2011), and to monitor the success of specific plant protection regulations (Cross and Edward-Jones, 2006; Gallivan et al., 2001).

where: I = Each individual ingredient of the plant protection product; DT= Acute toxicity; C= Chronic toxicity; P = Average score related to the active ingredient persistence; F = Toxicity to aquatic organisms; L = Long-term risk to aquatic organisms; Z = Toxicity to bees; T = Toxicity to other terrestrial organisms;

It can be observed that the first component, X1, measures the risk to farm workers and is defined as the sum of exposure by workers who apply the PPP (DT*5) and to workers who pick the produce (DT*P), multiplied by the long-term health effect or chronic toxicity (C). Within the farm worker component, applicator exposure is determined by multiplying the acute toxicity score (DT) by a coefficient of 5, to account for the increased risk associated with handling concentrated PPPs. Picker exposure is defined as acute toxicity (DT) multiplied by the score representing the product's half-life after application (Ioriatti et al., 2011).

The second component, X2, represents consumer risk and is defined as the sum of potential consumer exposure (C*P*SY) plus a score representing the risk of long-term adverse effects on aquatic organisms. The impact on aquatic organisms is included in consumer risk because it involves the stability of chemicals in the groundwater, which may affect human health (through drinking contaminated water) as well as wildlife (Ioriatti et al., 2011).

The third component, X3, represents the ecological element in the equation and refers to the impact on the water and terrestrial systems. The environmental impact on water systems is determined by multiplying the score for chemical toxicity to aquatic organisms (F) by the risk of long-term adverse effects on the aquatic environment (**L**). The impact on terrestrial systems is the sum of the chemical effects on bees (Z*P*3) and on other terrestrial organisms (T*P*5). Because terrestrial organisms are more likely than aquatic ones to come into contact with commercial farming systems, they are given greater weight by multiplying the risk rating for bees by three and the risk rating for other terrestrial organisms by five (Ioriatti et al., 2011).

If we examine the externalities of the use of pesticides on residents living near the farms where these products are used, a fourth component must be included. The premise used for quantifying this new component is that residents' exposure is like that of one of farm workers, without the risk associated with handling concentrated PPPs, but with the added risk of not using personal protective equipment. In addition, exposure:

a. correlates with drift, or the distance of the residence and/or place of transit from the treated farmland. Based on the results of a study in the province of Bolzano (Clausing, 2016; Dallemule, 2014; Federazione protezionisti Sudtirolesi, 2017), we assumed that drift would affect areas within 500 m of pesticide-treated crops.[7] This is a conservative value as recent investigations in Val di Sole (Tn) have shown the possibility of drifts up to 10 Km (Favaro et al., 2019). Because the exposure dose declines as distance increases, a normalization factor of 0.2 (assuming logarithmic decline as a function of distance) was used to determine chronic toxicity (C) and acute toxicity (DT), taking persistence (P) into account;

b. depends on the number of individuals in the area affected by drift. Here, potentially exposed persons were placed into two categories: b1) workers at other local farms; and b2) residents. Ideally, tourists and hikers should also be included, but given the difficulty of finding reliable data for these categories, it was decided to omit them from this study. To normalize the X1 component, the number of individuals (workers at other farms and residents) was used as a denominator with respect to the acreage of the crop in question. The workers were then allocated to the various crops by tallying the total number of farm workers in the area and dividing that value based on RICA-INEA[8] data on each crop's required hours of work per hectare;

c. depends on potential exposure time. This obviously differs for the two categories of individuals, farm workers and residents. The potential exposure time of the farm workers other than sprayers was estimated to be half that of the sprayers, assuming that they spent six out of twelve daylight hours outdoors. For residents, it was assumed that potential exposure time was one sixth that of the individuals who spray crops with PPPs, corresponding to the number of daylight hours they spent outdoors (two out of twelve).

Given all these factors, the relative likelihood that residents and bystanders, in comparison with farm workers, will be exposed to pesticides through drift can be estimated as:

$$C[(DT*P)*(Ha1/N1)*0.2*0.5]+C[(DT*P)*(Ha1/N2)*0.2*0.17] \quad (6)$$

Where:
Ha1 = hectares occupied by the crop in question;
N1 = number of farm workers in the area affected by drift (excluding those working on the crop in question);

[7] Clearly, this distance is purely indicative and should be quantified, where possible, on the basis of measurements taken from different areas with respect to topography and wind patterns.

[8] Italian farm accountancy data network. It is based on a sample of Italian farms and represents the only source of microeconomic data harmonised at agricultural level.

N2 = number of residents in the area affected by drift.

We can therefore define a new indicator, TEIQ, to consider this fourth component. Therefore, the indicator [1] newEIQi becomes:

$$TEIQi=(X1+X2+X3+X4); \quad (7)$$

or, in extended form as:

$$TEIQi=\{C[(DT*5)+(DT*P)]+[(C*P*SY)+(L)]+[(F*P)+(T*P*5)+(Z*P*3)+]+ C[(DT*P)*(N2/N1)*0.05]+C[(DT*P)*(N2/N1)*0.017]. \quad (8)$$[9]

This risk index accommodates all hazardous ingredients in a PPP and provides a classification system that may be fairly easy to implement using farmers' mandatory logbooks of pesticide treatments. For this new index, too, the weight assigned to each kind of hazard depends on the rating system used to classify the risks that a given substance or formulation poses to humans and the environment. The rating system derives from Directive 67/548/EEC or Directive 1999/45/EC and is set by an official agency in accordance with the biological and physicochemical properties of the ingredients and the outcome of toxicological studies (Ioriatti et al., 2011).

The modified rating system (TEIQ) does not overcome all the accuracy limitations of PRIs for estimating the health and environmental hazards of pesticides (Greitens and Day, 2007; Levitan et al., 1995; Van Bol et al., 2003), but it is the first to consider any potentially dangerous ingredients of a formulated product, which can, in some cases, have a greater impact than the active ingredient alone (Surgan et al., 2010).

Once the TEIQi has been calculated for every hazardous ingredient (**i**), the overall score for a pesticide, TEIQp**,** is obtained by combining all the single-ingredient TEIQi scores plus a TEIQf score for the entire product. The TEIQf is based on the hazard statements reported in Section 16 of the SDS with reference to the health, safety, and environmental labelling required by Directives 67/548/EEC and 1999/45/EC. Hazard statements currently differ according to whether the PPP was registered under the old standards (Directive 67/548/EEC, incorporated into Italian law by Legislative Decree 52/1997) (DSD classification with R-statements), or under the newer Regulation (EC) 1107/2009 (CLP Regulation with H-statements). Agrofarma (2014) has proposed a chart for converting from DSD to CLP classifications, which makes it possible to leave the scoring method more or less unchanged as it is defined in Ioratti et al. (2011). The transition to the new safety sheet and labeling standards was completed in 2017.

To summarize:

$$TEIQp = TEIQi1 + TEIQi2 + \dots TEIQin + TEIQf. \quad (9)$$

This step constitutes the first module of the newEIQ. The second and third modules incorporate the dosage of formulated products actually used on crops throughout the season, to estimate a farm's yearly newEIQ score .[10]

3. A STUDY IN THE TIBER VALLEY (TUSCANY AND UMBRIA) AND CHIANA VALLEY (TUSCANY)

This study evaluates the impact of pesticide use in two parts of central Italy: on one side the Tiber Valley and Upper Tiber Valley, located in the Tuscany Region neighboring the Umbria Region, and on the other the Chiana Valley, located in the Tuscany Region in the province of Arezzo. Appendix 2 describes the agricultural features of the two areas.

Data was gathered from 16 farms in the Tiber Valley areas and 10 farms in the Chiana Valley on the quantity and type of pesticides used in the regions. The data was collected in person every two weeks from the logbooks compiled throughout the crop year.[11]

We focused on annual crops, being more easily changeable compared to tree crops (such as vines and olive trees). We also included olives, because this crop is so prevalent in the area, albeit on small parcels of land at most of the farms studied. The farms specialized mostly in arable crops like tobacco, corn, and wheat (durum and soft), while some of them also grew olives or used the land as meadows and pastures. Table 2 shows their overall crop allocation.

To calculate the impact quotient, we began with safety data sheets (SDSs), specifically Sections 2 and 3, that list all hazardous ingredients along with their concentrations or concentration range, together with the hazard statements assigned as a function of physicochemical, health, and environmental risks. Pre-harvest intervals were taken from the registered labels of each pesticide. Unlike the original EIQ, the modified indica-

[9] To compare the impacts measured by using the new EIQ indicator with those assessed through the TEIQ, the former new EIQ should be multiplied by 3.

[10] Various authors have described how to combine the EIQ rating system in its original formula (Kovach et al., 1992) with an environmental cost estimate for every pesticide application. For example, Leach and Mumford (2008).

[11] While this laborious data collection method prevented us from surveying a greater number of farms, it provided greater accuracy than would different methods applied to a larger sample size.

Table 1. Breakdown of UAA (ha) at surveyed farms in the Tiber and Upper Tiber Valleys and the Chiana Valley.

Area	Total UAA	Soft wheat	Durum wheat	Corn	Tobacco	Forage, set-aside land, other	Olive and other trees
Tiber and Upper Tiber Valley	625.37	20.89	110.12	103.52	44.58	330.82	15.44
Chiana Valley	283.06	66.72	4.26	76.54	29.63	102.36	3.55

ISTAT data, 2010.

tor was not limited to the active ingredient but accommodated all dangerous ingredients and their corresponding hazard statements. For the evaluation of co-formulant products, the new indicator considers the hazard statements included on the label.

A score from 1 to 5 was assigned for each of the hazard phrases referring to acute and chronic toxicity and environmental risks, as shown in Appendix 1.

Regarding the first component of the TEIQp as per equation [7] (risk to farm workers), the values-obtained were compared (where possible) with the values obtained by Ioriatti et al. (2011). The comparison showed remarkable similarities between the two values compared.

To calculate the second and third components of equation [7] (consumer risk and environmental risk), the dose per hectare of the various crops obtained from our survey of the 26 farms in Tuscany and Umbria was used.

The fourth component of equation [7] (risk to residents) was calculated in agreement with the corresponding component of equation [8] using populations of 86,895 and 168,044 for the studied areas of the Tiber Valley and the Chiana Valley, respectively.[12] As noted in the geostatistical information presented in Appendix 2, in both regions studied, residential areas (except for a few scattered homes in mountainous areas) fell within a 500 m radius of mapped farmland.

Following the method described by Leach and Mumford (2008), the individual TEIQ scores per hectare-application of pesticide were combined to obtain each crop's TEIQp per hectare (Table 3).

It is important to note that the wide gap in TEIQ scores between durum wheat and soft wheat reflects the different treatments used for the two crops, as gleaned from the logbooks used to calculate field score: durum wheat was subject to more products and more sprayings than was soft wheat. More specifically, at the farms under study, soft wheat was not treated with glyphosate-based herbicides (Roundup or Ouragan), copper compounds, Axial Pronto 60, or Granstar 50SX. This

[12] Because crop data is from 2010, population data from the 2011 census was used.

Table 2. TEIQ per hectare in the two areas studied.

Crop	Sum of EIQ field scores per hectare in the Tiber and Upper Tiber Valleys	Sum of EIQ field scores per hectare in the Chiana Valley
Durum wheat	2,372.8	2,372.8
Soft wheat	66.6	66.6
Corn	316.1	316.1
Olives	193.2	193.2
Tobacco	6,923.8	7,006.8
Average for all five crops	1,974.5	1,990.6

Unfortunately, the results obtained cannot be compared with those obtained from other studies as no surveys like the one presented here are known.

explains the greater impact of one variety of wheat compared with the other. Obviously, the data from this sample is not necessarily representative of all or most crops in the area. Nonetheless, this data has been used as it is indicative of a different, but possible, method of farming.

Therefore, the impact score for all hectares planted with soft wheat, durum wheat, tobacco, olives, and corn in the Chiana Valley and the Tiber and Upper Tiber Valleys amounts to 69,204,800.8. If durum wheat and tobacco were replaced with soft wheat, that score would decrease substantially, to 3,429,371.7.

4. RESULTS: AN ATTEMPT TO QUANTIFY THE ECONOMIC EXTERNALITIES OF THE USE OF PESTICIDES

To identify the externalities resulting from the use of plant protection products, it is theoretically possible to use two different approaches. The first one is a direct assessment of the costs (in terms of health, environment, etc.) of using a given quality and quantity of plant protection products. Many studies have investigated the direct adverse effects of pesticides. Far fewer have sought to quantify the negative externalities associated with their use. The great number of substances to

Table 3. Calculation of total TEIQp scores.

Crop	TEIQ Tiber and Upper Tiber Valleys (per ha)	Tiber and Upper Tiber Valleys (no. ha)	TEIQpTiber and Upper Tiber Valleys	TEIQ Chiana Valley (per ha)	Chiana Valley (no. ha)	TEIQp Chiana Valley	Total TEIQp
Durum wheat	2,372,8	4,901.06	11,629,235.2	2,372,8	9,416.72	22,343,993.2	33,973,228.4
Soft wheat	66.6	1,385.28	92,259,6	66.6	2,139.63	142,499.4	234,759,0
Corn	316.1	770.87	243,672,0	316.1	1,088.62	344,112.8	587.784.8
Tobacco	6,923.8	4,073.41	28,203,476,2	**7,006.8**	695.02	4,869,866.1	33,073,342.3
Olives	193.2	865.86	167,284,2	193.2	6,047.63	1,168,402.1	1,335,686.3
Total	----------------	11,996.48	40,335,927.2	-----------	19,387.62	28,868,873.6	69,204,800.8

be considered, the time needed to determine the adverse consequences of direct and/or indirect exposure, our incomplete knowledge of metabolites and food chains, the problem of identifying means of contact, and a poor understanding of the relationships between different molecules and the environment make it challenging not only to identify potential harms, but also to put an economic price on them.

The second approach is based on the assessment of the willingness to pay (WTP) of a given population in order not to be exposed to the consequences of pesticide use in a given area. In our study, this approach seems to be the only one that could be pursued. A survey carried out in Veneto in 2009, offered some information useful for our study.

In the effort to quantify the economic variables at play, we referred to a meta-analysis conducted by Boatto et al. (2008) that determined the willingness to pay (WTP) of households in the Veneto region in 2006[13]. Socio-economic conditions in Veneto are like those in Tuscany. More specifically, in the two regions, the incomes of families are very similar (Banca d'Italia, different years)[14] Similarities are also found in social capital and attitudes towards the environment. (Carocci,2009; Sabatini, 2009; Istat, 2021).

On the basis of the equations reported in that analysis, and using the average income in the Tuscany Region,[15] we obtained the following WTP per household/year for the reported goals:

- having water free of pesticide residues (taking the low end of the range)[16]: €18.70;
- protecting biodiversity (taking the low end of the range): €23.60;
- being free of acute and chronic health issues caused by pesticides: €126.40.

Therefore, in total, the willingness to pay for a pesticide-free environment amounted to €168.7 per household per year.

According to ISTAT data for 2011, in the areas studied, the Tiber and Chiana Valleys, there were a total of 254,939 residents in 105,352 households. Applying the WTP per household from the Veneto study, the total potential willingness to pay for a pesticide-free environment would amount to €17,772,882 per year.[17] Assuming that the WTP rises in a straight line from 0 (no use of pesticides) to the TEIQp total impact score of more than

[13] Concerning the work made in the Veneto region, the WTP was obtained by a meta-analysis complemented by other assessments used according to the technique of value transfer, whose primary studies used both direct and indirect assessment methods. This has led (in Veneto) to the estimation of meta-functions which shows a satisfying statistical significance, and which differ for type and number of the explanatory variables featuring socio-economical, environmental and methodological factors. The WTP thus estimated, has made it possible to compare organic agriculture and conventional agriculture. The WTP concerning the non-use of pesticides in the conventional agriculture was estimated, in our case, by pairing it with the WTP estimated for obtaining the organic agriculture.

[14] In 2018, while the national average income per household was € 31,641, in Veneto region it was € 35,673 and in Tuscany € 33,792 (similar observations can also be made for previous years). At the same time, there is also considerable homogeneity in the distribution of family income. In fact, the Gini index has a value of 0.252 in Veneto and 0.277 in Tuscany (ISTAT).

[15] This statistic was used in place of the average income in the Veneto region, deflated by the ISTAT cost of living index to update the original 2006 figures to 2017. For the meta-analysis made in Veneto, among all the explanatory variables used, exclusively the income was considered since it has better explanatory qualities. Furthermore, the rest of the variables considered in Veneto, show similar values to those available in Tuscany in the same year.

[16] In Veneto Region, the WTP was reported as being a range between a minimum value and a maximum value. These values are connected with the different value attributed to the explanatory variables. In this work, as a precautionary measure, the minimum value of such rage was chosen.

[17] In this study, the municipality of Arezzo (98,144 inhabitants) was considered as if it were formally falling within the Chiana Valley area. The municipality of Arezzo was counted in this article because of its proximity to agricultural areas, as also shown in Figure A2.2 "Urbanization of rural areas in the Chiana Valley". If we exclude the municipality of Arezzo from the calculation, the total potential willingness to pay for a pesticide-free environment would amount to 14,825,154.23 euros per year.

Table 4 Changes in WTP, GSP, gross margin and operating margin, compared to baseline (scenario A).

	WTP Gain	Change in GSP		Change in Gross margin		Change in operating margin	
		Absolute values	Variation from scenario A=100	Absolute values	Variation from scenario A=100	Absolute values	Variation from scenario A=100
Scenario A (cultivations of tobacco)	baseline	51.833.950	100	39.850.087	100	-18.050.906	100
Scenario B (with soft wheat instead of tobacco)	8.436.983	23.481.044	45,3	20.885.942	52,4	-8.433.043	46.7
Scenario C (with corn instead of tobacco)	8.369.472	25.402.709	49,0	23.251.287	58,3	-8.170.781	45.3

17 million euros estimated for 2016. In this scenario, a reduction of one percentage point in the TEIQp index is equivalent to a WTP of EUR 25.68. It goes without saying that the value of the TEIQp index calculated in this way, can vary greatly from one year to the next one, depending on the crop growth, the climate variability and the cultivation techniques adopted. Consequently, the value of a percentage decrease (or increase) of the index itself will also vary. To get to define results useful for the economic policy purposes, it would therefore be necessary to calculate the index shown here in relation to average or standard values per crop, or per area. This calculation is possible but goes beyond the objectives of this paper.

On that basis, alternative scenarios were investigated in which one crop was hypothetically replaced with another to gauge variations in terms of WTP (here representing a replacement for welfare) as well as gross saleable production (GSP), gross margin, and operating margin (which is more representative than other variables of the actual difference between one crop and another in a farm's gross income).

Table 4 shows that while the welfare gain (measured as WTP) resulting from the elimination of the tobacco crop is lower than the loss in terms of GSP and gross margin, it does lead to a reduction in net operating margin losses. Table 4 demonstrates that while the welfare gain (measured as WTP) resulting from the elimination of the tobacco crop is lower than the loss in GSP and gross margin, it does lead to a reduction in net operating margin losses. To interpret Table 4 correctly, it should be noted that both the GSP and gross margin indicator refer to day-to-day operations, while the operating margin also includes other elements that are not included in ordinary operations[25]. For reasons of space, in this paper, we present an example in which the land used to grow tobacco (scenario A) is planted instead with soft wheat (scenario B), or with corn (scenario C).

5. CONCLUSIONS

Quantification of the negative externalities associated with cultivation methods can have interesting operational implications both in terms of land-use planning and in defining economic policies for the industry (Maietta et al., 2019). This is particularly true when defining support measures for agricultural activities under the RDPs (Rural Development Programmes).

It is not easy to evaluate the value of externalities linked to agricultural production activity. In most cases, positive externalities are considered, but also negative ones should also be considered. Among the latter, those connected with the use of plant protection products are particularly important. In fact, Italian agriculture can be considered 'urban agriculture', i.e., agriculture in which cultivated areas are intertwined with residential areas (Filippini et al. 2021). This situation makes it difficult, in many cases, to reconcile the needs of producers to protect their crops and those of citizens to have an unpolluted environment.

From this point of view, this work is characterised by at least two limitations. Firstly, the use of meta-analyses to evaluate the WTP for a pesticide-free environment approximates the real WTP of the inhabitants of the area considered. Secondly, the farms taken into consideration are not a probabilistic sample of the farms in the area considered, and the surveys of the pesticides used relate to a single agricultural year. Therefore, the TEIQp index values obtained, following more in-depth investigations, could lead to different values.

Finally, since this is an initial study, the methodology and the definition of indicators for specific regions will have to be refined. Specifically, field experiments to determine the actual range and persistence of pesticide drift will need to be conducted to reach results at the operational level. Despite these limitations, the results obtained lead us to believe that the application of tools like the one used in this case may have general validity.

Firstly, it should be noted that it is necessary to try to identify indicators that consider all possible externalities. Specifically, we believe that the TEIQ indicator proposed in these notes can be of help in all cases where intensive agricultural activities and residential and recreational activities take place in very close areas.

Secondly, this study also demonstrates that for the purpose of deciding how best to allocate farmland, the inclusion of potential externalities, such as the results of pesticide use, leads to significantly different results than can be obtained without considering such factors.

Thirdly, in a heavily subsidized industry like agriculture, modulating subsidies to reflect the extent of environmental externalities may be essential, given the goal of maximizing social welfare. When attempting to quantify the externalities of pesticide use, indicators such as those described in this study can make a valuable contribution.

Fourthly, the exercise conducted in this study confirms once again that the economic policy objective pursued must be assessed very carefully. In the present case, in addition to the obvious difference between profit maximization and social benefit, there is a difference also between gross marketable output and operating margin (Mack et al., 2019).

Finally, being able to rely on an indicator such as the one shown in the present study, make it possible to appropriately modulate the objectives of reducing the environmental impact of agricultural activity. Consequently, it would be possible to overcome the contrast between conventional farming and organic farming, coming to define the maximum levels of environmental impact that can be tolerated in a given area. These levels depend not only on the characteristics of the agricultural sector but also on the environmental and socio-economic context in which ~~it~~ the area is located.

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DATA AVAILABILITY

All data, associated metadata, and calculation tools are available through supplemental files upon request.

REFERENCES

Agnello, A.M., Atanassov, A., Bergh, J.C., Biddinger, D.J., Gut, L.J., Haas, M.J., Harper, J.K., Hogmire, H.W., Hull, L.A., Kime, L.F., Krawczyk, G., McGhee, P.S., Nyrop, J.P., Reissig, W.H., Shearer, P.W., Straub, R.W., Villanueva, R.T. and Walgenbach, J.F. (2009). Reduced-risk pest management programs for eastern U.S. apple and peach orchards: a 4-year regional project. *American Entomologist* 55: 184–197.

Agrofarma (2014). La classificazione e l'etichettatura degli agrofarmaci. Le nuove regole. Federchimica, May 2014.

Banca d'Italia (2008-2020 annate varie) L'economia della Toscana. Roma

Banca d'Italia (2008-2020 annate varie) L'economia del Veneto. Roma

Barbieri, C., & Buchi, G. (2004). Metodologie di redazione e di analisi di bilancio nelle aziende agrarie.

Boatto, V., Menguzzato, A. and Rossetto, L. (2008). Valutazione monetaria dei benefici esterni dell'agricoltura biologica. Working Paper — Sabio no. 6. Rome: Inea.

Clausing, P. (2016). Bewertung von Pestizidrückständen in Pflanzenmaterial (Grasproben vom 28.5.2016) aus Südtirol. http://www.pangermany.org/download/Bewertung_Grasproben_Final_160716.pdf

Cartocci R. (2007), Mappe del tesoro. Atlante del capitale sociale in Italia. Bologna: Il Mulino, 2007

Cross, P. and Edwards-Jones, G. (2006). Variation in pesticide hazard from arable crop production in Great Britain from 1992 to 2002: pesticide risk indices and policy analysis. *Crop Protection* 25: 1101–1108.

Dallemule, C. (2014). Versuche zur Effizienz abdriftmindernder Maßnahmen unter Freilandbedingungen im Obervinschgau. Agrarwissenschaften und Agrartechnologie Fakultät für Naturwissenschaften und Technik, academic year 2013–2014, 46.

Devillers, J., Farret, R., Girardin, P., Rivière, J.P. and Soulas, G. (2005). *Indicateurs pour Évaluer les Risques Liés à l'Utilisation des Pesticides*. Paris: Lavoisier.

Favaro, R., Bauer, L. M., Rossi, M., D'Ambrosio, L., Bucher, E., & Angeli, S. (2019). Botanical origin of pesticide residues in pollen loads collected by honeybees during and after apple bloom. *Frontiers in physiology*, *10*, 1069.

Filippini, R., Marraccini, E., & Lardon, S. (2021). Contribution of periurban farming systems to local food systems: a systemic innovation perspective. Bio-based and Applied Economics Journal, 10(1050-2021-1253), 19-34.

Gallivan, G.J., Surgeoner, G.A. and Kovach, J. (2001). Pesticide risk reduction on crops in the province of

Ontario. *Journal of Environmental Quality* 30: 798–813.

Greitens, T.J. and Day, E. (2007). An alternative way to evaluate the environmental effects of Integrated Pest Management: Pesticide Risk Indicators. *Renewable Agriculture and Food Systems* 22(3): 213–222.

Ioriatti, C., Agnello, A.M., Martini, F. and Kovach, J. (2011). Evaluation of the environmental impact of apple pest control strategies using pesticide risk indicators. *Integrated Environmental Assessment and Management* 7(4): 542–549. doi 10.1002/ieam.185

Ioriatti, C. and Martini, F. (2011). La protezione integrata del melo. Valutazione dell'impatto ambientale generato dall'uso dei fitofarmaci in Val di Non. *Economia Trentina* 60 (2-3): 64–67.

Istat (2001) BES 2020 Il benessere equo e sostenibile in Italia. Roma

Kovach, J., Petzoldt, C., Degni, J. and Tette, J. (1992). A method to measure the environmental impact of pesticides. *New York's Food and Life Sciences Bulletin* 139: 1–8.

Leach, A.W. and Mumford, J.D. (2008). Pesticide Environmental Accounting: A method for assessing the external costs of individual pesticide applications. *Environmental Pollution* 151: 139–147.

Levitan, L., Mervin, I. and Kovach, J. (1995). Assessing the relative environmental impacts of agricultural pesticides: the quest for a holistic method. *Agriculture, Ecosystems & Environment* 55: 153–168.

Mack, G., Ferjani, A., Möhring, A., von Ow, A., & Mann, S. (2019). How did farmers act? Ex-post validation of linear and positive mathematical programming approaches for farm-level models implemented in an agent-based agricultural sector model. Bio-based and Applied Economics Journal, 8(1050-2020-613), 3-19.

Maietta, O. W., De Devitiis, B., Destefanis, S., & Suppa, D. (2019). Human capital and rural development policy: evidence from European FADN regions. Bio-based and Applied Economics, 8(3), 239-259.

OECD (2002). Glossary of statistical terms. Consulted at https://stats.oecd.org/glossary/detail.asp?ID=3215.

Pretty, J.N., Brett, C., Gee, D., Hine, R.E., Mason, C.F., Morison, J.I.L., Raven, H., Rayment, M.D. and van der Bijl, G. (2000). An assessment of the total external costs of UK agriculture. *Agricultural Systems* 65(2): 113–136.

Sabatini F. (2009), Il capitale sociale nelle regioni italiane: un'analisi comparata. Rivista di Politica Economica, 99 (2), 2009, pp.167-220

Surgan, M., Condon, M. and Coc, C. (2010). Pesticide risk indicators: Unidentified inert ingredients compromise their integrity and utility. *Environmental Management* 45: 834–841.

Targetti, S., Raggi, M., & Viaggi, D. (2020). Benefits for the local society attached to rural landscape: An analysis of residents' perception of ecosystem services. Bio-based and Applied Economics Journal, 9(1050-2021-220), 155-170.

Turner, R.K., Pearce, D.W. and Bateman, I. (2003). *Economia Ambientale*. Bologna: Il Mulino.

Van Bol, V., Claeys, S., Debongnie, P., Godfriaux, J., Pussemier, L., Steurbaut, W. and Maraite, H. (2003). Pesticide indicators. *Pesticide Outlook* 14: 159–163.

APPENDIX 1

Table A1.1. Scoring system used to develop the new environmental impact quotient for pesticides (newEIQ). Scores range from 1 (no hazard statement) to 5 (hazard statements include high potential risk of acute or chronic toxicity or harm to the environment).

Hazard		R-phrases (DSD classification)	H-statements (CLP classification) (not all can be converted directly)	Score
Acute Toxicity = DT	harmful (by inhalation, contact with skin, ingestion)	R20, R21, R22	H300, H301, H310, H311, H330, H331	3
	toxic (by inhalation, contact with skin, ingestion)	R23, R24, R25		4
	very toxic (by inhalation, contact with skin, ingestion)	R26, R27, R28		5
	irritating (by inhalation, contact with skin, ingestion)	R36, R37, R38	H319, H335, H315	2
	may cause sensitization by inhalation or skin contact	R42, R43	H334, H317	5
	risk of serious damage to eyes	R41	H314, H318	3
	harmful: may cause lung damage if swallowed	R65	H304	2
	repeated exposure may cause skin dryness or cracking	R66	-	3
	vapors may cause drowsiness and dizziness	R67	H336	3
Chronic Toxicity = C	possible risk of impaired fertility	R62	H361	3
	may impair fertility	R60	H360	5
	teratogenic (possible risk of harm to the unborn child)	R63	H361D	3
	teratogenic (may cause harm to the unborn child)	R61	H360D	5
	mutagenic (possible risk of irreversible effects)	R68	H341	3
	mutagenic (may cause inheritable genetic damage)	R46	H340	5
	cancerogenic (limited evidence of a carcinogenic effect)	R40	H351	3
	cancerogenic (may cause cancer)	R45, R48, R49	H350 (H372, H373)	5
Aquatic Organisms = F	very toxic	R50	H400, H410	5
	toxic	R51	H411	4
	harmful	R52	-	3
Long-term adverse effects in the aquatic environment = L	may cause long-term adverse effects in the aquatic environment	R53	H410, H411, H412, H413	5
Bees = Z	toxic	R57	-	5
Other terrestrial organisms = T	toxic to flora, fauna, soil organisms	R54, R55, R56	-	5
Persistence = P	may cause long-term adverse effects in the environment	R58	-	5
	Pre-harvest interval < 2 days			1
	Pre-harvest interval > 2 < 15 days			3
	Pre-harvest interval > 14 days			5
Systematicity (SY)	Systemic			3

The different components considered are assessed by considering the following risk phrases:
DT = Acute toxicity defines the average individual rating for the risk of direct exposure to chemicals, considering the following DSD risk phrases: R20, 21, 22, 23, 24, 25, 26, 27, 28, 36, 37, 38, 41, 42, 43, 65, 66, 67.
C= Chronic toxicity defines the average individual rating for long-term fertility, and teratogenic, mutagenic, and oncogenic risks (DSD risk phrases R40, 45, 46, 12 48, 49, 60, 61, 62, 63, 64, 68).
P= Average score related to the active ingredient persistence based on the pre-harvest interval (PHI) of the agricultural produce intended for human consumption; and to long-term environmental impact (DSD risk phrase R58).
F= Toxicity to aquatic organisms DSD risk phrases R50, 51, 52.
L= Long-term risk to aquatic organisms DSD risk phrase R53.
Z= Toxicity to bees DSD risk phrase R57.
T= Toxicity to other terrestrial organisms DSD risk phrase R54, 55, 56.

APPENDIX 2

Farming in the Tiber Valley (Tuscany) and the Upper Tiber Valley (Umbria)

The Tiber Valley and Upper Tiber Valley form a geographical area in the Central-Northern Apennines. The area consists of 11 municipalities in two Italian regions: Umbria (province of Perugia) and Tuscany (province of Arezzo).[18] It falls mainly on the flood plain of the Tiber River, with the exception of some mountain communities (e.g. Caprese Michelangelo, Badia Tedalda, Sestino, and Monte Santa Maria Tiberina) adjacent to the plain. In the valley there are numerous residential districts and scattered homes, while in the mountain communities, anthropization is more limited to the village centers. The area covers a total of 75,285 ha, with UAA of 35,644 ha or 47% of the total. More specifically, arable crops take up 70% of the cultivated land, meadows and pastures 23%, and permanent (woody) crops 7%. Of the arable crops, the most prevalent are cereals (36%), fodder (27%), and industrial crops (22%). The latter consist almost exclusively of tobacco.

Farming in the Chiana Valley

The Chiana Valley is a geographical area in Central Italy that was reclaimed as farmland during the 1900s.

All its municipalities[19] are in the province of Arezzo; they cover 74,258 ha with UAA of 46,714 ha (63% of the total). Arable crops take up 72% of the cultivated land, meadows and pastures 3%, and permanent (woody) crops 25%. Of the arable crops, the most prevalent are cereals (45%), fodder (13%), and industrial crops (15%). The permanent cropland is planted primarily with olive trees (6,047 ha), grapevines (3,618 ha), and orchards (1,512 ha).

Table A2.1 shows the total crop acreage of the two areas studied. Figures A2.1 and A2.2 come from the ISTAT database and refer to the latest agriculture census available, for 2010, as intercensal data only provides aggregate figures by province.

The two areas are characterized by a widespread urbanization of rural areas and by a significant proximity of intensive farming to residential areas where people frequently visit. Figures A2.1 and A2.2 present some buffer zones mapped within a 500 m radius of farmland. The centroids of the circular buffer zones (2 km radius) were selected using the geostatistical method with a semi-regular grid. The centroids were inter-distanced according to the density and distribution of the farms included in the study. The result was then superimposed on the colour orthophoto map of the Region of Tuscany.

Table A2.1. Total crop acreage in the municipalities of the Chiana Valley and Tiber/Upper Tiber Valley included in the study.

Area	Soft wheat	Durum wheat	Corn	Tobacco	Olives
Chiana Valley (Tuscany)	9,416.72	2,139.63	1,088.62	695.02	6,047.63
Tiber Valley (Tuscany) and Upper Tiber Valley (Umbria)	4,901.06	1,385.28	770.87	4,073.41	865.86

ISTAT data, 2010.

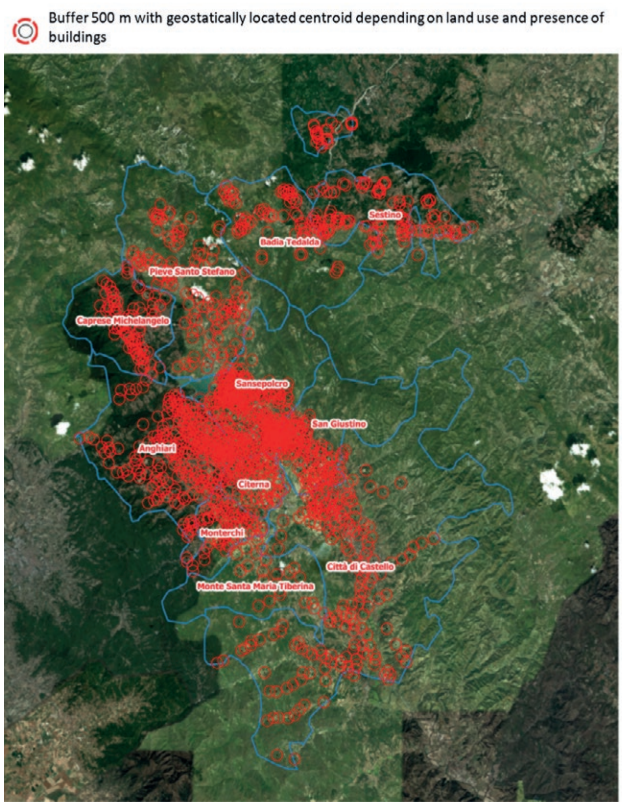

Figure A2.1. Urbanization of rural areas in Tiber Valley.

[18] The 11 municipalities are Sansepolcro (AR), Anghiari (AR), Pieve Santo Stefano (AR), Caprese Michelangelo (AR), Badia Tedalda (AR), Sestino (AR), Monterchi (AR), San Giustino (PG), Citerna (PG), Monte Santa Mara Tiberina (PG), and Città di Castello (PG).

[19] Arezzo, Castiglion Fiorentino, Cortona, Civitella in Val di Chiana, Monte San Savino, Foiano della Chiana, Lucignano, and Marciano della Chiana.

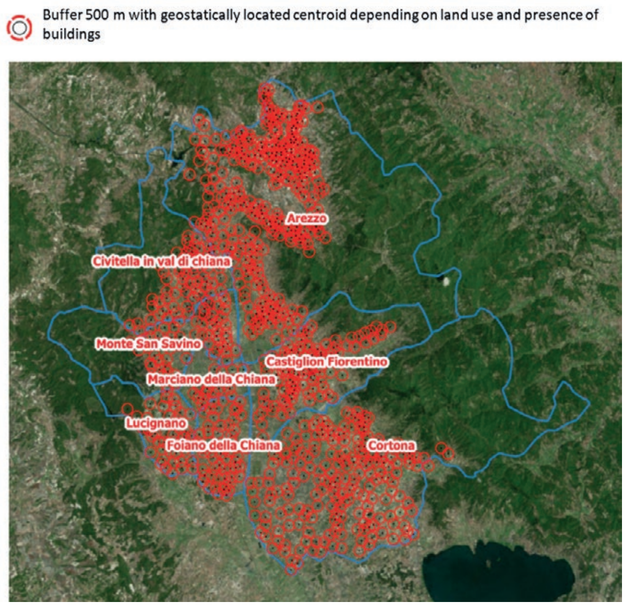

Figure A2.2. Urbanization of rural areas in the Chiana Valley.

APPENDIX 3

Glossary

"**Consumer protection**" Consumer health is protected by determining the maximum permitted residue of an active ingredient in foods meant for final consumption. In case of residue, the law defines the tolerance limit or Maximum Residue Limit (MRL) as the maximum amount of PPP active ingredients tolerated in food products, consistent with the amount that is safe for consumers.

"**Exposure**" This term refers to the likelihood of coming into contact with the substance, based on the quantity of substance to which the living organism or the environment is exposed and the length of time of the exposure. Exposure may have different origins, such as: direct human interaction while working with the substance (mixing, spraying, etc.); contaminated rain and volatilization; drift during spraying; or soil and groundwater contamination after spraying (runoff, leaching, drainage).

"**Gross margin and operating margin** " As known, this balance sheet partially deviates the traditional financial statements and from the annual consolidated financial statements (Barbieri et al., 2004). Specifically, the gross margin represents a value of the profitability of the company's production activities (crops and livestock), obtained as the difference between the total value of production (main product plus any secondary products) and the costs incurred in the production processes. At the same time, operating income is the economic result of the characteristic management of the agricultural enterprise, which includes all costs and revenues generated by the production processes and by active and passive services related to agricultural activities. It is calculated as the difference between the farm net product and the income distributed (wages and social security contributions, rents payable).In this specific balance sheet, since the operating margin considers both revenue and expenses different from those typical of the ordinary operations, there may be some cases where the operating margin is higher than the gross one. In the case under consideration, the considered RICA-INEA data report such situation for the olive growing in Tuscany.

"**Hazard-based classification criteria**" These criteria are based on: a) the median lethal dose (LD50), defined as the dose of active ingredient expressed in mg/kg body weight (ppm) that causes death in 50% of the lab animals exposed to the ingredient orally or through the skin; and b) the median lethal concentration (LC50), or the concentration in air or water of an active ingredient that acts in the gas or vapor state and leads to the same outcome as the median lethal dose. The LC50 thus expresses the same standard as the LD50 but refers to lab animals that are exposed to the active ingredient in the form of a gas or vapor.

"**Plant protection products**" (PPPs) In this paper include all active ingredients, as well as commercial preparations containing one or more active ingredients, used in farming for the purposes of: protecting plants or produce from harmful organisms or preventing the effects thereof; assisting or regulating plant metabolism (except for fertilizers); preserving produce (except for preservatives governed by specific regulations); clearing the crop of weeds or other undesired plants; and removing parts of plants or halting or preventing their undesired growth.

"**Selectivity**" PPPs selectivity can be physiological or ecological. It is physiological if it derives from the characteristics of the PPPs itself.

"**Spectrum of action**" This term means the range of pests a PPP is meant to control. For example, an insecticide that simultaneously acts against aphids, moth larvae, and fruit flies has a broad spectrum of action.

"**Systemic action**" indicates the PPP's ability to penetrate the plant and fight infections within organs that cannot be reached directly by substances that work through contact action (surface-active ingredients).

"**Toxicological classification**" PPPs are currently classified on the basis of: a) acute toxicity, expressed as LD50 for solid and liquid preparations and as LC50 for gases, fumigants, and aerosols; b) chronic toxicity, which depends on the product's hazardousness, indicated as risk to the farm worker, the consumer, and the environment as a function of exposure to the PPPs.

"**Worker protection**" While the pre-harvest interval protects consumers by affecting the amount of residue remaining on foodstuffs, the restricted entry interval is the amount of time that must elapse between pesticide treatment and workers' access to the treated area for pruning, thinning, picking, etc. without personal protective equipment (PPE).

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The journal *Bio-based and Applied Economics* (*BAE*) provides a forum for presentation and discussion of applied research in the field of bio-based sectors and related policies, informing evidence-based decision-making and policy-making. It intends to provide a scholarly source of theoretical and applied studies while remaining widely accessible for non-researchers.

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