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Maria Laura Ojeda,
Exequiel Romero-Gomez
Luca Salvatici,
Cristina Vaquero Piñeiro

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Dipartimento di Economia
Università degli Studi Roma Tre
Via Silvio D'Amico, 77 - 00145 Roma
Tel. 0039-06-57335655 fax 0039-06-57335771
workpapers.economia@uniroma3.it
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The sustainability of agri-food systems: is organic production part of the solution?

Maria Laura Ojeda[1,2,3], Exequiel Romero-Gomez[1,2,3], Luca Salvatici[3,4] y Cristina Vaquero-Piñeiro[3,4]

[1] *Universidad de Buenos Aires. Facultad de Ciencias Económicas. Departamento de Economía. Buenos Aires, Argentina.*
[2] *CONICET-Universidad de Buenos Aires. Instituto Interdisciplinario de Economía Política. Buenos Aires, Argentina.*
[3] *Department of Economics, Roma Tre University, Rome, Italy*
[4] *Department of Economics, Rossi-Doria Centre, Roma Tre University, Rome, Italy*

Abstract

Satisfying the increasing food demand while supporting the sustainability of agri-food systems in the face of climate change is seen as a major global challenge in the future. This study investigates how environmental policies, such as higher organic production targets, might affect the sustainability of agri-food systems.
By using simulations from the Simplified International Model of Agricultural Prices, Land Use, and Environment (SIMPLE) model, extended for the first time to distinguish organic from conventional production, we project socio-economic and emission outcomes in response to the 25% of organic farmland by 2030 fixed by the European Union Farm to Fork (F2F) strategy in Italy.
Overall, results indicate that even though the F2F strategy in Italy is projected to increase crop production and reduce Greenhouse gas (GHG) emissions by 2030, it will also raise crop prices, slightly increase land use, and intensify non-land input demands under conventional agriculture. The findings underscore the need for complementary policies and coordinated action plans to balance economic, social, and environmental sustainability.

Keywords: organic transition, organic farming, agriculture, SIMPLE model, Italy
Jel Codes: Q18, O13, C63, F63

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Introduction

With the world population expected to hit between 8.3 billion (Samir & Lutz, 2017) and 8.5 billion (UN, 2024) by 2030, addressing future food demand is seen as a major challenge, especially if linked to the global quest for more sustainable agri-food systems (Rieger et al., 2023). Nonetheless, agriculture intensification, often based on intensive farming practices, is considered a key driver of climate change, biodiversity loss, soil degradation and, eventually, food insecurity. In turn, however, agriculture is also one of the economic sectors most hit by extreme climate events and socio-economic external shocks (i.e., conflicts), especially in terms of economic and social consequences. National and international institutions are working on strategies and measures to provide enough food to feed the growing population while minimizing environmental impacts and optimizing global consumption (Seufert et al., 2012).

Organic agriculture has been recognized as one concrete, though controversial, way of ensuring a sustainable food system (Muller et al., 2017). Organic production, as defined by the Regulation (EU) 2018/848[1], is "an overall system of farm management and food production that combines best environmental and climate action practices, a high level of biodiversity, the preservation of natural resources, and the application of high animal welfare standards and high production standards…" (p.1). From a practical standpoint, it refers to agricultural practices avoiding the use of synthetic fertilizers, chemical pesticides, genetically modified organisms and sewage sludge while actively employing organic seeds, crop rotation and organic fertilizers (Meemken & Qaim, 2018).

By the end of 2022, the European Union managed over 16.9 million hectares of organic agricultural land (10.4% of the total EU agricultural area), mainly located in France, Spain and Italy (Willer et al., 2024). The number of organic producers is increasing up to 419,000 producers across the continent. Italy, followed by Greece and France, is the country with the highest number of organic producers (Willer et al., 2024). This scenario is not only the result of a common shift towards more health-conscious and environmentally driven consumer choices (Eyinade et al., 2021), but also of a set of supply-side policy interventions aiming at expanding organic farmland to promote environmental and socio-economic sustainability while safeguarding natural resources and improving farmers' livelihoods.

The Farm to Fork (F2F) strategy, framed within the European Green Deal,[2] highlights organic farming as a central pathway toward a more sustainable agrifood system and sets an ambitious target of achieving 25% organic utilized agricultural area (UAA) across the EU by 2030, calling on all member states to contribute to this collective effort.[3] While some member states have shown limited ambition in promoting organic farming, casting doubt on the feasibility of reaching the 25% organic land target across the EU, others have proactively taken up the challenge incorporating the target into their National Strategic Plans (NSPs) of the 2023-2027 Common Agricultural Policy (CAP). The goal is to achieve 25% by 2027 rather than by 2030.[4] This is the case for Italy.

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[1] Available at: https://eur-lex.europa.eu/eli/reg/2018/848/oj.

[2] European Commission. What is the European Green Deal it, 2019.

[3] European Commission. Farm to fork strategy: For a fair, healthy and environmentally friendly food system, 2020.

ORGAN(47(1)(d)) - produzione biologica o integrata. *ISO Is Ortofrutta04 - Programmi Operativi del settore ortofrutticolo – Produzione biologica o integrata*

[4] The European Green Deal is the EU political framework to support green transition in the whole economy, while the Farm to Fork strategy is the Green Deal-related strategy specific for the agri-food sector. The concrete policy interventions to implement in the EU to achieve the F2F objectives are defined by the Common Agricultural Policy. To adopt the EU

This paper aims to investigate the extent to which this effort on organic production could be part of the solution to guarantee the sustainable transition of agrifood systems. Existing literature on whether and to what extent implementing organic practices generates benefits is, in fact, quite controversial, and conclusions mainly depend on the variables under analysis. Organic agriculture alone appears insufficient to nourish the growing population worldwide and guarantee equal food access. While organic farmers account for lower yields, increasing the demand for land use and, potentially, the overall GHG emissions (Muller et al., 2017; Smith et al., 2018; Feuerbacher et al., 2018), consumers are required to pay higher prices, driven by higher production costs and certification premium pricing (Li et al., 2025; Abraben et al., 2017). At the same time, however, organic production seems to have positive effects in contributing to preserving biodiversity, enhancing food quality and ensuring food safety (Murphy et al., 2022). Starting from this evidence, the paper studies the implications of increasing organic farming on two sustainability dimensions, i.e. economic and environmental, by simulating the effects of the 25% organic target on production, yields, GHG emissions and food prices in Italy.

The analysis is based on an extension of the Simplified International Model of Agricultural Prices, Land Use, and Environment (SIMPLE) partial equilibrium model (Baldos & Hertel, 2013). Specifically, we start by incorporating a distinction between organic and conventional agricultural production within the model and, later, singling out Italy[5] as a new distinct region. The resulting structure is used to simulate how higher organic farming targets in Italy might affect both the national and world agricultural economy by 2030 in the face of a growing population, income, biofuel demand and technological development. With 14.8% of its cropland already certified organic, Italy has a solid foundation for its organic transition and a highly successful rate of achieving 25% (FAO et al., 2024).

Results offer a comprehensive view of the potential effects of introducing the F2F strategy in Italy. By 2030, crop production is projected to increase while crop prices are expected to rise due to higher production costs in both organic and conventional farming. From an input perspective, the model suggests that reducing the amount of land for conventional agriculture would bring about a substitution effect, increasing non-land input use (such as labour and chemical fertilizers). From an environmental perspective, results indicate that overall agricultural emissions are expected to slightly decrease under the F2F strategy. This highlights a key trade-off of the F2F strategy: while it contributes to lowering agricultural GHG emissions, it also drives up food prices, posing potential challenges for food security.

The paper offers a twofold contribution. Firstly, it is the first study to conduct an ex-ante quantitative analysis for Italy to address the role of organic-related policy shock. Our results offer valuable insights into how to achieve sustainability targets, with implications for policy design and monitoring.

Secondly, from a methodological point of view, the innovative contribution is to expand the original SIMPLE framework to incorporate a distinction between organic and conventional crop production while also including Italy as a distinct region of the model. This model variation involved modifying the existing structure and creating a global dataset that captures production, prices, and inputs differentiated for organic and conventional crops. As a result, the model provides an effective

CAP, each member state must design a National Strategic Plan with specific policy measures. In doing so, they have the possibility of adapting the general CAP to countries' needs and objectives.

[5] So far, the SIMPLE model presented a world disaggregation of 16 regions where Italy was included within the European Union.

framework for analysing shocks aimed at increasing organic crop production at the national (Italy) and international levels.

The rest of the paper is organised as follows: Section two discusses the contextual framework and related literature, while section three describes the empirical setting, with details on model, data, and simulation design. Section four presents the results. Section five reports limitations and future developments. The paper concludes with some general takeaways.

2. Contextual framework and literature review

2.1 Organic agriculture: socio-economic and environmental effects

Organic practices are a global reference for farming and food production that provides a formal recommendation for promoting environmental protection, maintaining biodiversity, and building consumer trust in organic products. (Reg (EU) 2018/848).[6] Producing organic means respecting the specific rules established at the national or regional level for different products (e.g., agriculture, livestock and food chain). Within the international framework of IFOAM standards, which can be internationally applicable for organic certification, each country can adopt its regulatory framework.[7] Given the institutional effort and the growing consensus on considering organic production as a key driver of agrifood sustainable transition, a recent body of literature has shed some light on the potential challenges of this strategy. Organic production could be more vulnerable than conventional agriculture in the face of some external shocks (e.g. climate change and natural diseases) given that farmers cannot use agrochemicals to contrast them. Such risks may affect productive capacity, profitability, efficiency, as well as social welfare and environmental sustainability more than in the case of conventional productions (Rasche, 2021; Sharna et al., 2024). Conversely, organic production may be more resilient to trade wars and international dependencies, given the type of non-land input used.

Among studies investigating the effects of organic practices, and raising an alert on potential negative effects, the first group refers to the potential of organic farming to cater for the growing food demand worldwide. By simulating a 100% organic transition, Smith et al. (2018) show that, in the case of England and Wales, total food output under organic practices would only reach 64% of that under conventional agriculture. Barbieri et al. (2021) confirmed that if the world's agricultural production were to shift to 100% organic, total food production would be reduced by 36% compromising food security. With organic farming total agricultural production could significantly decrease, as demonstrated also by Feuerbacher et al. (2018) and Beckman et al. (2022). Beckman et al. (2022) demonstrated that, due to the organic shift set by the F2F, the EU's competitiveness would be reduced between 7-12%. More recently, Kremmydas et al. (2023) and Kremmydas et al. (2024) also assessed the macroeconomic implication of the F2F strategy. By using a quantitative approach, they model both the macroeconomic implications of the organic transition and the farm-level decision-making.

[6] There are specific provisions covering different food products, such as feed, processed agricultural products, live or unprocessed products, aquaculture, yeast, as well as non-food products, such as raw wool, raw cotton, essentials oils and beeswax (Reg (EU) 2018/848). Products from fishing and hunting of wild animals are excluded, while harvest of wild plants when certain natural habitat conditions are respected.

[7] IFOAM: International Federation of Organic Agriculture Movements Standards.
Currently, for example, we have the Regulation (EU) 2018/848 adopted by the EU Member States, the Organic Foods Production Act in the US, the Organic Products Regulations for Canada, the National Organic Product Standard (GB/T 19630) in China and the Resolution No. 1286/1993 under the National Agrifood Health and Quality Service (SENASA) in Argentina.

Overall, their results align with the ones obtained by Beckman et al. (2022), confirming that total agricultural production would be reduced. However, the detrimental effects on production may be mitigated by efficiently distributing the costs of the F2F strategy across member states.

Other papers looked at the effects of organic practices on food prices, finding heterogeneous results. For example, by looking at the case of Italian wines, Abraden et al. (2017) concluded that while overall organic farming results in higher prices, this is no more valid in the case of higher quality wines, for which organic practices are associated with a lower price. However, when it comes to other crop productions authors such as Feuerbacher et al. (2018), Beckman et al. (2022), Meemken & Qaim (2018) and Kremmydas et al. (2024) conclude that, given the potential output reductions because of the adoption of organic practices, crop prices will tend to increase.

Arguments in favour of organic agriculture are usually related to environmental issues and health diets. From an environmental perspective, studies demonstrated that on average, organic agricultural practices preserve biodiversity 50% more than conventional techniques (Bengtsson et al., 2005; Tuck et al., 2014; Seufert & Ramankutty, 2017). More recently, these results were confirmed by the meta-analysis conducted by Tscharntke et al. (2021) that found that the diversification practices involved in organic agriculture enhanced biodiversity by 40%. However, Meemken & Qaim (2018) also emphasize that the biodiversity lost due to increases in conventional land use may offset the potential gains. As far as food security is concerned, the adoption of organic practices has been stressed as a strategy to enhance food quality and safety (Rempelos et al., 2021; Shepon et al., 2016). As stressed by Mie et al. (2017), however, the literature is not conclusive due to likely residual confounding, such as healthier lifestyles of consumers of organic food.

Another group of papers focused on the land use and environmental implications of extending organic practices, particularly on their relationship with yields and GHG emissions (Chiaricò et al., 2022). The meta-analysis conducted by Lee et al. (2015), for instance, concluded that organic farming results in higher GHG emissions compared to conventional agriculture. This difference is attributed to the lower yields of organic practices, which place greater pressure on land use and consequently elevate total emissions. The expansion of organic agriculture could significantly affect the environment not only through emissions but also through an increase in land use driven by the yield disparities affecting the overall level of emissions. (among others, McGee, 2015; Tuck et al., 2014; Muller et al., 2017; Calabro & Vieri, 2024; Basnet et al., 2023).

The lack of consensus on the effectiveness and sustainability of organic production, as briefly presented here, can be partially attributed to the severe data limitations on organic production, as well as on economic and biophysical factors, at the disaggregated level. In the following section, we describe the empirical setting and the related database created to conduct the analysis. A common thread in the literature is the lack of a framework for quantitatively assessing the F2F strategy in Italy, considering projected changes in population, income per capita, biofuel demand, and agricultural technology by 2030. In this respect, the SIMPLE model enables the construction of a baseline scenario, providing a comprehensive evaluation of this policy's economic and biophysical implications.

2.2 SIMPLE model: overview and existing applications

The SIMPLE model, originally introduced by Baldos & Hertel (2013), is a partial equilibrium model specifically designed to analyse the impact of different drivers on the aggregate demand and supply of agricultural products, including their prices, production levels, and land use. As summarised by Fuglie (2022, p. 7): "SIMPLE focuses on the key drivers and economic responses which govern long-run developments in the farm and food system". SIMPLE can, therefore, accurately reproduce historical changes in cropland use, crop price, crop production and average crop yields at the global scale. Baldos & Hertel (2013) developed the SIMPLE model by considering 7 global regions and their socioeconomic drivers of cropland use. By conducting a validation exercise spanning the historical period from 1961 to 2006, they assessed the model's accuracy in predicting agricultural dynamics, arguing that the model successfully reflects historical trends in global agricultural supply and demand, with population, income, and total factor productivity (TFP) serving as key determinants. Similar exercises were carried out by Baldos & Hertel (2016) and Hertel et al. (2016) who also extended the model to portray 15 distinct regions. Starting from this baseline structure, several are the modules and variables that can be added to address different issues about agricultural economics.

Lobell et al. (2013) and Hertel et al. (2014) extended the SIMPLE model to incorporate a GHG emission module capable of capturing the effects of climate change adaptation policies and technological advancements on global GHG levels and crop production. For example, Hertel and Baldos (2016) employed the framework extension to evaluate different policies aimed at attaining environmental security.

Baldos & Hertel (2014) added a food security module, which captures the global and regional effects of climate change and mitigation policies on caloric intake. By using this extension, Baldos & Hertel (2015) demonstrated that reducing market barriers could bolster food security worldwide and regionally in the face of climate change challenges to agriculture. More recently Kabir et al. (2023) used this framework to investigate the effects of different policy scenarios on food security outcomes in rural and urban Niger into 2050.

Even though the literature using this model is quite recent, papers have highlighted its unique value and proposed extending it in different contexts. This paper goes in this direction and proposes a new setting to distinguish crop supply between organic and conventional crops. In the following section, we describe the empirical setting and the related database created to analyse Italy.

3. Empirical setting

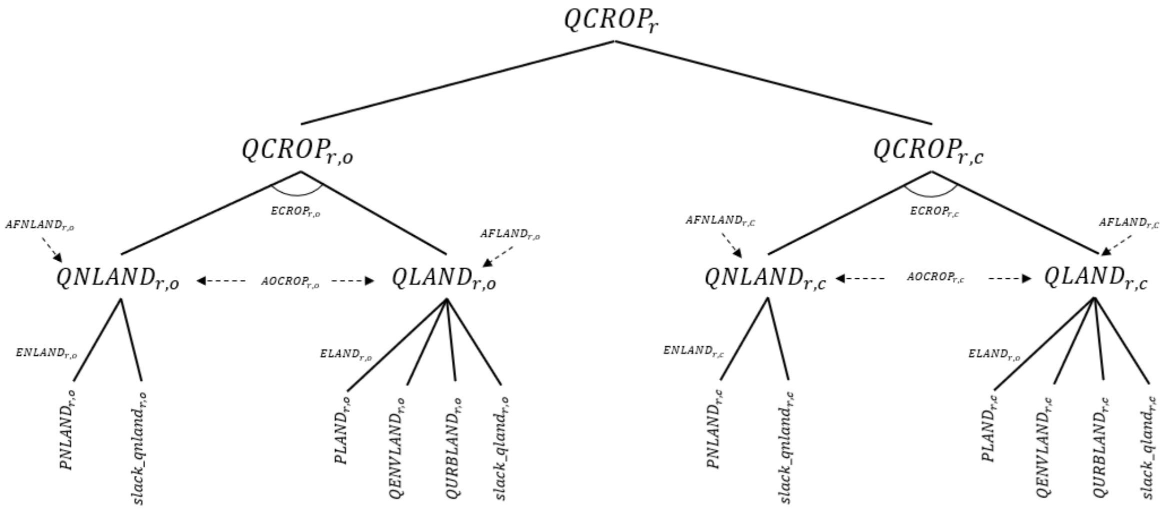
3.1 SIMPLE-IT model

As previously mentioned, the SIMPLE model was first introduced by Baldos & Hertel (2013) and Lobell et al. (2013) to comprehensively capture the key socioeconomic factors influencing cropland use at the global level. The model operates on the assumption of a single aggregate crop that is produced and consumed across different regions. In the original version of the model published by Baldos (2023b), the world was subdivided into 17 distinct regions, in which Italy was included within the EU. For this work, Italy was established as an independent region following the guidelines of Baldos (2023b).

Regional crop demand is driven by population, income per capita and biofuel demand changes, while crop supply is mainly governed by TFP changes in the agricultural sector. Regional crop production systems are modelled using a constant elasticity of substitution production framework. Crops are produced by combining land and an aggregate nonland input, with the latter input representing all other factors of production - excluding land - which are used by the crops sector, including fertilizer, labour, and machinery, among other farm inputs. (Baldos et al., 2020a; Fugile et al., 2022).

Since the purpose of this research is to evaluate the implications of increasing the percentage of organic practices in Italy, we have extended the original framework by splitting total crop production into organic and conventional crops. From a technical standpoint, the main structure developed for this model application is presented in Figure 1. As far as GHG emissions are concerned, this version of the model distinguishes the emissions produced under the two types of crop production.

Figure 1. Regional crop production structure – organic *vs* conventional



Note: r: regional index. o: index for organic agriculture. c: index for conventional agriculture.
In Figure 1 we use the name of the variable are the same of the model. QCROP: crop production. QNLAND:Non-land inputs. QLAND: land inputs. PNLAND: price of non-land inputs. PLAND: price of land inputs. QENVLAND: land reduction for environmental reasons. QURBLAND: land reduction for urban development reasons. slack_qnland: slack variable for non-land inputs. Slack_qland: slack variable for land inputs. AFLAND: land biased technological change. ANFLAND: non-land biased technological change. AOCROP: input neutral technological change.
Source: Own elaboration

3.2 Data

We use a database including 18 regions because of the separation of Italy from the rest of the EU. To achieve this, we followed the guidelines and parameters presented by Baldos (2023b) based, primarily, on FAO (2024). The chosen calibration year is 2017. On the one hand, data availability, particularly for organic agriculture, was taken into consideration in order to determine the base year. On the other hand, international agricultural price variations were also considered. For example, according to FAO (2022), the global trend in producer price index for cereals denoted a consistent upward trajectory from 2018, accelerating its increase from 2019. These phenomena, according to FAO (2022) are attributed to a series of events spanning from food supply chain disruptions (COVID-19 pandemic), conflicts and negative economic shocks. Hence, in line with Baldos (2023b) 2017 was selected as the most updated year for calibration. A second step was to calibrate the data considering the changes presented in the previous section. Cropland had to be divided into land advocated for organic crop production and conventional. To achieve this, country-level data from FAO (2024) was used by taking 2017 as the base year. As a result, it was possible to establish, for each of the 18 regions of the SIMPLE model, which percentage of cropland was destined for organic crop production. To maintain the consistency of the data, these shares were applied to the total cropland of the original dataset.

Data regarding crop production, non-land input use, and prices were more difficult to obtain for all world regions[8]. However, data for Italy was available through the EU Farm Accountancy Data Network (FADN), which is a yearly survey that collects farm-level information across the country regarding production, costs and prices. Given the nature of this survey, it is possible to distinguish between organic and conventional farms. In addition to the Italian FADN database, Eurostat data were employed to estimate the production values for the rest of the EU, while FAO (2024) was the main data source for the rest of the 16 regions of the model. Table 1 shows the main results obtained for Italy.

Table 1. Key variables for organic and conventional production for Italy 2017.

Variable	Value	Percentage Structure	
		Organic	Conventional
Crop Output (in 1000 MT: corn-eq)	132,549	13%	87%
Value of Crop Output (in 1000 usd)	29,028,232	17%	83%
Cropland cover (in 1000 ha)	9,218	15%	85%
Value of Cropland (in 1000 usd)	4,830,647	16%	84%
Value of Non-Land Inputs (in 1000 usd)	24,197,585	13%	87%
GHG emissions for Crop Production (in MT of CO2-eq)	1,085,920	9%	91%
GHG emissions for Cropland (in MT of CO2-eq)	3,431,788	10%	90%
GHG emissions for Non-land inputs (in MT of CO2-eq)	4,021,161	12%	88%

Source: Own elaboration based on FAO (2024), Italian FADN and Eurostat.

3.3 Simulation design

Two scenarios were developed to assess the impact of the strategy of increasing organic land by 25%.

The first is a baseline scenario designed to capture the potential demand and supply dynamics influencing crop production, land use, and prices by 2030. Within the framework of the SIMPLE model, projected changes in population, per capita income, and biofuel demand through 2030 are considered from the demand side. On the supply side, anticipated changes in TFP are also incorporated to provide a comprehensive outlook.

Following existing literature (Baldos et al., 2020a, Haqiqi et al., 2023, Baldos 2023b), population growth rates were derived using the projections developed by Samir & Lutz (2017), while GDP per capita estimates were based on projections by Crespo Cuaresma (2017) and future biofuel demand by IEA's estimations (2024).[9]

For the TFP, econometric estimations were performed using a time series model to forecast output and input data for 2030 based on a panel data structure (see the Appendix). Values of the drivers to 2030 are presented in Table 2.

[8] It should be noted that, according to FAO (2024), many regions of the world do not have organic agriculture practices.
[9] These projections follow the intermediate Shared Socioeconomic Pathway (SSP2) created by the International Institute for Applied Systems Analysis (IIASA).

Table 2. Estimated percentage variations of demand and supply drivers from 2017 to 2030.

Region	Demand Drivers			Supply Drivers TFP growth[2]	
	Population	Income per capita	Biofuel demand	Organic	Conventional
E_Euro	-1.97	59.91	0	18.54	20.9
N_Afr	17.28	33.27	0	42.84	48.3
SSA	38.17	67.84	16243.2[1]	14.1	15.9
S_Amer	13.51	46.24	58.33	9.58	10.8
BRA	22.01	40.92	97.74	16.59	18.7
AUS_NZ	4.26	39.46	6.67	-0.56	-0.5
EU	17.8	144.12	52.86	6.3	7.1
S_Asia	13.48	41.23	0	16.14	18.2
CC_Amer	11.9	49.55	58.33	0.8	0.9
S_Afr	9.68	38.59	0	13.48	15.2
SE_Asia	12.15	100.2	224.75	3.81	4.3
CAN	15.41	29.57	64.23	11.8	13.3
US	1.32	126.32	24.29	9.14	10.3
CHINA	22.4	30.12	19.56	8.96	10.1
M_East	-1.92	9.03	331.03	16.23	18.3
JPN_KR	30.61	334.19	224.75	3.46	3.9
C_Asia	11.83	20.83	224.75	26.79	30.2
ITA	0.77	69.7	103.38	1.51	1.7

[1]Note: Values for Biofuel demand at a regional level were extracted from the IEA (2024) database. However, due to data restrictions, values for the Sub-Saharan Africa region were taken from Baldos (2023).
[2] Note: We have assumed that TFP growth for organic production is 11% less than conventional. Said assumption is based on the productivity gap obtained from the Italian FADN data. Productivity has been calculated based on utilised agricultural area (in the case of agriculture) and adult livestock unit.
Source: Own elaboration.

The second scenario simulates the organic transition of Italian agriculture in line with the F2F Strategy. More specifically, we perform an exogenous shock in the share of organic land to increase the original 14.8% (in 2017) to 25% (in 2030). At the same time, in order to simulate a conversion of land, we include an additional shock in the share of conventional land to set its overall participation in total cropland to 75%.

The comparison of the two scenarios (baseline plus organic transition) shows what would be the implications in terms of production, prices and resource use of the F2F strategy bearing in mind the potential evolution of both demand and supply to 2030.

4. Results

Table 3 provides simulation results for Italy[10]. From the baseline scenario (without F2F simulation) to 2030, evidence shows that both organic and conventional crop production are expected to increase

[10] It should be noted that the SIMPLE model also produces results at a world level. However, since the simulation design of the F2F strategy was applied only to Italy, results at a world level are minor. Hence, they are not presented in this paper.

in Italy (Table 3, panel a). More specifically, organic crop production is projected to rise by 1.7%, while conventional crop production would increase by 9.5%.

A decomposition of the exogenous drivers' effects on production reveals that demand factors (see section 3.1), such as population growth, boost crop production for both conventional and organic agricultural practices by rising per capita income and increasing biofuel demand.[11] However, potential increases in TFP have an impact mainly only on conventional crops, accounting for a 7.5% increase by 2030.[12] The TFP growth spurs production increase and shifts part of the organic crop production to conventional crops, given that conventional crop productivity is assumed to grow faster (Table 2). The shift in production affects both land use and non-land inputs, with production growth driving greater resource use. Higher productivity reduces input needs, but the productivity gap between conventional and organic crops leads to lower organic input use and higher conventional input use. As a result, land use for conventional crops increases by 0.7%, and non-land input utilization rises by 6.8%. The baseline results show an increase in crop prices under conventional agriculture mainly driven by TFP. This is a cost-driven rise. Given the productivity differentials between organic and conventional production, the increases in demand for land and non-land conventional inputs imply an increase in their prices, which result in higher crop prices.

In terms of emissions, the simulation results in a total emissions increase of 5.8% for conventional production, while almost no increase for organic production. Introducing the F2F regulation alters these baseline results (Table 3, panel c). Because of this initial shock, the F2F regulation significantly affects organic crop production, which increases by 11%, while conventional crop production remains stable, driven by an even greater intensification of non-land input with respect to the baseline.

As far as agricultural prices are concerned, since the F2F strategy is increasing organic crop production, this leads to a reduction in organic crop prices with respect to the baseline (-1.6%). On the contrary, conventional crop prices will rise under the F2F strategy by 2.7% in comparison to the baseline scenario. As in the case of the baseline scenario, the increase is cost driven and mainly due to the increase in non-land input use.

Finally, the impact on GHG emissions is noteworthy. Emissions from organic crops increase due to higher production and input use, even if they feature lower emissions per kilogram produced and per hectare compared to conventional crops. Meanwhile, emissions from conventional crops declined by 3.5%, primarily due to reduced land use.

[11] The model highlights that biofuels have a significant impact on organic crop production, this aligns with European regulations, which mandate that biofuel production must utilize organic crops -Commission Delegated Regulation (EU) 2023/1640-.

[12] Under organic practices the variation is 0.1%.

Table 3. Simulation results-Italy

	Crop Production		Crop Prices		Cropland		No Land Inputs		GHG Emissions	
	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional
Baseline scenario-Percentage variation from base year 2017 (Panel a)										
Population	1.0%	1.3%	0.9%	1.2%	0.1%	0.2%	1.2%	1.5%	0.8%	0.9%
Income Per Capita	0.2%	0.2%	0.1%	0.2%	0.0%	0.0%	0.2%	0.2%	0.1%	0.1%
TFP	0.1%	7.5%	-2.8%	3.4%	-0.2%	0.7%	-1.7%	6.7%	-0.9%	4.3%
Biofuels	0.5%	0.6%	0.4%	0.5%	0.1%	0.1%	0.5%	0.7%	0.3%	0.4%
Total	**1.7%**	**9.5%**	**-1.3%**	**5.4%**	**0.0%**	**1.00%**	**0.2%**	**9.1%**	**0.4%**	**5.8%**
F2F Simulation (Panel b)										
Population	1.1%	1.3%	0.9%	1.2%	0.2%	0.2%	1.2%	1.5%	0.8%	0.9%
Income Per Capita	0.2%	0.2%	0.1%	0.2%	0.0%	0.0%	0.2%	0.2%	0.1%	0.1%
TFP	0.1%	7.5%	-2.8%	3.5%	-0.6%	0.7%	-1.7%	6.8%	-1.0%	4.4%
Biofuels	0.5%	0.6%	0.4%	0.5%	0.1%	0.1%	0.5%	0.7%	0.4%	0.4%
F2F	10.9%	0.0%	-1.5%	2.6%	67.4%	-11.5%	1.7%	2.5%	25.8%	-3.5%
Total	**12.7%**	**9.6%**	**-2.9%**	**8.1%**	**67.4%**	**-10.6%**	**1.9%**	**11.7%**	**26.2%**	**2.3%**
F2F Simulation - Difference with between F2F Simulation and Baseline (Panel c)										
Population	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Income Per Capita	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TFP	0.0%	0.1%	0.0%	0.1%	-0.1%	0.0%	0.0%	0.1%	0.0%	0.1%
Biofuels	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
F2F	10.9%	0.0%	-1.5%	2.6%	67.4%	-11.5%	1.7%	2.5%	25.8%	-3.5%
Total	**11.0%**	**0.1%**	**-1.6%**	**2.7%**	**67.4%**	**-11.6%**	**1.7%**	**2.6%**	**25.8%**	**-3.5%**

Source: Own elaboration.

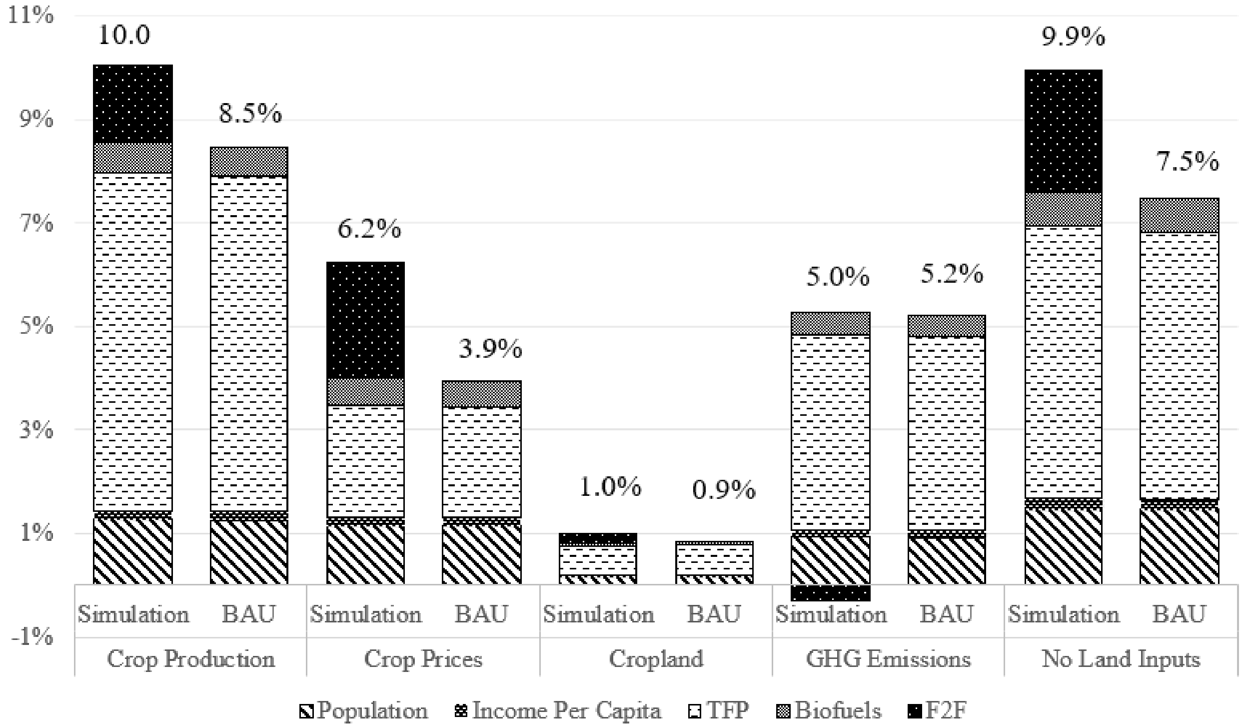
Figure 2 presents the combined results of the baseline scenario and the F2F strategy. This will allow us to interpret the effects along two main dimensions of sustainability: environmental and economic.

Starting from crop production, results indicate that if Italy were to introduce the F2F strategy, total crop production would experience a 17.6% increase with respect to the baseline scenario. However, crop prices in Italy will increase by nearly 60% compared to those without the implementation of the F2F strategy. This upward trend is mainly explained by the fact that the organic crop production process is more expensive than the conventional one and, therefore, characterised by higher production costs that result in higher final prices. At the same time, conventional crop prices are also expected to rise due to increased input costs, and, as a result, there will be an overall increase in crop prices. Some reflections should arise from this evidence. On the one hand, higher prices may positively reflect a better value distribution along the supply chain in favour of farmers and producers, but we do not have this evidence from the model. On the other hand, despite higher availability, food prices may remain an issue to be addressed by food and agricultural policies, even in a developed country such as Italy (FAO et al., 2024).

Regarding emissions, even though Table 3 showed an increase in organic agriculture emissions, total GHG emissions from the agricultural sector will be slightly reduced under the F2F strategy (Figure 2). This result can be explained by the intensification of the conventional crop sector, leaving the door open for potential trade-offs among environmental impacts (e.g., fertilizers).

The non-land input used will, in fact, increase, and it may be explained by two different channels. The first regards the fact that organic production is more human-capital intensive than conventional, and labour is included in the model as a non-land input. The second one is the intensification of conventional crops, for which non-land inputs (e.g., fertilizers, pesticides) are crucial to support yields and productivity (Fuglie, 2015). Therefore, while the presence of organic fields can reduce pesticide use on organic fields, it may increase it on adjacent conventional fields due to the so-called pest spillover effects (Larsen et al., 2024) and negatively affect the environment.

Figure 2. Aggregated results for Italy – Farm2Fork Simulation *vs* Baseline scenario



Note: In percentage variations with respect to the base year 2017.
Source: Own elaboration.

5. Conclusion, limitations and future research

To improve the response to societal demands on food and health, including high-quality, safe, and nutritious food produced in a sustainable way, the EU is promoting the adoption of organic practices and fixing specific land targets to achieve in the next decades. Organic practices have been assumed by policy-makers and practitioners as a concrete solution to address sustainability issues. This strategy will be remained in the post2027 EU Agenda, as attractive options combining economic possibility and environmental results (EC, 2025).

In this context, the paper investigated the environmental and economic sustainability consequences of achieving the 25% organic target by 2030 in Italy. The management system shift, from conventional to organic, is implemented in a modified version of the SIMPLE model.

By looking at the results on the Italian national food system, the increase of organic land as set by the EU strategy will positively affect food availability and crop production but negatively affect prices. The concern on price increases goes in line with previous works such as Feuerbacher et al. (2018), Beckman et al. (2022), Meemken & Qaim (2018) and Kremmydas et al. (2024). On the one hand, these higher prices could guarantee better economic conditions for farmers, in line with the CAP strategic objective of "improving farmers' position in the value chain" (SO3), but, on the other hand, they could undermine food affordability for consumers. It is also worth mentioning that the impact of the implementation of the F2F strategy in Italy will not have significant impact in the crop prices of the rest of the world.

From the environmental perspective, the reduction in GHG emission, together with the increase in land and non-land use, highlights an even more controversial situation. While the GHG reduction support the CAP specific objective (SO2)[13], as in the case of 2014-2020 CAP (Barreiro-Hurle, 2021), meeting the targets in the context of the F2F might contrast the aim of efficiently manage natural resources such as soil and reduce chemical dependency (SO5).

In this discussion, however, a key question remains open: who will pay for the organic transition? From production perspective, in fact, organic conversion is, first, not something that happens overnight and producers will have to face costs to become organic. Second, the maintenance of such production system is more expensive than a conventional one and, therefore, without public subsides, it is reasonable to expect an increase in prices. Additionally, as pointed out by Möhring et al. (2024), public policies should not only be focused on relieving the cost associated to organic transition but also on awareness and agricultural knowledge. This point will also imply further costs and transitions times.

To guarantee the organic transition without an excessive price increase, the CAP provides economic support to farmers. While in the case of I Pillar, funds for organic are provided in tandem with other measures, in the case of II Pillar, Italy has fixed approximately 2 billion EUR specifically to support organic land (16.4% of the entire Fund).[14] The II Pillar is based on competitive allocation and aimed at financing specific place-based aims, such as organic diffusion (Caravaggio et al., 2025). For instance, farmers will receive 341 EUR per hectare per year for arable crops if the land is transitioning towards organic production, while 284 EUR per hectare per year if already organic. The highest average amount for vineyards is 887 EUR per hectare per year for vineyards in transition, while 775 per hectare per year for already organic vineyards. The paper has some limitations, but also some potential for future research.

First, extending the study to other sustainability and resilience dimensions (EC, 2025), or other countries, is technically feasible, but not straightforward for now. Regarding data limitations, they may be addressed in the future thanks to the new Farm Sustainability Data Network (FSDN), which

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[13] SO2: Contribute to mitigating climate change and adapting to it, including through the reduction of greenhouse gas emissions and the improvement of carbon sequestration, as well as promoting sustainable energy.
[14] SRA29: Pagamento al fine di adottare e mantenere pratiche e metodi di produzione biologica.

will replace the current FADN since 2025 survey year. The aim of the reformed survey is to collect information not only on economic sustainability, but also on environmental and social performances.[15]

Second, extending the analysis to other countries is even more complex, due to limitations in dataset construction. To create a dataset feasible for running SIMPLE model, we need a huge, and very specific, list of variables that are not available for every country. Even in the case of countries particularly performant in terms of data collection (such as Italy), data comes from different datasets, meaning a significant challenge in data collection and harmonisation.[16]

Regarding the model structure, another potential extension could be the modification of the demand side of the model allowing for a distinct demand between organic and conventional crop production. However, data availability may represent a challenge in this respect.

Lastly, while the SIMPLE model demonstrated success in validating historical periods on a global scale, scholars such as Hertel et al. (2018) highlight a primary limitation of this approach. It lacks the capability to consider the local effects of a given policy due to the absence of spatially explicit data in its framework. In this context, works such as Liu et al. (2017) and Baldos et al. (2020) first incorporated a gridded dimension into the SIMPLE model known as SIMPLE-G. So far, the SIMPLE-G model exists only for the US (Baldos et al., 2020b), China (Wang and Liu, 2021) and Brazil (Wang et al., 2022). Our future research agenda is to create SIMPLE-G for Italy.

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[15] Commission Implementing Regulation (EU) 2024/2746 of 25 October 2024 laying down rules for the application of Council Regulation (EC) No 1217/2009 setting up the Farm Sustainability Data Network and repealing Commission Implementing Regulation (EU) 2015/220. The implementation regulation was adopted in October 2024, data have been collected since 2025, but they will be available only since 2028/2029.

[16] In the case of Italy, for example, we collect data from eight different database, each of which with a specific observation units, time span and readable formats. For Italy they were: FAOSTAT, Earthstat, ISIMIP, AQUASTAT, GCWM, ISMEA Mercati, Italian FADN, CREA land value database.

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Annex. Detailed Results

		Crop Production		Crop Prices		Cropland		No Land Inputs		GHG Emissions	
		Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional
Italy											
BAU	Population	1.03%	1.29%	0.90%	1.21%	0.14%	0.17%	1.18%	1.52%	0.80%	0.94%
	Income Per Capita	0.15%	0.18%	0.13%	0.17%	0.02%	0.02%	0.17%	0.22%	0.12%	0.13%
	TFP	0.06%	7.45%	-2.75%	3.43%	-0.19%	0.73%	-1.66%	6.65%	-0.91%	4.33%
	Biofuels	0.45%	0.57%	0.40%	0.53%	0.06%	0.07%	0.52%	0.67%	0.35%	0.41%
	Total	**1.70%**	**9.50%**	**-1.32%**	**5.35%**	**0.02%**	**1.00%**	**0.21%**	**9.05%**	**0.36%**	**5.81%**
F2F Simulation	Population	1.05%	1.30%	0.89%	1.21%	0.18%	0.16%	1.18%	1.52%	0.82%	0.94%
	Income Per Capita	0.15%	0.18%	0.13%	0.16%	0.02%	0.02%	0.17%	0.21%	0.12%	0.13%
	TFP	0.08%	7.54%	-2.79%	3.54%	-0.25%	0.70%	-1.70%	6.79%	-0.95%	4.39%
	Biofuels	0.47%	0.57%	0.40%	0.54%	0.08%	0.07%	0.52%	0.67%	0.36%	0.41%
	F2F	10.92%	0.04%	-1.52%	2.60%	67.39%	-11.51%	1.74%	2.49%	25.80%	-3.54%
	Total	**12.68%**	**9.62%**	**-2.89%**	**8.06%**	**67.42%**	**-10.56%**	**1.92%**	**11.69%**	**26.15%**	**2.33%**
World											
BAU	Population	1.85%	3.31%	1.50%	3.76%	0.61%	1.43%	2.02%	3.56%	1.65%	2.35%
	Income Per Capita	0.64%	2.20%	0.54%	2.33%	0.23%	0.75%	0.70%	2.41%	0.62%	1.77%
	TFP	2.76%	67.38%	-7.76%	36.43%	-0.93%	16.37%	-3.22%	53.72%	-1.94%	37.93%
	Biofuels	0.43%	0.65%	0.35%	0.66%	0.15%	0.36%	0.47%	0.70%	0.32%	0.38%
	Total	**5.68%**	**73.54%**	**-5.36%**	**43.18%**	**0.06%**	**18.91%**	**-0.04%**	**60.38%**	**0.65%**	**42.44%**
F2F Simulation	Population	1.86%	3.31%	1.47%	3.76%	0.61%	1.43%	2.02%	3.56%	1.65%	2.35%
	Income Per Capita	0.64%	2.20%	0.52%	2.33%	0.23%	0.75%	0.70%	2.41%	0.62%	1.77%
	TFP	2.77%	67.38%	-7.58%	36.42%	-0.94%	16.37%	-3.23%	53.72%	-1.94%	37.94%
	Biofuels	0.43%	0.65%	0.35%	0.66%	0.16%	0.36%	0.47%	0.70%	0.33%	0.38%
	F2F	2.98%	0.01%	-0.51%	0.03%	10.21%	-0.06%	0.47%	0.03%	3.17%	-0.01%
	Total	**8.68%**	**73.55%**	**-5.74%**	**43.20%**	**10.27%**	**18.86%**	**0.42%**	**60.41%**	**3.83%**	**42.43%**

Appendix.
Technical details of total factor productivity estimation

The first step was to estimate an econometric model using panel data and a fixed effects estimation based on International Agricultural Productivity data (Van Beveren, 2007). To linearize the production function, we applied a logarithmic transformation, considering capital, labour, materials, and the Hicks-neutral efficiency level.[17] The estimated equation is:

(1) $y_{it} = \beta_0 + \beta_k Capital_{it} + \beta_l Labor_{it} + \beta_{mfeed} Feed_{it} + \beta_{mfert} Fertilizer_{it} + \omega_i + \varphi_t + u_{it}$

where $Capital_{it}$ represents the value of the agricultural capital stock for region *i* at time *t*, $Labor_{it}$ refers to the number of economically active individuals in agriculture, $Feed_{it}$ and $Fertilizer_{it}$ denote the use of materials in agriculture, and u_{it} is the error term. From this estimation, we obtain the coefficients, which can then be used to calculate sector productivity, defined as:

(2) $\widehat{\omega_{it}} = y_{it} - \widehat{\beta_k} Capital_{it} - \widehat{\beta_l} Labor_{it} - \widehat{\beta_{mfeed}} Feed_{it} - \widehat{\beta_{mfert}} Fertilizer_{it}$

Thanks to this equation and the available data, we estimate productivity (the exponential of ω_{it}) for each for region *i* at time *t,* between 2017 and 2021. To project productivity through 2030, the model needed to be supplemented with forecasts of output and inputs, leading to the estimation of several time series models.[18]

[17] While this method can be extended to other production functions if certain additional conditions are met (Ackerberg et al., 2007), it was estimated using a Cobb-Douglas specification for simplicity.
[18] For each of the variables in every region, an ARIMA model was determined for each series and with that model each value between 2022 and 2030 was forecasted. Using these forecasts and the parameters estimated in the panel data model, an estimate of productivity in 2030 can be obtained for each of the regions (equation 2).