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The EU's farm-to-fork strategy: An assessment from the perspective of agricultural economics

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Abstract

The EU Farm to Fork (F2F) strategy includes a number of policy objectives that have implications for agricultural production in the EU and beyond. This contribution discusses the possible implications from an economic perspective. We draw on economic assessments by other authors and discuss their wider implications by considering only partially quantified benefits and costs. Overall, the assessments indicate a decline in EU agricultural production in quantitative terms. The F2F strategy negatively affects aggregate consumer surplus and—depending on the assumption made—a net increase or decrease in producer surplus, thereby inducing an overall net welfare loss. Partially quantified benefits and costs include the environmental benefits and costs linked to the F2F strategy, such as implications for greenhouse gas emissions, biodiversity, or the landscape. Therefore, by launching the strategy, policy makers have implicitly concluded that the additional net benefits outweigh the losses in consumer surplus. The economic studies combined with studies on the impact of agricultural practices on biodiversity and the emission of greenhouse gases do not support this claim without further technological and institutional changes, such as supporting the application of modern biotechnology by reducing regulatory hurdles. Also, whether most consumers will share this view remains to be seen. EU policy makers have it in their hands to implement the necessary institutional changes.

KEYWORDS
agriculture policy, economic impact, EU, farm to fork strategy

JEL CLASSIFICATION
Q1, Q2, Q5, L5

The European Green Deal (EGD) is one of the six political priorities of the von der Leyen Commission. It aims at making Europe the first climate-neutral continent by 2050. The EGD includes several strategies for achieving its objective, with the Farm to Fork (F2F) strategy at its heart (EC, 2020b). The F2F strategy includes specific actions: ensuring sustainable food production; stimulating sustainable food processing, wholesale, retail, hospitality, and food services' practices; promoting sustainable food consumption, facilitating the shift toward healthy, sustainable diets; and reducing food loss and waste (EC, 2020b). The F2F strategy also shows several overlaps with the EU biodiversity strategy (Barreiro-Hurle et al., 2021). While many stakeholders have applauded the EGD and the F2F, the publication of specific F2F strategy targets, summarized in Tables 1 and 2, linked to the specific actions raises concerns about their implications for the EU agriculture and food sector and beyond (Beckman et al., 2020;

TABLE 1 Key quantitative targets of the F2F strategy to be reached by 2030

Reducing the use and risk of chemical pesticides by 50%
Reducing the use of more hazardous pesticides by 50%
Reducing nutrient losses by at least 50% while ensuring no deterioration in soil fertility
Reducing fertilizer use by at least 20%
Reducing the sales of antimicrobials for farmed animals and in aquaculture by 50%
Increasing total farmland under organic farming to 25%
Reducing per capita food waste at retail and consumer levels by 50%
EUR 10 billion under Horizon Europe (2021–2027) to be invested in R&I related to food, bioeconomy, natural resources, agriculture, fisheries, aquaculture, and the environment

Source: EC (2020a).

TABLE 2 Key qualitative targets of the F2F strategy to be reached by 2030

Creation of a healthy food environment supporting healthy and sustainable food choices
Mandatory harmonized front-of-pack nutrition labeling
Sustainable food labeling framework that covers the nutritional, climate, environmental, and social aspects of food products
Collaboration with third countries and international actors to support a global move toward sustainable food systems
Support via EU Horizon Europe key funding programs for research and innovation.

Source: EC (2020a).

Paarlberg, 2022). Concerns from a legal perspective, including constitutional as well as international trade issues, have been raised as well (Pelkmans, 2021; Purnhagen, 2022).

Several authors have discussed the economic implications of the F2F strategy, including Barreiro-Hurle et al. (2021), Beckman et al. (2020), Bremmer et al. (2021), Henning et al. (2021), and Noleppa and Cartsburg (2021). Studies on the economic impacts mainly include those F2F actions linked to quantitative targets. The soft targets are more difficult to assess, although they might be even more relevant (Purnhagen, 2022).

Furthermore, from an economic perspective, it is obvious that implementing the F2F strategy will not be a costless exercise. The strategy requires reallocating resources at the farm level and along the food supply chain, as the strategy aims to transform the current food system. This also suggests that the technological changes observed in the past cannot compensate for the additional costs, as more radical changes will be necessary for inducing the transformation (Barreiro-Hurle et al., 2021; Henning et al., 2021). In addition, transformative processes often include specific administrative and information and communication costs that need to be considered and often are not well captured in many of the applied partial and general equilibrium models (van Kooten, 2021). Whether they will differ from the costs linked to the current food system is difficult to assess. However, it is reasonable to assume that the administrative and information and communication costs will not be lower and will stay the same or will even be higher.

In this contribution, the economic implications of the F2F strategy will be discussed. This analysis is not on the goals of the EGD as such but focuses on the concrete targets and instruments proposed under the F2F and whether these are really useful to achieve the goals. The results of different empirical studies will be assessed and compared regarding their quantitative and qualitative results. As the studies cannot capture all the effects of the F2F quantitatively but, in general, conclude that the overall welfare effects that have been considered are largely negative, the possibility that other effects might compensate for the negative welfare effects will be discussed. In the following, first, the objectives of the F2F strategy and the EGD will be presented and linked to the reform of the European Common Agriculture Policy (CAP) initiated in 2018. These links are important to better understand the possible implications of the F2F strategy. An assessment of the quantitative studies follows before discussing wider implications considering more difficult to quantify F2F targets. This study concludes with an overall discussion about the implications for the future of EU agriculture and policy.

THE EU GREEN DEAL, F2F STRATEGY, AND THE CAP

The Green Deal is one of the political priorities of the von der Leyen Commission (EPRS, 2020). The EGD is seen as the EU's response to threats posed by climate change and environmental degradation. In the words of the European Commission (2022), "*the European Green Deal will transform the EU into a modern, resource-efficient, and competitive economy, ensuring the following:*

- *no net emissions of greenhouse gases by 2050*
- *economic growth decoupled from resource use*
- *no person and no place left behind*"

Under the EGD, more than one trillion Euros of investments are expected to be mobilized. About 0.6 billion Euros of the Next Generation EU (NGEU) recovery plan and the EU's seven-year budget will finance the EGD. The financing is expected to mobilize the remaining 0.4 billion to reach the one trillion targets.

The F2F strategy, the biodiversity strategy, and the circular economy action plan are policy instruments chosen by the EC to reach the EGD's objectives. According to the EC (2020b), the F2F strategy is "*at the heart*" of the Green Deal. The F2F strategy is not yet a legally binding policy. Nevertheless, the strategy will be translated into legal documents to achieve its objectives (EC, 2020c).

Different groups have raised concerns regarding the F2F strategy's objectives and, in particular, regarding the impacts a realization of the targets may have for the EU and the agriculture sector. Criticism has been raised that the F2F strategy was not supported by an impact assessment, as commonly done for initiatives expected to have significant economic, social, or environmental impacts. At the commission site, this was not yet seen as necessary as the legislative proposals, and the implementing and delegating acts translating the F2F strategy into practice remain under development. For those proposals and acts, an impact assessment supporting them would be provided. Nevertheless, member states (MSs) expect that, under the new CAP (nCAP) from 2023 to 2027, the targets identified under the F2F strategy will become a more or less mandatory policy objective. Under the nCAP, MSs must develop national CAP strategic plans (CAP-SP) that detail how the nCAP will be implemented in their country. The nCAP is expected to provide MSs with more individual freedom as they can choose how much of the budget they like to allocate to the different nCAP actions. This flexibility is expected to result in a more efficient CAP. MSs must submit their national strategies to the EC by the end of 2021. The EC will assess the strategies submitted and approve or ask for further refinement. The nCAP includes nine specific objectives, covering the three dimensions (economic, environmental, and social) of sustainability, alongside a crosscutting objective on knowledge and innovation (see Table 3).

At the MS level, the competent authorities for climate change and the environment must be involved in developing the CAP-SP. A minimum of 30% of the CAP-SP funding has to be allocated under the CAP Pillar II for rural development for environmental and climate-related support. The EC considers this support to directly follow the objectives of the EGD (EC, 2020c). Hence, even if the objectives of the EGD and the F2F are not yet translated into legally binding

TABLE 3 Objective of the EU new CAP 2023–2027

Three overall objectives
Foster a smart, resilient, and diversified agricultural sector ensuring food security;
Bolster environmental care and climate action and contribute to the environmental- and climate-related objectives of the Union;
Strengthen the socio-economic fabric of rural areas.
Nine specific objectives
Ensure fair farm income
Increase competitiveness
Rebalance power in food chains
Climate change action
Environmental care
Preserve landscapes and biodiversity
Support generational renewal
Vibrant rural areas
Protect food and health quality

Source: EC, 2020b.

documents, they are already having an impact via the CAP-SP on agriculture production and the food chain at the MS level. The example from the Netherlands, where a substantial amount of support for agriculture has been moved from activities under Pillar I to Pillar II, exemplifies the impact (Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2021).

ECONOMIC ASSESSMENT OF THE F2F STRATEGY

An economic assessment of agricultural policies is not a trivial task. All economic assessment models are a simplification of reality; hence, all models are wrong, but some are less wrong than others. Nevertheless, models can help to support the debate by providing information about possible implications of policy choices. In the EU new laws and policies require an impact assessment including foresight studies under the Better Regulation agenda to ensure in the words of the commission "*evidence-based and transparent EU law-making based on the views of those that may be affected.* " (EC, 2022). Yet, exactly when impacts assessments need to be conducted and how detailed impacts assessments need to be is intensively discussed not only among economists (see e.g. the debate in Agra-Europe (2021) on *The Future of German Agriculture* report or Jongeneel (2021)).

Several applied models have been developed to assess EU agriculture policies. They can be divided into partial and general equilibrium models. They differ regarding the time and space dimensions they cover, the details of the sectors they cover, and the environmental and other impacts they include, often via satellite accounts, and behavioral assumptions made (see Varacca et al. (2020) for a recent overview comparing different models assessing EU policies).

A set of models for assessing the impact of EU agriculture policies are maintained and continuously updated at the Joint Research Center of the European Commission. One widely used model is the Common Agricultural Policy Regionalized Impact (CAPRI) model. This is a tool for the ex-ante impact assessment of agricultural and international trade policies with a detailed regionalization of the EU. Barreiro-Hurle et al. (2021) and Henning et al. (2021) used the CAPRI model to assess the impact of the F2F strategy.

Noleppa and Cartsburg (2021) used a multi-market model described by Lüttringhaus and Cartsburg (2020) and Beckman et al. (2020), the GTAP–AEZ (Global Trade Analysis Project – Agro Ecological Zone) multiregional, multisector, computable general equilibrium model to assess the impact of the F2F strategy. The F2F strategy assessment by Bremmer et al. (2021) combines detailed crop-specific case studies for ten crops (apples, citrus, grapes, hops, maize, oilseed rape, olives, sugar beet, tomatoes, wheat) for seven countries (Finland, France, Germany, Italy, Poland, Romania, and Spain) with the partial equilibrium model AGMEMOD (Agricultural Member State Modeling).

All five studies address different parts of the F2F strategy. Table 4 provides an overview of the regional and sectoral coverage and F2F targets considered by the studies. They are all open economy models mostly treating the EU as a *big country*. They all include consumer utility from the consumption of goods. The models do not include direct utility from a higher level of biodiversity, of organic agriculture, and/or of other amenities the EGD may generate. Those direct utility effects are more difficult to measure than changes in prices and quantities of traded goods. There has been a long debate in the economic literature to what extend these effects are already priced-in via individual behavior affecting prices and quantities, captured by policies, and more. Hence, adding them in the utility function may result in double counting (Coase, 2006; Wesseler and Smart, 2014).

TABLE 4 Studies on the impact of the F2F strategy and its coverage

F2F and other targets assessed	Beckman et al.	Barreiro Hurle et al.	Bremmer et al.	Henning et al.	Noleppa/ Cartsburg
Reducing the use and risk of chemical pesticides by 50%	X	X	X	X	X
Reducing the use of more hazardous pesticides by 50%			X		
Reducing nutrient losses by 50%			X		
Reducing nitrogen balance by 50%		X		X	
Reducing fertilizer use by at least 20%	X		X	X	
Reducing nitrogen fertilizer use by 20%					X
Reducing the sales of antimicrobials by 50%	X				
Achieving 25% of total farmland under organic farming		X	X	X	X
Increasing fallow area to 10%		(X)[1]	(X)[1]		
Reducing productive agricultural area by 10%	X				X
Sharing high diversity landscape features of at least 10%		X	X	X	

Source: Based on the studies cited.
[1]high diversity landscape features is included in the model by increasing fallow area.

The situation in the EU is not one where environmental impacts are not priced. At EU and at MS level a number of policies regulate the use of fertilizer, plant protection agents, GHG emissions, have identified areas for nature conservation and more internalizing many of the externalities of agriculture and food production. If this is already enough is an open debate. For some this might already been enough for others more is needed. Hence, the modeling approaches and their results, albeit not having explicitly modeled in the utility functions the direct utility effects mentioned above, cover those effects indirectly via the effects of agricultural, environmental, and other policies on prices and quantities. The resulting overall negative effects discussed below can be understood as an amount that needs to be covered by utility benefits not captured in the models.

One of the challenges in modeling the F2F strategy is the combination of different targets as impacts overlap. An increase in organic agriculture already implies a reduction in chemical pesticide and mineral fertilizer use. All the five models consider the overlaps between the different targets. The increase in nature-protected areas (e.g., to a share of 10% of total utilized agriculture area [UAA]) has been modeled by increasing the share of unused and set-aside land to 10% (Henning et al., 2021). Most studies also implement sensitivity analyses regarding parameter values. Henning et al.'s (2021) study also does a sensitivity analysis that considers an ex-post 20% reduction in meat consumption with a 20% compensation for the reduced caloric consumption with increased consumption of vegetables, fruits, and legumes; import restriction for soy; reduced economic growth in China; and a carbon dioxide price of 100 Euro per ton applied to emissions from agriculture. Beckman et al. (2020) include three scenarios where the EU-only adopts F2F, adoption by some countries with explicit EU trade restrictions against non-adopters, and global adoption.

The F2F strategy's targets include a substantial reduction in crop production inputs, such as fertilizers and pesticides (see Table 2). Fertilizer use has a yield-increasing effect, while pesticide use has a yield-securing effect. These interactions were quantified in the models. Henning et al., for example, used a 10% decrease in pesticide use in the F2F fertilizer scenario and a 14% decrease in mineral fertilizer use in the F2F pesticide scenario.

The indirect effects of the F2F strategy on land use, land use change, and forestry (LULUCF) are calculated by converting the increase in imports and decrease in exports into additional land needed for production abroad. The LULUCF show an increase in the area under agriculture (+6.6 mio. ha) and grassland (+0.5 mio. ha) and a decrease in forest land (−2.0 mio. ha) and other land (−4.5 mio. ha) (Henning et al., 2021). Bremmer et al. calculate an increase in land under agriculture of about 6.9 mio. ha. By separately modeling targets, the F2F strategy's effects can differ. The reduction in pesticide use results, for example, in a decrease in agricultural land use and an increase in forest land (Henning et al., 2021). The changes in land allocation also increase the price for agricultural land, with some substantial increases in Denmark and the Netherlands of over 200% (Barreiro-Hurle et al., 2021; Henning et al., 2021).

The target of 25% of the land allocated to organic agriculture is expected to further reduce crop yields. The studies have shown that, depending on the specific assumptions made, these targets result in a substantial reduction in wheat and oilseed rape production. Also, fruit and vegetable production will be affected, as they use relatively high amounts of fertilizers and pesticides under open-field cultivation. If they will be more strongly affected than grains and oilseed rape depends on the differences in fertilizer and pesticide yield response, the relative changes in inputs and outputs, and the availability of alternatives. Nevertheless, the studies unanimously report a decline in fruit and vegetable production.

The envisaged reduction in fertilizer use by 20% will consequently reduce crop yields. The yield reduction will be crop and location specific. There are substantial differences in fertilizer use within the EU. The main fertilizer in quantitative terms is nitrogen. While the nitrogen balance is about 50 kg for 2015, for some countries, the balance is more than three times as large. Some negative environmental impacts have been linked to fertilizer use. They include the pollution of water resources and negative implications for biodiversity. The 20% reduction in fertilizer use and the 50% decrease in the fertilizer balance will substantially affect the production of agricultural commodities. Bremmer et al. (2021) calculated a decrease in the value of production for 2030 of about 92 billion Euros, an increase in food prices but below 20%, and an increase in land use between two and three million hectares. The study conducted by Barreiro-Hurle et al. (2021) from the Joint Research Center of the European Commission revealed similar results for the fertilizer scenario. This also follows the results of the study by Henning et al. (2021) for the Grain Council, the one by Noleppa and Cartsburg (2021) for Euroseed, and the USDA study by Beckman et al. (2020) (Table 4).

Furthermore, objectives related to pesticide use are expected to decrease agricultural productivity within the EU. Pesticides are applied as a defense against potential yield loss. A reduction in pesticide use without alternatives being available for pest and disease control will reduce productivity in agriculture, including organic agriculture if copper sulfate, a plant protection product considered hazardous, and other plant protection products are included under chemical pesticides (as it seems to be the case) (EC, 2020c). Bremmer et al. (2021) reported average annual yield losses of 2% for maize and up to 25% for olives. The aggregated results on agriculture production are summarized in Table 5.

Similar impacts on productivity are expected by increasing the share of land allocated to organic agriculture to 25%, from currently under 10%. The yield of major crops in organic agriculture is below the yield from nonorganic agriculture. See Figures 1 and 2 on the share of organic agriculture in Europe and productivity differences. The difference depends on the crop and the region. They can reach over 50% for wheat and almost 40% for grain maize in some countries, but the differences can also be substantially lower (EC, 2019b). The revenue per hectare and per full-time work unit show a different picture. Farmers in some of the most productive countries receive, even with organic agriculture, a substantially higher income than other farmers with nonorganic agriculture. The differences between MSs can be manifold. In particular, a look at the Eastern European countries shows that the differences between organic and nonorganic agriculture are not as strong as in Western European countries, while the differences in standard output measured in Euros per hectare or per annual work unit can be quite substantial between Eastern and Western European Union MSs.

In summary, Beckman et al. (2020), Barreiro-Hurle et al. (2021), Henning et al. (2021), and Noleppa et al. (2021) observed a larger average decline in agriculture output in the EU due to the F2F strategy. The impacts differ based on assumptions made and the coverage of F2F targets. Outputs are about to decline by 7% to 12% (Beckman et al., 2020) to more than 20% (Noleppa et al., 2021). Barreiro-Hurle et al. (2021) and Henning et al. (2021) provided declines in output that are somewhere in between, but, for some crops, they are above the results reported by Noleppa et al. (2021) (see Table 6).

The decrease in production within the EU has implications for international trade and indirect land use. The products where the EU is a net importer will increase in import volume and value. These include, in particular, the import of grain maize and soy beans. The United States, Canada, Argentina, and Brazil will benefit from the increase in exports of dairy products, while Argentina and Brazil will benefit from the increase in wheat. The EU will substantially reduce its wheat exports and, under some scenarios, even turn from a net-exporter into a net-importer of wheat. Also, a decline in net-exports for vegetables and perennial crops (wine) is expected to happen. Due to the reduction in agricultural output in quantitative terms, food prices will

TABLE 5 Study results on the impact of the F2F strategy on agriculture production in % in the EU

Cereals	Oilseeds	Fruits, vegetables, and permanent crops	Fodder crops	Beef meat	Dairy	Author
−15.0	−15.0	−12.0		−13.0	−10.0[d]	Barreiro-Hurle et al.
−48.5[a]	−60.7	−5.2[c]		−13.5	−11.6	Beckman et al.
−18.0[a]						Bremmer et al.
−23.6	−7.3	−13.0	−30.0	−17.0	−6.0	Henning et al.
−26.0[a]	−24.0[b]					Noleppa et al.

[a]Wheat only.
[b]Oilseed rape only.
[c]Fruits and vegetables only.
[d]Raw milk supply.
Source: Derived from the studies cited.

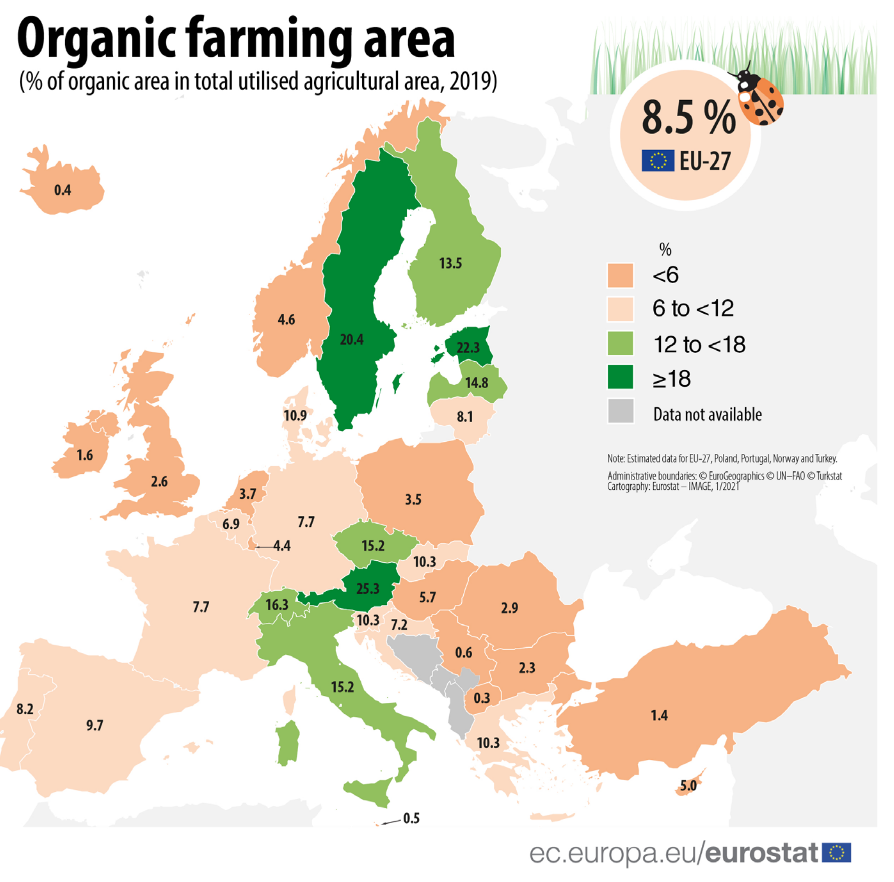

FIGURE 1 Organic farming area in the EU and selected other countries in 2019 (*source*: Eurostat, 2021)

increase globally with known impacts for food-importing countries. Beckman et al. (2020) discussed these impacts extensively.

Overall, the EU's reduction in food production will increase its food prices. Consumers will bear these extra costs. All the studies predicted a reduction in consumer surplus. Some predicted an increase in farm income caused by an increase in producer surplus. This may be surprising at first sight. However, considering that aggregate food demand in general is inelastic and aggregate food supply is elastic, this is no longer surprising and is basically an inverse technological change effect in combination with policy-induced production constraints. Henning et al. (2021) refer to quasi inverse Cochrane Treadmill effect. This can even happen in an open economy model, where some factors of production are quasi-fixed or where trade policies reduce result in import restriction from selected countries. The supplementary material includes an illustrative example related to policy-induced changes in the EU honey market (Purnhagen & Wesseler, 2016). The net increase in producer rents for agriculture does not imply that all farmers and all participants along the supply chain will experience a positive income effect. In agriculture, positive effects are observed for cattle producers, while crop producers mainly use. The suppliers of inputs and the processors of food within the EU are expected to observe a net-negative surplus. This can be explained by the decrease in quantities

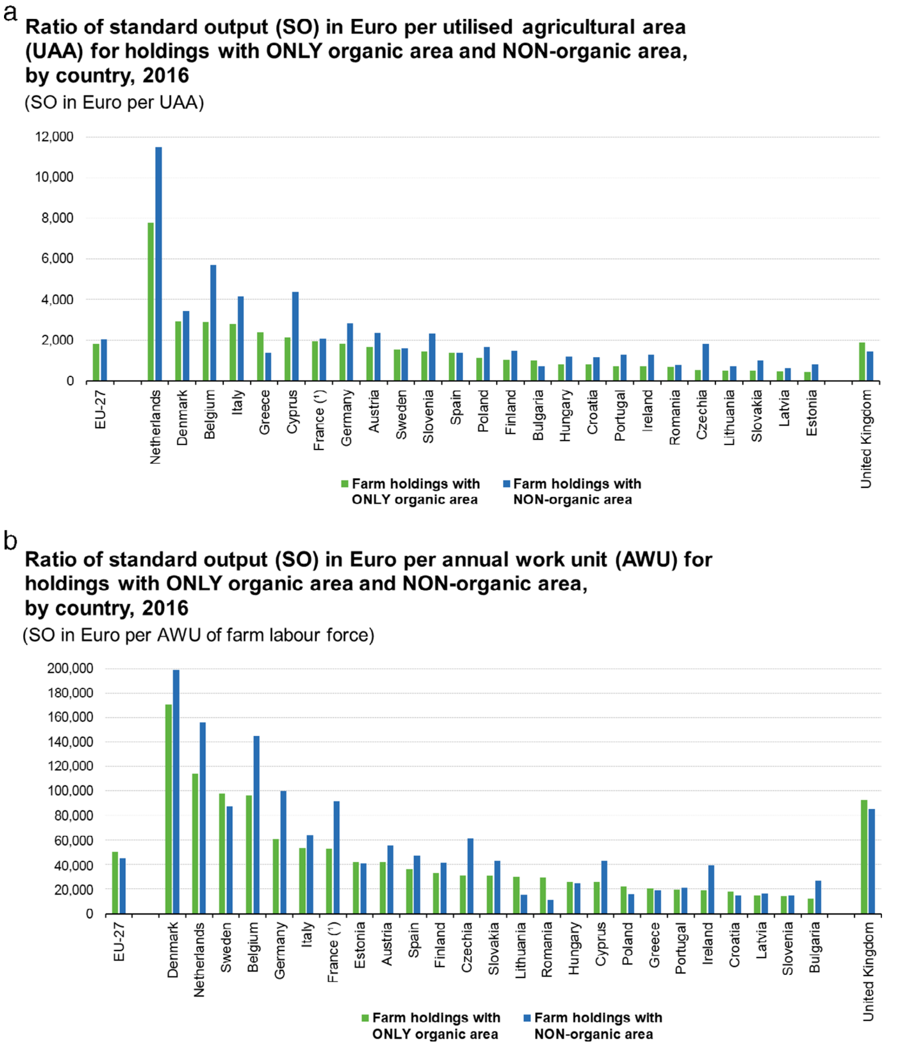

FIGURE 2 Comparison of standard output from organic and nonorganic agriculture among member states per utilized agriculture area (a) and per agriculture work unit (b). Kitchen gardens are excluded from the UAA. Malta and Luxembourg are excluded from the country breakdown to protect confidentiality due to the low number of organic farms. Only farm holdings with a UAA above 2 ha are included, in order to have comparable holding sizes between organic and non-organic holdings. *Source*: Eurostat (2021)

produced and traded within the EU, the increase in imports from and the decrease in exports to the rest of the world (e.g., Henning et al., 2021).

WIDER IMPLICATIONS BY CONSIDERING ADDITIONAL BENEFITS AND COSTS

The impacts on biodiversity and climate change are only partially considered in the empirical studies. This is understandable as the information needed for including those effects

TABLE 6 Study results on the aggregate economic impact of the F2F strategy

Farm income	Food expenditure	GDP	EU production value (billion)	Author
Increase	Increase	Decrease[c]		Barreiro-Hurle et al.
−16%	153.2 USD/capita	−84.2 billion USD[d]		Beckman et al.
Decrease			−140 Euro	Bremmer et al.
+35.08 billion Euro	70 billion Euro[b]	Decrease	Increase	Henning et al.
>15 billion[a]	Increase[c]	Decrease[c]	Decrease	Noleppa et al.

[a]Only plant production considered and calculated for 2040.
[b]Expressed in total consumer surplus.
[c]Indirectly concluded from the decline in output and the general model description.
[d]For the EU only.
Source: derived from the studies cited.

quantitatively is lacking at a level that one could use this information with a high level of confidence or not available at all.

Barreiro-Hurle et al. (2021) and Henning et al. (2021) assessed the F2F strategy's impact on greenhouse gases (GHG) emissions. They reported that the F2F reduces the GHG emissions of EU agriculture between 20% and 35%. The major share comes from changes in fertilizer use. Nevertheless, leakage is significant. More than half of the GHG emissions saved in the EU are leaked to the rest of the world according to Barreiro-Hurle et al. (2021), while Henning et al. (2021) only observe an almost zero impact. The leakage effects occur mainly in Africa, Asia, and South America (Henning et al., 2021). They have been calculated by linking the increase in imports of agricultural goods with changes in land use. The CAPRI model does not yet capture leakage effects well. Henning et al. (2021) argue, if the effect on forest lands are explicitly included, the F2F will increase and not reduce GHG emissions. Noleppa and Cartsburg (2021) point out that this not necessarily has to be the case considering progress in plant breeding. According to their calculations, almost half of the increases in GHG emissions due to the F2F and the biodiversity strategy can be avoided by 2030 and turned into an overall reduction in GHG emissions by 2040. A better regulatory environment for using new plant breeding technologies might further substantially contribute to reducing GHG emissions from agriculture.

Biodiversity is difficult to measure, and measuring the impact of agricultural practices on biodiversity is even more difficult. Henning et al. (2021) applied an agriculture produciton related biodiversity indicator and reported a positive increase in index from 0.62 to 0.70 of about 13%. The indicator captures biodiversity friendly production (BFP) differentiated by four group of farming practices: arable crops, grassland, permanent crops, and olive groves (Paracchini & Britz, 2010). While the assignment of weights and initial values is ad-hoc, the changes in values provides some indication for positive or negative developments. Here are also important trade-offs to consider. Although using herbicide-tolerant crops has often increased the adoption of reduced or zero tillage practices with a marked positive impact on biodiversity (Smyth et al., 2011), it has been criticized because of the perceived negative effects on the environment and human health. This has resulted at several places in the ban of glyphosate-based herbicides.

The BFP indicator does not capture implications for biodiversity on-farm and off-farm and related trade-offs. While a more intensive production system might reduce on-farm biodiversity it might increase off-farm biodiversity by sparing land and vice versa. The example for herbicide tolerant crops shows, that a higher productivity not necessarily has to result in lower biodiversity (ibid). There is also the question about what comprises biodiversity (Weikard et al., 2006) and who decides what kind of biodiversity to prefer (Welch et al., 2021). The nitrogen debate in the Netherlands is one of the examples. A higher nitrogen level in the atmosphere is expected to change the biodiversity of nature reserves, and a debate emerges as to whether these changes in biodiversity should be considered bad and whether they justify stringent policies that possibly avoid them (Economisch Statistische Berichten, 2020).

Leakage is another problem that might undermine the sustainability effects of the F2F strategy. Barreiro-Hurle et al. (2021) reported a leakage effect of about 66% on GHG emissions saved in the EU. The EU intends to reduce leakage by introducing border taxes related to the GHG emissions of imported goods from abroad under the Carbon Border Adjustment Mechanism (CBAM) (EC, 2021a). Under the CBAM, "*EU importers will buy carbon certificates corresponding to the carbon price that would have been paid, had the goods been produced under the EU's carbon pricing rules*." (EC, 2021b). From an economic viewpoint, this raises some problems as the efficiency gains from allocating the production of goods to countries and regions where they can be produced more efficiently from an emission perspective will be undermined. Another problem is the carbon emission calculation. For the time being, industries where this is less complicated are included in CBAM. Other industries are expected to follow. In particular, regarding agriculture, the calculation will be more complicated and, according to the current application, discriminating against environmentally friendly production methods. Considering oilseed rape, adopting herbicide-resistant oilseed rape has substantially reduced GHG emissions via the adoption of reduced or zero tillage practices and the release of toxic chemicals into the environment (Brookes and Barfoot, 2018; Smyth et al., 2011). If the import of oilseed rape from Canada will be charged with carbon emission quantities observed in the EU, discrimination against those imports is very likely. Similar arguments apply to imports of herbicide-resistant soybeans and other GHG emission-reducing cultivation practices and are expected to raise a number of issues in international trade (Pelkmans, 2021).

The effect of dietary changes has not been explicitly considered by the studies cited above. These changes are difficult to quantify. Supporting dietary changes are expected to decrease the demand for meat, generating health benefits and indirectly a decline in GHG emissions via the reduced consumption of animal products. The dietary changes are expected to be supported by nutrition and other forms of labeling (EC, 2020a). While accumulating evidence has shown that food producers adjust the ingredients of processed food products to reach a better nutriscore, experiences of a combination of labels on consumer choices are scarce. A survey result in France indicated that consumers are guided by red colors and that the nutriscore dominates the environmental sustainability score (Marette, 2022). However, doubts remain regarding whether labeling results in substantial changes in behavior supporting sustainable development. Nevertheless, the labeling may improve the well-being of those consumers who care about nutrition and sustainability. Moreover, considering whether nutriscores and other labels and the related problems of identifying the correct scores—if this is possible at all—are an efficient policy remains unexplored. The identification of environmental scores will be complicated for products traded internationally because this also requires companies exporting into the EU to provide the information needed for labeling (Venus et al., 2018).

ASSESSING LONGER RUN IMPLICATIONS

The EGD and the F2F strategy alongside the nCAP have created a complicated and sophisticated bureaucratic climate governance policy. The design also shifts power balances. The overall policy design, for example, may induce important shifts in power in MSs and, in general, supports those that are currently in government and weakens the opposition. The argument here is that a state with a well-established administration can easily impose new regulations on its citizens (Stasavage, 2020). Considering the nCAP, the EC grants more rights to MSs. The MSs must develop their national CAP-SP. The MSs can choose, among several nCAP actions, their implementation and financial support under the two pillars of the CAP. The national CAP-SP must be submitted to the EC for assessment and approval. The national strategic plans have to be in line with the objectives of the Green Deal. This procedure is a substantial change governing the CAP. The nCAP increases the EC's power while assessing and approving the national strategies. The change also increases the power of those who are in power in the MSs as mentioned above. They can now choose the CAP policies to financially more strongly support. Having the nCAP follow the EGD and the F2F strategy will depend on the political power of different groups in the specific MS (for the example of biotechnology, see Shao et al., 2020). In MSs in which the environmental lobby groups are stronger, one can expect that their influence on the design of the national CAP-SP will be stronger, and the CAP-SP will readily follow the F2F strategy. One indicator is the nCAP budget allocation between Pillar I and Pillar II tools. The tools under Pillar II include many more that are directly linked to the F2F strategy (EC, 2020b), such as those related to eco schemes.

While the reallocation of budgets will reflect more the needs at the MS level, the money does not compensate for the decline in physical output and the negative indirect effects outside the EU. Solutions will be needed reducing or avoiding the negative effects on output via technological change while allowing EU agriculture to be more resilient and adaptable to climate change (Purnhagen et al., 2021). One often mentioned solution, but not the only one, is Artificial Intelligence (AI). AI in agriculture, such as precision agriculture, is one of the less controversial solutions allowing to increase the efficient use of inputs (Wesseler, 2019) and contributing to some of the F2F objectives, such as reducing pesticide and fertilizer use. Nevertheless, there are limits to what can be gained within already highly efficient agricultural systems.

Another possibility might be factor reallocation. As EU agriculture productivity is highly diverse, the F2F strategy may induce factor reallocation by intensifying agriculture production in MSs, where productivity levels remain relatively low and, in some cases, not even reaching possible productivity levels for organic agriculture. Take the wheat and spelt for example: The organic wheat and spelt yield per hectare in the Netherlands for 2018 using Eurostat data was about 5.60 tons per hectare. The yield for nonorganic wheat and spelt in Romania the same year was 4.75 tons per hectare, a difference of about 17%. This example is a bit of cherry picking, but it illustrates that the potential for increasing yields with current technologies and following the F2F strategy in some cases might be possible. Nevertheless, one needs to be very careful with such kind of comparisons. Substantial productivity differences can be observed, see for example, Ihle et al. (2017) for the EU cattle sector, but they can be explained by local differences such as mountainous terrain versus river valleys.

Hence, it is reasonable to assume that more needs to happen to compensate for the potential negative productivity impacts of the F2F strategy that what AI and factor reallocation has to offer. Purnhagen et al. (2021) highlighted, among others, the importance of new plant breeding technologies (NPBTs) and, in particular, for increasing the productivity and climate change adaptability of organic agriculture. NPBTs have potential not only in organic agriculture but also in general agriculture (Purnhagen & Wesseler, 2021). Similarly, different biological control methods that can serve as substitutes for chemical pesticides under the F2F strategy are possible. See, e.g., the special issue of the journal *Pest Management Science* (Duke et al., 2019). As with NPBTs, their availability is substantially reduced by the approval process currently applied within the EU (Frederiks & Wesseler, 2019). The cases of NPBTs and biological control agents highlight the need for reforming the approval process for plant protection products and for approving planting material in the EU to provide the boost needed for successfully implementing the F2F as mentioned by Purnhagen et al. (2021).

A further problem that might arise with the successful F2F strategy is linked to 25% organic agriculture. This would require tripling the current level of organic production, as organic agriculture is linked to animal husbandry for getting the nutrients needed for plant production and may result in an increase in cattle with related GHG emissions. Further, one needs to consider that organic agriculture is a political construct. Policy makers and other stakeholders have identified what farming practice is and what is not to be considered organic agriculture, often lacking the underlying scientific support for environmental and animal friendliness and part of what Zilberman et al. (2022) call the "green paradigm" of future agriculture. Also, an increase in the supply of organic-labeled food products may induce a substantial decline in the producer prices of those products. Already today, not all the products produced according to organic standards can be sold at a price premium for organic products, enter the often lower priced market for nonorganic products, and are only able to survive with government subsidies (Offermann et al., 2009).

Over all, the impact of the F2F strategy will largely depend on the rate and kind of technical change. The studies mentioned consider either no technological change or continuation of past trends. This result in an increase in food prices and reduces consumer surplus. The studies differ with respect to their impact on producer surplus. The overall impact on GHG emissions and biodiversity are consider to be modest or negative, mainly due impacts on the rest of the world. These negative impacts can be mitigated by technical change. The studies treat technical change as continuation of past trends in their baseline analysis. More of what has been observed in the past needs happen for translating the F2F strategy in a strategy generating overall positive effects and in particular providing a significant contribution to reaching the carbon neutral goal of the EGD. Bremmer et al. (2021) and Noleppa and Cartsburg (2021) stress the importance of providing better access to the use of new plant breeding technologies by improving regulations. Barreiro-Hurle et al. (2021) and Henning et al. (2021) do not explicitly address technological change. Nevertheless, their result point in the same direction.

CONCLUSION

The F2F strategy, as part of the EGD, reduces the production of agriculture within the EU and induces an increase in food prices. This is expected to further fuel consumer price inflation within the EU and beyond. Farmers' incomes within the EU are expected to increase. The F2F strategy results in the redistribution of rents from consumers to farmers in the EU. Studies assessing the economic impact of the F2F strategy reveal, on average, a decline in welfare within the EU due to the F2F targets' implementation. However, the studies do not completely quantify the environmental and health benefits of the F2F strategy. Doubts remain regarding whether its impacts on the environment and human health will be sufficient to compensate for the calculated decline in welfare. Doubts also remain regarding the logical consistency of the F2F objectives and the targets and links to the EGD and the objectives of nCAP. The decline in agriculture output within the EU may result in leakage effects in regions outside the EU, undermining the EGD objectives.

Achieving the targets under the F2F strategy is expected to increase soil cultivation. Soil cultivation has been linked to an increase in GHG emissions. The effect of the F2F strategy on reducing GHG emissions, the core objective of the strategy, remains highly questionable. Although studies assessing the F2F have reported the positive effects of GHG emissions, the changes in land use practices remained unexplored. A positive effect of the F2F strategy on food security also remains questionable. All studies predicted a decrease in output for the EU and an increase in food prices. The production of agricultural products such as cereals and other crops is exposed to a higher level of production risks by having fewer strategies available caused by a reduction in pesticide use for responding to biotic and abiotic stresses. This is expected to decrease the food security of low-income households within the EU and to reduce the EU contribution to food security abroad.

The impact on biodiversity of the F2F strategy is difficult to assess. Different forms of agriculture have different effects on biodiversity. Whether the effect will be positive or negative depends on how biodiversity is measured. Using measures that consider number of some species and some abundance among species may not induce a higher level of biodiversity, following the F2F strategy's targets. A more detailed assessment would require ranking the value of species, and this raises the question of implementing the ranking and civil society's participation in it. One study used a biodiversity indicator and reported a positive impact on biodiversity at the farm level.

The implications discussed are based on the assumption that no further drastic changes for technological and institutional changes are to be expected. In the longer run, the F2F strategy can be expected to result in input factor reallocation, increasing production and allocation efficiency in agriculture within the EU. These changes will take time. At the policy level, the time length of these changes can be influenced. Factor reallocation can be made easier by reducing restrictions on the exchange of land or on foreign direct investments from within and outside the EU. Technological change can be supported by reducing the time needed to get alternatives to chemical pesticides approved for application and providing stronger incentives for using modern biotechnology to address the several challenges in crop production. EU policy makers have it in their own hands translating the F2F strategy into a well-being-increasing strategy by implementing the institutional changes needed.

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