Economic and Environmental impacts of the Green Deal on the Agricultural Economy: A Simulation Study of the Impact of the F2F-Strategy on Production, Trade, Welfare and the Environment based on the CAPRI-Model

by
Prof. Dr. Dr Christian Henning (University of Kiel) and Dr. Peter Witzke (EuroCare, Bonn)

– Executive Summary –

09.09.2021

Background of the Study

According to the EU Commission, the Green Deal will be implemented through on the Farm to Fork Strategy (F2F), which was published in May 2020, as well as the EU's Biodiversity and Climate strategy. Therefore, the Grain Club has commissioned a study to analyse the effects of the F2F Strategy on production, consumption and trade of relevant agricultural products within the EU as a whole and with particular focus on Germany. The analysis was conducted based on the CAPRI-model, which is a regionalised partial equilibrium model focused on the agricultural sector including environmental and land-use effects induced by farm production. To include international trade flows and corresponding agricultural price effects, the CAPRI sector model is linked to an international trading model. Based on the new trade theory, the trading model assumes that traded agricultural commodities are not perfectly homogeneous goods, but rather imperfect substitutes. Therefore, agricultural trade involves a non-linear transaction cost and trade flows that respond only in a limited way to changed terms of trade (TOT), i.e. changed price relation on domestic and international markets.

The F2F Strategy will initially focus on the implementation of the Green Deal's agricultural main goals, which are defined as the following technical production restrictions and target values:

(1) Reduction of mineral fertilizer use by 20%

(2) Reduction of pesticide use by 50%

(3) Reduction of the Nitrogen-balance surplus by 50%

(4) Share of high diversity landscape features of at least 10%

(5) Share of organic farming of at least 25%

In addition to that, the induced effects on the relevant ecosystem services (Nitrogen-balance, biodiversity and CO2-emission) associated with those changes as well as the implied welfare effects for relevant socio-economic groups (farmers, agribusiness and consumers) were analysed under several framework conditions: (a) decrease of the domestic demand for meat products by 20% at constant prices of the baseline scenario in the EU, (b) complete ban of soy imports into the EU, (c) decrease of China's economic growth, (d) integration of agriculture into the European CO2-permit trading system at an exogenous permit price of 100 Euro/t CO2eq. and (e) assuming constant export and import prices for the EU.

Main results of the study

A. **Production structures**

- The F2F Strategy would lead to a **significant decline in production** and a respective price increase within the EU, with the reduction of the N-balances by 50% generating the strongest effects. In practice, the decrease in production ranges from -**20% for beef, -6.3% for milk** as well as -**21.4%** and -**20 % for cereals and oilseeds, respectively**, throughout the EU. The number of animals would be even further reduced with a decline of -**45% for feeder cattle and -13.3% for milk cows and young cattle** while **cereal and oilseed areas** would only be reduced by -2.6% and -6%, respectively. When compared to the N-balance reduction of 50%, all other F2F measures would lead to more moderate production adjustments which generally lie below 10%. The same kind of adjustments would also apply to Germany, except for feeding cattle where the reduction would be less with -30%, which would still generate the same reduction of production output with -20%.
- The strong decrease in production would imply an equally significant price increase within the EU and in Germany. The strongest price effects could be observed for **beef with an increase of +58%, followed by pork with a +48% increase followed by raw milk with approximately +36% increase.** Price increases for crops would vary between **+15% for fruits & vegetables** (including permanent crops and wine), **+18% for oilseeds** and **+12.5% for cereal**. In parallel to the production impacts, the strong price effects could also be attributed to the N-balance reduction of 50%, while the price effects of the other F2F measures would yield a moderate increase of +5%, with the exception being the reduction of pesticides, which would lead to a price increase of +10% for oilseeds and fruits & vegetables.
- Compared to the **price increase** within the EU, the price increases for **non-EU countries** are much more moderate with an average price increase of **+7.4% for beef, +10.2% for pork** and **+4% for raw milk**. For crops, price increases would vary between **+1.5% for fruits & vegetables** (including permanent crops and wine), **+3.3% for oilseeds** and **+3.8% for cereals.**
- In the EU, the use of mineral fertilizer per hectare (ha) and pesticides per ha is strongly reduced by -**51% and -58%**, respectively, while the use of organic fertilizer is reduced by -25%. Germany, however, reduces its use of mineral fertilizer only by -45% and the use of organic fertilizer by -18%. This insufficient decline in fertilizer and pesticide use can partially be compensated by increased efforts in other areas such as mechanical weed control and soil cultivation, which leads to an increase in costs of +50% in those areas.
- With regard to land-use the implementation of the F2F Strategy by definition implies **a strong growth of set-aside and ecological priority areas by +11 Million ha**, with 1.9 Million of those ha in Germany alone, while the use of utilised agricultural area (UAA) as grassland increases by 0.5 Million ha, with 58 thousand ha in Germany. However, the implementation of the F2F Strategy also implies a transformation of 1.5 Million ha of forest land into UAA, with 0.38 Million ha of those transformed forest areas being in Germany.

- With regard to adjustments of the input and land-use structures the strongest effects are again obtained by reducing the N-balance. One exception would be the reduction of pesticide use by 50%, which by design yields a strong effect of -50% on the use of pesticides. Similarly, an increase of high diversity landscape features to at least 10% would yield an extension of set-aside areas by approximately 10 Million ha. Interestingly enough, the N-balance reduction itself would result in an extension of set-aside areas by +5 Million ha, while an increase of organic farming would only result in a 0.33 Million ha extension of those areas. In addition to that, an extension of organic farming as well as the reduction of pesticides and mineral fertilizer would result in an increase of forest land, with a margin of 0.125, 0.35 and 0.06 Million ha, respectively.

B. **Trade structures**

- The decrease of production of the European agriculture implies a general reduction of net exports by the EU. If all F2F measures are simultaneously implemented, the EU net export position for cereals and beef would revert to a net import position. According to the F2F Strategy, the current net export of cereals would be reduced from +22 Million tonnes to a net import of -6.5 Million tonnes, while the net beef export would sink from +22.5 thousand tonnes to a net import of -950 thousand tonnes. Furthermore, pork would be reduced from a net export of +4.3 million tonnes to +1 million tonnes, milk export would be reduced from +5.9 million tonnes to +4.9 million tonnes while the net import of oilseeds would increase from -17 to -22 million tonnes. Lastly, the net import of fruits & vegetables would also increase from -10 million to -22 million tonnes.
- The F2F Strategy would imply a reduction of net exports for German agriculture as well. However, the export-import reversion would only apply to poultry as the current net export would be reduced from +70 thousand tonnes to a net import value of -170 thousand tonnes. While the net milk export would remain essentially unchanged, the net export of pork would also be strongly reduced from +1.26 million tonnes to 0.5 million tonnes. Lastly, the respective net import values for cereals and beef would increase from -4.7 million tonnes to -7.4 million tonnes and -0.08 million tonnes to -0.19 million tonnes.
- Depending on the product, the domestic demand would respond with a varying elasticity. For example, if the domestic production is reduced by 1%, the domestic demand would disproportionally be reduced by less than 1%, which would result in an elasticity value of less than 1. The domestic demand would be quite inelastic for animal products, especially for pork with an elasticity value of 0.12, but also milk and beef with an elasticity value of 0.34 each. There would also be similarly inelastic responses for oilseeds, with a value of 0.14, while the domestic demand for cereals and fruits & vegetables would be more elastic with values of 0.51 and 0.27 respectively.

C. **Ecosystem services**

- The F2F measures significantly increase the ecosystem services of all EU member states. Similar to the production effects, the strongest effects would once again be generated by the reduction of the N-balance.
- In fact, this would cause a **N-balance reduction of approximately -50%** from 61 kg/ha to 30 kg/ha of utilised agricultural area (UAA). This effect can mainly be attributed to the 50% N-balance reduction, however, the reduction of mineral fertilizer by 20% would also result in a significant reduction of the nitrogen loss by -10 kg/ha. Other individual measures only yield a moderate to no effect as increasing organic farming to 25% would only implied a rather minor nitrogen loss reduction of -5 kg/ha, while the increase of high diversity landscape features would only result in a reduction of -2.5 kg/ha.

- **Agricultural GHG-emissions would be reduced of -109 million t CO2eq.**, which translates to a -**29%** reduction of the agricultural global warming potential (GWP) compared to *baseline*. Looking at the individual GWP-components, N_2O-emissions would be reduced by -37.5%, while CH_4-emissions would be reduced by -22.7%. With regard to GHG-emissions the strongest impact is again observed for the 50% N-balance reduction, which results in a GHG-emission reduction of -26%. All other measures would only produce lower reduction rates, all of which are less than -5%, with the sole exception of the 50% reduction of pesticides, which would imply a reduction of -5.5%.
- Besides direct agricultural GHG-emissions, the GHG-balance of the LULUCF sector (Land-Use, Land-Use Change and Forestry) is also crucial for a comprehensive assessment of the F2F Strategy's impact on the GHG-balance of European agriculture. The EU LULUCF sector is explicitly integrated in the CAPRI-model, which predicts that the implementation of the F2F Strategy would lead to a reduction of CO2 storage in the LULUCF-sector by 50 million tonnes of CO2eq. This can mainly be attributed to the transformation of forest into UAA, resulting in a net balance of 109-50=59 million tonnes of CO2eq. Each individual F2F measure yields different LULUCF effects. While N-balance reduction and the extension of high diversity landscape features imply a negative effect on the LULUCF sector, positive effects can be observed for the reduction of pesticides as well as mineral fertilizer use with a respective CO2 storage of -2.7 and -5.9 million tonnes CO2eq. Increasing organic farming further induces a positive effect on the LULUCF-sector with a CO2 storage of -5.1 million tonnes CO2eq., however, increasing high diversity landscape features only leads to an extension of agricultural land and thereby has a negative LULUCF effect with a GHG-emission range of +21 million tonnes CO2eq.
- The influence of agricultural production on biodiversity is difficult to assess based on the current state of science and therefore even harder to predict and model. The CAPRI-model approximates this influence by using a so-called **Biodiversity friendly production index (BFP)**, which can attain values between 0 and 1. Through the implementation of the F2F Strategy, the **CAPRI-Biodiversity index** would increase from 0.62 to 0.7, which equals 0.08 units or **+12.9%**. Interestingly, increasing high diversity landscape features to 10% and reducing the N-balance both have a positive effect on biodiversity, with a BFP-index increase of 0.06 units or +9.7%. One weakness of the BFP-index, however, is that it does not include the direct impact of pesticide use on biodiversity. As a consequence, simulations based on the CAPRI-model only imply very limited positive effects of a 50% pesticide reduction on biodiversity with a modest BFP-index increase of 0.01 units or +1.6%.

D. **Public welfare**

- The implementation of the F2F Strategy leads to corresponding public **adjustment costs** of approximately **42 billion Euro**.
- Due to strong price responses projected by the CAPRI-model based on assumed low Armington elasticities (corresponding to low trade response, please see also point G. below), the major share of **adjustment costs would be financed by consumers** with an estimated consumer welfare loss of 70 billion Euro (money metric), equalling to 157 Euro per capita. Germany alone would face a loss in consumer welfare of 13.4 billion Euro. In contrast to that, the **farmers' income** is expected to increase by up to +35 billion Euro (of which 4.7 billion corresponds to the increase of German farm income), while profit margins in the dairy and oil processing industry are being reduced by -4 billion Euro each. Looking at the individual F2F measures, the reduction of pesticides by 50% would require a high social cost of 38 billion Euro while the N-balance reduction would only require 15 billion Euro. Increasing high diversity landscape features to 10% and increasing organic farming to 25%, would entail a rather moderate cost of 2.6 billion Euro and 10 billion Euro, respectively. However, in order to fully assess each individual F2F measure,

adjustment costs alone are not a conclusive indicator. On the one hand, there are clear synergies between each measure, and on the other hand, the induced additional ecosystem services need to be factored in as well. The relevant factor is the net benefit, meaning the difference between the benefits and the cost of the increased ecosystem services.

- Increasing agricultural income through the implementation of the F2F Strategy seems unexpected and counterintuitive at first glance, however, it can be explained by the very inelastic demand for agricultural products and the low reactivity of agricultural trading. If the European demand is sufficiently inelastic and agricultural trading is sufficiently less reactive (conditions which especially apply with regard to animal products within the EU), a decline in production leads to a disproportionate price increase resulting in an overall increase in the added value of European agriculture, despite the decline in production. This phenomenon can be considered as a reverse treadmill effect based on the theory of Cochrane. The latter is empirically proven with regard to agriculture and explains the unexpected negative effects of technical progress on agricultural incomes. The production restrictions imposed by the F2F Strategy correspond to a negative technical progress, resulting in a reversed treadmill effect. However, the F2F Strategy impacts asymmetrically on animal and crop production. While the **gross margins for animal products**, especially milk, beef and pork, **increase by 55 billion Euro** (24.5 billion Euro for milk, 6.5 billion Euro for beef and 24 billion Euro for other meat, especially pork), **the gross margins for crop production** is reduced by -21.3 billion Euro, with a reduction of -**5.8 billion Euro for cereals and oilseeds and -9.2 billion Euro for fruits & vegetables** (including wine).
- The F2F adjustment costs are not only distributed asymmetrically between consumers and farmers but also among the farmers themselves. While consumers face a cost of 157 Euro per capita, farmers are looking at a profit margin of up to 4,022 Euro per capita. However, those implied profits vary depending on the specialisation of production. On average, the F2F Strategy implies an increase of total gross margins by 218 Euro per ha UAA. As mentioned, the adjustment costs vary for each farming specialisation with a -94 Euro decrease per ha UAA for cereals, equalling to -26% of the gross margin realized in the baseline, a -661 Euro per ha UAA for fruits & vegetables - translating to -11% of the gross margin in the baseline - while beef and milk producers are faced with a gross margin increase of 423 Euro and 693 Euro per animal, respectively, as a result of the F2F Strategy[1].
- When interpreting each individual component of the total social costs, it is important to note that the calculated welfare for each consumer and farmer are used as a mere estimate of the total welfare change implied by the implementation of the F2F Strategy. The fully realised welfare impact for each socio-economic group depends on the concrete agricultural implementation of the F2F Strategy, which has not been explicitly included in the CAPRI-simulations. It is also important to note that the calculated welfare changes correspond to aggregated measures and can therefore vary across individual members within a specific socio-economic group. In fact, even among the clear beneficiaries of the F2F Strategy, i.e. the milk and beef producing farmers, a heterogeneous distribution of the individual benefits is to be expected. It is especially likely that the induced decrease in supply would be distributed asymmetrically among individual farms: less competitive farms would completely give up production and more competitive farms survive to collect the higher profits resulting from higher farm prices while exiting farms would realise a loss.
- If all F2F measures are implemented as planned, they will yield an average profit increase of 218 Euro per ha. This increase can be mainly attributed to the 50% N-balance reduction, which alone implies an increase in value-added of approximately 300 Euro per ha, while other F2F measures,

[1] Calculated per animal as well as per UAA gross margins that are based on UAA and animal head counts of the baseline.

such as the reduction of pesticides by 50% or increasing organic farming imply a decrease in value-added of -146 Euro and -33 Euro, respectively.

- In contrast to farmers, agricultural processing industries are faced with a decrease in value-added by the F2F strategy, varying from -0.02% up to -26.9% depending on the industry. For example, the processing industry only faces a relatively mild loss of profit by the 25% increase of ecological priority areas with -0.25% for milk and -3.3% for other processing industries, while the 20% reduction of mineral fertilizer implies a low profit loss for the dairy industry and a moderate loss of roughly 5% for the oil processing industry. A 10% expansion of organic farming results in a -3.6% loss of profit for the oil processing industry and an even mild profit gain of 0.15% for the dairy industry. In contrast to that, a 50% N-balance reduction would lead to a strong profit reduction for the milk processing industry with a loss of -14.5% and -13.2% for other processing industries.
- When putting the absolute welfare reduction in relation to the income per capita or rather total food expenditures, they become strongly relativised. In absolute numbers, the cumulated loss of welfare only amounts to 0.26% of the total income or 3% of total food expenditures of European consumers, while the increase in farmer income amounts to 49% of total profits by European agriculture.

E. **Leakage-Effects**

- As F2F measures have a **direct effect on the consumption and production** of agricultural commodities in **non-EU countries**, they thereby also affect the transformation of ecosystem services and economic welfare in those non-EU countries. For global environmental goods such as climate change, the ecosystem services induced by the F2F Strategy in non-EU countries are directly relevant to the welfare of EU society and therefore require a comprehensive welfare analysis. This also applies to other ecological and economic spill over effects of the F2F Strategy, as long as those are considered to be global public goods from a European standpoint. For example, F2F causes changes of the food security, poverty or biodiversity in non-EU countries that can be considered as relevant for the European society. Considering the welfare aspects of the N-balance in non-EU countries with regard to European society, a general prediction can be difficult as it depends on the specific framework conditions given in each country. For example, assuming an increased N-drift in non-EU countries leads to increased pollution of the ocean implies that it can therefore be considered as relevant for the European society. However, assuming an increased N-drift induces a local air and water pollution in non-EU countries, it probably would not be considered as welfare relevant from the perspective of the European society and hence are not considered as leakage effects.
- **The F2F Strategy is not effective against climate change!** With regard to GHG-emissions, a **leakage effect** of **54.3 million t CO2eq.** becomes apparent, meaning that the implementation of the F2F Strategy would lead to additional GHG-emissions of 54.3 million tonnes CO2eq. in the agricultural sector of non-EU countries. Including this leakage effect, an overall negligible GHG-balance of 109 - 50 - 54 = +5 million t CO2eq. results due to the implementation of the F2F Strategy, not including effects in the LULUCF sector of non-EU countries. The LULUCF sector of non-EU countries has not been integrated into the CAPRI model yet, however, the implementation of the F2F Strategy implies a reduction of forestry areas by approximately 5 million ha in non-EU countries, hence including the LULUCF sector of non-EU countries is expected to lead to an even more negative GHG-balance of the F2F Strategy.
- When looking at product-specific leakage effects, the strongest leakage effects can be observed within animal production. The F2F induced **additional beef production in non-EU countries** alone yields additional **36 million t CO2eq**, while pork and milk production only result in additional GHG-emissions of 6 and 4 million t CO2eq., respectively, in non-EU countries. Similar

to that, **cereals and oil seeds** also result in rather **low leakage effects** of 3 and 1 million t CO2eq., respectively. Regionally, leakage effects are especially prominent in Africa (27%), South America (25%) and South Asia (36%).

F. **Heterogeneous regional effects of the F2F Strategy**

- The different production structures and economic-ecological conditions lead to heterogeneous effects for each individual EU member state and within the different regions of those member states. Based on the CAPRI model, a detailed simulation of those regional effects has been conducted and analysed. The following results with regard to regional distribution of the effects of the F2F Strategy deserve a deeper highlight:
  - The adjustment costs for the implementation of the F2F Strategy are asymmetrically distributed among EU member states, with the consumer loss of welfare per capita ranging from -0.2% in Ireland to -1.4% in Romania. Similarly, the F2F induced agricultural income change varies from 3 Euro per ha of land area in Bulgaria to 945 Euro per ha of land area in Belgium. The expected change in welfare in Germany is estimated to be around -0.33% (equalling to -166 Euro per capita) on the consumer side, while the agricultural income will increase by 4.7 billion Euro, or 285 Euro per ha, through the implementation of the F2F Strategy.
  - The induced ecosystem services are also distributed unevenly among each member state, as the nitrogen loss per ha of UAA varies from 20.6 kg/ha in Romania up to 193.7 kg/ha of UAA area in the Netherlands. Meanwhile, Germany is expected to have an average N-balance of 68 kg/ha of UAA from baseline. As the F2F Strategy intends for a homogeneous reduction of the N-balance among all member states, the absolute differences in the nitrogen loss of all European member states will be reduced by the F2F Strategy. Therefore, the historically grown nitrogen loss of different magnitude needs to be cut down successively.
  - In addition to that, the biodiversity of each member state also varies considerably. Using the BFP-index as a reference, the spectrum ranges from very low biodiversity levels of 0.41 in Slovenia or 0.45-0.47 in Denmark, Belgium and Malta to very high levels of biodiversity such as 0.8 in Portugal followed by 0.75 in Ireland or 0.71 in states such as Italy and Romania. Germany, however, remains in a rather even position regarding its biodiversity with a BFP-index of 0.56, which is expected to only experience a slight increase to a BFP-value of 0.58 through the F2F Strategy. As observed with the nitrogen loss, the F2F Strategy tends to balance the biodiversity among the European member states towards a generally higher level.
  - Agricultural GHG-emissions present a similar variance among the European member states, with baseline emissions varying from 0.9 t CO2eq. per ha of land area in Romania to as much as 10 t CO2eq. per ha land area in the Netherlands. Similarly to the nitrogen loss levels, the levels of GHG-emissions are directly correlated to the amount of animal production. The higher the levels of animal production are, the higher ceteris paribus. are the GHG-emissions. Through the F2F Strategy, GHG-emissions will be reduced by a margin of -15% to -30%, depending on the region and country. In general, however, the F2F Strategy leads to an approximation of the CO2 emissions of the European member states towards a generally reduced level, ranging from 0.64 t CO2eq. in Romania to 7.5 t CO2eq. in the Netherlands. The German agriculture is expected to reduce its GHG-emissions from 3.7 t CO2eq. to 2.7 t CO2eq. per ha of UAA, as a result of the F2F Strategy. This equals a net reduction of -22%, which ranks rather low compared to other states such Denmark or Poland, who have a similarly high animal production, and are expected to reduce their GHG-emissions by as much as -30%.

G. **Sensitivity of F2F Strategy effects**

The described effects of the F2F Strategy generally remain stable even if framework conditions change (a)-(d). However, there are still some important differences that have substantial implications with regard to the political implementation of the F2F Strategy. Especially if the relevant welfare effects depend on the responsiveness of agricultural trading. Since previously conducted studies implied an elastic responsiveness of agricultural trading - basically assuming constant world market prices - they would often come to fundamentally different results. As a result, an additional F2F scenario (e) has been simulated based on constant agricultural prices. The assumption of constant agricultural prices is empirically wrong, however, in order to assess the possible effects of an increased responsiveness of agricultural trading, this unrealistic and extreme scenario has been simulated as well. The key results of all undertaken sensitivity analyses can be summarized as follows:

- **An increased responsiveness of agricultural trading implies a fundamental redistribution of adjustment costs between farmers and consumers as well as significantly increased leakage-effects:** The price-, trade balance- and welfare-effects all strongly depend on the inclusion of the European agricultural market into international agricultural trading. This especially applies to animal products such as beef or milk. The stronger the international supply or rather the international demand for agricultural resources responds to changed TOTs, the lower are the F2F induced price effects. If one assumes perfect responsiveness, meaning that there will be no changes in agricultural prices, the costs of implementing the F2F Strategy would basically and completely be borne by the farmers. In fact, this assumption would entail an **income reduction of almost -40 billion Euro for farmers** (equalling to -242 Euro per ha agricultural area), while consumer welfare as well as the profit for the processing industry would remain constant. This would lead to a much larger reallocation of production and subsequently additional GHG-emissions in non-EU countries. The latter imply such strong leakage effects that would completely defy the climate efficacy of the F2F Strategy.
- **A reduced European meat consumption significantly reduces leakage effects** with a total reduction of GHG-emission leakage effects from **54 to 31 million t CO2eq.**, especially for beef production with a leakage effect reduction from 36 to 16 million t CO2eq. Overall, the climate efficacy of the F2F Strategy would be increased through the effective reduction of worldwide GHG emissions by 27 million t CO2eq. However, this only equates to 8% of the total GHG-emissions produced by the European agriculture, not factoring in the effects in the LULUCF sector and in non-EU countries. Nonetheless, the results further illustrate that adjustments to the consumer side present an effective strategy to reach the Green Deal goals in agriculture. Similar to the reduction in meat consumption, a general reduction of food waste in European food supply chains can have a positive impact on leakage-effects. Minimizing the food loss in supply chains corresponds to technical progress, allowing to reduce the effective food demand in the EU without changing the preference or welfare of the consumer. This furthermore leads to less production spillovers in non-EU countries induced by the F2F Strategy.
- **Including agriculture into CO2-allowance trading increases the climate efficacy of the F2F Strategy**. A CO2-allowance price of 100 Euro per t CO2eq. implies a much higher reduction of agricultural GHG-emissions by -140 million t CO2eq. or -39% from baseline. In addition to that, there would be a significant reduction of losses in the European LULUCF sector with 17.8 million t CO2eq. instead of 50 million t CO2eq. by the standard implementation of the F2F Strategy. The explicit inclusion of agriculture into CO2-allowance trading thereby leads to an increased net-reduction of European agricultural GHG emissions of -122 million t CO2eq. compared to -54 million t CO2eq. through the standard implementation of the F2F Strategy. However, there would also be higher leakage effects with 65 million t CO2eq. compared to the 54.3 million t CO2eq. by the standard implementation of the F2F Strategy. Overall, however, there would still be a net-reduction of GHG-emissions by -57 million t CO2eq., meaning that

the incorporation of an active climate policy into the F2F Strategy would have a positive impact on climate efficacy. Comparing the reduced GHG-emissions to the overall GHG-emissions from baseline only yields a relative effect of 16% of the total GHG-emissions of European agriculture.

Implications for agricultural policies

The formulation of individual F2F measures was mostly ad hoc and did not rely on a specific scientific foundation. The goals of the Green Deal, however, are stated clearly, namely the complete reduction of the pollution from nitrogen, climate neutrality as well as reaching and securing an acceptable level of biodiversity. The fact that agriculture, or rather the consumption of agricultural goods, in the European Union can and has to play an important role in reaching those goals is also undisputed. It is also undisputed that neither the current agricultural mode of production nor the current consumption patterns are consistent with the goals of the Green Deal and require an adaptation in both areas. It is also clear that the respective modifications in production and consumption can only be achieved within an appropriate common European agricultural framework. However, the question remains how such an agricultural framework may look like. This study has delivered important insights and results with regard to this matter, all of which may be summarised as follows:

A. **The F2F Strategy itself does not yet correspond to a consistent agricultural policy strategy**: Individual F2F measures do rather correspond to specific production restrictions which are not yet providing a consistent agricultural policy framework designed to achieve an effective and efficient implementation of the Green Deal's goals in agriculture. The unsolved key issues are:

    1. **Leakage Effects**: One of the main weaknesses of the F2F Strategy is that it is not yet effective to reduce climate change. One major factor corresponds to leakage effects with regard to GHG emissions. In general, leakage effects can be avoided when an internationally coordinated climate policy is implemented within an international governance structure. However, since the establishment of an international climate policy is a difficult undertaking unlikely to deliver results in the foreseeable future, the agricultural adaptation to the Green Deal goals should include second best options in order to minimise leakage effects. Said options can include but are not limited to: (a) promoting technological progress in order to increase and secure a sustainable production within the agricultural sector, (b) promoting technological progress in the processing and consumption of agricultural commodities (reduction of *food waste*) as well as (c) trade policy interventions in order to avoid shifts of production into non-EU countries.
    2. **Inclusion of the LULUCF-Sector**: Another reason for the limited climate-efficacy of the F2F Strategy are the induced land-use changes, which amount to 48% of the compensation of the F2F induced reduction of GHG-emissions in agriculture, making them an important factor together with leakage effects. In contrast to controlling leakage effects, controlling LULUCF effects in the EU is relatively easy to achieve through respective regulatory measures. In addition to that, proven incentives for land-use change, such as reforestation or rewetting of moors, can be used as an effective measure to control the LULUCF effects within European agriculture.
    3. **Minimising adjustment costs**: The imposed actions stated by the F2F Strategy are to be considered ad hoc and not validated by a scientific foundation with regard to the type of intervention as well as their scale. In general, the agricultural measures taken should be goal oriented. With regard to the F2F Strategy, the political restriction of the maximum N-balance as well as GHG-emissions seems reasonable, as those directly target the respective ecosystem services provided by agriculture. In contrast to that, restricting agricultural production to specific technologies without any evidence-based foundations that these technologies contribute effectively and efficiently to achieving the set goals of the Green Deal, appear rather ineffective. A good case in

point is the extension of organic farming to 25%. This holds especially true if agricultural policy measures are available that provide direct incentives to farmers to produce relevant ecosystem services. For example, this is the case with regard to nitrogen, phosphorus and potassium nutrient cycles as well as GHG-emissions. However, it is more difficult for biodiversity. In this regard, further research is definitely needed to identify adequate indicators and incentive schemes that allow an effective and efficient public management of biodiversity.

4. **Socially just distribution of adjustment costs**: The effective implementation of the Green Deal goals requires a considerable collective effort of the entire European society. Thus, it is of the utmost importance that all cornerstones of the F2F Strategy are collectively implemented by all member states. Furthermore, it is also important to realise a fair distribution of costs and benefits resulting from the implementation of the Green Deal goals among the European member states and their individual regions as well as among the relevant socio-economic groups, namely farmers and consumers. The latter includes a fair distribution of cost and benefits between farmers, i.e. animal and crop producers, and lastly among the consumers as well, i.e. between households of different socio-economic statuses and income.

B. **Smart and innovative governance mechanisms are required**:

1. The effective and efficient implementation of the Green Deal goals does not only require the use of disruptive technology in agricultural production, but rather innovative and smart governance mechanisms which combine the flexibility and incentive compatibility of market mechanisms with the planning security of regulative policy interventions.
2. Furthermore, these effective governance mechanisms should allow a flexible adaption of regional and temporal distribution of the costs and benefits to changing framework conditions, such as technological progress or changing international trade flows.
3. In this context, tradable allowances (emissions trading systems), as they have already been established for CO2-emissions in the non-agricultural sector, present a promising tool and could also be developed for the effective and efficient monitoring of other ecosystem-services such as the N-balance or even biodiversity. In addition to that, allowances trading systems allow a flexible and transparent division of the costs to provide each individual ecosystem-service between farmers and consumers as well as between the individual social groups among farmers and consumers.