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Assessing the Socioeconomic Impact and Uncertainties of Cleaner Production Practices: An Analysis of the European Agricultural Sector

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Abstract

The socioeconomic effects of introducing cleaner production practices or other structural changes in industries can be analysed by integrating the structural changes identified from life-cycle analysis or other means into economywide models. The analysis results allow for identifying impacts in a broader context and, therefore, a better assessment of their impact on society. This is particularly relevant in the case of new cleaner production practices and emerging technologies. However, there are considerable uncertainties in such cases, as not all technologies have reached sufficient maturity. On the other hand, especially in the case of disruptive innovations, the changes may reflect a significant transformation of the industries (e.g. the complete abandonment of fossil fuels in some industries implies a shift not only in the energy sources but also in the technologies used). Since technology development goes hand in hand with anticipating its socioeconomic impact, it makes sense to approach the issue from the opposite angle, identifying the desired directions of change in the structure of industries. This paper analyses agriculture in the European Union using the economywide general equilibrium model CleanProdEU and sensitivity and uncertainty analysis software SimLab. The simulation of scenarios of change in the structure of agriculture allows for identifying changes in the structure of agriculture that would contribute to growth in gross domestic product, employment growth and emissions reduction. As these objectives are contradictory in some scenarios, the multi-criteria analysis summarises the results in different impact areas. The results point to a reduction in the consumption of petroleum, energy and chemical products and an increase in the role of labour, construction and the retail trade as areas to be pursued for agricultural transformation.

Keywords: socioeconomic impacts, cleaner production, structural change, economic model, agriculture

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1. Introduction

The introduction of cleaner production processes and other transformations in different economic activities is essential to reduce production's environmental impact and achieve decarbonisation objectives. However, this poses serious challenges, as not all the solutions needed for the transition from conventional to more advanced production exist and are mature enough to be deployed in real market conditions. On the other hand, the positive economic or environmental impact of a solution or technology in one company does not necessarily translate into positive effects at the whole economy level. The introduction of abatement solutions in one sector of the economy may require increased production in other, more polluting industries, where abatement solutions are more difficult to introduce, and thus a negative net effect is generated. Therefore, the impact of cleaner production solutions needs to be seen in the context of the whole economy, considering cross-sectoral linkages and feedback effects.

The agriculture is unique in the context of cleaner production because of a combination of several factors. Agriculture is one of the most significant sources of greenhouse gas emissions: in 2020, agriculture accounted for 13.78% of total greenhouse gas emissions in the European Union, behind only industry as a whole (22%), households (20.48%) and energy (19.42%) (Eurostat, 2022a). While the energy sector has rather well-described decarbonisation pathways, the agricultural transition seems more uncertain, because of changing consumer preferences and, presumably, the implementation of behaviour change measures, climate change, which is having a particularly strong impact on agriculture due to the high dependence of traditional activities on weather conditions. Sudden changes such as the Covid19 pandemic also affect agriculture in many ways (Beckman & Countryman, 2021). Finally, existing solutions such as biotechnology are already leading to profound structural changes in agriculture (Balmann, Dautzenberg, Happe, & Kellermann, 2006). In this context, a narrow definition of structural change that focuses on farm size and similar factors (Goddard, Weersink, Chen, & Turvey, 1993) is not appropriate, as changes in agriculture can be more transformative. On the other hand, it is important to ensure that productivity growth in agriculture is not only environmentally friendly (Staniszewski, Guth, & Smędzik-Ambroży, 2023) but also meets other sustainability criteria.

To assess the socioeconomic and other effects of cleaner production in agriculture and other economic activities, a specific modelling framework has been developed, including a detailed representation of production processes and practices using life cycle analysis tools and an economywide model built in a bottom-up spirit. This framework allows for the detailed mapping of cleaner production practices in an economywide model and then analysing their impact in a broader context. Such analysis provides valuable information for selecting the alternatives that bring the most benefits to society but requires detailed information on changes in the economic activity under consideration. In a context of deep uncertainty, where the characteristics of new technologies or processes are not yet known with certainty, such an assessment is complicated by sensitivity to input parameters. Still, a prior analysis of possible structural changes in industries can provide valuable information on the socioeconomic acceptability of emerging technologies and processes for both decision-makers and technology developers.

In this paper, we approach the assessment of the socioeconomic effects of cleaner production from a different perspective. Instead of modelling cleaner production practices and integrating their characteristics into a general equilibrium model CleanProdEU, we assume that structural change can occur in a wide range of areas and that the directions of breakthroughs are not well defined. We, therefore, use sensitivity and uncertainty analysis, which, in combination with general equilibrium modelling, allows us to identify desirable directions for structural change in agriculture.

The rest of the paper is structured as follows: the second section presents the methodology and data sources used in the study, the third section designs scenarios for uncertain structural change in agriculture, the fourth section presents the results of the simulations, and the paper ends with a conclusion section.

2. Methodology and data sources

The research flow is illustrated in Figure 1, which shows the main steps: generation of the factors of the cost structure of agriculture to be analysed, generation of cases for Monte Carlo analysis, general equilibrium modelling, and sensitivity and uncertainty analyses. The cases (randomly generated sets of different agricultural cost structures) are integrated into the general equilibrium model ClenProdEU and equilibrium effects are calculated. The indicators selected for further analysis are gross domestic product as a key economic indicator and an integrated indicator covering gross domestic product, employment and greenhouse gas emissions. This integrated indicator is considered to reflect the three dimensions of sustainability (economic, social and environmental). The final stage of the analysis assesses the impact of the factors of structural change in agriculture on the values of these two indicators, thus identifying the directions to be pursued in terms of changes in the structure of agriculture.

The initial stage of the analysis is the selection of the sensitivity and uncertainty analysis factors and the structure of the cases to be analysed. This phase identifies the areas of structural change to be analysed (which changes in resource use in agriculture will be further examined) and defines the conceptual framework for structural change. A structural change in agriculture resulting from cleaner production processes can be seen, for example, as a reduction in the consumption of fossil fuel products, which in practice goes hand in hand with other changes that also affect intermediate consumption or the demand for production factors. From a methodological point of view, it is also important to define how efficiency gains are distributed within agriculture, which is an essential component of the conceptual framework for structural change, as initial assumptions about the distribution of additional income or costs can have an important impact on the new equilibrium state.

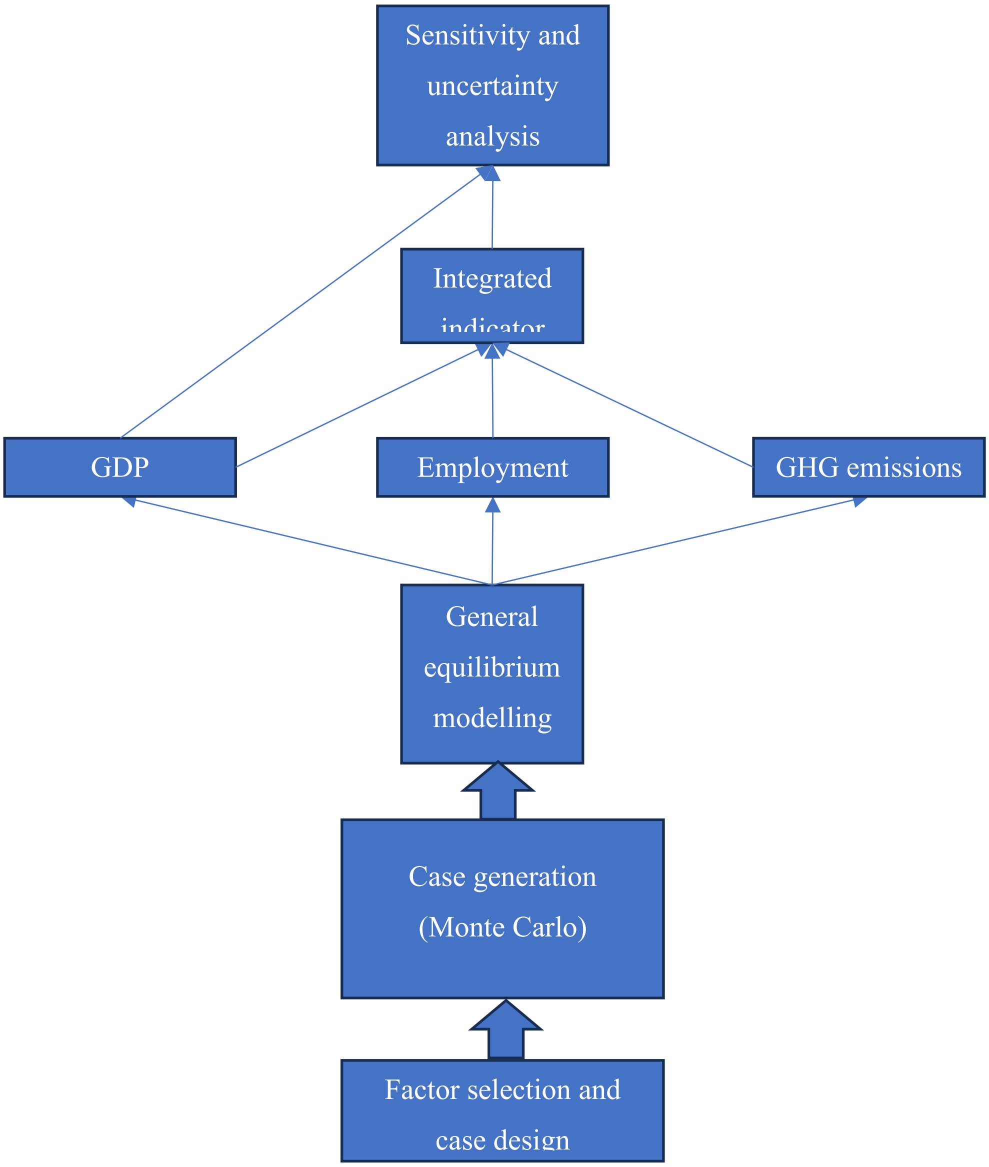


Fig 1. Research flow

The structure of the model itself was used to define the factors. In the CleanProdEU model, agriculture is represented through 63 intermediate consumption commodities, labour and capital, taxes on production and products and imports for intermediate consumption. Each of these elements can be seen as a potential factor for change in the cost structure of agriculture. In this study, the factors to be included in the simulations were selected on the basis of (a) the share of intermediate consumption products in total intermediate consumption; and (b) the potential for different product groups to play a greater/lesser role in agricultural consumption. In addition, labour as an important factor of production and imported resources used in agricultural intermediate consumption were included in the list of factors to be modelled.

Another issue directly related to the definition of the scenarios is the choice of assumptions for the Monte Carlo simulation. In this study, the values of the increase or decrease in each of the factors considered were directly generated. It should be noted that when analysing changes in the structure of a branch of the economy, it makes sense to take the current level into account and to assume that the possible decreases or increases depend on it. While this would provide a realistic picture of evolutionary development, it does not represent breakthrough innovation, where one or other area undergoes a radical change. In keeping with the balanced approach, it has been decided to frame the analysis cases in terms of visible but moderate changes, with an absolute value of up to 2% of the total value of intermediate consumption for each factor. This means that changes in the cost structure are independent of the current consumption of one or other product in agriculture, which may not seem realistic for some products, but the qualitative selection of the factors to be modelled serves as a screening function for some of them.

Endogenous equilibrium modelling is used to find the new equilibrium state of the economy after the implementation of structural changes in agriculture, and the difference between the general equilibrium before and after the changes in the structure of agriculture is considered as the net effect. For the general equilibrium modelling in this study, we use the European Union's general economic equilibrium model ClenProdEU. The model is specifically designed to assess the socio-economic effects of cleaner production practices and therefore allows for a detailed representation of changes in the structure of industries. Although the model consists of 63 commodities, the analysis of cleaner production practices includes the possibility to disaggregate existing industries and to analyse the components of interest in more detail. On the other hand, the bottom-up nature of the model means that it retains a reflection of physical relations, which is often lacking in models focused exclusively on economic linkages. Unlike some other general equilibrium models, CleanProdEU assumes the possibility of unemployment. Unemployment is modelled by integrating the empirical relationship established by (Blanchflower & Oswald, 1995, 2005). and is therefore well suited for analysing the employment effects of cleaner production practices.

The main data sources for the general equilibrium modelling and assumptions are the FIGARO (Eurostat, 2021; Remond-Tiedrez & Rueda-Cantuche, 2019) database 2022 edition (Eurostat, 2022b) and Eurostat's datasets on non-financial transactions (Eurostat, 2022c)), which have been combined to create the social accounting matrix of the CleanProdEU model. The final version of the SAM used in the simulations presented in this article is available online (Lekavičius, 2023).

Depending on the values of the factors, the results are different for different case executions, which is why the sensitivity analysis examines the impact of changes in the values of the factors on the gross domestic product and on the integrated indicator, which is calculated by normalising and integrating the individual components with equal weighting.

SimLab 2.2.1 software (EU Science Hub, 2022; Saltelli, Tarantola, Campolongo, & Ratto, 2004) is used for both the factor generation and the sensitivity and uncertainty analysis of the results.

3. Cases Design

The list of factors included in the simulations is given in Table 1. As mentioned above, the selection of factors first identified which commodities account for the largest share of agricultural consumption (inclusion criterion: 2% of the total value of intermediate consumption). In addition, commodities seen as potentially involved in agricultural transformation were included, as well as labour and imports used in intermediate consumption.

Table 1. Factors included into analysis

Factor	**CPA code/short name**	**Total output share**
Products of agriculture, hunting and related services	CPA_A01	0.1282
Mining and quarrying	CPA_B	0.0015
Food, beverages and tobacco products	CPA_C10T12	0.1074
Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	CPA_C16	0.0024
Coke and refined petroleum products	CPA_C19	0.0149
Chemicals and chemical products	CPA_C20	0.0333
Computer, electronic and optical products	CPA_C26	0.0001
Machinery and equipment n.e.c.	CPA_C28	0.0045
Repair and installation services of machinery and equipment	CPA_C33	0.0162
Electricity, gas, steam and air conditioning	CPA_D35	0.0165
Constructions and construction works	CPA_F	0.0101
Wholesale trade services, except of motor vehicles and motorcycles	CPA_G46	0.0548
Retail trade services, except of motor vehicles and motorcycles	CPA_G47	0.0218
Land transport services and transport services via pipelines	CPA_H49	0.0107
Financial services, except insurance and pension funding	CPA_K64	0.0129
Architectural and engineering services; technical testing and analysis services	CPA_M71	0.0024
Scientific research and development services	CPA_M72	0.0001
Advertising and market research services	CPA_M73	0.0007
Other professional, scientific and technical services and veterinary services	CPA_M74_75	0.0130
Employment services	CPA_N78	0.0092
Labour	LAB	0.1174

Another methodological choice concerned the distribution of efficiency gains. If the introduction of cleaner production practices leads to more efficient production, there is the potential for higher profits at company level. At the level of the whole economy, the possible cases range from proportionate increases in profits to a full distribution of benefits to consumers. The impact of these types of choices on the final result was assessed in the preparatory calculations. Having found a rather strong correlation between the results of the calculations based on the different methodological alternatives, it was decided to base the design of the cases presented in this paper on the assumption that only changes in the factors affect the structure of agriculture in the model.

4. Results

For the factors discussed in the previous section, 100 random values corresponding to the uniform distribution were generated, their combinations were integrated into the ClenProdEU general equilibrium model and new equilibrium states were found. In the simulations carried out, depending on the combination of factors, the impact on the real GDP of the European Union varies between EUR -12.5 and +11 billion. The employment effects fall in the range between -833 and 900 thousand jobs. In the overall context, the higher variation obtained was largely due to the fact that agricultural employment was treated as one of the uncertainty factors. The impact on greenhouse gas emissions, without taking into account the potential direct emission reductions in agriculture, which would depend on the specific solution, ranges between -14.1 and +14.2 million tonnes of CO_2 equivalent. The probability distributions for these indicators, as well as for the integrated indicator, are shown in Figure 2.

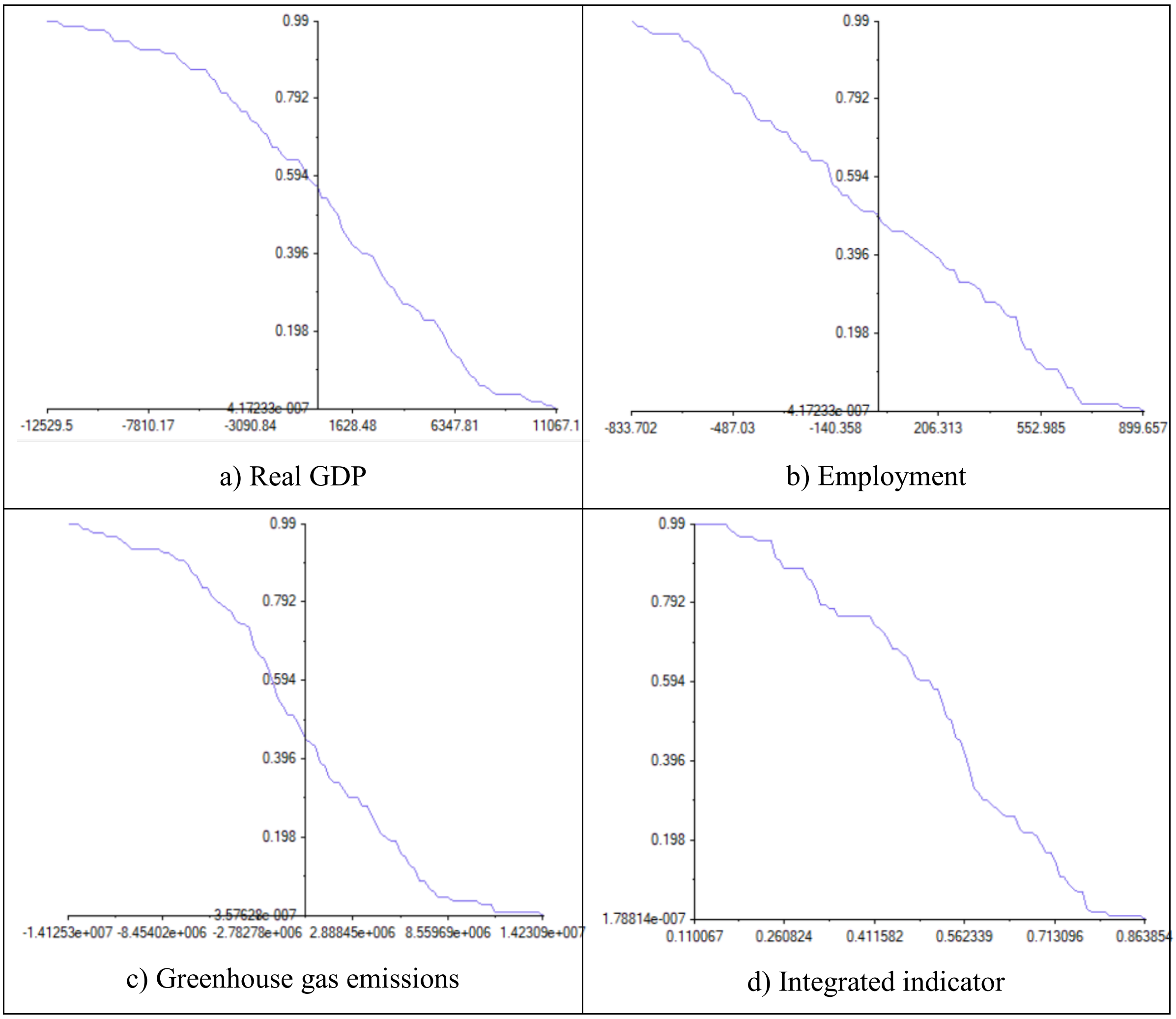
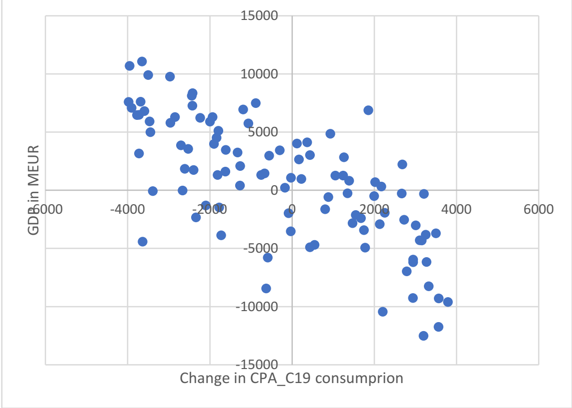


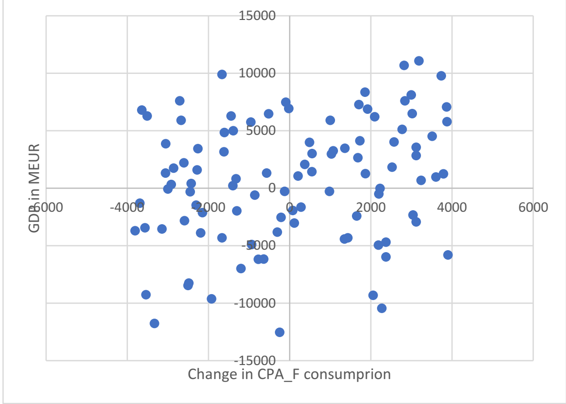
Figure 2. Uncertainty in results due to changes in the values of the factors analysed

In the graphs, the y-axis represents the probability and the x-axis the values of the indicators. As mentioned, depending on the combination of factors, the potential effects of structural change can be both positive and negative. On the contrary, the integrated indicator has been calculated by normalising the values of the individual indicators and should therefore theoretically fall in the range 0 to 1. In the simulations carried out, the integrated indicator falls in the range 0.11 to 0.86, as there was not a single case in the set of 100 executions in which the scenario had maximum or minimum estimates in all three categories.

The factors examined had different influences on the uncertainties presented. Figure 3 provides illustrative breakdowns showing the relationship between gross domestic product and the values of the factors.



a) Coke and refined petroleum products



b) Constructions and construction works

Figure 3. Scatterplots of relationship between the changes in consumption of selected products in agriculture and GDP

As can be seen from part (a) of the figure, there is clear correlation between the consumption of petroleum products in agriculture and the GDP, suggesting that this factor has a significant impact on the value of GDP: decreasing consumption of petroleum products in agriculture leads to the GDP increase. By contrast, in the case of constructions and construction works (part (b) in the Figure 2), the dispersion of values is much broader, although some positive relationship can be seen, suggesting that the impact of this factor on GDP is not as strong in the context of factor set analysed. A similar analysis of all the factors can also be used to predict the trends in structural change in agriculture to be pursued.

Table 2 shows the Spearman rank correlation coefficients of the factors analysed with GDP and the integrated index. A positive correlation indicates that higher values of GDP and/or the integrated indicator are achieved when the factor increases in value, while a negative correlation indicates an inverse relationship.

Table 2. Spirmen rank correlation coefficients between GDP, integrated index, and factors analysed

	GDP	**Integrated indicator**
Products of agriculture, hunting and related services	-0.046	-0.227
Mining and quarrying	-0.020	-0.242
Food, beverages and tobacco products	0.133	-0.136
Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	0.048	-0.030
Coke and refined petroleum products	-0.731	-0.546
Chemicals and chemical products	-0.124	-0.276
Machinery and equipment n.e.c.	-0.003	-0.153
Repair and installation services of machinery and equipment	0.021	-0.088
Electricity, gas, steam and air conditioning	-0.151	-0.458
Constructions and construction works	0.231	0.157
Wholesale trade services, except of motor vehicles and motorcycles	0.212	0.027
Retail trade services, except of motor vehicles and motorcycles	0.279	0.124
Land transport services and transport services via pipelines	0.166	0.097
Financial services, except insurance and pension funding	0.114	-0.024
Architectural and engineering services; technical testing and analysis services	0.126	0.043
Scientific research and development services	0.109	-0.064
Advertising and market research services	-0.046	-0.122
Other professional, scientific and technical services and veterinary services	0.069	-0.120
Employment services	0.165	0.018
Labour	0.471	0.715

As can be seen from the table, for GDP, the highest negative correlation is recorded with the consumption of petroleum products (-0.731), while the highest positive correlation is observed for agricultural employment. The latter result is partly due to the specification of the model used, as empirical studies have modelled that rising real wages reduce the unemployment rate, so that equilibrium effects have not eliminated the direct impact on the labour market of an increase in agricultural employment. Other structural developments that are positively correlated with GDP include increased consumption of trade services and construction in agriculture. Energy and chemicals consumption have a negative impact on GDP.

Looking at sustainability impacts using an integrated indicator covering economic, social and environmental aspects shows broadly similar trends. The integrated assessment reinforces the importance of the value added directly generated by agricultural work, so that the correlation with the integrated indicator is even higher. On the other hand, as in the case of GDP, the consumption of petroleum products shows the highest negative correlation with the integrated indicator, as well as a strong negative correlation with the consumption of energy and chemical products (the negative correlation with GDP is reinforced by the negative environmental impact). It should also be noted that efforts should be made to increase the efficiency of the use of agriculture, mining products and equipment when looking at the integrated sustainability impact.

5. Conclusions

The study shows that the desired trends in agricultural structural change are fairly well aligned with current policy objectives. Priority areas for cleaner production processes in agriculture include reducing the use of petroleum, energy and chemical products and increasing the role of labour, construction and retail. This reflects to a large extent the transformation of agriculture towards more environmentally friendly farms that are closer to local communities. A sensitivity analysis focusing on the impact on GDP shows that this trend is also consistent with the objectives of economic growth.

References

Balmann, A., Dautzenberg, K., Happe, K., & Kellermann, K. (2006). On the Dynamics of Structural Change in Agriculture:Internalc Frictions, Policy Threats and Vertical Integration. *Outlook on Agriculture,* *35*(2), 115-121. doi:10.5367/000000006777641543

Beckman, J., & Countryman, A. M. (2021). The Importance of Agriculture in the Economy: Impacts from COVID -19. *American Journal of Agricultural Economics, 103*(5), 1595-1611. doi:10.1111/ajae.12212

Blanchflower, D. G., & Oswald, A. J. (1995). An Introduction to the Wage Curve. *The Journal of Economic Perspectives,* *9*(3). Retrieved from http://dspace.stir.ac.uk/bitstream/1893/10329/1/Blanchflower_1995_An_Introduction_to_the_Wage_Curve.pdf

Blanchflower, D. G., & Oswald, A. J. (2005). *The Wage Curve Reloaded*. Retrieved from http://ftp.iza.org/dp1665.pdf

EU Science Hub. (2022). SIMLAB and other software. Retrieved from https://joint-research-centre.ec.europa.eu/sensitivity-analysis-samo/simlab-and-other-software_en

Eurostat. (2021). *FIGARO methodology*. Retrieved from https://ec.europa.eu/eurostat/documents/51957/12767369/Figaro-methodology.pdf

Eurostat. (2022a). *Air emissions accounts by NACE Rev. 2 activity [ENV_AC_AINAH_R2__custom_6269433].*

Eurostat. (2022b). *ESA supply, use and input-output tables - Eurostat*. CSV matrix format (FIGARO 2022 edition) - Annual EU inter-country input-output tables product by product 2020. Retrieved from: https://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/data/database

Eurostat. (2022c). *Non-financial transactions - annual data*. Retrieved from: https://ec.europa.eu/eurostat/web/products-datasets/-/nasa_10_nf_tr

Goddard, E., Weersink, A., Chen, K., & Turvey, C. G. (1993). Economics of Structural Change in Agriculture. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 41*(4), 475-489. doi:https://doi.org/10.1111/j.1744-7976.1993.tb03772.x

Lekavičius, V. (2023). *EU27 social accounting matrix for 2020*. Retrieved from: https://doi.org/10.5281/zenodo.8004481

Remond-Tiedrez, I., & Rueda-Cantuche, J. M. (Eds.). (2019). *European Union inter-country supply, use and input-output tables — Full international and global accounts for* *research in input-output analysis (FIGARO)* Luxembourg: Publications Office of the European Union.

Saltelli, A., Tarantola, S., Campolongo, F., & Ratto, M. (2004). *Sensitivity Analysis in Practice: A Guide to Assessing Scientific Models*: John Wiley & Sons Ltd.

Staniszewski, J., Guth, M., & Smędzik-Ambroży, K. (2023). Structural conditions of the sustainable intensification of agriculture in the regions of the European Union. *Journal of Cleaner Production, 389*. doi:10.1016/j.jclepro.2023.136109