Received: 19 May 2021 | Revised: 13 July 2021 | Accepted: 30 July 2021

DOI: 10.1002/bse.2879

RESEARCH ARTICLE

Business Strategy and the Environment WILEY

The sustainability prism of structural changes in the European Union agricultural system: The nexus between production, employment and energy emissions

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Funding information
European Social Fund, Grant/Award Number: 09.3.3-LMT-K-712-01-0007

Abstract

Over the recent decades, the evolution of the European Union (EU) agricultural system has resulted in significant structural changes in member states. Knowledge about the nature and main patterns of structural change is critical to select a sustainable development path for the EU agriculture. This paper contributes to the academic discourse on structural changes in agriculture demonstrating the nexus between socio-economic and environmental aspects of development. In this regard, results are important to understand the contribution of the EU agriculture to climate change, because study deals with energy use and greenhouse gas emissions. The research covers period from 2008 to 2018 and investigates the fundamental structural change measures, namely, gross value added, labour and agriculture-related energy emissions, in EU member states. Structural changes are investigated applying a shift-share analysis that allows calculating a performance of individual member states, compared to the EU economy. The applied shift-share model investigates the situation of individual member states employing three components. The first component tracks the development of the selected measures with the EU economy growth, the second component shows the change due to effect of economic activities and the third shows competitiveness of agriculture in member states. The shift-share analysis empowers ranking member states in accordance with their progress towards the sustainable development. Findings suggest that EU economy faces the outflow of labour from agriculture and this trend is common for most countries. The changes of gross value added and emissions for fuel combustion demonstrate both upward and downward trends. However, research results suggest that new member states often face more fundamental changes.

KEYWORDS
environmental pressures, European Union, GHG emission, shift-share approach

Abbreviations: EEA, European Environment Agency; EU, European Union; GDP, gross domestic product; GHG, greenhouse gas; GVA, gross value added; NACE, Statistical Classification of Economic Activities in the European Community (Nomenclature statistique des Activités économiques dans la Communauté Européenne).

1 | INTRODUCTION

During recent decades, the European Union (EU) agricultural system had survived dramatic structural changes that led to the emergence of numerous academic studies investigating different aspects of change. A considerable amount of academic research focuses on the role of agriculture and forestry in sustainable development and investigates important energy-related issues. For example, Arabatzis and Malesios (2013), Deen (2017), Kolovos et al. (2011), Kyriakopoulos et al. (2010a, 2010b), Procentese et al. (2019) and Usmani (2020) investigate biofuel potential-related issues in forestry or agriculture and challenges of the switch to renewable energy, while Dauber and Miyake (2016) focus on strategies that show the nexus between food, energy crops and biodiversity issues. The sustainability assessment of other economic sectors is also important due to the recent initiatives on combating the climate change and improving resilience (Turturean et al., 2019).

Indeed, handling the agricultural system in studies on structural change leads to the two main research directions. The first group of academics has a particular interest in structural changes of the economic system, while agriculture is treated as a component of this system. The second research niche has a specific focus on multiple aspects of changes in agricultural systems and contributes to the understanding of the structural change phenomenon.

The methodological research frameworks of the aforementioned academic studies strongly depend on the research object and vary in terms of their sophistication level. A considerable amount of studies on structural change applies different structural change indices (Bessonov, 2002; Brakman et al., 2013; Dietrich, 2012; Lilien, 1982; Pannell & Schmidt, 2006; Wolff, 2002), index decomposition analysis (Chang & Lahr, 2016; Hatzigeorgiou et al., 2010; Junsong & Canfei, 2009; Wier, 1998), input–output analysis frameworks (Bruckner et al., 2019; Ciobanu et al., 2004; Pattnaik & Shah, 2015; Stadler et al., 2018; Zhang & Diao, 2020) that often support general and partial equilibrium analysis, the shift-share analysis (Bielik & Rajčániová, 2008; Lv et al., 2021; Nengli et al., 2009; Tłuczak, 2016; Xia et al., 2011) and so on.

This paper contributes to the academic discourse on structural change in agricultural systems employing the results of the shift-share analysis in order to get a better understanding of sustainable development trends in the EU agriculture. Since the shift-share analysis framework introduction by Dunn (1960), this method is widely applied to investigate structural changes. Examples of the shift-share application include Herath et al. (2013) who investigate changes in employment with dynamic spatial model and Mayor et al. (2007) who employ a dynamic shift-share framework and ARIMA model to forecast the development of regional employment. Andersson and Lindmark (2008) investigate labour productivity, Bielik and Rajčániová (2008) use the shift-share framework to study the driving forces that determine the employment growth, Artige and van Neuss (2014) create a shift-share framework that allows separating two effects and employ a new method to investigate employment, while Brox and Carvalho (2008) include different cohorts of age and sex in traditional shift-share model to understand the nature of structural changes.

Indeed, the application of the shift-share analysis is not limited by the social dimension of sustainability. For example, Otsuka (2016, 2017) uses the dynamic shift-share analysis in order to explore determinants of change in energy demand. O'Leary and Webber (2015) employ the shift-share specification to analyse the link between the productivity growth and structural changes, Lv et al. (2021) focus on gross domestic product and investigate changes in rural economy applying the shift-share analysis, Tłuczak (2016) uses the shift-share approach to understand changes in the structure of agricultural production, Le Gallo and Kamarianakis (2011) employ the shift-share framework and space–time econometric models to study regional productivity, while Liu and Yao (1999) apply this method to investigate the economic growth. Cieślak et al. (2019) create a multicriteria framework and use the shift-share analysis to investigate changes in the sustainable development. It should be noted that Bielik and Rajčániová (2008), Lv et al. (2021), Nengli et al. (2009), Tłuczak (2016) and Xia et al. (2011) apply this method with a specific focus that allows monitoring the development patterns of agricultural systems.

The studies by Loveridge and Selting (1998) and Brox and Carvalho (2008) address main criticism of this method and recognize benefits that encourage academic society to use the shift-share frameworks and introduce further developments and modifications. The shift-share analysis is attractive for the investigation of regional structural changes, because it allows investigating the evolution of the selected measures decomposing the actual change into three components. These components empower the benchmarking of the real situation with possible developments that apply growth rates of the investigated system, its structural and local components.

The inclusion of the environment-related variables in the analysis is yet another important avenue for the research. For instance, Chen, Fan, et al. (2020), Chen, Gao, et al. (2020) and Wang et al. (2019) considered the carbon emission as the result of economic activity and energy consumption. Kwakwa and Adusah-Poku (2020) considered carbon emission stemming from the financial and manufacturing activities. The increasing use of the renewables may reduce the carbon emission (Tkachuk et al., 2019). Therefore, including the environmental pressures in the analysis provides valuable information for guiding the development of an economic sector.

This study employs the shift-share analysis framework and the decoupling concept to investigate structural changes covering three dimensions of sustainability. The results show changes in gross value added (GVA), employment and greenhouse gas (GHG) emissions from fuel combustion in agriculture, forestry and fishing economic activity over the period 2008–2018. Furthermore, the study uses the results of the shift-share analysis for clustering in order to combine the growth rates of three structural change measures and identify the main structural change patterns in the EU.

This paper is organized as follows. Section 2 provides detailed information on data and methodological developments. Section 3 introduces the main findings of the shift-share analysis for GVA, employment and GHG emissions from fuel combustion over the investigated period. Furthermore, this section is supplemented by decoupling and clustering outcomes that allow making the overall assessment of the main development patterns in the investigated economic activity. Discussion in Section 4 considers the nexus of the main findings with the previous research results. Finally, the concluding remarks are provided in Section 5.

2 | DATA AND METHODOLOGICAL RESEARCH FRAMEWORK

2.1 | Research data

Structural change is a complex phenomenon that supports the emergence of studies with multiple research objects and questions. To describe structural changes, academics refer to transformations of economic systems with a specific focus on changes of the total size and structure of the economic activities, the reallocation of resources. Lankauskienė and Tvaronavičienė (2013) provide a long list of indicators that could be employed to investigate structural changes. However, value added and employment-related measures (van Neuss, 2019) are introduced in the dominant share of the studies as appropriate measures of structural change, because they cover key aspects of socio-economic dimension of sustainability. The review of the main sectoral transition models that investigate structural changes relying on employment and gross domestic product is provided by Pannell and Schmidt (2006).

From the environmental point of view, an important measure of structural change is GHG emissions. This undesirable output component is linked to the efficiency of agriculture (Moutinho et al., 2018). On the other hand, the environmental concerns often link energy consumption and climate mitigation issues. For this reason, the study selects a narrower structural change measure, namely, GHG emissions from fuel combustion, as an important structural change measure allowing to monitor a progress towards more sustainable agricultural systems. Indeed, these emissions are energy related and account for only part of GHG emissions in the EU agriculture.

This study investigates structural changes in the EU agricultural system from 2008 to 2018. The main EU enlargement had finished before the investigated period. Thus, the number of countries stabilized and accounted for 28 member states. The conducted research relies on Eurostat and European Environment Agency (EEA) data. As EEA data on GHG emissions are collected based on sectoral approach required by United Nations Framework Convention on Climate Change reporting guidelines, some discrepancies could be noticed benchmarking EEA activities falling within agriculture, forestry and fishery economic activity, compared to Eurostat NACE Rev. 2 breakdown into economic activities. Although this research limitation should be considered, EEA data are a reliable source that could assist in mapping the main development trends over the investigated period.

Another research limitation is related to the nature of GVA. Eurostat provides data in current values; however, EU member states have faced different inflation rates over the investigated period. This study conducts the shift-share analysis converting current prices into real terms indicator by applying Eurostat implicit deflators (2015 = 100) for agriculture, forestry and fishing economic activity and the EU economy. This procedure influences the final outcome and growth rates of GVA in member states.

2.2 | Methodological developments

The study adopts the basic static three-component shift-share analysis framework proposed by Dunn (1960), also discussed by Herath et al. (2013). The logic of the applied method suggests that the actual growth rate of the structural change measure in the particular location could be decomposed into three individual components, namely, the growth rate of the investigated system, the growth rate of the main structural elements of this system and the growth rate of the local subelements that determine the growth rate of the structural elements and the entire system. The aforementioned relationship could be employed to investigate structural changes in the EU economic system and expressed as follows:

$$GR_{ij} = GR + (GR_i - GR) + \left(GR_{ij} - GR_i\right), \tag{1}$$

where GR_{ij} refers to the actual growth rate of the investigated structural change measure in ith economic activity of the jth member state, GR denotes the growth rate of the EU economic system, while GR_i shows the growth rate for the ith economic activity of the EU economic system. Although Equation 1 introduces the main research logic, this study focuses on the evolution of one economic activity; accordingly, the symbol i refers to agriculture, forestry and fishing economic activity. Furthermore, it is important to note that Equation 1 is employed to calculate the growth rates for GVA, employment and GHG emissions from fuel combustion individually.

The decomposition of the growth rate into three components allows introducing the corresponding breakdown of the actual change into three useful indicators (also referred as effects) empowering the benchmarking of the actual structural change with different growth rate assumptions. Equation 2 describes the nexus between the actual change and main effects:

$$\Delta CM_{ij} = GR_{ij} \times CM_{ij,b} = CM_{ij,e} - CM_{ij,b} = EU_{ij} + EA_{ij} + MS_{ij}, \tag{2}$$

where ΔCM_{ij} denotes the actual change of the investigated structural change measure in ith economic activity of the jth member state over the selected period, while b and e refer to the base and end years of the period, respectively. EU_{ij} shows the EU economy growth effect for the ith economic activity of the jth member state, that is, the change at the rate of the EU economy. EA_{ij} denotes economic activity mix effect for the ith economic activity of the jth member state, that is, ($GR_i - GR$) growth rate shows negative or positive impact of member state specialization in individual economic activities that could exceed or stay below the growth rate of the EU economy. MS_{ij} refers to the member state effect for the ith economic activity of the jth member state and demonstrates the degree of the possible change in member state calculating the $(GR_{ij} - GR_i)$ growth rate that shows the development dynamics taking into consideration the economic system of the individual member state and the shifts in the structure of economic activities. As in the case of Equation 1, Equation 2 is calculated for GVA, employment and GHG emissions from fuel combustion individually.

Based on the aforementioned equations, the calculation of the main effects is carried out applying the following formulas:

$$EU_{ij} = CM_{ij,b} \times GR = CM_{ij,b} \times \left(\frac{CM_e - CM_b}{CM_b}\right), \tag{3}$$

$$EA_{ij} = CM_{ij,b} \times (GR_i - GR) = CM_{ij,b} \times \left(\frac{CM_{i,e} - CM_{i,b}}{CM_{i,b}} - \frac{CM_e - CM_b}{CM_b}\right), \tag{4}$$

$$MS_{ij} = CM_{ij,b} \times \left(GR_{ij} - GR_i\right) = CM_{ij,b} \times \left(\frac{CM_{ij,e} - CM_{ij,b}}{CM_{ij,b}} - \frac{CM_{i,e} - CM_{i,b}}{CM_{i,b}}\right), \tag{5}$$

where CM denotes the investigated structural change measure at the level of the EU economy, CM_i means the investigated structural change measure for the selected ith economic activity.

The shift-share results are complemented by decoupling results. Tapio (2005) advocates applying the decoupling framework in order to demonstrate the degree of coupling or decoupling between the investigated variables. This study employs decoupling framework to investigate the link between GVA and another structural change measures, namely, employment and GHG emissions from fuel combustion. GVA elasticity of employment (E_L) is calculated as follows:

$$E_L = \frac{\frac{(L_e - L_b)}{L_b}}{\frac{(GVA_e - GVA_b)}{GVA_b}} = \frac{\frac{\Delta L}{L_b}}{\frac{\Delta GVA}{GVA_b}}, \tag{6}$$

where L refers to the employment (labour force).

GVA elasticity of GHG emissions from fuel combustion (E_{EFC}) is calculated applying the formula:

$$E_{EFC} = \frac{\frac{(EFC_e - EFC_b)}{EFC_b}}{\frac{(GVA_e - GVA_b)}{GVA_b}} = \frac{\frac{\Delta EFC}{EFC_b}}{\frac{\Delta GVA}{GVA_b}}, \tag{7}$$

where EFC denotes energy-related GHG emission (i.e., those rendered by fuel combustion).

The economic interpretation of elasticity results depends on GVA change direction. According the decoupling framework used by Tapio (2005), the positive change in ΔGVA over the period could result in strong decoupling (elasticity < 0), weak decoupling (elasticity $\in$ [0, 0.8]), expansive coupling (elasticity $\in$ [0.8, 1.2]), expansive negative decoupling (elasticity > 1.2), while the negative change in ΔGVA could lead to strong negative decoupling (elasticity < 0), weak negative decoupling (elasticity $\in$ [0, 0.8]), recessive coupling (elasticity $\in$ [0.8, 1.2]) and recessive decoupling (elasticity > 1.2). Results will contribute to the shift-share analysis explaining the link between GVA growth and transformations of social and environmental dimensions.

This study calculates the actual change and main effects for GVA, employment and GHG emissions from fuel combustion individually. Thus, results empower the analysis of main effects and their positions, compared to the actual change, along one measure. The shift-share framework does not allow making a conclusion concerning main development trends on the basis of the combined assessment of three investigated structural change measures, while elasticity gives some important insights. In order to identify main development trends for agriculture, forestry and fishing economic activity within the EU, the hierarchical cluster analysis is employed to find homogeneous groups of member states with similar evolution patterns. The clustering relies on the growth rate applied to calculate the actual change, namely, GR_{ij}, because the measure of the actual change could lead to misleading conclusions due to differences in scales of national economies and their contribution to the EU economy.

Hierarchical cluster analysis is carried out applying IBM SPSS Statistics 22 software. This study employs centroid clustering applying squared Euclidean distance for standardized growth rates of GVA, employment and GHG emissions from fuel combustion. The number of clusters was set using agglomeration schedule coefficients and the dendrogram linkages. It is important to note that clustering results strongly depend on the selected methods and data standardization. For this reason, the study provides additional data description for each cluster in order to inform on the relevance of the further possible splits within the identified homogenous groups.

3 | RESULTS

3.1 | The shift-share analysis results by member states

Results of the shift-share analysis for GVA, employment and GHG emissions from fuel combustion are provided in Tables 1 and 2. During the period from 2008 to 2018, Belgium, Bulgaria, Germany, Estonia, Croatia, Cyprus, Luxemburg, Hungary and Poland had demonstrated the decline in GVA in real terms for agriculture, forestry and fishing economic activity. The comparison of EU_{ij} values with the actual change of GVA shows that only in 12 member states the EU economy growth effect is lower than the actual change rate, while in the dominant share of countries, the actual growth rate of GVA in agriculture, forestry and fishing economic activity has the slower pace than the growth rate of the EU economy.

Indeed, the comparison of effects EU_{ij} and EA_{ij} for GVA demonstrates the opposite development trends. In Table 1, all values of economic activity mix effect are negative. These results imply that the importance of agriculture, forestry and fishing economic activity in

TABLE 1 Results of the shift-share analysis for agriculture, forestry and fishing economic activity, 2008–2018

	GVA (million euro) (2015 = 100)				Employment (thousand persons)				GHG emissions for fuel combustion (thousand tonnes)			
Country	EU_{ij}	EA_{ij}	MS_{ij}	Actual change	EU_{ij}	EA_{ij}	MS_{ij}	Actual change	EU_{ij}	EA_{ij}	MS_{ij}	Actual change
BE	282.40	−186.57	−377.63	−281.81	2.55	−14.85	1.99	−10.30	−352.54	291.81	461.54	400.80
BG	255.79	−168.99	−359.49	−272.70	27.11	−157.60	18.32	−112.17	−92.30	76.40	3.45	−12.45
CZ	348.32	−230.12	585.02	703.21	6.26	−36.39	25.59	−4.54	−225.56	186.70	7.78	−31.08
DK	229.33	−151.51	187.50	265.32	2.73	−15.85	10.28	−2.84	−369.92	306.19	−481.93	−545.66
DE	2718.88	−1796.29	−9436.53	−8513.95	24.18	−140.58	67.39	−49.00	−1082.05	895.63	358.41	171.98
EE	58.93	−38.94	−246.72	−226.72	0.92	−5.35	0.93	−3.50	−37.66	31.17	35.76	29.27
IE	194.50	−128.50	521.80	587.80	4.26	−24.78	12.27	−8.25	−185.69	153.70	−330.50	−362.49
GR	640.31	−423.04	847.45	1064.72	19.49	−113.28	71.00	−22.80	−489.92	405.51	−2154.55	−2238.96
ES	2845.17	−1879.73	4501.75	5467.20	30.22	−175.71	123.78	−21.70	−1897.40	1570.49	1302.43	975.53
FR	3428.39	−2265.05	1776.11	2939.45	29.33	−170.53	98.20	−43.00	−2230.02	1845.81	−758.55	−1142.76
HR	221.05	−146.04	−653.47	−578.46	8.36	−48.61	−83.29	−123.54	−147.46	122.05	−92.38	−117.79
IT	3560.79	−2352.52	−950.29	257.98	35.40	−205.81	146.41	−24.00	−1500.44	1241.93	79.44	−179.07
CY	43.73	−28.89	−79.16	−64.32	0.63	−3.65	0.83	−2.19	−15.38	12.73	−4.43	−7.08
LV	76.28	−50.40	69.29	95.17	2.93	−17.06	−0.48	−14.60	−67.63	55.98	114.59	102.94
LT	114.45	−75.61	−10.59	28.24	4.22	−24.52	4.28	−16.02	−42.13	34.87	−5.57	−12.83
LU	12.12	−8.01	−19.44	−15.33	0.15	−0.85	0.37	−0.34	−5.09	4.22	−3.40	−4.28
HU	558.16	−368.76	−717.14	−527.74	6.66	−38.72	41.89	9.83	−214.76	177.76	330.58	293.58
MT	7.47	−4.94	25.15	27.69	0.09	−0.55	0.43	−0.02	−3.39	2.80	0.08	−0.50
NL	1160.21	−766.52	849.10	1242.79	7.69	−44.72	29.03	−8.00	−1907.79	1579.09	−781.94	−1110.63
AT	435.99	−288.05	120.00	267.95	7.52	−43.75	−11.00	−47.22	−203.08	168.09	−165.59	−200.58
PL	1082.48	−715.17	−886.52	−519.20	80.84	−469.96	−240.08	−629.20	−2064.24	1708.59	1180.15	824.50
PT	382.24	−252.54	69.03	198.74	21.36	−124.18	−56.99	−159.81	−212.16	175.60	59.36	22.81
RO	744.07	−491.59	1568.71	1821.20	107.04	−622.28	−380.26	−895.50	−119.78	99.14	866.44	845.80
SI	83.94	−55.46	131.81	160.29	3.06	−17.80	4.72	−10.01	−47.24	39.10	−15.54	−23.68
SK	158.67	−104.83	720.10	773.94	3.01	−17.51	4.84	−9.66	−75.15	62.20	−42.36	−55.31
FI	433.54	−286.43	675.89	823.00	4.20	−24.39	−6.00	−26.20	−284.74	235.68	−228.44	−277.50
SE	624.23	−412.41	146.32	358.14	3.40	−19.77	24.87	8.50	−300.91	249.07	−385.42	−437.26
UK	1669.65	−1103.09	421.36	987.92	13.77	−80.07	97.25	30.95	−822.65	680.92	650.60	508.87

Source: Own calculations based on Eurostat statistics.

TABLE 2 Contributions of the main effects to the actual change of structural change measures in agriculture, forestry and fishing economic activity, 2008–2018

	GVA (%) (2015 = 100)				Employment (%)				GHG emissions for fuel combustion (%)			
Country	EU_{ij}	EA_{ij}	MS_{ij}	Actual change	EU_{ij}	EA_{ij}	MS_{ij}	Actual change	EU_{ij}	EA_{ij}	MS_{ij}	Actual change
BE	100.21	−66.20	−134.00	−100.00	24.76	−144.17	19.32	−100.00	−87.96	72.81	115.15	100.00
BG	93.80	−61.97	−131.83	−100.00	24.17	−140.50	16.33	−100.00	−741.37	613.65	27.71	−100.00
CZ	49.53	−32.72	83.19	100.00	137.89	−801.54	563.66	−100.00	−725.74	600.71	25.03	−100.00
DK	86.44	−57.10	70.67	100.00	96.13	−558.10	361.97	−100.00	−67.79	56.11	−88.32	−100.00
DE	31.93	−21.10	−110.84	−100.00	49.35	−286.90	137.53	−100.00	−629.17	520.78	208.40	100.00
EE	25.99	−17.18	−108.82	−100.00	26.29	−152.86	26.57	−100.00	−128.66	106.49	122.17	100.00
IE	33.09	−21.86	88.77	100.00	51.64	−300.36	148.73	−100.00	−51.23	42.40	−91.17	−100.00
GR	60.14	−39.73	79.59	100.00	85.48	−496.84	311.40	−100.00	−21.88	18.11	−96.23	−100.00
ES	52.04	−34.38	82.34	100.00	139.26	−809.72	570.41	−100.00	−194.50	160.99	133.51	100.00
FR	116.63	−77.06	60.42	100.00	68.21	−396.58	228.37	−100.00	−195.14	161.52	−66.38	−100.00
HR	38.21	−25.25	−112.97	−100.00	6.77	−39.35	−67.42	−100.00	−125.19	103.62	−78.43	−100.00
IT	1380.26	−911.90	−368.36	100.00	147.50	−857.54	610.04	−100.00	−837.91	693.54	44.36	−100.00
CY	67.99	−44.92	−123.07	−100.00	28.77	−166.67	37.90	−100.00	−217.23	179.80	−62.57	−100.00
LV	80.15	−52.96	72.81	100.00	20.07	−116.85	−3.29	−100.00	−65.70	54.38	111.32	100.00
LT	405.28	−267.74	−37.50	100.00	26.34	−153.06	26.72	−100.00	−328.37	271.78	−43.41	−100.00
LU	79.06	−52.25	−126.81	−100.00	44.12	−250.00	108.82	−100.00	−118.93	98.60	−79.44	−100.00
HU	105.76	−69.88	−135.89	−100.00	67.75	−393.90	426.14	100.00	−73.15	60.55	112.60	100.00
MT	26.98	−17.84	90.83	100.00	450.00	−2750.00	2150.00	−100.00	−678.00	560.00	16.00	−100.00
NL	93.36	−61.68	68.32	100.00	96.13	−559.00	362.88	−100.00	−171.78	142.18	−70.41	−100.00
AT	162.71	−107.50	44.78	100.00	15.93	−92.65	−23.30	−100.00	−101.25	83.80	−82.56	−100.00
PL	208.49	−137.74	−170.75	−100.00	12.85	−74.69	−38.16	−100.00	−250.36	207.23	143.14	100.00
PT	192.33	−127.07	34.73	100.00	13.37	−77.70	−35.66	−100.00	−930.12	769.84	260.24	100.00
RO	40.86	−26.99	86.14	100.00	11.95	−69.49	−42.46	−100.00	−14.16	11.72	102.44	100.00
SI	52.37	−34.60	82.23	100.00	30.57	−177.82	47.15	−100.00	−199.49	165.12	−65.63	−100.00
SK	20.50	−13.54	93.04	100.00	31.16	−181.26	50.10	−100.00	−135.87	112.46	−76.59	−100.00
FI	52.68	−34.80	82.13	100.00	16.03	−93.09	−22.90	−100.00	−102.61	84.93	−82.32	−100.00
SE	174.30	−115.15	40.86	100.00	40.00	−232.59	292.59	100.00	−68.82	56.96	−88.14	−100.00
UK	169.01	−111.66	42.65	100.00	44.49	−258.71	314.22	100.00	−161.66	133.81	127.85	100.00

Source: Own calculations based on Eurostat statistics.

the GVA structure of the EU is diminishing, while the growth rate of this economic activity at the EU level is lower than the growth rate of the EU economy. The values of member state effect MS_{ij} combine both positive and negative developments, while results differ significantly and depend on the national evolution of GVA.

During the period 2008–2018, the actual change of employment in agriculture, forestry and fishing economic activity demonstrates the decline in labour force in EU member states, with the exception of the upward trend in Hungary, Sweden and the United Kingdom. Although the EU economy growth rate suggests the increase in employment and results in positive EU_{ij} values, the negative values of the actual change support the conclusion on the ongoing migration of labour force to other economic activities. In fact, EA_{ij} values confirm this development trend as the economic activity mix effect-related growth rate is negative. According to results, the dominant share of EU countries demonstrates the positive development of member state effects, but in reality, gaps between the actual changes and MS_{ij} values are dramatic.

In 2018, actual changes in GHG emissions for fuel combustion allow identifying only 10 countries showing unfavourable upward trend in comparison with 2008, namely, Belgium, Germany, Estonia, Spain, Latvia, Hungary, Poland, Portugal, Romania and the United Kingdom. Although the dominant share of the EU member states reduced GHG emissions from fuel combustion in agriculture, forestry and fishing economic activity, only Denmark, Ireland, Greece and Sweden demonstrate the performance at the higher rate than the EU economy. In this context, the comparison of EU_{ij} and EA_{ij} values implies that the entire EU economy succeeded in reduction of GHG emissions from fuel combustion, while the economic activity mix effects show unfavourable progress in agriculture, forestry and fishing economic activity. Member state effects depend on the country and balance both positive and negative development trends.

In Table 2, the absolute change over the investigated period is treated as an equivalent of 100.0%, while converted effects show the decomposed percentage contributions that determine the actual change. This transformation of shift-share results demonstrates the leading contributions of the main effects to the actual change of GVA, employment and GHG emissions from fuel combustion in member states.

3.2 | Elasticities and decoupling results by member states

Figure 1 shows calculated E_L and E_{EFC} values in member states. Countries demonstrate different combinations for two types of elasticity values in terms of the development directions and gaps between elasticity values. For example, the gap between the elasticity values in Czech Republic, Malta and Slovakia are minor, while the alteration of elasticity values in Poland and Romania is dramatic.

The classification of member states in accordance with the decoupling theoretical framework is provided in Table 3. Results suggest that elasticity values in a remarkable share of countries have a strong decoupling, that is, the positive change in GVA is accompanied

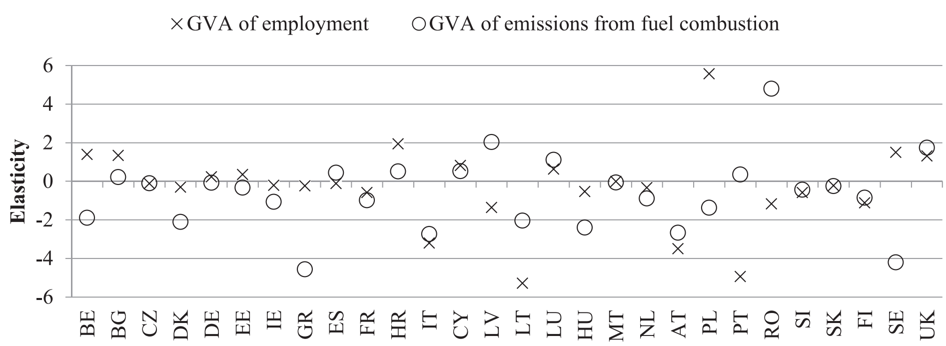

FIGURE 1 GVA elasticity of employment and GVA elasticity of emissions from fuel combustion, 2008–2018. Source: own calculation based on Eurostat statistics

TABLE 3 Decoupling of employment and GHG emissions for fuel combustion from GVA in the EU member states

		Strong decoupling (elasticity < 0)	Weak decoupling (elasticity ∈ [0, 0.8])	Expansive coupling (elasticity ∈ [0.8, 1.2])	Expansive negative decoupling (elasticity > 1.2)
$\Delta GVA > 0$	E_L	CZ, DK, IE, GR, ES, FR, IT, LV, LT, MT, NL, AT, PT, RO, SI, SK, FI	-	-	SE, UK
	E_{EFC}	CZ, DK, IE, GR, FR, IT, LT, MT, NL, AT, SI, SK, FI, SE	ES, PT	-	LV, RO, UK
		Strong negative decoupling (elasticity < 0)	**Weak negative decoupling (elasticity ∈ [0, 0.8])**	**Recessive coupling (elasticity ∈ [0.8, 1.2])**	**Recessive decoupling (elasticity > 1.2)**
$\Delta GVA < 0$	E_L	HU	DE, EE, LU	CY	BE, BG, HR, PL
	E_{EFC}	BE, DE, EE, HU, PL	BG, HR, CY	LU	-

Source: Own elaboration.

by negative change of employment and GHG emissions from fuel combustion. In fact, Czech Republic, Denmark, Ireland, Greece, France, Italy, Lithuania, Malta, the Netherlands, Austria, Slovenia, Slovakia and Finland have similar development patterns for both elasticity values. The classification of Hungary as a country with strong negative decoupling and the United Kingdom as a country with expansive negative decoupling is also based on the results of two elasticity values. For other member states, the combinations of change in GVA and development patterns of E_L and E_{EFC} demonstrate stronger differences and countries combine different degrees of decoupling for two types of elasticity. Indeed, several countries have coupled changes in GVA and other measures of structural change.

To conclude, the shift-share results demonstrate significant and often undesirable structural changes in agriculture, forestry and fishing economic activity over the period from 2008 to 2018. In member states, development patterns of the selected structural change measures differ remarkably. This study applies hierarchical cluster analysis in order to generalize findings and take into account three structural change measures.

3.3 | Clustering by GVA, employment and GHG emissions from fuel combustion actual growth rates

Agglomeration schedule coefficients and the dendrogram linkages assist in identifying eight clusters that include member states with different patterns of growth rates for GVA, employment and GHG emissions from fuel combustion. The selected clustering includes even four clusters covering only one member state with dramatic differences in development trends, compared to other member states. According to alternative clustering outcomes that reduced the total number of clusters, the aggregation of these groups results in clusters with the higher range of variation between minimal and maximum values and hides groups with important individual development trends.

Cluster 1 includes Belgium, Bulgaria, Cyprus, Latvia, Lithuania, Luxemburg, Austria, Poland, Portugal and Finland (Figure 2). This cluster is characterized by the low average negative growth rate of GVA (−0.8%) and GHG emissions from fuel combustion (−1.0%), while the average growth rate of employment accounts for −18.6%. According to the results, the main characteristics of this group are related to negative socio-economic development patterns, particularly the remarkable outflow of labour force from agriculture, forestry and fishing economic activity, while the positive contribution to environmental dimension is negligible.

Although academic research provides the evidence that the Common Agricultural Policy hinders the exit of agricultural labour force (Olper et al., 2014; Tocco et al., 2013), the situation in Cluster 1 demonstrates that some EU member states experience steep decrease in employment. Indeed, the unfavourable agricultural employment situation could be driven by a combination of different factors, such as differences in agricultural market and production structure, the agricultural support model, on-farm income level and ageing situation in agriculture during the investigated period. However, Cluster 1 has a relatively high gap between minimum and maximum values, and the dendrogram suggests that it could be further subdivided into meaningful smaller clusters.

Cluster 2 covers Czech Republic, Denmark, Spain, France, Italy, the Netherlands, Slovenia, Sweden and the United Kingdom. Characteristic features of this group are the stronger average growth rate of GVA (12.1%), the moderate negative average growth rate of employment (−1.7%) and the higher negative average growth rate of GHG emissions from fuel combustion (−7.2%), compared to Cluster 1. In fact, this group of member states has a remarkable positive progress in economic and environmental dimensions, while the negative developments in social dimension is negligible, compared to the situation in Cluster 1.

According to Parajuli et al. (2019), the economic development is led by a switch from income and employment concerns to environmental issues and its regulation. The environmental situation has exacerbated due to replacement of horses by tractors, use of herbicides, switch from manure to mineral fertilizers (Bentsen et al., 2019), growth of energy demand for livestock facilities (ventilation, lighting, heating, etc.), greenhouses and irrigation (Harchaoui & Chatzimpiros, 2018). Harchaoui and Chatzimpiros (2018) argue that the distinct feature of the preindustrial agriculture was self-fuelling

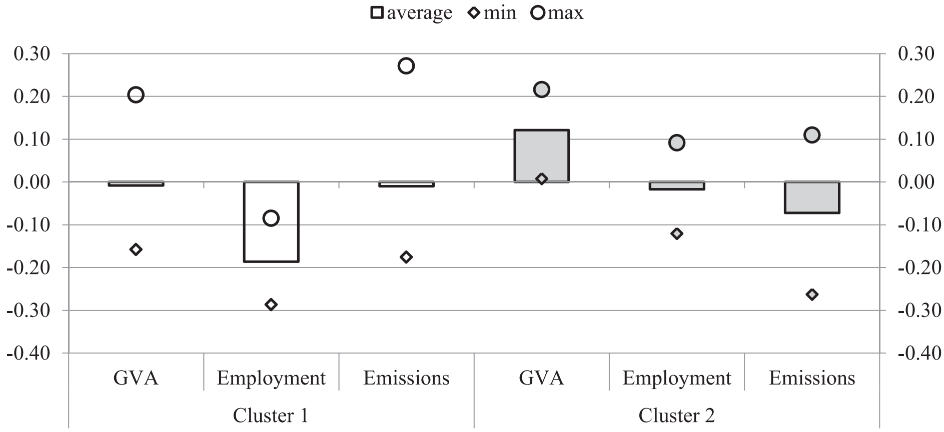

FIGURE 2 Distribution of actual growth rates in Clusters 1 and 2. *Source:* own elaboration

that resulted in energy neutrality, while the progress implied the demand for external energy inputs. Nowadays, the future of agriculture is linked to the concepts of energy neutrality and circularity, energy mix diversification and introduction and dissemination of good practices that allow to reduce GHG emissions from fuel combustion in the EU agriculture. Thus, Cluster 2 covers member states that have managed to decouple GVA growth from GHG emissions from fuel combustion. Bentsen et al. (2019) show the importance of national regulation and strategic goals in this context, while Parajuli et al. (2019) argue that the nexus between economic growth and pollution becomes the issue of concern only when countries accumulate the certain level of capital stocks. It is also worth noting that, starting from 2008, the progress towards the higher consumption of renewable energy in agriculture and forestry was observed in Czech Republic, Spain, France and the Netherlands.

Cluster 3 includes Germany and Estonia (Figure 3). This group has a remarkable negative average growth rate of GVA (−37.4%), compared to other identified clusters. Although both these countries demonstrate the growing GVA in current prices, the application of the implicit deflator introduces a remarkable gap between those results and GVA values in real terms. The average growth rate of employment is negative and accounts for −10.7%, while the growth rate of GHG emissions from fuel combustion amount to 8.3%. As a result, Cluster 3 demonstrates negative contributions to the sustainable development in agriculture, forestry and fishing economic activity.

As in many EU countries, the remarkable increase in the average farm size allows to attract capital and replace labour force by technology. However, the increase of GVA in current prices is led by higher level of GHG emissions from fuel combustion. Furthermore, energy mix diversification also faces challenges. Although Germany is the largest EU biogas producer (Stolarski et al., 2020), Thrän et al. (2020) argue that this market with good GHG emissions saving potential introduces undesired competition for land and could have a negative impact on ecosystems. In fact, this cluster needs further developments of policy measures and introduction of good practices in order to strengthen the decoupling of economic growth from GHG emissions from fuel combustion.

Cluster 4 is represented by Ireland, Malta and Slovakia. These countries demonstrate the most remarkable average growth rate of GVA (41.5%), the moderate negative average growth of employment (−6.6%) and a remarkable negative average growth of GHG emissions from fuel combustion (−16.8%). In fact, Cluster 4 shows the similar development patterns as Cluster 2, but the growth rates are significantly higher, while the range of growth rates' variation is lower. Kijek et al. (2020) classify these countries as member states with high or medium agricultural development level. Our results imply that economic growth is not resulting in the corresponding growth of employment and GHG emissions from fuel combustion.

The remaining clusters include only one member state with strong differences in development patterns, compared to the aforementioned clusters (Figure 4). *Cluster 5* is represented by Greece. The corresponding growth rates of GVA, employment and GHG emissions from fuel combustion account for 17.8%, −4.3% and −81.4%, respectively. Although the development directions of Greece are similar to Clusters 2 and 4, the main feature of this country is related to the extremely high progress in reduction of GHG emissions from fuel combustion.

The study by Vardopoulos et al. (2018) demonstrates that the highest contribution to GHG emissions in Greece comes from agricultural machinery use that shows a downward trend, while another important element is the use of fertilizers. During the investigated period, the share of consumption of renewable energy, compared to the total consumption in agriculture and forestry, increased remarkably. Multiple academic studies show that GHG emissions from fuel combustion could be reduced replacing fuel by other types of energy (Foteinis & Chatzisymeon, 2016) or changing farming and management practices (Gkisakis et al., 2020; Michos et al., 2012).

Cluster 6 includes Croatia. Compared to other clusters, Croatia has the most dramatic negative growth rate of employment (−54.4%) combined with the remarkable negative growth rate of GVA (−28.1%) and GHG emissions from fuel combustion (−14.2%). Although the development directions of Cluster 6 are similar to Cluster 1, Croatia experiences more dramatic structural changes. In fact, this country demonstrates a positive contribution to climate change mitigation on the account of the negative socio-economic structural changes. The

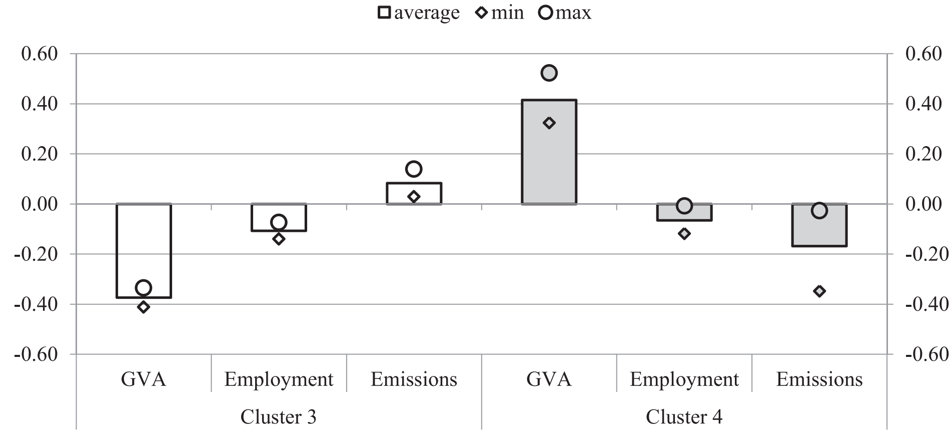

FIGURE 3 Distribution of actual growth rates in Cluster 3 and 4. *Source:* own elaboration

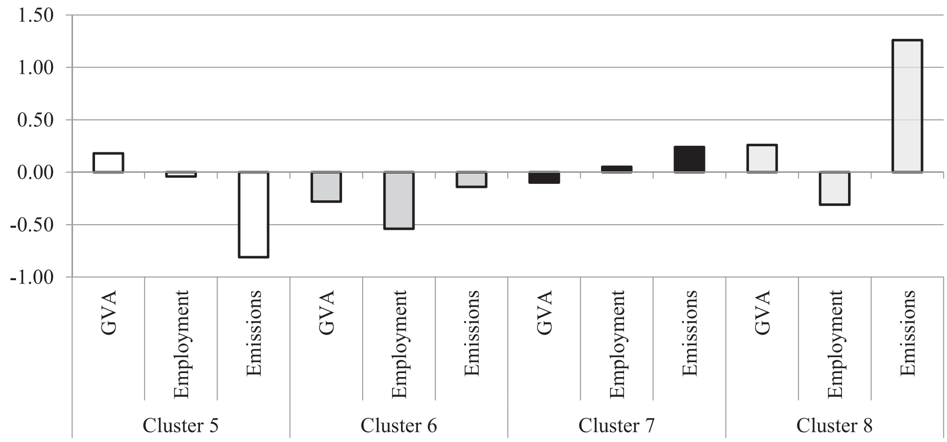

FIGURE 4 Distribution of actual growth rates in Clusters 5, 6, 7 and 8. *Source:* own elaboration

study by Kijek et al. (2020) underlines that Croatia was the last country that joined the EU and classifies this member state as a country with the low level of agricultural development. Indeed, the decrease in employment and low productivity patterns go in lines with the situation that had been observed in many countries that joined the EU after 2003.

Cluster 7 is represented by Hungary. The corresponding growth rates of GVA, employment and GHG emissions from fuel combustion amount to −10.1%, 5.4% and 24.3%, respectively. Thus, results suggest the negative development trends of economic and environmental dimensions combined with the moderate positive progress in the social dimension. The post accession period in Hungarian agriculture shows increase in growth of GHG emissions form fuel combustion. This finding corresponds to the study by Gołasa et al. (2021) that shows the growing role of gas and diesel oil consumption in the structure of energy consumption in Hungarian agriculture. Nevertheless, academic research (Goyal & Sivanappan, 2017) demonstrates the great potential of renewable energy increase in the future.

Cluster 8 covers Romania. This country has an impressive growth rate of GHG emissions from fuel combustion (125.7%) that results in the strong negative contribution to the climate change mitigation in agriculture, forestry and fishing economic activity. The growth rate of GVA is estimated at 26.2%, while the growth rate of employment amounts to −30.8%. As a result, Romania demonstrates a growth of GVA on the account of negative patterns in social and environmental dimensions.

Burja and Burja (2016) explain the situation by post-accession economic growth on commercial agricultural holdings that resulted in remarkable increase in total farm output. According to aforementioned study, during this period, the output growth was accompanied by dramatic increase in use of fertilizers and crop protection products as well as energy. Indeed, Burja et al. (2020) argue that a highly fragmented structure of the Romanian agriculture is not compatible with the European model. Thus, the further structural changes that support the movement towards the more competitive farm structure will result in labour replacement by technologies, while the main features of technical endowment could have an impact on sustainability.

4 | DISCUSSION

Results of this study are in line with the previous academic research reporting on the diminishing role of agriculture in the structure of economy (Bah, 2011; Brakman et al., 2013; Pannell & Schmidt, 2006; van Neuss, 2019). In case of employment, the growth rate of agriculture, forestry and fishing economic activity is negative and tends to create a significant unfavourable gap between growth rates of the EU economy and this economic activity. Findings suggest that most of the EU member states face labour force reallocation within national economic systems. In fact, the most recent data used for this study confirm that the process of labour outflow from agriculture which has started several centuries ago is not complete. Compared to the mostly negative development patterns of employment, a remarkable share of countries demonstrates the positive change in GVA over the investigated period. However, results for GVA growth rates strongly depend on inflation which often reduces the growth rate during the period from 2008 to 2018. The development patterns are country-specific rather than reflex the overall trend. Although GVA shows the upward trend, the pace of change of the EU economy is higher than the development of the economic activity.

The shift-share analysis shows the decrease in GHG emissions from fuel combustion in the dominant share of member states, whereas the findings suggest that agriculture, fishery and forestry economic activity implements reduction of GHG emissions on a remarkably slower pace than the EU economy. According to West and Marland (2002), the shifts in agricultural practices and irrigation systems, changes in machinery, production of fertilizers, pesticides and seed contribute to the changes in emissions from fuels in agriculture. Indeed, the historical legacy of member states and structural changes on farms may result in significant differences in GHG emissions from fuel combustion. Common fuel mixes in national agriculture, the nexus between energy efficiency and emission-related issues of machinery in use, excessive fuel consumption due to the differences in agricultural practices and the use of fertilizers could be mentioned among important factors explaining variations of national GHG emissions from fuel combustion. In this context, the Common Agricultural Policy becomes an important tool facilitating the shift towards more sustainable paths of development and spread of efficient, low-carbon technologies and agricultural practices in member states. These measures contribute to the European Green Deal action plan. However, according to Moutinho et al. (2018), the Common Agricultural Policy has stronger effect on the energy efficiency in new member states.

It is widely recognized that the decoupling of GDP growth from resource use and emissions is important to meet the global climate change and sustainable development challenges. According to Klinger and Weber (2020), the evidence of Germany shows that the decoupling of GDP and employment depends on the structural changes of economic system and the growing importance of service sector. Nevertheless, the decoupling of GVA growth from labour force in agriculture, where the share of employment in the structure of economy used to have a historically important role, has both negative and positive aftermaths. On the one hand, COVID-19 crisis has highlighted the vulnerability of the large-scale EU agriculture and the overreliance on the cheap migrant labour force. The lockdown and free movement restrictions encouraged to invest in innovations allowing to reduce dependence on labour force or replace it by new technologies. On the other hand, the sudden outflow of labour force has dramatic consequences on structural changes in agricultural system of the EU and the current Common Agricultural Policy support measures that deal with human resources in agriculture in order to govern dramatic negative changes in the social dimension.

The knowledge about the nexus between economic growth and GHG emissions is critical for climate change mitigation. Thus, this topic has attracted researchers around the world. For example, Haberl et al. (2020) provide a comprehensive review of the most recent academic research on decoupling issues and introduce a list of studies that confirm the relevance of different degrees of decoupling investigating the link between gross domestic product and emissions from fuel combustion. This study contributes to the aforementioned academic discourse providing the most recent E_{EFC} values. Findings suggest that the main share of member states has strong positive decoupling of the change in two measures and a positive progress towards more sustainable agricultural systems, because the growth of GVA does not result in the corresponding increase in GHG emissions. However, elasticity values and clustering results demonstrate significant differences in development patterns and progress towards more sustainable agricultural systems in member states.

Results of the hierarchical cluster analysis support findings by Bah (2011) who recognizes that structural change scenarios in agriculture depend on the country's development level. Member states with differences in historical background and the duration of the membership in the EU often demonstrate alternative development patterns. Examples of the most dramatic structural changes are Clusters 6, 7 and 8 that include post-transition countries with the later accession to the EU. Ciobanu et al. (2004) argue that Greece, represented by Cluster 5, also has faced serious socio-economic structural transformations after the accession to the EU.

According to Bański (2018), unfavourable agrarian structures with high level of land fragmentation have negative impact on the production efficiency. In most of the countries that had joined the EU in 2004 and later, dominant small farms became the important barrier towards the greater competitiveness of these countries. At the same time, open borders facilitate structural changes (van Neuss, 2019) in order to gain competitive advantages. Thus, remarkable growth rates of the investigated measures are often explained by the reaction of member states to the new business environment and support models, while, according to Błażejczyk-Majka et al. (2011), longer periods of relatively stable business conditions assist in the establishment of higher efficiency.

Another interesting point is that the dominant share of member states are covered by two main clusters. Cluster 1 includes even 10 countries and demonstrates serious outflow of labour force from the investigated economic activity in member states, while changes in GVA and GHG emissions from fuel consumption are negligible, compared to other clusters. Cluster 2 is represented by nine countries and demonstrates more balanced transition towards sustainable systems, that is, GVA growth is led by decrease in GHG emissions from fuel combustion, while the negative changes in employment are moderate. Findings highlight the diversity of structural change patterns in the EU and imply the importance of target policy measures corresponding to the specific challenges of the countries.

5 | CONCLUSIONS

The shift-share analysis implies that structural changes in agriculture which have started several centuries ago are not complete. The most recent data shows that the process of labour force outflow from agriculture remains a serious challenge, while the growth rate of GVA for agriculture, forestry and fishing economic activity is below the pace of change of the EU economy. Results also demonstrate a lower decline in GHG emissions from fuel combustion in agriculture, forestry and fishing economic activity, compared to the EU economy growth rate, and the corresponding challenges to benefit from climate change mitigation in this area.

Over the investigated period, the dominant share of member states demonstrate that the GVA growth is decoupled from the changes in employment and GHG emissions from fuel combustion. In case of employment, these results suggest that growing GVA does not contribute to higher employment in agriculture, forestry and fishing economic activity and social dimension needs special policy measures. On the other hand, the decoupling of GVA growth from the increase in GHG emissions for fuel combustion shows progress towards more sustainable agricultural systems.

Clustering demonstrates the diversity of structural change patterns in agriculture, forestry and fishing economic activity of member states and identifies eight groups with similar development trends and different contributions to sustainability. On the one hand, results show that the most dramatic changes are often typical for countries which joined the EU later (e.g., Croatia, Hungary and Romania). On the other hand, results do not allow making general conclusions concerning the pace of structural changes in member states judging on the criterion of accession as countries demonstrate individual development patterns and the largest Clusters 1–2 cover both EU-15 and EU-13 countries.

Results of this study suggest that the current direction of the Common Agricultural Policy development post 2020 assists in addressing the relevant challenges of the EU agriculture. Indeed, findings imply that member states vary significantly in terms of the problem's extent they face. The combined assessment of the shift-share analysis and clustering and the decoupling analysis allow identifying countries with negative development patterns and the undesired contribution to the establishment of sustainable systems. These results could be used to foster additional research clusters, covering target member states, in order to develop specific measures and disseminate strategies allowing to deal with challenges in homogeneous groups of countries.

ACKNOWLEDGEMENTS

This research has received funding from the European Social Fund (Project No. 09.3.3-LMT-K-712-01-0007) under a grant agreement with the Research Council of Lithuania (LMTLT). An earlier version of this paper has been presented at the 16th SDEWES conference.

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How to cite this article: Jurkėnaitė, N., Baležentis, T., & Štreimikienė, D. (2021). The sustainability prism of structural changes in the European Union agricultural system: The nexus between production, employment and energy emissions. *Business Strategy and the Environment*, 1–14. https://doi.org/10.1002/bse.2879