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RESEARCH ARTICLE

Contribution of the Common Agricultural Policy to agricultural productivity of EU regions during 2004–2012 period

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Abstract
The aim of this paper is to investigate the influence of Common Agricultural Policy (CAP) subsidies on agricultural (labour and total factor) productivity growth of EU regions during the period 2004–2012. The objective is to assess the impact of this policy on agricultural growth and competitiveness of regions, first in the aftermath of the fundamental reforms of the decoupling policy and second during the historic eastward enlargement of the EU, which deepened asymmetric spatial patterns and may have led to the CAP having a different spatial impact. The analysis uses an econometric approach based on an augmented Cobb-Douglas production function. The impact is proved to be mixed; positive when the *change* of subsidies with a 1-year lag is considered, which is related to farm strategies, and negative when the *level* of subsidies, which is based on reference data, is considered. In the case of the new member states, the effect is negative, confirming the CAP's incompatibility with the agricultural structures of the area.

Keywords Common Agricultural Policy · Subsidies · Agricultural productivity growth · EU regions

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Introduction

The Common Agricultural Policy (CAP) is a system of agricultural subsidies and programmes of vital importance that was established in 1957 and launched in 1962. It initially accounted for over 50% of the European Union (EU) budget, while nowadays, it has been reduced to about 38% (European Commission 2015a), which still makes this policy the EU's most expensive budgetary commitment (McCloud and Kumbhakar 2015). The CAP has undergone many adjustments[1] in an attempt to better achieve its five goals: to improve agricultural productivity, to ensure that EU farmers can make a reasonable living, to guarantee food security, to contribute to a sustainable environment, and to insure that rural areas remain attractive (European Commission 2012; De Boissieu 2007). The philosophy of CAP support has evolved over time; however, the improvement of agricultural productivity remains a major goal for the rural economic vitality. According to Brehon (2010), among the five original objectives, only one has retained its power: the growth of agricultural productivity and, its corollary, competitiveness.

A key question that has inevitably been widely raised is whether and to what degree the CAP has fulfilled its objective by contributing inter alia to higher productivity growth (Rizov et al. 2013; Zhu and Lansink 2010). In this respect, the effects of the CAP, and consequently the answer to the aforementioned question, appear to be ambiguous (Pokrivcak et al. 2008; Arovuori and Yrjölä 2015) since there are no outcomes that clearly indicate its positive contribution, with several studies having reached different conclusions showing influences that are positive (Kazukauskas et al. 2011), negative (Rizov et al. 2013; Zhu and Lansink 2010; Karagiannis and Sarris 2005; Iraizoz et al. 2005), or positive under certain conditions (Hennessy 1998; Ciaian and Swinnen 2006; Skuras et al. 2006). This 'conditional influence' of the CAP (that is, particular aspects having different impacts under specific conditions) is partly explained by the fact that the CAP, as a multi-functioning policy (Potter 2004), can be studied by several scientific fields and across different areas, spatial levels, or time periods, leading to different conclusions.

The CAP is, moreover, always under pressure from new developments and the changing hierarchies of issues (Roederer-Rynning 2010). The recent financial turmoil in Europe has also emphasised the role of access to capital and the possibility of credit rationing in agriculture throughout the EU (Pietola et al. 2011). Consequently, the continuous emergence of major challenges that the CAP should confront has emanated from economic, social, and environmental changes, as well as from enormous heterogeneities within the EU due to its eastward expansion. There is, therefore, a need for a re-evaluation of its role. The urgency of such an undertaking is also indicated by the

[1] In the 1980s CAP, spending was mainly on price support through market mechanisms (intervention and export subsidies), and due to this, agricultural surpluses were increased. This policy benefited large holdings (20% of agricultural holdings were taking 80% of the funds) and certain production specialisations (mainly field crops and grazing livestock farms), which led to low productivity levels and fail to exploit comparative advantages. Thus, the 1992 (MacSharry) CAP reform reduced the market price support and replaced it with producer support in the form of direct payments. Agenda 2000 introduced rural development policy as a second pillar. In the 2003, reform most direct payments were decoupled from current production as they were based on the farmer's historical receipts, while rural development expenditure continued to increase. The 2008 Health Check continued along the path of CAP reform, and further reduced market support (European Commission 2016a; Ezcurra et al. 2010).

deep crisis of confidence in the CAP and its need to acquire new legitimacy (Brehon 2010; Bureau 2010).

Based upon the above arguments, this paper aims to investigate the influence of CAP subsidies on the agricultural productivity growth of EU regions during the period 2004–2012. The goal is to assess the impact of the CAP on the agricultural growth and competitiveness of the regions, first in the aftermath of the fundamental reforms of the decoupling policy, which represented new objectives, strategies, and practices for the CAP, and second in the context of the historic eastward enlargement of the EU and the extension of the CAP to include new areas, which would deepen asymmetric spatial patterns and might lead to the CAP having a different spatial impact.

The significance of the first point comes from the fact that the decoupling policy reforms, especially those of 2003, introduced a radical rebuilding of the CAP with new measures aimed to reduce market distortions, improve market access, create more space for national manoeuvre, and generate greater benefits (OECD 2006), while consequently including new expectations regarding efficiency and competitiveness. Moreover, despite the fact that during the last two decades CAP subsidies have long been discussed in the literature, there is no clear evidence about their effectiveness (Dudu and Kristkova 2017), so the quantification of the CAP's impact is a crucial research topic. To be adequately disentangled and to evaluate the CAP's effects on efficiency, the analysis is performed at the regional (NUTSII) level, which allows for territorial specificities to be better taken into consideration.

The importance of the second point comes from the fact that the CAP being the largest component of the EU's expenditure, with the accession of Eastern European countries of particular importance in quantitative and qualitative terms due to the large number of new member states (NMS) (during the period under study, ten countries joined the EU in 2004 and two in 2007), their socioeconomic characteristics, and the historical legacies of socialism (Gorton et al. 2009). While the NMS found it difficult to adjust to the new regime, there was also an unwillingness of the old EU countries to adjust the CAP to the NMS' needs, thereby raising issues of a 'two-class EU' or a 'two-tier CAP'. The kind of challenges that the CAP faces and also the level of its effectiveness is therefore in question. For this reason, the analysis evaluates the contribution of the CAP to regional agricultural productivity for all of the EU regions, as well as separately in three sub-areas: the regions within the NMS, the regions within the EU's Mediterranean countries, and the regions within the EU10 (the EU15 minus the Mediterranean countries).

The remainder of this paper is organised as follows: Section 2 provides a literature review; Section 3 presents a general view of the regional distribution of CAP subsidies and explains the methodological issues; Section 4 describes the theoretical model; Section 5 specifies the econometric model and presents the empirical results; finally, Section 6 offers the conclusions.

Literature review

The CAP has experienced sequential reforms in attempts to improve its efficiency. The MacShary reform of 1992 made direct payments to farmers, which were intended to alter the CAP's pricing policy, which had mainly favoured large holdings and certain specialisation patterns (Ezcurra et al. 2010), and to correct for internal market imbalances, stabilise the budget, and meet the EU's World Trade Organization commitments (Gorton et al. 2009). In the next step, Agenda 2000 introduced a new rural development policy that was initiated as a second pillar of the CAP that aimed to help farmers to diversify, to improve their product marketing, and to otherwise restructure their businesses (European Commission 2011), while the first, and largest, pillar was directed at production support. The 2003 reform led to fundamental changes, first with a single payment scheme decoupled from production, with the goal of making farmers more market oriented, and second by strengthening rural development programmes towards the goal of raising quality standards and improving environmental sustainability.

Yet, despite these reforms, the CAP has been broadly criticised for its limited effectiveness and failure to achieve its goals. Although theoretical studies indicate that subsidies should increase productivity, whether by generating a selection process in which the less productive farms exit (Ciliberti and Frascarelli 2015), or by constituting an incentive to innovate or switch to new technologies, specific practical studies have thrown doubt on the role of subsidies due to the way they allow loss-making enterprises to continue, not incentivise cost-cutting, or prevent the reallocation of inputs towards more productive uses (Matthews 2013). Focusing on the post-2003 reform period, the contribution of the decoupled payment system (in which payments are no longer linked to production) is not given in all cases, even if it is believed to have helped to change farms' economic performance (Zhu and Lansink 2010; Kumbhakar and Lien 2010; Happe et al. 2008) and to have had a positive relation to productivity (Kazukauskas et al. 2011).

Various studies based on data envelopment analysis (DEA), stochastic frontier analysis (SFA), or production function analysis have thus reached both positive and negative assessments of the relation between subsidies and productivity change[2]. More analytically, a positive relation of subsidies to labour productivity has been found for the EU27 during 2004–2014 (Garrone et al. 2018), for Ireland, Denmark, and the Netherlands during 2002–2007 (Kazukauskas et al. 2011), and for Irish dairy farms during 2001–2007 (Kazukauskas and Newman 2010). A significant bulk of the bibliography comes to the conclusion, however, that there is a negative relation of subsidies to technical efficiency which is a component of total productivity factor (TFP) change. More specifically, this evidence derives from studies that analyse the dairy farms in Denmark, France, Germany, Ireland, Spain, the Netherlands, and the UK during 1990–2007 (Latruffe et al. 2011), organic farms in Denmark during 2002–2004 (Sauer and Park 2009), or organic milk farms in Germany during 1995–2006 (Lakner 2009). Other studies found weak or no evidence of any positive effect of subsidies on TFP (in dairy farms in Ireland during 2005–2006, Carroll et al. 2008), or reach conditional conclusions that is a positive relation of subsidies to productivity (subsidies are related positively to land productivity under the assumption of a credit constriction for the new EU member states during 2003–2005, Ciaian and Swinnen 2009).

Moreover, there is a considerable number of studies that reach mixed conclusions about the correlation of subsidies to productivity such as there being a negative influence of subsidies on the TFP, but a positive influence on the technical efficiency of grain farms in Norway during 1991–2006 (Kumbhakar and Lien 2010), a positive effect on technological

[2] The DEA and SFA methods decompose total factor productivity changes into the contributions of technical change, technical efficiency change, allocative efficiency change, and scale efficiency change.

efficiency change and a negative one on technological change for dairy farms in Ukraine during 2004–2005 (Nivievskyi 2009), and positive, negative, and insignificant effects on TFP across the countries of the EU15 during 1990–2008, with the effect made positive by improvements in the credit sector and negative or insignificant in cases of market imperfections or partial decoupling (Rizov et al. 2013). As both positive and negative impacts can be expected a priori, the actual impact of subsidies on performance is a topic for empirical investigation (Zhu and Lansink 2010).

This paper emphasises the contribution of the CAP subsidies to the productivity growth of the NMS due to the adjustments required from the accession countries as well as from the European agricultural policy, so that both meet their needs. For the NMS, the impact of subsidies on agricultural productivity has proven to be similarly ambiguous, as a limited number of studies reach different conclusions about the relation of subsidies to productivity, such as a negative relation of subsidies to technical efficiency in farms of Hungary during 2001–2005 (Bakucs et al. 2010) or a positive effect on the allocative efficiency, but a negative one on the technical and economic (overall) efficiency of farms in Slovenia during 2004–2006 (Bojnec and Latruffe 2013). The differences between the rural regions of the EU15 and the NMS of Central and Eastern Europe (CEE) are discernible, however, and thus the ability of the CAP to address the needs of the NMS is questionable (Gorton et al. 2009). Imperfections in land markets in the CEE countries were found to affect the distributional effects of these payments (Ciaian and Swinnen 2006). The transfers of the CAP to CEE are associated with a process of policy penetration leading to a poor match between the CAP and the real rural development needs of the NMS (Gorton et al. 2009).

CAP subsidies and agricultural productivity in the EU

This paper investigates the impact of CAP subsidies on the EU's regional agricultural productivity following the implementation of the decoupling policy, an issue that remains important for the improvement of the production and the competitiveness of agricultural activities, as well as for the design and effectiveness of agricultural policies. For the purpose of the analysis, Farm Accountancy Data Network (FADN) database is used. The FADN is an instrument for evaluating the income of agricultural holdings and the impact of the CAP on a microeconomic basis. Through harmonised principles, every year it collects data from a sample of agricultural holdings covering approximately 80,000 farms throughout the European Union. They represent a population of about 5,000,000 farms in the EU covering approximately 90% of the total utilised agricultural area (UAA) and account for about 90% of the total agricultural production (European Commission 2016b). Moreover, the FADN provides data at the regional administrative level, which coincides in most cases with the NUTSII level of European regions. The dataset includes data for the EU (administrative FADN) regions for 2004–2012. The two recent member countries (Bulgaria and Romania) are excluded from the dataset due to the lack of data, while Croatia became an EU member after the period under study. Subsidies are expressed in real values[3] and have been weighted by the area

[3] The variable was deflated to real values in 2005 prices using the index for goods and services currently consumed in agriculture (Petrick and Kloss 2012). All deflators are provided by Eurostat (2018).

(that is, divided by the total utilised agricultural area) in order to take into account the intensity of the financial aid associated with the size of the agricultural area in a region rather than its production.

Figure 1 displays the total subsidies, as well as the subsidies excluding those for investments (defined as those on current operations linked to production and not to investment), per utilised agricultural area for 2004–2012. Spatial differences between the two maps are slight and present in general a pattern of higher per hectare subsidies in regions of Finland, Greece, the Netherlands, Belgium, Austria, Slovenia, southern Germany, and of specific areas in Italy. On the contrary, subsidies have been at low levels in the CEE countries and in Spain. Farmers in the NMS received arguably lower direct payments (Kosior 2014) due to the phasing in of the direct payments from initially 25% of the level of the EU15, rising in increments of 5% per annum (Gorton et al. 2009).

The size of the subsidies should be analogous to their contribution to a region's growth and productivity improvements. Productivity is a fundamental source of a larger income stream (Bharati and Fulginiti 2008), while agricultural productivity determines the ability of physical elements and human capital to help create value (Burja 2012). Labour productivity is a better guide for short-term periods, while TFP is more useful for the analysis of long-run economic trends (Ezcurra et al. 2010). Both indicators are used in the present analysis in order to increase the robustness of the results. Labour productivity in agriculture is estimated by the ratio of output to labour in the sector. Output is defined as the real value of the total annual output and labour as the total full-time equivalent labour input measured by hours per year. TFP is the ratio of output to total production inputs. All variables have been extracted from the FADN database.

Labour and total factor productivity in FADN regions are depicted in Figs. 2 and 3 respectively, displaying similar trends. Particularly, high levels of (labour and total factor) productivity were present in the northern EU regions, and more specifically in regions of northern France, Belgium, the Netherlands, northern Germany, and southern Sweden. On the contrary, especially low levels of productivity were displayed in all regions of Greece, Latvia, and Lithuania, and in large parts of Portugal, Hungary, and Italy. The spatial distribution of agricultural productivity growth, since it is the outcome

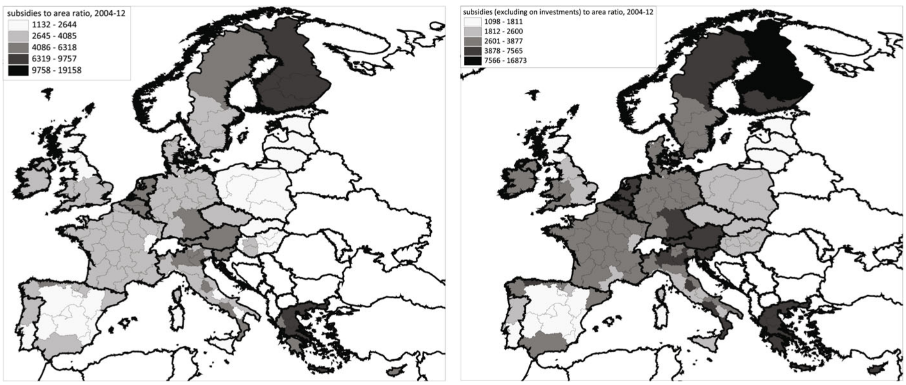

Fig. 1 Total subsidies per area ratio (€/ha) (left) and subsidies excluding on investments per area ratio (€/ha) (right) in the EU FADN regions for the period 2004–2012. FADN is the Farm Accountancy Data Network of European Union. Source: Authors' elaboration from FADN (2016)

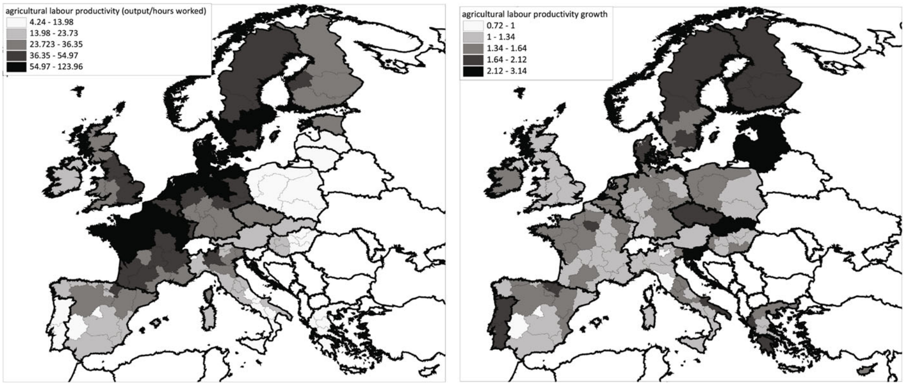

Fig. 2 The level of labour productivity (2012) (left) and the growth of labour productivity (2004–2012) (right) in agriculture in the EU FADN regions. FADN is the Farm Accountancy Data Network of European Union. Source: Authors' elaboration from FADN (2016)

of various types of adjustment processes, is likely to be uneven (Ezcurra et al. 2010), yet the spatial heterogeneity and the north-south divide in productivity among the EU regions is clear, thereby drawing speculation about the influence of European policies on regional cohesion.

The pattern of (labour and total factor) productivity growth for 2004–2012 was quite different from that of productivity levels (Figs. 2 and 3) as the regions that displayed higher productivity changes were those with mainly low productivity levels. Thus, regions of Eastern Europe (the Baltics, Slovakia, and Slovenia), as well as of Portugal and Greece, that belong to low productivity areas had significant productivity gains. Regions of Sweden constitute an exception as they displayed high productivity levels and high productivity growth.

Finally, it is important to ascertain whether regions of initially higher agricultural productivity levels received greater amounts of CAP subsidies during 2004–2012 as this could eventually play a significant role in their further productivity expansion.

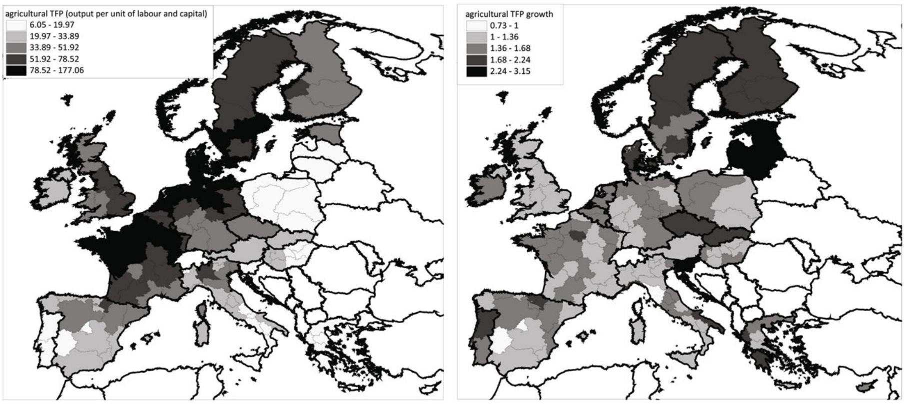

Fig. 3 The level of total factor productivity (2012) (left) and the growth of total factor productivity (2004–2012) (right) in agriculture in the EU FADN regions. FADN is the Farm Accountancy Data Network of European Union. Source: Authors' elaboration from FADN (2016)

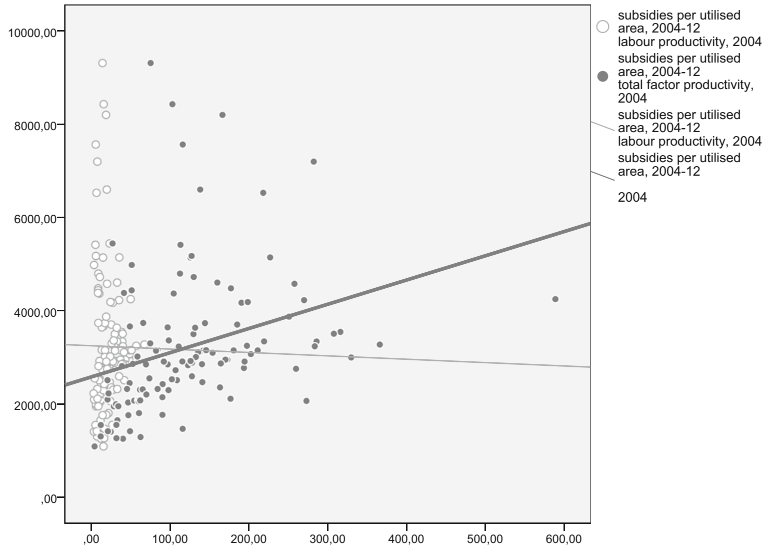

Fig. 4 Correlation of cumulative CAP subsidies per agricultural utilised area (2004–2012) to agricultural labour productivity level (2004) and total factor productivity level (2004) in EU FADN regions. FADN is the Farm Accountancy Data Network of European Union. Source: Authors' elaboration from FADN (2016)

Figure 4 shows that there was a (non-) significant relation between regions of initially higher agricultural (labour) total factor productivity and those with higher CAP transfers, indicating that the more advanced regions in terms of multifactor productivity were favoured by larger subsidy receipts. The econometric analysis that follows will investigate inter alia whether the provision of greater subsidies to specific regions has led to their higher productivity growth and consequently to their divergence from other regions.

Theoretical framework

This paper aims to investigate the contribution of CAP subsidies to the agricultural productivity growth of EU regions by employing the following methodological analysis, which is based on an augmented[4] Cobb-Douglas production function: $Y_t = K_t^a H_t^\beta (A_t L_t)^{1-a-\beta}$, where Y is the output, K is the physical capital stock, H is the stock of human capital, L is the labour, A is the level of technology, α and β are the share of physical and human capital respectively in output (elasticities), 1-α-β is the effective unit of labour's share in output, and t is time.

Defining k as the stock of capital per effective unit of labour, the accumulation of physical capital is governed by: $\dot{k}_t = s_k y_t - (n + g + \delta) k_t$, where s_k is the fraction of output that is invested, n is the growth rate of labour, g is the growth rate of technology, and δ is the rate of depreciation. Analogously, the evolution of human capital (h) is defined as follows: $\dot{h}_t = s_h y_t - (n + g + \delta) \mathrm{h}_t$ where s_h is the human capital accumulation rate as a fraction of output.

[4] Augmented with the inclusion of human capital, following Mankiw et al. (1990).

The steady-state level of income per capita from the assumption of diminishing returns to capital can be derived from the following production function:

$$ln\frac{Y_t}{L_t} = lnA_0 + g_t - \left(\frac{a+\beta}{1-a-\beta}\right)ln(n+g+\delta) + \frac{a}{1-a-\beta}ln(s_k) + \frac{\beta}{1-a-\beta}ln(s_h) \quad (1)$$

According to the Solow model (Mankiw et al. 1990), the speed of convergence is given by the form: $\frac{dlny_t}{dt} = \lambda(lny^* - lny_t)$, where $\lambda = (n + g + \delta)(1 - a - \beta)$, and y^* is the steady-state level of income per effective worker. This further implies (Moomaw et al. 2002): $lny_t = (1 - e^{-\lambda t})\, ln\, y^* + e^{-\lambda t}\, ln\, y_0$, where y_0 is the income per effective worker at an initial date. Subtracting lny_0 from both sides:

$$lny_t - lny_0 = \left(1-e^{-\lambda t}\right)lny^* + \left(1-e^{-\lambda t}\right)lny_0 \quad (2)$$

Substituting the income steady-state function (1) into the new convergence Eq. (2) yields the augmented Solow growth of income function (Siriopoulos and Asteriou 1998):

$$lny_t - lny_0 = \left(1-e^{-\lambda t}\right)lnA_0 + \left(1-e^{-\lambda t}\right)g_t + \left(1-e^{-\lambda t}\right)\frac{a}{1-a-\beta}ln(s_k) + \left(1-e^{-\lambda t}\right)\frac{\beta}{1-a-\beta}ln(s_h) - \left(1-e^{-\lambda t}\right)\frac{a+\beta}{1-a-\beta}ln(n+g+\delta) - \left(1-e^{-\lambda t}\right)lny_0$$

where s_k is the physical capital, s_h is the human capital, g is the rate of technology growth, n is the rate of exogenous growth of the labour force, $n+g$ is the rate of growth in the number of effective units of labour, δ is the depreciation rate, and A_o is the initial level of technology.

The final form of the econometric model is as follows (Kosfeld et al. 2006):

$$\ln y_t - \ln y_0 = \gamma_1 + \gamma_2 \ln(s_k) + \gamma_3 \ln(s_h) - \gamma_4 \ln(n+g+\delta) + \eta_i + \mu_i + \varepsilon \quad (3)$$

where

$$\gamma_1 = \left(1-e^{-\lambda t}\right)lnA_0 + \left(1-e^{-\lambda t}\right)g_t$$

$$\gamma_2 = \left(1-e^{-\lambda t}\right)\frac{a}{1-a-\beta}$$

$$\gamma_3 = \left(1-e^{-\lambda t}\right)\frac{\beta}{1-a-\beta}$$

$$\gamma_4 = \left(1-e^{-\lambda t}\right)\frac{a+\beta}{1-a-\beta}$$

η_i is a set of time dummies to take into account exogenous shifts over time (Aiello and Scoppa 2009), μ_i is a set of conditional variables, and ε is the error term.

This extended form of production function is an outcome of the progress in the literature on explaining systemic influences on output across production units that do not only come from changes in observable inputs like standard labour or capital measures (Syverson 2011).

Empirical analysis

Econometric specification

On the basis of the above theoretical econometric approach and aiming to obtain empirical evidence, Eq. (3) is estimated to investigate the influence of CAP subsidies on the agricultural productivity growth in EU regions. In order to allow technology to differ across countries, however, the coefficient γ_1 of the equation is not considered constant and identical for all regions but it is estimated as follows: $\gamma_{1i} = \alpha_0 + a_1 y_{it-1}$, where y_{it-1} is the productivity level for each region i for the initial year t_{-1} (Christopoulos and Tsionas 2004; Bairam and McRae 1999).

Therefore, the empirical analysis is conducted by the estimation of the following econometric model:

$$\begin{aligned} PRODGR_{it} = {} & a_0 + a_1 PROD_{it-1} + a_2 INV_{it} + a_3 HUMAN_{it} + a_4 EXQU_{it} \\ & + a_5 SUB_{it-1} + a_6 SUBCH_{it} + a_7 SUBCH_{it-1} + a_8 LIAB_{it-1} \\ & + a_9 LIABCH_{it} + a_{10} CRISIS_i + a_{11} SPRODGR_{it} + \varepsilon_{it} \end{aligned} \quad (4)$$

where two separate regressions run, of which PRODGR in the first case refers to the natural logarithm of agricultural labour productivity growth, while in the second case, it refers to the TFP growth of region i in year t. INV is the logarithm of investments, HUMAN is the logarithm of human capital, EXQU is the exogenous quantities, SUBCH is the change in per capita subsidies, and LIABCH is the liabilities-to-assets ratio change. Moreover, PROD, SUB, and LIAB are respectively the initial levels of productivity, subsidies per capita, and the liabilities-to-assets ratio of region i in year t_{-1}, CRISIS is a dummy variable that aims to capture any crisis-induced productivity change, SPROD is the spatially lagged variable of the dependent variable, and ε is the error term.[5] The construction of all the financial variables was based on data extracted from the FADN database. The time period spans from 2004 to 2012.

Our dataset is at regional level and includes 120 FADN administrative regions from 24 EU countries (Bulgaria and Romania were excluded due to a lack of data, Malta was

[5] The econometric model was based on Eq. (3), so the physical capital stock s_k was represented by the variable of investments (INV), the human capital stock s_h due to the difficulty of measurement of investments in human capital was substituted for (following Kosfeld et al. 2006) by the indicator of the level of human capital (HUMAN), the parameters of the labour and technology growth (n+g) and of the depreciation rate δ were represented by the exogenous quantities (EXQU), the time variable(s) η_i were represented by the time dummy variable of crisis (CRISIS), and the set of conditional variables μ_i consists of the variables of subsidies (SUB, SUBCH) and liabilities (LIAB, LIABCH).

an outlier case, while Croatia joined the EU after the period under study). To capture any spatial asymmetries in the pattern of productivity gains from subsidies, the econometric model was applied not only in the 120 regions of the EU24 but also in sub-groups defined on the basis of common characteristics. Thus, regions were classified into the sub-areas of the Mediterranean countries (Greece, Italy, Spain, Portugal, and Cyprus), the EU10 (the EU15 minus the five Mediterranean countries), and the NMS (Poland, Hungary, Czech Republic, Slovakia, Slovenia, Estonia, Latvia, and Lithuania). The Mediterranean and NMS regions exacerbated the need to analyse them in separate territorial groups as Mediterranean regions have similar climatic and structural features (a high proportion of mountainous areas, small-scale farming, and low productivity agricultural sector, Caraveli 2000; Eurostat 2018) that diverged from those of northern Europe, while the NMS came from a totally different economic and production system, and they were initially regulated by a different CAP regime. The explanation and measurement of each variable are analysed as follows, while the basic descriptive statistics for each of them are provided in Table 1.

For the analysis of agricultural productivity, the indices of labour and TFP were used. Labour productivity is defined as the output to labour ratio, where output is the real value of total annual output (deflated by the price index of agricultural goods output)[6] and labour is the total full-time equivalent labour input measured by hours per year. TFP is the ratio of output to total production inputs.

The inclusion of the initial level of productivity (PROD) in the model aims to embody the technological heterogeneity in the econometric analysis and to investigate its effect on agricultural productivity growth[7] (Christopoulos and Tsionas 2004).

Investments (INV) are a proxy for the physical capital stock ratio and estimated by the perpetual inventory method.[8] The total fixed capital (deflated by the price index of goods and services contributing to agricultural investment) includes both owned and rented capital, following the methodology of Rizov et al. (2013). Most studies support a positive relation of investment per worker to the agricultural productivity (Ezcurra et al. 2010); however, a negative association has also been detected in the literature, which is attributed to the higher cost of public investment in relation to its effective efficiency (Scoppa 2007).

Human capital (HUMAN) is viewed as an index of qualified labour (Kosfeld et al. 2006), and it thus uses the percentage of the labour force with advanced educational qualifications and, more specifically, the percentage of the labour force with tertiary education[9] (Kosfeld et al. 2006; Niebuhr 2001). The role of human capital has been underlined by the new growth theory (Lucas 1988), which describes it as an engine of growth since its accumulation raises the productivity of both labour and physical capital.

[6] All deflators are region-specific (by country) and are for agricultural sector (they are not commodity-specific). Moreover, the indexes are not bilateral and thus do not allow comparisons between countries (Ball et al. 2001).

[7] Technological heterogeneity also exists between sectors but the present analysis focuses on its spatial dimension.

[8] $I_t = K_{t+1}-(1-\delta)K_t$, where K is the total fixed capital stock, t is the time period, and δ is the depreciation rate (Rizov et al. 2013).

[9] An equally common proxy of human capital used is the average years of schooling of employees (Ciccone et al. 2004).

Table 1 Descriptive statistics

	Mean	std dev
PRODGR	0.04	0.12
INV	4.56	0.70
HUMAN	0.03	0.06
EXQU	0.72	0.10
SUB	353.81	173.88
SUBCH	1.00	0.17
$SUBCH_{t-1}$	1.02	0.17
LIAB	0.17	0.16
LIABCH	1.08	1.12
CRISIS	0.71	0.45
$PROD_{t-1}$	3.06	0.67
SPRODGR	8.21	7.72

The exogenous quantities (EXQU) include the rate of growth of the number of effective units and the depreciation rate. The first term denotes technology growth and labour growth. The rate of technological progress is considered to be 0.02% per year (Mankiw et al. 1990; Moomaw et al. 2002). Labour growth is defined as the growth of the total full-time equivalent labour input measured in hours worked annually (Rizov et al. 2013). The depreciation rate represents the consumption rate of fixed assets and has been deflated by the price index of goods and services contributing to agricultural investment (Petrick and Kloss 2012).

The impact of CAP subsidies on agricultural productivity growth was the main question that drove the present analysis. For this reason, the initial level of subsidies (SUB) and the subsidies change (SUBCH) for both years t and t_{-1} were included in the econometric model. The aim of the present analysis is to investigate whether considerable CAP transfers, measured in levels or in changes in rates, received in year t or with a time lag t_{-1} have benefited positively and strongly enough the European regions through productivity improvements in their agriculture. Subsidies were estimated as those on current operations linked to production (and not to investment) deflated by the price index of goods and services contributing to agricultural investment and divided by the utilised agricultural area.

The initial level (LIAB) and the change (LIABCH) of the liabilities-to-assets ratio were also explored in relation to productivity growth in the production function econometric model, acknowledging its importance in influencing output as it affects capital and technology use (Syverson 2011; Petrick and Kloss 2012). The liabilities-to-assets ratio is an index of a farm's ability to meet its obligations in the long term or its capacity to repay liabilities if all of the assets were sold. A high ratio is not necessarily a sign of a financially vulnerable position as it might indicate the solvency and economic viability of a farm. This occurs as its indebtedness not only may lead to a heavy recourse to outside financing, but also may compromise its financial health. Correspondingly, a low ratio might reflect difficulties in accessing credit markets (as in the case of the Mediterranean member states (European Commission 2015b) but also a lower exposure. Therefore, financial potential might offer opportunities but risks as well. There are claims that support both the positive and negative aspects of having high liabilities. More specifically, it has been proven that credit use boosts farm productivity (in the case of CEE countries, Ciaian et al. 2011) and that it has a positive effect on productivity (Zhengfei and Lansink 2006; Sabasi and Kompaniyets 2015), but that credit also has a negative effect on farm output (Carter 1989), it presents a low marginal product (Feder et al. 1990), and farm debt might be capitalised into fixed assets and can create problems of moral hazard (OECD 2015).

The econometric model, with the intention to explore the performance of agricultural productivity growth and the resilience of the agricultural sector during the crisis period, included the dummy variable CRISIS, taking the value 1 for the recession period (2009–2012) and 0 otherwise.

Finally, recognising the influence of spatial location on the process of productivity growth and with the intention of avoiding the presence of biased and misleading results, the spatial heterogeneity and dependence on agricultural productivity growth specification were tackled. The inclusion of the spatially lagged dependent variable (SPRODGR) in the econometric model aims to capture any spillover effects of agricultural productivity growth (Bronzini and Piselli 2009).

To tackle any potential endogeneity issues, a Generalized Method of Moment (GMM) estimator (Arellano and Bond 1991; Blundell and Bond 1998) that treated explanatory variables as potentially endogenous has been implemented (Aiello and Scoppa 2009; Kloss and Petrick 2014; Kosfeld et al. 2006). The methodological approach of the dynamic GMM (Arellano-Bover/Blundell-Bond) uses the estimators and moment conditions from a system of equations, which has better properties in terms of bias and efficiency than that of the GMM estimators for differences (Arellano and Bover 1995; Blundell and Bond 1998), and combines the first differenced regression with the level equation, in addition to the usual lagged levels as instruments for equations in first-differences. The use of robust standard errors provides consistent estimates in the presence of heteroscedasticity and autocorrelation.

Econometric results

The results of the econometric analysis are displayed in Tables 2 and 3. They show respectively the econometric models of agricultural labour productivity growth and total factor productivity growth in the regions relying on dynamic panel GMM estimations that controlled for endogeneity, variable omission, and spatial dependence problems.[10]

The estimation of both econometric models (with the dependant variable in the first case the labour agricultural productivity growth and in the second case the total factor agricultural productivity growth) shows that investments (INV) have a positive and statistically significant contribution to agricultural labour productivity growth in the regions of the EU24, as well as in the sub-areas under study (EU10, Mediterranean, and NMS). Their relation to TFP growth is strong in the case of the EU10 and marginally

[10] The overall validity of instruments was tested by the Hansen test of over identifying restrictions that failed to reject the null hypothesis at the 5% confidence level for all the cases and by the difference-in-Hansen test of exogeneity of instrument subsets that verified the exogeneity and thus the appropriateness of the instruments used in the econometric model. The Arellano-Bond test also failed to reject the null hypothesis of no autocorrelation.

Table 2 Econometric results of the labour productivity growth

	Whole area	Sub-areas		
	EU24	EU10	Mediterranean	NMS
Constant	1.99***	1.58***	1.93***	1.58***
$PROD_{t-1}$	− 0.66***	− 0.56***	− 0.7***	− 0.53***
INV	0.02**	0.008**	0.02**	0.02**
HUMAN	− 0.11	− 0.06	− 0.11	− 0.08
EXQU	0.24	0.19	0.23	0.18
SUB	− 0.0008	− 0.001***	− 0.0007	− 0.0004
SUBCH	− 0.03	0.02	− 0.01	− 0.21
$SUBCH_{t-1}$	0.08*	0.18**	0.15	− 0.23**
LIAB	0.40	0.92**	5.97	− 0.56
LIABCH	− 0.02	− 0.02	− 0.02	0.16
CRISIS	− 0.01	− 0.01	− 0.01	− 0.01
$PRODGR_{t-1}$	0.59*	0.32	0.67	0.34
SPRODGR	0.001	0.001	0.001	0.0007
Specification results				
Arellano-Bond test for AR(3) (*p* value)	0.83	0.69	0.69	0.41
Hansen test (*p* value)	0.07	0.05	0.12	0.17
Dif-in-Hansen test (*p* value)	0.91	0.51	0.99	0.40

EU24 includes EU28 countries except Bulgaria, Romania, Croatia, and Malta

EU10 includes EU15 except the five Mediterranean countries Greece, Italy, Spain, Portugal, and Cyprus

Mediterranean countries include Greece, Italy, Spain, Portugal, and Cyprus

NMS include Poland, Hungary, Czech, Slovakia, Slovenia, Estonia, Latvia, and Lithuania

The number of asterisks denotes the significance level of the coefficients: ***significant at the 1% level; **significant at the 5% level; *significant at the 10% level. Figures in parentheses are *p* values

non-significant in the cases of the Mediterranean and NMS regions. Thus, the present paper is, on the one hand, similar to several studies in detecting a differentiated by area impact of investments on regional productivity growth, while, on the other hand, it has the merit of studying the whole EU and its sub-areas, reaching interesting conclusions that indicate a strong ability of investments to boost regional TFP growth only for the EU10. The exogenous quantities (EXQU), which consist of labour and technology growth and the depreciation rate, have a positive, but statistically marginally non-significant correlation with the TFP growth in the regions. Human capital (HUMAN) has a trivial effect on agricultural productivity growth, thereby indicating the minor importance of this factor on the basis of the data of the present analysis. Thus, physical capital seems to be transformed more easily into productivity gains relative to human capital, which suggests not so much an adequacy in the skills of the latter, but a weakness in agricultural employment policies. The minor importance of human capital vis-à-vis physical capital is also highlighted by the recent study of Garrone et al. (2018), as it is proved that investments in physical capital lead to investment-induced productivity gains.

Table 3 Econometric results of the total factor productivity growth

	Whole area	Sub-areas		
	EU24	EU10	Mediterranean	NMS
Constant	1.68***	2.07***	1.73***	1.78***
$PROD_{t-1}$	− 0.14**	− 0.27***	− 0.15**	− 0.12
INV	0.01	0.01*	0.01	0.01
HUMAN	0.09	0.06	0.08	0.08
EXQU	0.15	0.18	0.14	0.14
SUB	− 0.0003*	− 0.001***	− 0.0002	− 0.0007*
SUBCH	0.01	− 0.05	0.008	− 0.23**
$SUBCH_{t-1}$	0.09	0.31***	0.10	− 0.19***
LIAB	0.36	0.16	− 0.96	2.40***
LIABCH	− 0.002	− 0.008	− 0.005	0.22***
CRISIS	0.02	0.01	0.02	0.01
$PRODGR_{t-1}$	− 0.61***	− 0.32*	− 0.59***	− 0.67***
SPRODGR	0.007*	0.004	0.008*	0.006
Specification results				
Arellano-Bond test for AR(4) (*p* value)	0.31	0.85	0.64	0.74
Hansen test (*p* value)	0.99	0.19	0.98	0.54
Dif-in-Hansen test (*p* value)	0.97	0.24	0.93	0.38

EU24 includes EU28 countries except Bulgaria, Romania, Croatia, and Malta

EU10 includes EU15 except the five Mediterranean countries Greece, Italy, Spain, Portugal, and Cyprus

Mediterranean countries include Greece, Italy, Spain, Portugal, and Cyprus

NMS include Poland, Hungary, Czech, Slovakia, Slovenia, Estonia, Latvia, and Lithuania

The number of asterisks denotes the significance level of the coefficients: ***significant at the 1% level; **significant at the 5% level; *significant at the 10% level. Figures in parentheses are *p* values

Regarding the issue of technological heterogeneity between regions, the analysis shows that during the period 2004–2012, there were strong trends of convergence in agricultural (labour and TFP) productivity growth as the coefficient of the initial productivity level is negative and statistically significant, signifying that regions with initially higher productivity levels display lower productivity growth (the exception is the NMS regions in the case of TFP). This convergence trend has also been highlighted by other studies of agricultural productivity (Ezcurra et al. 2010).

The influence of the *level* of subsidies (SUB) on the agricultural productivity growth of the regions is proven to be strongly negative in terms mainly of agricultural TFP in nearly all the cases (the exception is its weak negative impact on the productivity growth of Mediterranean regions), which signifies that regions with high subsidies were associated with low agricultural productivity changes. Similarly, the effect of subsidies *change* (SUBCH) on regional agricultural productivity growth is shown to be of minor importance as it is either statistically insignificant or strongly negative, as in the case of the NMS in the model of TFP growth.

However, this ambiguous or minor initial role of subsidies change on the evolution of regional productivity is reversed into a consistent and major one when the 1-year time lag of subsidies change is considered. Subsequently, the analysis shows a lag structure in the positive effect of subsidies on regional agricultural (mainly total factor) productivity growth, although it is weaker in the Mediterranean regions. The NMS are a different case, in which the time lag effect of subsidies change on agricultural productivity growth is strongly negative, proving the weakness of subsidies to contribute to the growth of regional agricultural productivity, as well as the inappropriateness of the CAP to cover the needs of the NMS.[11] This outcome is consistent with the recent results of Garrone et al. (2018), who found a significant positive effect of decoupled CAP subsidies on agricultural labour productivity growth in the EU-27, except in the NMS.

Regarding the level of liabilities-to-assets ratio (LIAB), it is proven to have a strong positive influence on the agricultural productivity growth in the case of EU10 regions (in labour productivity) and of NMS (in TFP) implying that there is little benefit of outside financing for the Mediterranean regions. Whilst the change of the liabilities-to-assets ratio shows an insignificant (negative) effect on the agricultural productivity growth of the majority of regions, its influence on both labour and total factor productivity in the NMS is importantly positive. This finding conforms with the evidence that shows the liabilities-to-assets ratio to be differently related to productivity growth in different areas. Specifically, a significant change in the liabilities-to-assets ratio, on the one hand, has a very weak effect on the productivity growth of the EU10 and Mediterranean regions, since it is related to an important short-term shift that disguises risks or there is an inability to convert it to productivity gains. On the other hand, NMS regions constitute a different case as productivity growth is influenced positively and statistically significantly from changes in the liabilities-to-assets ratio due to the developing financial sector and the low initial levels of the variable.[12]

Regarding the evolution of regional agricultural productivity growth during the crisis period (CRISIS), the analysis does not reveal any strong patterns of expansion or deterioration. It finds evidence of a weak trend of declining productivity growth rates in nearly all regions of which the negative sign signifies the shock that agriculture experienced during the period, while the low statistical significance of this relation suggests a relative resistance of the sector to the crisis.

The dynamic GMM model specification of this analysis inserts the lagged agricultural productivity growth (PRODGR_{t-1}) as an explanatory variable. The statistical significance of its coefficient, especially for TFP growth, demonstrates the importance of including this variable in the model, while its negative sign shows clear evidence of conditional convergence. Therefore, the analysis highlights the role of the policy of

[11] The hypothesis of biased and non-biased technological change has also been tested by running a simple specification model for all the cases (Ezcurra et al. 2010; Kazukauskas and Newman 2010), with explanatory variables being the level and change of subsidies, in order to be investigated whether the existence of a technologically improving environment leads to differentiated results.

[12] The inclusion of other variables that might capture spatial asymmetries and heterogeneities such as the changes in the utilised area, economic size, volume of agricultural exports, or highly educated employment did not yield any statistically significant results in the econometric model. A more spatially disaggregated level (than FADN regions) would provide a more insightful picture.

decoupling CAP payments in enhancing agricultural TFP growth in less competitive areas that is of low productivity growth.

Finally, the analysis does not detect any spatial autocorrelation effects of agricultural productivity growth in most of the cases as the positive correlation of the spatially lagged productivity growth (SPRODGR) to the dependent variable is statistically insignificant. The exception is observed in the Mediterranean regions (which is also reflected in the whole EU24 area), where the TFP growth of a region is influenced by the TFP growth of its neighbouring regions, thus highlighting the existence of clustering and technological or knowledge diffusion channels.

Conclusions

The aim of this paper has been to evaluate the impact of CAP subsidies on agricultural labour and TFP growth of EU regions during 2004–2012, which is an issue that has been highlighted as important, first in the aftermath of the 2003 reforms and the radical rebuilding of the CAP through the introduction of the decoupling policy, and second after the remarkable eastward enlargement of the EU to include countries of different economic and production systems that might compromise European cohesion and lead to a widening of the economic gap among the EU regions. Given the complex system of the decoupling policy and the national diversity, this paper has reached some useful conclusions.

On the one hand, the contribution of the *level* of CAP subsidies to the labour and TFP growth of regions was proven by this analysis to be negligible, as it has a particularly strong (for the regions of the EU10 and the NMS) or weak (for the Mediterranean regions) negative effect. This implies that regions that received a higher amount of subsidies for the whole period 2004–2012 presented lower productivity growth in different degrees.

Higher CAP receipts in the context of the decoupling policy were not associated with the production of farms (for the period that this policy was applied) but were defined by criteria based on reference data. Their negative relation to productivity growth implies that the level of subsidies was not associated with higher effectiveness of farms in terms of productivity growth. This implicitly shows that the criteria based on previous years (reference period or year of land declaration) and used to designate the *level* of CAP subsidies in farms for the next years (the 2004–2012 period under study) were not sufficient to enhance their agricultural productivity.

On the other hand, higher *changes* in subsidies with a 1-year lag were related positively with higher productivity growth of farms in EU10 regions. Changes in subsidies signify a dynamic process of structural changes from farms that were based on perceptions of the decoupling policy and met certain conditions of the cross-compliance notion. Thus, farms that changed their strategies and received higher CAP receipts were associated with productivity gains, while in parallel the cost of environmental requirements seems not to have led to productivity losses.

Overall, the contribution of the CAP's decoupling policy to regional productivity growth in the EU in a period (2004–2012) in which pioneering strategies and fundamental reforms were introduced with the aim of improving inter alia European regional productivity proved to be both positive and negative, which is conclusion similar to that of other studies that have had mixed findings regarding the CAP's impact. The novelty of the present analysis lies in the character of this differentiation. The positive aspect lies in the higher *change* of CAP subsidies in farms, which is shown in higher productivity growth and was based on farm strategies. The negative aspect lies in the higher *level* of CAP subsidies in farms that, despite their size, were not fully leveraged into productivity expansions and were based on reference data. Consequently, the decoupling policy entails two components: first, the potential of farmers' decision making based on the profitability of products and the promotion of the environment; and second, the connection with reference data (that is, the production of the historical period 2000–2002 and/or the eligible area declared in 2005). The former is proved to have generated more benefits in regional agricultural productivity than the latter. Interestingly, Mediterranean regions failed to exploit CAP subsidies for productivity gains, confirming the structural problems they face.

A second point that the present analysis underlines is the role of the CAP in counterbalancing regional imbalances and boosting regional cohesion. There were some concerns about the single farm payment, which, as it was based on historical entitlements and remained largely linked to farm size, might continue to benefit larger and often richer farmers (OECD 2004), although later the introduction of policies of modulation and digression aimed to contribute to a more fair distribution of income. This analysis detected trends of convergence between European regions in agricultural (mostly total factor) productivity growth terms during 2004–2012, appeasing any fears for further exaggeration of heterogeneity and magnification of dissimilarities inside the EU. Thus, it has proved that phenomena of path dependence and lock-in (Gkypali et al. 2019) during the period under study were not dominant and the regions' historical legacies do not seem to constitute an important burden that prevent them taking new growth paths. Moreover, technological heterogeneity captured by different levels of initial productivity levels proved to also be related to convergence trends as lower initial regional (both labour and total factor) productivity levels are associated with higher regional productivity growth rates.

Another equally significant outcome of this analysis is the inability of the CAP for the specific period to fulfil its goals for NMS regions as high levels of subsidies and especially high positive changes of subsidies are associated negatively with productivity growth. This confirms the peculiarities of the NMS, as the area by its accession to the EU and its integration into the CAP had to confront new competitive pressures, differing subsidy systems, and unfavourable conditions due to the dissimilarity of their farm structures (Somai 2014), as well as the incompatibility of CAP with the area's agricultural organisation.

Apart from CAP subsidies, other factors have been distinguished not only because of their positive impact on regional productivity growth but also because of the emergence of particular characteristics. Thus, investments in capital have led to investment-induced productivity gains, while investments in labour have had a subdued effect on productivity growth, which, together with the maintenance of the labour force from the decoupled policy (Garrone et al. 2018), reveal the weaknesses of employment policies. Liabilities, as opposed to subsidies, have a strong influence on the regional TFP growth of the NMS, highlighting their dependence for productivity improvements on credit markets. The detection of spatial autocorrelation in TFP growth in the Mediterranean regions also reveals the existence of technological or knowledge diffusion channels. Other farm or regional characteristics, such as economies of scale or the quality of labour, did not show significant correlation with productivity changes, highlighting, however, the importance of studying them at a disaggregated spatial level and through complementarities and interactions.

As a concomitant of all the above, the CAP and the dissimilarity of European regions, especially after the EU's eastern enlargement, show how easy it is for European regional cohesion to be undermined, how difficult it is for the EU to apply common policies that will meet the demands of each region, and how imperative it is to engage in a perpetual re-examination of (agricultural) policies, so that they can be aligned with emerging challenges and the changing needs of European regions. The CAP, as with any other policy, has to be taught from the past to assure its viability for the future.

Some limitations in the present study that have to be mentioned are firstly the rigid assumptions of the Cobb-Douglas technology in the production function estimates, as the analysis was based on the Cobb-Douglas model, which is often used as a convenient starting point for empirical analysis (Petrick and Kloss 2012), and secondly that the sectoral heterogeneity has not been incorporated into the analysis. The efficiency of CAP subsidies is a crucial factor that could also explain the differentiation of productivity levels (Rizov et al. 2013). Further research will be based on alternative functional forms, the inclusion of additional parameters for sectoral heterogeneity, and the expansion of the period being studied.

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