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Impact of CAP Pillar II Payments on Agricultural Productivity

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Abstract

The impact of agricultural subsidies on productivity has long been discussed in the literature without any clear conclusions. Many studies attempted to shed light on the topic by using various methods and data (mostly relying on geographically limited farm-level data). Depending on the model specification, statistical method and data source mixed results are reported. This study aims at estimating the impact of common agricultural policy Pillar II payments on agricultural productivity by using NUTS-2 (Nomenclature of territorial units for statistics) level data for the years 2007-2013 for the European Union member state countries. We use a rather novel approach by simultaneously estimating a Constant Elasticity of Supply production function with productivity coefficients linked to the Pillar II payments. We use 4 categories of Pillar II payments (i.e. human capital, physical capital, agro-environmental and rural development) to explain the total factor productivity in agricultural sector. Our results suggest that regions receiving higher Pillar II payments for physical capital investments, human capital development or agro-environmental measures increase productivity. On the other hand, payments related to rural development do not have significant impact on productivity. The results do not change among the member states, date of access to the European Union (i.e. old or new member states), spatial characteristics (i.e. being in the south, north or east) or size of the countries (i.e. big or small economies).

Keywords: Factor productivity, agricultural sector, Pillar 2 CAP subsidies, CES production function, NUTS-2

1 Introduction

The impact of agricultural subsidies on productivity has long been discussed in the literature without any clear conclusions. Depending on the model specification, statistical method and data source, mixed results are reported. The empirical evidence shows that there is still a large gap in the literature regarding the understanding of the role of Common Agricultural Policy (CAP) Pillar II subsidies on agricultural productivity:

- Few studies comprehensively look at the impacts of CAP subsidies at NUTS II level for the EU member states and compared the productivity effects across the different CAP subsidy categories.
- Most studies use farm-level data (mostly from Farm Accountancy Data Network (FADN)). However, analysing the impact of subsidies on farm-level only captures private returns but it does not capture the public or social returns that are obtained from the public investment.
- In most of the studies, agricultural subsidies are treated ad-hoc and mostly as a uniform category. However, as Minviel and Latruffe (2014) point out, when separating the individual subsidy groups, productivity effects of subsidies might turn positive.
- The biggest proportion of the empirical evidence relies on using the Stochastic Frontier Approach or Data Envelopment Analysis (DEA) concluding a negative effect of subsidies on technical efficiency which does not exclude their positive effect on productivity.
- All existing studies consider the effects on total factor productivity, whereas in reality, different types of CAP subsidies might provoke a factor-biased technical change (for instance, human capital subsidies are expected to stimulate labour productivity more than land productivity).
- None of the studies so far can provide reliable inputs for parametrization of economy-wide models (e.g. partial or general equilibrium models such as MAGNET or CAPRI) due to different use of functional forms (typically Cobb-Douglas or translog functions instead of CES are used) and due to the prevalence of micro-level studies (causing difficulty of generalization of the results on the sector level).

This lack of understanding is both a constraining factor for policy makers that are interested in ex-post evaluation of the effectiveness of public investments and for modellers who need a reliable quantification of subsidies impact on productivity in their ex-ante exercises such as Scenar 2020, Nowicki et al., (2006) and Nowicki et al., (2009). The contribution of this empirical estimation is thus to bridge this gap by providing a comprehensive empirical assessment of the role of CAP subsidies on productivity across EU-27 countries.

In this study, the impact of common agricultural policy Pillar II payments on agricultural productivity is quantified by using NUTS-2 level data for the years 2007-2013 for the selected EU member states. Applying a rather novel methodological approach, we estimate a Constant Elasticity of Supply (CES) production function with productivity coefficients linked to the Pillar II payments. To achieve this, we derive and estimate factor demand equations with factor-augmenting technical change from the first order conditions of

the cost minimization problem. We use 4 categories of Pillar II payments (i.e. human capital, physical capital, agro-environmental and rural development) to explain the growth of factor productivity in the agricultural sector.

Our results should be considered carefully since, as they are described in the relevant sections of this report, data issues put serious limitations on the country and regional coverage of the study. We used multiple data imputation methods to keep as much information as possible within the selected sample. However that was not enough to keep some key countries such as Germany and Italy in the sample.

2 Agricultural subsidies and productivity: An on-going debate

Agricultural subsidies related to human or physical capital might have both positive and negative impacts on productivity. The negative effect results from the loss of allocative and technical efficiency related to support of less productive entities. On the other hand, the negative effects may be counterweighted by investment-induced productivity gains due to improved management practices, credit access and increase in investment (Minviel and Latruffe, 2014). On the other hand, the agri-environmental payments aim to encourage farmers and other land managers to introduce or maintain production methods compatible with the protection of the environment, the landscape and its features, natural resources, the soil and genetic diversity that go beyond mandatory standards. Their theoretical effects on productivity may be either neutral or negative. Many scholars assume that agri-environmental payments represent additional subsidies for land. However, given that the agri-environmental payments require strict conditions on input use, they might have negative productivity effects. Finally, rural development payments are generally assumed to have positive regional effects which are not related to agricultural sector as such, but to support of other sectors such as construction or tourism.

Various approaches exist in the literature to quantify agricultural productivity. Usually, these studies can be grouped in two categories: the growth accounting based and the frontier based approaches. The traditional growth accounting and regression analysis derive productivity growth as a mechanical residual. The frontier approaches such as the non-parametric data envelopment analysis (DEA) and the parametric stochastic frontier analysis (SFA), have an advantage in deriving technical efficiency and technical change and combining them into the Malmquist TFP index. It is important to stress here that technical efficiency is only one of the components of total factor productivity (TFP) which measures the distance of the individual to the frontier which represent the best possible production technology for the sample. On the other hand TFP also includes the technical change which is the movement of the estimated frontier over time.

The most recent and detailed analysis in the literature suggests that annual average TFP growth in the EU agricultural sector is around 1.6 percent in the EU. TFP growth in western and eastern EU countries is generally reported to be between 1% and 1.5%. The Southern and Baltic EU countries exhibit higher rates of TFP growth around 1.8% (Fuglie, 2015; USDA, 2016).

Cechura et al. (2014) presents a detailed analysis of TFP growth in the EU where they estimate TFP in 24 EU countries at NUTS-II level for crop, milk and pork production. Authors report annual TFP growth rates between 0.7% and 1.3% for NUTS-II regions. Eastern member states exhibit lower TFP growth in crop and milk production while TFP growth is generally higher in Southern and western countries in these sectors. Baltic countries generally have higher TFP growth in pork production. Authors conclude that although there is a positive trend in TFP growth for most member states, there is no catching up among NUTS II regions and there are substantial differences between countries and regions. However, authors do not link their findings to agricultural subsidies.

Many studies investigated the effects of CAP subsidies on production and input allocation, but only few have investigate specifically the impact of subsidies on agricultural productivity (Rizov et al., 2013). In this chapter, the review of the recent empirical findings is provided, distinguishing the variety of quantitative approaches that have been used.

One of the most recent empirical works is presented by Mary (2013), who investigated the effect of CAP Pillar I and Pillar II subsidies on French crop farms using a **panel data approach**. Highlighting the advantage over the SFA approach, Mary (2013) applied a GMM technique that enables to address the fact that inputs are likely to be correlated with productivity shocks. In the first step, the author estimated a Cobb-Douglas production function with standard inputs and productivity component, composed of time effect, farm-specific effect and stochastic effects following autoregressive (AR) and moving average (MA)

processes. In the second stage, the estimated farm and time-specific TFP is used in a Generalized Method of Moments (GMM) regression that links farm subsidies to productivity. The results show that set-aside, Less Favoured Areas (LFA) payments and livestock payments have statistically negative effect on productivity (100 EUR of subsidies reduces TFP for about 0.02%). Next to that, the investment subsidies as well as agri-environmental payments parameter have negative sign but are not statistically significant.

Parallel to Mary (2013), Rizov et al. (2013) also looked at the impact of CAP subsidies on agricultural productivity, using farm level FADN data for all EU-15 countries. The authors attempt to investigate the effect of subsidies on aggregate farm productivity using a **structural semi-parametric approach**. Similarly to Mary (2013), the authors estimated a Cobb-Douglas production function with labour, materials, capital stock and an unobserved farm specific productivity as inputs. In the first stage regression, only coefficients of labour and material can be calculated as it is not possible to separate the effect of capital on unobserved productivity modelled semi-parametrically, and production. In the second stage, capital parameter is recovered after isolating the productivity component from the production function. The strength of this approach is that unlike in most other studies, the effect of subsidies is accounted for in the productivity function and the endogeneity problem of subsidies is filtered out. The impact of subsidies on productivity is assessed using a correlation coefficient across the EU-15 MS. The results show that the effect of CAP subsidies on productivity is negative and improves after decoupling. The correlation coefficient between TFP growth and decoupled subsidies ranges from +0.02 (Netherlands) to +0.1 (Portugal). Despite this advanced approach, the authors do not distinguish among different subsidy groups and therefore it is not possible to separate the effects of investment subsidies from other types.

Plenty of work attempted to assess the link of subsidies to farm efficiency using a **Stochastic Frontier Analysis**. Serra et al. (2008) investigates the impact of decoupled government support on technical efficiency of the farmers by using farm level data for Kansas. They show that the impact of subsidies on technical efficiency is ambiguous and depends on the production risk and risk preference of the farmers.

Latruffe et al. (2009) investigated the effect of subsidies on technical efficiency in 7 EU-15 countries and found that farms with higher subsidy rates had lower technical efficiency. The subsidies group include the percentage share of subsidies in output and membership in agro-environmental schemes (AES). The inefficiency effect of total share of subsidies ranges from 0.04% to 0.13%. Regarding AES subsidies, in most of the countries (except Spain), farms with AES subsidies present a lower average technical efficiency, confirming the negative link between efficiency and subsidies. Other applications of SFA are provided by

Lakner (2009) who investigated the efficiency of organic milk. The results showed that agro-environmental payments contributed negatively to efficiency scores. As Lakner (2009) explains, since the goal of the agro-environmental programs is the provision of environmental goods and services, this result shows that some market distortions (i.e. promotion of inefficient farms) from this type of payment cannot be excluded in the organic milk sector.

Zhu and Lansink (2010) and Zhu et al. (2012) analysed the impact of CAP subsidies on technical efficiency in selected EU-15 countries and confirmed the negative role of subsidies in technical efficiency. More comprehensive study of productivity was recently performed by Cechura et al. (2016). Using a stochastic meta-frontier approach for 24 EU countries, the authors analysed the convergence of milk productivity across the EU member states and found that several regions in Eastern Europe are falling behind, despite the CAP goals of promoting productivity.

Kumbhakar and Lien (2010), on the other hand, report a positive link between subsidies and technical efficiency in their study where they analyse the efficiency of Norwegian grain farms during 1991-2006. In their model they treat subsidies as endogenous variables. The authors also conclude that subsidies have a negative impact on farm productivity.

Fogarasi and Latruffe (2009) compared the effect of subsidies on farm performance in France and Hungary, using **DEA approach** combined with econometric estimations. The farm-level analysis provided interesting insight – although the share of subsidies in total output is negatively correlated with technical efficiency, the effect on TFP for dairy farms is neutral and for crop farms, it is in fact positive. This shows that there is an important difference between the way how subsidies affect technical efficiency and productivity and these two concepts should not be interchanged. It is also interesting to observe that dairy farms have lower sensitivity on subsidies than crop farms. In a more recent study, Latruffe and Desjeux (2016), estimates the relationship between CAP subsidies, technical efficiency and productivity change for

French farms between 1990 and 2006 focusing on three types of farms: field Crop, dairy and beef cattle producers. They follow a similar methodology developed in Fogarasi and Latruffe (2009) using the FADN data. Latruffe and Desjeux (2016) report that investment subsidies generally do not have any impact on technical efficiency, technological change and productivity. On the other hand production subsidies have positive effect on productivity and technical efficiency while their impact on technological change is insignificant. Lastly rural development subsidies do not have any impact on technological change or technical efficiency but increase the productivity. They conclude that effect of subsidies are ambiguous and depends on specialisation of farms and efficiency indicator used.

Propensity score matching is an alternative approach for assessing the impact of subsidies on productivity, by comparing the effects in the treated group with the control group. For instance Pufahl and Weiss (2009) assessed the performance of German farms (2000-2005) but found no significant effects on land productivity. The impact of agri-environmental payments was studied by Chabe-Ferret and Subervie (2011). However none of these studies specifically focus on isolating the effects of subsidies on productivity, rather they analyse other indicators of farm performance. Similarly, Ratering et al. (2015) analysed the effect of investment support to agriculture (modernisation of agricultural holdings) in the Czech Republic using two different farm-level databases (FADN and Albertina) for 2007 – 2013. The authors found significant effects of the investment support measures in terms of production expansion and gross value added (GVA) improvement and the support to mobilise additional financial sources of banks. The authors also attempted to analyse the link to TFP, but the results were not conclusive.

The role of subsidies in agricultural productivity is also studied using the **ex-ante computable general equilibrium (CGE) approaches**. Nowicki et al. (2009) apply the so-called LEITAP model (forerunner of the MAGNET model (Woltjer et al., 2013)) and assume that investments in human capital under Pillar II of the CAP of the EU are likely to lead to an overall increase in productivity. The technical change is assumed equal to the rate of return used for physical capital investments (i.e., 30%). Nowicki et al. (2009) model the agri-environmental payments under Pillar II of the CAP as a payment to land. In order to capture the negative productivity effect of agri-environmental payments mentioned in the literature (see above) it is assumed that labor and capital productivity decreases by 10% of the increase in land payment rate.

In the most recent work of Schroeder et al. (2015), the authors extend the CAPRI model with a regional CGE model to estimate the effects of the Pillar II of the Common Agricultural Policy. The authors explicitly implement 11 measures of Pillar II, although the choice of the parameters is not justified in the paper. Comparable to Nowicki et al. (2009) it is assumed that human and physical capital payments under Pillar II will help farmers to save costs. For instance, investments to modernisation of agricultural holdings (measure 121) in Germany result in a shift of the production function by 0.06% (increase in productivity) and by lowering capital taxes. Investments in human capital such as technical assistance, vocational training and advisory services (measures 511, 111 and 114) are implemented partially as a governmental demand for education and as a shifter of production function. Finally, the rural development measures are implemented as government demand for construction. The results of the simulation show that public investments crowd-out private investments.

Another ex-ante simulation concerning the impact of Pillar II CAP is found in Psaltopoulos et al. (2011). Using the regional CGE models built for Greece and the Czech Republic, the authors implement investment subsidies as increase in the exogenous investment demand for construction leading to increase in factor demand and household incomes. The authors conclude that the supports to Rural Development bring rather small and mixed effects and they cannot compensate the negative effects of decoupling. As the authors also point out, so far very few CGE applications exist that would explicitly model regional effects of Pillar II policies not only due to lack of data, but also due to the fact that the effects of these measures tend to be small relative to Pillar I measures.

Finally, a possible approach of analysing the role of subsidies on productivity is using **the meta-analysis**. Minviel and Latruffe (2014) analysed 195 results about effect of subsidies, extracted from a set of 68 studies carried out from 1972 to 2014. The authors found an interesting result - aggregating all subsidies received by farmers into total subsidies increases the probability of a negative effect of subsidies on farms' technical efficiency and for instance, when isolated, investment subsidy is positively related to farms' technical efficiency. Minviel and Latruffe (2014) point that public subsidies may improve technical efficiency if they are used to update the farm's productive capacity through replacement investment or net investment in advanced technologies. Also, public subsidies may enable farmers to achieve scale economies through

investments. However it should be also taken into account, that the effects of public investments may not accrue immediately as there is a lag connected with adjustment costs.

With respect to the more recent evidence on the impact of **agricultural extension**, some works can be found in the US literature. Huffman and Evenson (2006) built a panel data set for 48 US states over 1970 – 1999. They constructed public agricultural extension stock from full-time equivalent professional extension staff allocated to agriculture, using a geometric distribution over five years. The results proved statistically significant effects of public R&D and extension with the elasticity of TFP with respect to domestic R&D stock in range of 0.14 – 0.2 and the elasticity of TFP with respect to extension in range of 0.11 – 0.16. Most recently, Jin and Huffman (2015) updated the regression with longer time series and derived the elasticity of TFP for research stock at about 0.2 whereas with respect to extension in range of 0.1. The newly quantified rates of return to agricultural research reach 67% and to agricultural extension over 100%. As Jin and Huffman (2015) further comments, the public investment project could pay a very high interest rate (66% for agricultural research and 100% for extension) and still have a positive net present value.

Outside of USA, there is some evidence from Australia and New Zealand. Sheng et al. (2011) analysed the relationship between public research and development (R&D) and extension investment and productivity growth in Australian *broadacre* (large-scale crop) agriculture over 1953 - 2007. The elasticity of TFP to knowledge stocks of research and extension were estimated to be around 0.20–0.24 and 0.07–0.15, respectively. This shows that the marginal impact of extension knowledge is about half of that of public R&D stock, which is in line with findings of Huffman (2006 and 2015). In terms of returns, the authors found that public extension generated significantly higher IRRs than those for public R&D and reached values of around 48 %.

Similarly, Hall and Scobie (2006) analysed productivity growth of New Zealand agriculture for 1926 – 2004 based on extension workers, human capital, current and past domestic R&D and foreign patents. The human capital stock was calculated as the sum of current and past numbers of students enrolled in agricultural related courses (using a lag length of 15 years). Extension was included in the TFP equation as it has a direct effect on agricultural productivity as well as speeding the adoption of new technology. The results showed that in various model specifications, the extension effect on productivity was negative and not significant.

3 Methodological approach

3.1 Theoretical Framework: Productivity under a CES Production function

We characterize the production technology by a **Constant Elasticity of Substitution (CES)** production function with constant returns to scale and factor-specific technology parameters. The simple non-nested form of production function combines the inputs of land, capital and labour to create value added (assuming identical elasticity of substitution among the three production factors). This specification is in line with production technology modelled in most of CGE models such as MAGNET model. The cost minimization problem would then be as follows:

$$\begin{aligned} \min C_{i,t} &= PD_{i,t} D_{i,t} + PK_{i,t} K_{i,t} + PL_{i,t} L_{i,t} \\ \text{s.t. } VA_{i,t} &= \left[\alpha_D (A_D \cdot D_{i,t})^{\left(\frac{\sigma-1}{\sigma}\right)} + \alpha_K (A_K \cdot K_{i,t})^{\left(\frac{\sigma-1}{\sigma}\right)} + \alpha_L (A_L \cdot L_{i,t})^{\left(\frac{\sigma-1}{\sigma}\right)} \right]^{\left(\frac{\sigma}{\sigma-1}\right)} \end{aligned} \quad (1)$$

where C is the cost, VA is value added, D is land, K is capital stock and L is labour. PD , PK and PL stands for the prices of land, capital and labour, respectively. Further α_D , α_K and α_L are the distribution parameters in CES function; A_D , A_K and A_L are factor-augmenting technology parameters for land, capital and labour respectively and T is total factor productivity. Lastly δ is the elasticity of substitution between capital, land and labour.

Solving the minimization problem yields factor demand equations which can be expressed in growth rates:

$$(d_{i,t} - va_{i,t}) = (\sigma - 1)a_D + \sigma(pva_{i,t} - pd_{i,t}) \quad (2)$$

$$(k_{i,t} - va_{i,t}) = (\sigma - 1)a_K + \sigma(pva_{i,t} - pk_{i,t}) \quad (3)$$

$$(l_{i,t} - va_{i,t}) = (\sigma - 1)a_L + \sigma(pva_{i,t} - pl_{i,t}) \quad (4)$$

Furthermore, it is taken into account that factor-augmenting technology parameters a_F in the agricultural sector are not exogenous (constant), but they are explained by various technology drivers. Given that the subject of our interest is to quantify the impact of the CAP Pillar II subsidies on growth of productivity, a_F parameters are explicitly linked to shares of subsidies in agricultural output:

$$a_L = \delta_{EXO} + \delta_{MS}MS + \delta_{HC} \log \frac{HC}{OUT} + \delta_{RD} \log \frac{RD}{OUT} \quad (5)$$

$$a_K = \delta_{EXO} + \delta_{MS}MS + \delta_{PC} \log \frac{PC}{OUT} + \delta_{RD} \log \frac{RD}{OUT} \quad (6)$$

$$a_D = \delta_{EXO} + \delta_{MS}MS + \delta_{AE} \log \frac{AE}{OUT} + \delta_{RD} \log \frac{RD}{OUT} \quad (7)$$

Equation (5) shows that growth of factor-augmenting technical change consists of an autonomous part (exogenous) δ_{EXO} and an endogenous part, which depends on a dummy variable controlling for new or old member state status MS as well as on CAP Pillar II subsidies – physical capital subsidies PC , human capital subsidies HC , rural development RD and agro-environmental subsidies AE , each expressed as a ratio to gross agricultural output. The respective parameters δ_{MS} , δ_{PC} , δ_{HC} , δ_{RD} and δ_{AE} indicate change in growth of factor productivity (factor-augmenting technical change) if the share of subsidies in agricultural output grows by 1%.

Substituting equation for technical change (5) - (7) into the system of demand equations (2) - (4) yields the final estimated form with sub-indices for NUTS 2 region $i = (1 \dots 84)$ and year $t = (1 \dots 6)$.

Estimated system of equations:

$$(d_{i,t} - va_{i,t}) = \sigma(pva_{i,t} - pd_{i,t}) + (\sigma - 1) \left(\delta_{EXO} + \delta_{MS}MS + \delta_{AE} \log \frac{AE_{i,t}}{OUT_{i,t}} + \delta_{RD} \log \frac{RD_{i,t}}{OUT_{i,t}} \right) \quad (8)$$

$$(k_{i,t} - va_{i,t}) = \sigma(pva_{i,t} - pk_{i,t}) + (\sigma - 1) \left(\delta_{EXO} + \delta_{MS}MS + \delta_{PC} \log \frac{PC_{i,t}}{OUT} + \delta_{RD} \log \frac{RD_{i,t}}{OUT_{i,t}} \right) \quad (9)$$

$$(l_{i,t} - va_{i,t}) = \sigma(pva_{i,t} - pl_{i,t}) + (\sigma - 1) \left(\delta_{EXO} + \delta_{MS}MS + \delta_{HC} \log \frac{HC_{i,t}}{OUT_{i,t}} + \delta_{RD} \log \frac{RD_{i,t}}{OUT_{i,t}} \right) \quad (10)$$

where: d is the growth rate of land input, k is the growth rate of capital input, l is the growth rate of labour input, va is the growth rate of value added, pva is the growth rate of value added price, pd , pk , pl is the growth rate of land, capital and labour price respectively. RD/OUT , AE/OUT , PC/OUT , HC/OUT are the ratio of rural development, agro-environmental, physical capital related and human capital related subsidies in agricultural output, respectively. δ_{EXO} stands for exogenous rate of factor-augmenting technical change for land, capital and labour respectively while δ_{RD} , δ_{AE} , δ_{PC} and δ_{HC} are the elasticities of factor-augmenting technical change with respect to the share of rural development, agro-environmental, physical capital related, man capital related subsidies, respectively.

3.2 Data and Estimation Method

We use the "Economic Accounts for Agriculture Rev 1.1." (EAA97) data set of Eurostat (2016) for the years 2007-2013 for 84 NUTS2 regions that has complete data for agricultural production, capital and labour accounts.

Main identities in the EAA97 database are as follows:

$$KD_{i,t} = PD_{i,t}D_{i,t} + PK_{i,t}K_{i,t} \quad (11)$$

$$VA_{i,t} = KD_{i,t} + PL_{i,t}L_{i,t} \quad (12)$$

$$Y_{i,t} = VA_{i,t} + PM_{i,t}M_{i,t} \quad (13)$$

where $KD_{i,t}$ is denoted the "Operating Surplus/Mixed Income", $VA_{i,t}$ is denoted as "Gross Value Added at Basic Prices", $PL_{i,t}L_{i,t}$ is denoted as "Compensation of Employees", $Y_{i,t}$ is denoted as "Output of Agricultural Industry" and $PM_{i,t}M_{i,t}$ is denoted as "total intermediate consumption" in the EAA97data set. Agricultural value added is calculated as net of subsidies and taxes to avoid any endogeneity problem in the estimations. Note that EAA97data reports only the values of these parameters. Thus we had to calculate the growth rates required by our model by using some auxiliary data under some simplifying assumptions.

The variables required for the estimation of our model can be translated into the EAA97variables as follows:

$$va_{i,t} + pva_{i,t} = \text{gr}(VA_{i,t}) \quad (14)$$

$$d_{i,t} + pd_{i,t} = \text{gr}(PD_{i,t}D_{i,t}) \quad (15)$$

$$k_{i,t} + pk_{i,t} = \text{gr}(PK_{i,t}K_{i,t}) \quad (16)$$

$$l_{i,t} + pl_{i,t} = \text{gr}(PL_{i,t}L_{i,t}) \quad (17)$$

where the function $\text{gr}(x)$ denotes the growth operator defined as

$$\text{gr}(X_{i,t}) = \ln(X_{i,t}) - \ln(X_{i,t-1}) \quad (18)$$

In other words the growth rates of variables from the EAA97 dataset are the sum of the growth rates of price and quantity variables required for the estimation of the model. Since EAA97 data set do not report the

prices and quantities separately we use some auxiliary data and simplifying assumptions to calculate price and quantity growth rates.

First, we use the ratio of current value added to constant value added (i.e. as a price deflator) from EAA97 database as a proxy for value added price, i.e. $pva_{i,t}$. However, EAA97 reports value added at current and constant prices only at national level. Thus we assume that prices are same within a country. Considering the fact that we are working with growth rates rather than levels, we are actually assuming that the growth rate of price of value added is same within a country, which is not very unrealistic. Then by subtracting these growth rates from the growth rates reported by NUTS-II level EAA97 data, i.e. $gr(VA_{it})$, we calculate the growth rate of the quantity of value added $va_{i,t}$.

Decomposition of price and quantity of labour, i.e. $PL_{i,t}L_{i,t}$ is done by using agricultural employment data from EuroStat (2016c). We use the growth rate of agricultural employment reported by EuroStat (2016c) at NUTS II level as a proxy for $l_{i,t}$. Then we subtract this growth rate from the growth rate of labour compensations reported by EAA97 dataset, i.e. $gr(PL_{i,t}L_{i,t})$ to calculate the growth rate of price of labour $pl_{i,t}$. $PD_{i,t}D_{i,t}$ and $PK_{i,t}K_{i,t}$ (i.e. land and capital income) are not reported separately in the database. Thus we use the growth rate of "Total Utilized Area" reported by Crop Statistics data set of EuroStat (2016b) as a proxy for $d_{i,t}$.

Then, we use the growth rate of "Rents and Other Real Estate Rental Charges to be Paid" variable reported by EAA97 dataset, as a proxy for land price, i.e. $pd_{i,t}$. That is, we assume that the total area of rented land does not change significantly overtime and hence the growth in the rent payments is likely to be mostly explained by the changes in the land price. Considering the fact that we are working with a 7 year series, this assumption is not very unrealistic, as contracts for renting agricultural land are mostly long term contracts.

We use the "Fixed Capital Consumption" variable that is reported in the EAA97 data set and country specific depreciation rates, i.e. λ_i , reported by Görgiz (2007) to calculate the growth of quantity of capital, i.e. $k_{i,t}$, as:

$$k_{it} = \text{gr} \left(\frac{FCC_{it}}{\lambda_i} \right) \quad (19)$$

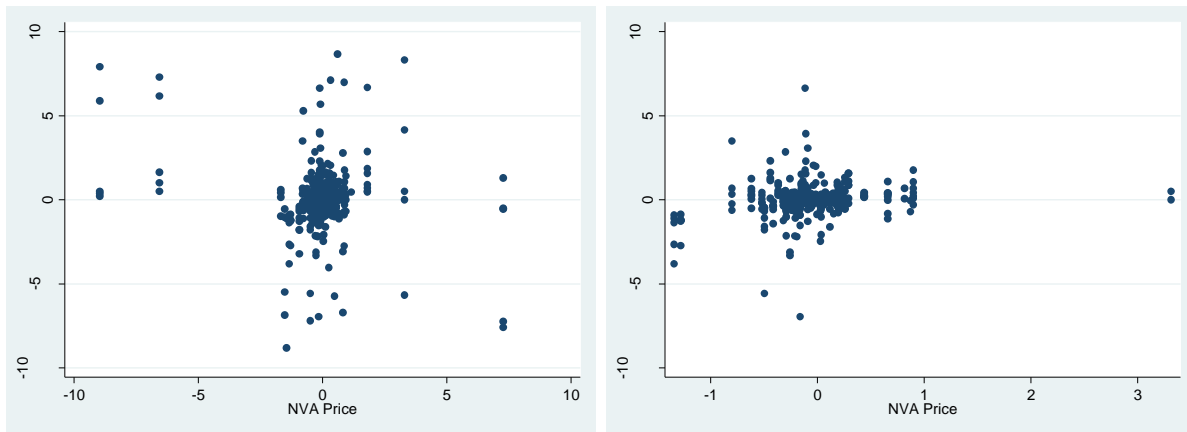
In other words, we are again assuming that the depreciation rate is same across all regions within a country. Lastly we calculate the growth rate of price of capital from the national "Fixed Capital Consumption" data series of EAA97 reported at constant and current prices as we explained for the value added before. In the same way, we are assuming that the capital price change is same for all regions in a country.

We start cleaning the data by dropping all observations with at last one missing observation for the variables employed in the estimation data (see **Error! Reference source not found.** for details). Consequently we are left with Austria, Bulgaria, Czech Republic, Denmark, Greece, Finland France, Hungary, Netherlands and Portugal in the database, adding up to a total of 616 observations.

Then we clean the data from 20 outliers which are all for Finland data. The outlier detection is done by using the blocked adaptive computationally efficient outlier nominators (BACON) algorithm implemented in Stata. The distribution of growth of Net value added (NVA) price and quantity data before and after cleaning 20 outlier observations in Finland is given in

Figure 1.

Figure 1: NVA variables before and after outlier cleaning



Source: Authors' calculation

The descriptive statistics of the growth rate of the variables suggest a high heterogeneity across the countries and regions (**Error! Reference source not found.**). The average growth rate of value added over 2007-2013 is around 4%. Employment of labour has declined by almost 2% on average while the labour cost has increased by 5. On the other hand capital employment had increased around 3% with a price decline of 2%. Land use has also declined slightly by 0.3% while the price of land has increased around 4%. Note that there is significant variation in all variables, with quite high standard deviation across countries and regions.

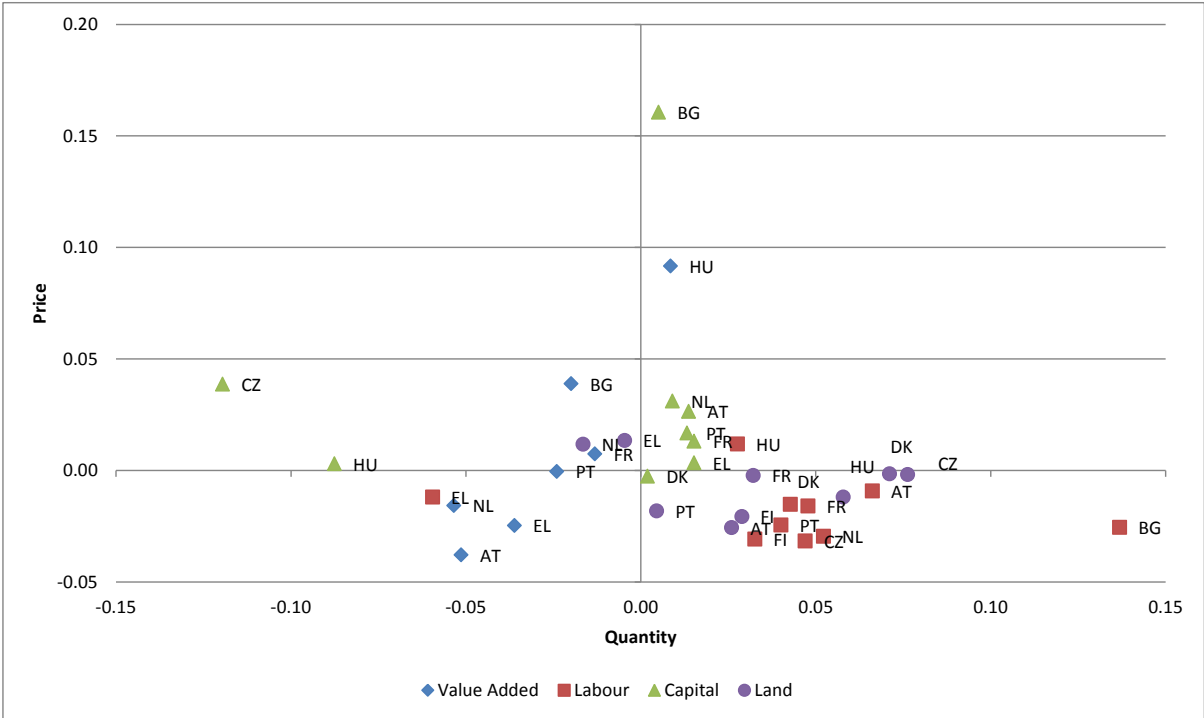
Growth of NVA quantity and price in Finland and Denmark are quite high, but we kept them in the sample as the routine used for outlier detection did not specify them as outliers. Note that Finland has only 6 observations while Denmark consists of 35 and hence these regions are not likely to affect the estimations results significantly anyway.

The growth of agricultural wage rates indicates a movement along the labour demand curve, i.e. negative quantity growth accompanied by positive price growth for all countries except Greece and Hungary. We observe a shift of labour demand curve to left, i.e. both quantity and price growths are negative, in Greece and a shift to right, i.e. both quantity and price growths are positive in Hungary. On the other hand, both capital demand and price increases in 7 out of the 10 countries in the sample. A positive capital demand growth is accompanied by a negative price growth only in Czech Republic, Finland and Hungary. The land price and quantity relations indicate a rather complicated picture. Quantity and price of land moves in opposite directions for Austria, Finland, Hungary and Portugal indicating a move to left on the land demand curve. However, for the other countries land prices and quantities move on the same direction, both of them being positive. Thus for these countries we can expect a shift in land demand.

Figure 2 denotes the distribution of mean price and quantity growths with respect to net value added for labour, capital and land and the trend lines for the relationship between mean price and quantity. There is a strong negative relationship between value added price and quantity among the countries. The trend lines for land and capital indicate a weak relationship while the relationship between wages and employment are negative but not as strong as that of value added. Note that the mean growth rates indicate a switch to capital intensive technologies for all countries except Denmark and Hungary. In Denmark quantity growth is negative for all factors, while in Hungary both labour and capital growths are positive, with labour growth is higher. Growth of land quantity is negative for Austria, Finland, Hungary and Portugal while it is positive in other countries.

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Figure 2: Mean price and quantity growth for value added, labour, capital and land per country



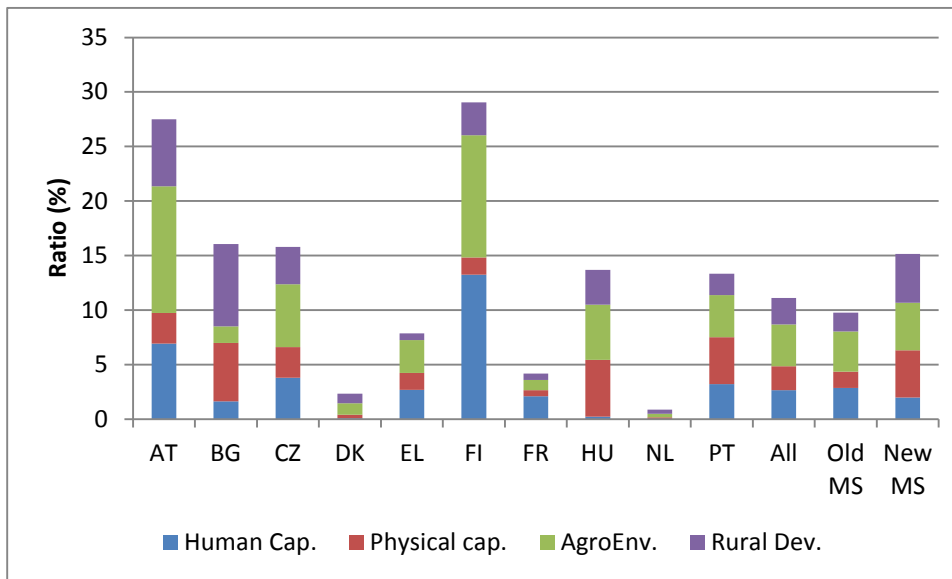
Note: some countries are left out to make the graph more readable.

Source: Authors' calculation

We use the Clearance Audit Trail System (CATS) data (European Commission, 2013) compiled by Boulanger and Philipidis (2016). CATS data compiles of all CAP payments reported by the Member States for the period 2008-2013. Boulanger and Philipidis (2016) classify more than 10 thousand budget codes in the CATS data into 46 Pillar II measures. We then classify these 46 measures into 4 categories of subsidies in our model: human capital, physical capital, rural development and agro-environmental payments (**Error! Reference source not found.**). Then we calculate the ratio of these payments in total agricultural industry output. Descriptive statistics of subsidy shares in total agricultural output can be found in **Error! Reference source not found.**

Figure 3 shows the ration of each subsidy group in total agricultural output for all countries in the sample. Ratio of human capital, physical capital and rural development payments to agricultural output is around 2.5 percent, while that of agro-environmental payments is close to 4%. In our sample, the ratio of subsidies to the agricultural output is significantly higher for old member states with 15% compared to 10% of the new member states. The composition of subsidies also differs between new and old member states. Agro-environmental and human capital subsidies are higher for old member states. For the new member states, ratio for the human capital subsidies is lower than that of the old member states while the ratio of agro-environmental is higher and equal to physical capital subsidies. The highest ratio for the new member states is rural development subsidies with 4.5%.

Figure 3: Ratio of subsidy groups in total agricultural output per country



Source: Authors' calculation

The estimations are done in STATA using the two step Generalized Method of Moments (GMM) system estimator with heteroscedasticity-autocorrelation consistent standard errors (Newey and West algorithm) which takes care of potential endogeneity problems along with many other advantages over the alternative estimation strategies. We first estimated the model by using the independent variables themselves as instruments.

There are several econometric methods that can be used to estimate the system of equations (6-8), such as Seemingly Unrelated Regression (SUR) that takes into account the fact that the residuals in both FOCs are correlated and enables to impose the constraint of equal substitution elasticities in each equation. Alternatively, a non-linear version of SUR (NLSUR) can be used that enables to estimate a direct structural form of the equations instead of a reduced form that is required for SUR. In this paper, the GMM system estimator was applied as it provides the advantages of NLSUR and it also enables to deal with a potential endogeneity problem that might be present due to high aggregation of the dataset. The procedure for dealing with endogeneity in the paper was the following: at first, a default version of the model was estimated using two-step GMM with heteroscedasticity-autocorrelation consistent standard errors (Newey and West algorithm). Endogeneity of prices was investigated by comparing the over-identifying restriction test statistics (Hansen's J Chi Square) of the basic model and a model estimated using instrumental variables. Provided that there is an endogeneity problem, the over-identifying restrictions test in the standard model variable will strongly reject the H_0 . In this case, the standard GMM estimates might not be consistent and instead, parameters obtained from GMM with instrumented prices are reported. The strength of the instruments was checked from the F-test of the reduced form regression.

The final specification under which does not suffer from endogeneity problem uses price variables lagged by one period as instruments for price variables. Higher order lags were not considered because i) the number of observations becomes prohibitively low, ii) there is no economic reason to believe that prices in earlier periods would contain information about recent periods. Regarding the endogeneity of the four types of subsidies, it was found that most of subsidies are exogenous to the system and there is no need for lagged instruments. There is also no serious multi-collinearity between the different subsidies ratios. The exception is rural development subsidies, which caused an endogeneity problem if included in the original form. To obtain a desirable value of the Hansen's J Chi square test, rural development subsidies were included in the form of a 2-period time lag of ration of rural development payments in output in equation (6), respecting the fact that there might be certain delay in the way how these types of subsidies impact productivity.

4 Results and Discussion

Estimation results are given in **Table 1**. Our results suggest that human capital, physical capital and agri-environment related payments have statistically significant positive effects on labour, capital and land productivities respectively. On the other hand, payments related to rural development do not have a significant impact on productivity. The results are robust with respect to the member states, date of access to the EU (i.e. old or new member states), spatial characteristics (i.e. being in the south, north or east) or size of the countries (i.e. big or small economies)¹.

The substitution elasticity (σ) between labour, capital and land is estimated to be 0.28 and is statistically significant, indicating a good fit of the data to the CES production function specification with single nest. Note that our estimation is very close to the assumed elasticity of 0.264 for agricultural sectors in the MAGNET model.

The exogenous productivity growth coefficient (δ_{EXO}) coefficient is found to be statistically insignificant. This implies that the CPA Pillar II subsidies can explain almost all of the productivity growth in the sampled regions over the period 2007-2013.

The coefficients of human capital, physical capital and agro-environmental subsidies are all positive and significant implying a positive contribution of these subsidies on labour, capital and land productivity respectively. If the share of human capital related subsidies in total agricultural output is doubled, then labour productivity in agriculture increases by 3%. The coefficient of agro-environmental and physical capital related subsidies is found to be 0.05. This means if the share of physical capital related subsidies or agro-environmental subsidies in total agricultural output is doubled, capital or land productivity in agriculture increases by 5 %. Coefficient of rural development subsidies is statistically insignificant and does not affect factor productivity in agriculture.

Table 1: Estimation results

GMM estimation				
Number of parameters=	7			
Number of moments=	15			
Initial weight matrix:	Unadjusted			
Number of obs =	408			
GMM weight matrix:	HAC Bartlett 27			
	(lags chosen by Newey-West)			
	Coef.	HAC Std. Err.	P>z	
Sigma(σ)	0.28	0.09	0.00	***
Delta (δ_{EXO})	0.17	0.12	0.15	
MS Dummy(δ_{MS})	0.10	0.06	0.11	
Human Capital (δ_{HC})	0.03	0.01	0.01	***
Rural development (δ_{RD})	-0.02	0.02	0.28	
Physical Capital (δ_{PC})	0.05	0.02	0.01	***
Agroenvironmental (δ_{AE})	0.05	0.02	0.01	***

Note: Instruments: equation 1: MS Dummy, 2nd lag of human cap., 2nd lag of rural dev., 1st lag of labour price
equation 2: MS Dummy, 2nd lag of physical cap., 2nd lag of rural dev., 1st lag of capital price
equation 3: MS Dummy, 2nd lag of agro-env. pay., 2nd lag2 of rural dev., 1st lag of land price
Test of overidentifying restriction: Hansen's J $X^2(8) = 11.9359$ ($p = 0.1541$)

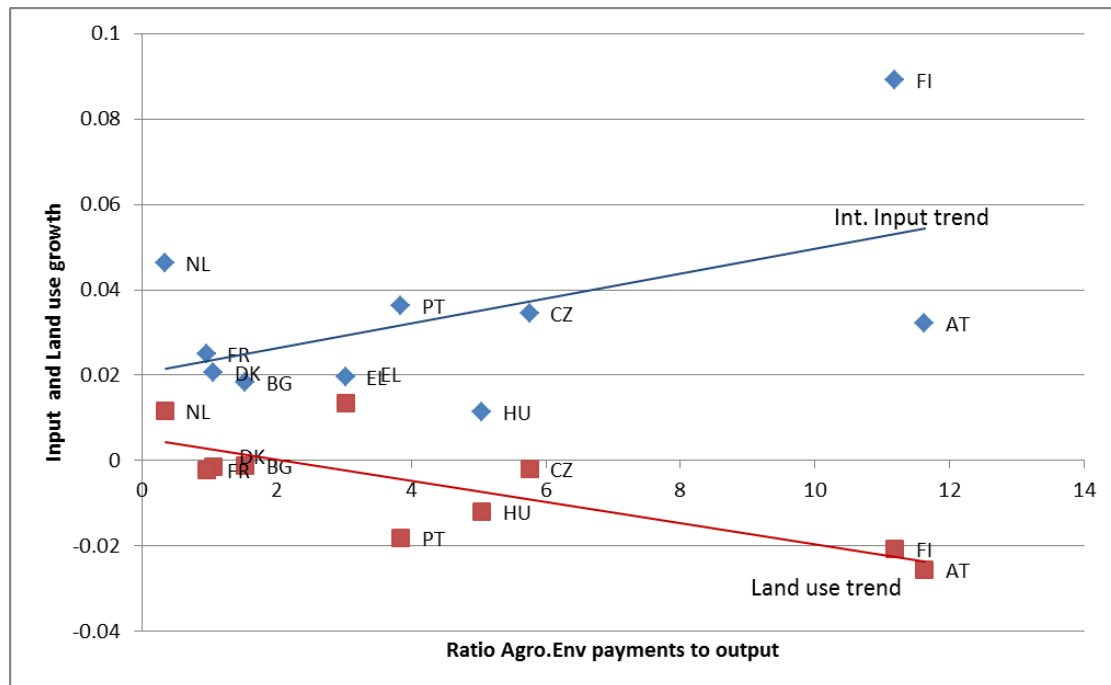
Source: Authors' estimations

¹ Many variations of the model that include control variables for those factors are estimated but are not reported since they all suggest that these factors are irrelevant.

The positive and significant impact of human and physical capital related subsidies is in line with expectations. However, the coefficient of agro-environmental subsidies seems to be counter intuitive as the measures under agro-environmental subsidies such as "extensive farming systems, a mosaic of landscapes, environmentally sound farming techniques adapted to region-specific needs, or extensive pasture systems" (DG-AGRI, 2017) are generally assumed to be counterproductive as they are presumably lower the intermediate input use such as fertilizers and pesticides to protect environment. Our estimation suggests that these measures improve land productivity. Analysis of the relationship between intermediate input use and agro-environmental subsidies do not support this presumption as the ratio of agro-environmental payments to agricultural output increases with intermediate input use (**ncrease the** land productivity).

Figure 4) as suggested by the strong positive slope of the trend line. On the other hand, when we plot agro-environmental payments ratio against the land use growth, the relationship is found to be negative and strong. That is, agro-environmental payments do have a negative impact on land use, as intended by the policy. This would mean, agro-environmental payments relates to implementation of more inputs with less land, which is likely to increase the land productivity.

Figure 4: Agro-environmental payments vs. Intermediate input and Land use



Source: Authors' elaboration

5 Conclusion

Quantifying the effectiveness of Common Agricultural Policy measures is highly relevant both for ex-post and ex-ante impact assessments. Yet, owing to multiple reasons, the empirical evidence of the productivity impact of CAP investment subsidies is rather scant and most of the impact assessments rely on empirical evidence outside of agricultural sector. Therefore, this study attempts to shed more light on the role of different CAP subsidies on factor productivity in agriculture. The contributions are three-fold: i) the study uses regional (NUTS-2) level data and therefore it enables to capture a sector rather than farm-level perspective, ii) the effects of the four major types of Pillar II subsidies on factor-augmenting technical change can be compared in a systematic way, iii) the adopted methodological framework enables to simultaneously estimate both CES substitution elasticity and productivity parameters, which can be readily used in the impact-assessment models.

One of the major constraints for a comprehensive assessment of this kind is the data availability, as for many EU countries, agricultural accounts and subsidies records are not available. To (partially) overcome this problem, this paper uses a novel approach of data imputation technique in which missing observations

are estimated in multiple repeated samples. This enables to derive robust estimations and graphically report the distributions of parameters and p-values.

The estimation results showed that the substitution elasticity between capital, land and labour is highly significant and robust with values far from unity, confirming thus the CES case over the Cobb-Douglas production technology.

The results confirmed significant positive effects of physical, human capital and agro-environmental payments on factor-augmenting technical change in agriculture. It has been found that human capital subsidies stimulate labour-augmenting technical change, whereas physical capital subsidies increase capital-augmenting technical change. Agri-environmental payments are in turn important in stimulating land-augmenting technical change. The magnitude of the parameters is rather small (elasticities ranging from 0.03% -0.05%), i.e. doubling of subsidies share in output would bring an additional productivity growth of 3% - 5%, which is very moderate, but in line with magnitudes reported in other studies reviewed in the chapter 2. Regarding rural development payments, their impact has proved not significant, which is not surprising as rural development payments are mostly directed to non-agricultural rural sectors such as transport and tourism. Finally, the consequent step in after this estimation is to implement the results into the impact-assessment model MAGNET. This will enable to quantify the economy-wide impacts of alternative CAP Pillar II measures.

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