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TEP Working Paper No. 0221

April 2021

Trinity Economics Papers
Department of Economics

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Abstract

Resource misallocation has been identified as an important source of aggregate productivity loss, yet to date there is a notable dearth of studies exploring the nature and extent of misallocation in the agricultural sector, despite the fact that it continues to receive significant government supports. In this paper, we analyse resource misallocation in the agricultural sector of the European Union with the aim of quantifying the impact of capital misallocation on aggregate productivity and disentangling its sources. We find that misallocation contributed to a 30 percent loss in productivity in the sector between 2001 and 2010. We can attribute about one third of this loss to distortionary government subsidies which disproportionately benefit relatively less productive farms. We find no evidence that the decoupling reform of the CAP in the mid-2000s reduced the distortionary effect of CAP subsidies on the allocation of capital. Our results provide an important benchmark for understanding misallocation in the context of a modern developed agricultural sector and other industries that benefit from potentially distortionary government supports.

Key Words: Resource misallocation, productivity, subsidies, agriculture
JEL Codes: D22, D24, O13, Q12, Q18

Acknowledgments: We would like to thank the Department for Agriculture and Rural Development of the European Commission for giving us access to the FADN data for this project and their support and availability.

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1 Introduction

Resource misallocation has been identified as an important source of low aggregate productivity growth. Misallocation, usually measured as the dispersion in the average or marginal productivity of inputs, can result from a number of factors, including efficient factors, such as adjustment costs or uncertainty, but also distortions induced by particular policies, institutions or other firm-specific factors. A large and growing literature has emerged that focusses on analysing the extent of misallocation in different settings and contexts, as well as on identifying the sources of misallocation.[1] Most of the related studies were concerned with the extent of misallocation in the manufacturing sector (Hsieh and Klenow 2009; Bartelsman et al. 2013; Asker et al. 2014; David and Venkateswaran 2019), with a notable dearth of analyses addressing how misallocation impacts on productivity in the developed agricultural sectors of the world.[2]

This is surprising given the fact that agriculture receives significant government supports in the form of subsidies, price supports and trade protection measures in most of the large economies of the developed world, even though it no longer accounts for a significant proportion of output or employment.[3] For example, EU supports for agriculture amounted to almost €58 billion in 2019, with €41 billion of these given in the form of direct income supports and another €14 billion to support rural development initiatives. In total, around 26 percent of income from agriculture in the EU comes from subsidies (European Commission 2020). Similarly, in the US, direct farm payments amount to around 23 percent of farm income. Agriculture is essential for food production and provides important public goods, such as producing food in a sustainable and environmentally way and maintaining soils and biodiversity. Subsidies can clearly be justified on food security and environmental grounds, but they are likely to have distortionary impacts on resource allocation and productivity. Quantifying these impacts is important for making informed policy decisions on the costs and

[1] Restuccia and Rogerson (2017) provide an overview of the literature to date on the causes and costs of misallocation.

[2] There is a growing literature on the extent of misallocation within agriculture in developing country contexts (Adamopoulos et al. 2017; Adamopoulos et al. 2017; Chari et al. 2017; Chen et al. 2017; Foster and Rosenzweig 2017; Gollin and Udry 2021; Maue et al. 2020; Restuccia and Santaeulalia-Llopis 2017) but few studies that have provided a comprehensive analysis of the extent and source of misallocation for the agricultural sector in developed countries or regions.

[3] The agricultural sector in the EU accounted for 1.3 percent of GDP in 2019 (0.6 percent in the US) contributing €176.4 billion towards overall GDP (€112.3 billion in the US) (Eurostat 2020). Moreover, the EU is the world's top exporter of agri-food products with total exports amounting to €151.2 billion in 2019 (equivalent figure for the US was €115.5 billion in 2018). See the United States Department of Agriculture for up to date statistics for agriculture in the US https://www.usda.gov/.

benefits of providing such supports to the sector. Moreover, there are potentially important lessons to be learned for other sectors from examining how such policy-induced distortions contribute to resource misallocation and productivity in the sector.

In this paper, we examine the implications of resource misallocation and its sources for agricultural productivity in the European Union (EU). We focus on capital allocation and use data on a large representative sample of farms operating in the EU15 countries between 2000 and 2010 from the Farm Accountancy Data Network (FADN) to measure the extent of capital misallocation in European agriculture and to disentangle its sources. We choose this time period as it allows us to explore the extent to which distortions created by the subsidies given to farms under the Common Agricultural Policy (CAP) induced inefficient allocations of capital and quantify the consequences for overall productivity. We also examine how the impact of subsidies on misallocation and productivity changed with the reform to the CAP which decoupled subsidies from production.

We use the methodology developed by David and Venkateswaran (2019) (hereafter DV), who build a unified framework for identifying and measuring the contribution of a number of factors to misallocation (the dispersion in average revenue capital productivity) and their consequential impact on productivity. We consider five main sources of misallocation: adjustment costs, uncertainty/informational frictions, correlated distortions, fixed distortions and transitory distortions. The availability of farm-specific data on the level and type of government subsidies received allows us to drill into these sources and identify how government subsidies distort the allocation of capital in the agricultural sector and its implications for productivity.

We find that the extent of capital misallocation, measured by the dispersion of the average revenue productivity of capital, is higher in the European agricultural sector than in US manufacturing and agriculture and that a large share of this dispersion can be explained by government subsidies. Correlated distortions account for the lion's share of the misallocation, and we can attribute half of this to CAP subsidies. Overall, we find that misallocation contributes to a 30 percent loss in productivity, one third of which can be attributed directly to distortions induced by farm-level subsidies. In practical terms, this means that in the absence of subsidies, a reallocation of capital to more productive farmers would have led to 10 percent higher productivity, all else equal. Considering that gross value added of the sector was €1,632 billion during the period 2001 to 2010, this is an economically significant loss. We do not find any evidence that the reform to the CAP, which decoupled subsidies from production, affected the way in which subsidies impact resource misallocation and productivity. Additional reduced-form analysis suggests that an important channel through which subsidies impact misallocation is by favouring less productive farms. Finally, we explore other possible sources of capital misallocation and find that heterogeneity in mark-ups and in production technologies also play a role but cannot explain the dispersion in capital that we attribute to subsidies.

Our paper is related to the large body of literature focussing on quantifying the impact of resource misallocation on productivity (Hsieh and Klenow 2009; Restuccia and Rogerson 2008) and the more recent literature focussed on identifying the specific factors that contribute to misallocation. These include Asker et al. (2014) who focus on the role of adjustment costs, Peters (2020) who examines the implications of dispersion in mark-ups for misallocation. A number of studies have focussed on how financial frictions lead to misallocation of capital (Brandt et al. 2013; Caballero et al. 2008; Caggese and Cuñat 2013; Gopinath et al. 2017; Midrigan and Xu 2014) while others have focussed on channels through which labour is misallocated such as a reduction in gender and race discrimination (Hsieh et al. 2019) or policies that affect the size distribution of firms (Bento and Restuccia 2017; Guner et al. 2008). Our paper also relates to an emerging literature on the extent and sources of misallocation in agriculture in developing country contexts (Adamopoulos et al. 2017; Adamopoulos et al. 2017; Chari et al. 2017; Chen et al. 2017; Foster and Rosenzweig 2017; Gollin and Udry 2021; Maue et al. 2020; Restuccia and Santaeulalia-Llopis 2017). This literature points out that the dispersion in total factor productivity is larger in developing countries and that greater misallocation, particularly in the agricultural sector, is one possible contributing factor. These studies highlight that an important source of agricultural misallocation in developing countries is the existence of distortions that allow low productivity establishments to survive.

Our paper contributes to this literature in three main ways. First, this is the first paper, to our knowledge, to examine misallocation and its sources in a comprehensive way for a modern well-developed agricultural sector. While a large body of work has been devoted to the extent of misallocation in the manufacturing sector (Asker et al. 2014; Bartelsman et al. 2013; David and Venkateswaran 2019; Hsieh and Klenow 2009), relatively little is known about whether misallocation is as prevalent in the agricultural sector and whether the sources of misallocation align with those found to be prevalent for manufacturing. The lack of a comprehensive analysis of the agricultural sector is a clear gap in the literature. This study provides an important benchmark for comparisons with existing estimates of misallocation in the manufacturing sector of other developed countries and regions, but also for the emerging literature on resource misallocation in agriculture in developing countries cited above.

There are reasons to believe that misallocation and its sources might be different for the agricultural sector. Uncertainty may play a larger role given that production is very dependent on climatic factors. Adjustment costs might also be larger given that one of the most important inputs for most of the sector is land which is a fixed and scarce resource. Most notably, as mentioned above, the sector is one of the most supported by government both in the EU and the US with subsidies accounting for around one quarter of farm income. The relative homogeneity of the use of subsidies to support the sector in the EU provides a unique opportunity to isolate their effect on productivity. The second main contribution of our paper is that it is the first, to our knowledge, to empirically assess the impact of firm-specific government subsidies on misallocation and productivity. Given that we have data on the actual subsidies that farms receive we can explore directly how these subsidies affect resource misallocation and quantify the implications for productivity. While our focus is on the EU, there are significant lessons to be learned for the agricultural sector in other contexts including the US. Our findings are also relevant for any sectors where there is heavy government subsidisation at the firm level.

Finally, this paper contributes to the body of literature exploring the impact of measures associated with the implementation of the CAP on productivity. More specifically, we provide new evidence on the impact of the decoupling of subsidies from production, which was part of the CAP reform in the mid-2000s, in an attempt to reduce distortionary impacts of subsidies on production decisions. The literature on this topic has generally focussed on how decoupled subsidies impact output or the productivity of farms, in both EU (Kazukauskas et al. 2014; Rizov et al. 2013; Zhu and Lansink 2010) and US (Goodwin and Mishra 2006; Weber and Key 2012) contexts, but has generally remained silent on the impact of decoupling on the distribution of resources within the sector and aggregate productivity. Theoretical contributions on the topic of decoupling (Ahearn et al. 2006; Chau and De Gorter 2005) suggest that decoupling might affect the allocation of agricultural inputs across heterogeneous producers in an ambiguous way. On the one hand, it should redistribute inputs towards relatively more productive sectors and so improve allocative efficiency. On the other hand, it could also result in the reduction of the exit rate of less productive farmers by relaxing their credit constraints and/or by giving them a constant and reliable source of income.[4] Decoupling could also raise the price of land and in turn increase the barriers to entry of perspective potentially productive farmers, protecting the less efficient ones. By providing the first estimates of the impact of decoupling on allocative efficiency, this study will contribute to the evidence base

[4]Some empirical evidence for this channel in a European context is provided by Kazukauskas et al. (2013).

and help inform policy makers on this potential side effect of the CAP reform, as well as on their magnitude.

The rest of the paper is structured as follows. In section 2 we set out the theoretical model underpinning our analysis and our methodology. The data are described in section 3. Our main results are presented in section 4 where we focus on the contribution of subsidies to misallocation. In section 5 we provide some additional reduced form analysis of the link between subsidies and productivity. In section 6 we explore further the sources of capital misallocation focussing on the contribution of heterogeneity in mark-ups and production technologies. Section 7 concludes.

2 Theoretical framework and methodology

To study the magnitude and the source of capital misallocation in the context of EU agriculture, we adopt the methodology developed by DV. As illustrated in their original paper, the main advantage of this technique is that it allows the forces contributing to the dispersion in the revenue capital productivity (*arpk*) to be disentangled and measured. Unlike previous approaches, this methodology builds a unified framework rather than focusing on a single source of dispersion in the capital product, and provides a more robust estimate of the contribution of each source. More specifically, the sources considered are: adjustment costs, uncertaintly/informational frictions, and other firm-specific distortions.

Interpreting correctly the dispersion in *arpk* and disentangling the impact of each of these forces is of absolute importance for policy purposes. While on a theoretical level all these factors can contribute to dispersion in capital productivity, the policy implications are strictly contingent on the actual source.

More specifically, the observed dispersion in *arpk* can be the consequence of investment costs, which means farms may not fully adjust their capital when they experience a productivity shock, which in turn will increase the static dispersion of capital productivity. Similarly, informational frictions and uncertainty can cause lags in the (or lack of) responsiveness of farmers to price and production shocks which can result in high variance in capital across farms.

Both of these sources are considered to be "efficient" in the literature as they reflect optimal response behaviours of farms rather than policy-induced distortions. As an example, a farmer experiencing a positive productivity shock might optimally decide to avoid increasing the size of their holding because doing so would result in prohibitive adjustment costs (e.g. administrative costs and paperwork to acquire/rent new land) or because the shock is perceived to be only transitory (uncertainty and lack of information about future outcomes).

On the other hand, distortions are conceptualized as farm-specific factors directly affecting investment decisions. These can either be fixed (e.g. tax advantages and subsidies granted to a specific sector or area) or related to some farm characteristics (size, productivity, etc). Such policies result in differences in the capital productivity of farms in equilibrium that can be directly attributed to the said interventions rather than to some "exogenous" constraint (like adjustment costs and uncertainty). As such, they can lead to inefficiencies in the factor distribution across farms, the so-called misallocation.[5]

In practical terms, the methodology involves estimating the parameters that determine the severity of each source of capital misallocation by matching empirical moments from the covariance and autocorrelation matrices of firm-level investment, productivity and value added. We estimate the DV model for each EU 15 country using harmonized farm-level data from the Farm Accountancy Data Network (FADN) for the period from 2001 to 2010. In order to study the impact of subsidies on capital misallocation (and its sources), we will compute the model twice. In the benchmark specification, the value added of each farm is calculated net of subsidies to obtain figures on the dispersion of the actual productivity of capital and its decomposition; then, we re-estimate the model explicitly including subsidies in value added to study the role they play in shaping farm-level investment decisions and the resulting distribution of capital across heterogeneous units. Comparing the two solutions allows us to compute the impact of subsidies on each component of capital dispersion and in turn measure the impact on the aggregate productivity of EU agriculture. Finally, we estimate these models before and after the CAP 2005 reform, which decoupled subsidies with the objective of improving the productivity of farming in the EU, to assess whether it had any effect on agricultural capital misallocation.

In what follows, we describe the main features of the DV model and refer readers to the original work for a more in-depth exposition of the model. The economy is composed of a representative household inelastically supplying a fixed quantity of labour N, with preferences defined over a final good Y with discount rate β, and of a continuum of farms of dimension 1 indexed by i, each producing output according to a Cobb-Douglas production function with

[5]The term distortions is admittedly a bit misleading since some conceptually *efficient* sources of capital dispersion such as variance in mark-ups and production technologies are captured empirically as firm-specific distortions. In this paper, we will focus on the distortions directly caused by the CAP subsidies and disentangle them from the impact of within sector mark-up dispersion and heterogeneity in production technology.

constant returns to scale:

$$Y_{it} = K^{\hat{\alpha}_1} N^{\hat{\alpha}_2} \tag{1}$$

In the context under analysis, K represents the sum of land and agricultural capital used by farms while N is the amount of labour employed.

Farm production is aggregated to the economy level using a CES function with elasticity of substitution θ using $Y_t = \left(\int \hat{A}_{it} Y_{it}^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}}$ where A_{it} represents the farm-specific idiosyncratic productivity and demand shock. As a result, firm-level revenues are:

$$P_{it} Y_{it} = Y_t^{\frac{1}{\theta}} \hat{A}_{it} K_{it}^{\alpha_1} N_{it}^{\alpha_2} \tag{2}$$

where the revenue elasticities of labour and capital are obtained by multiplying the production elasticities from Equation 1 by $1 - \frac{1}{\theta}$. Each farm will select the amount of capital and labour to use to maximize their expected profits. Farms can hire labour on a period-by-period basis after observing their productivity shocks and at the competitive market wage W. On the other hand, capital is a semi-fixed input whose level in period t is determined in $t-1$. Additionally, farms need to pay a cost ϕ when investing, which is a quadratic function of the relative increase in capital:

$$\Phi_t \left(K_{t+1}, K_t \right) = \frac{\hat{\xi}}{2} \left(\frac{K_{t+1}}{K_t} - (1-\delta) \right)^2 K_{it} \tag{3}$$

where δ represents the depreciation rate of capital and $\hat{\xi}$ determines the severity of the adjustment costs and is one of the key parameters the model aims to estimate.

Unlike labour, the cost of capital is assumed to be farm specific and to depend on a number of institutional and farm-specific factors. These are captured by a farm and time specific wedge T_{it}^K, following Hsieh and Klenow (2009). The farm's problem in recursive form is therefore expressed as (after substituting for the profit maximizing level of labour N):

$$\begin{aligned} V \left(K_{it}, I_{it} \right) = & \max_{K_{it+1}} E_{it} \left[G A_{it} K_{it}^{\alpha} - T_{it+1}^K \left(1 - \beta \left(1 - \delta \right) \right) - \Phi_t \right] \\ & + E_{it} \beta \left[V \left(K_{it+1}, I_{it+1} \right) \right] \end{aligned} \tag{4}$$

which can be used to find the stationary equilibrium and solve the model.[6]

The resulting Euler equation is:

$$
\begin{aligned}
E_{it}\left[\beta\Pi_1'\left(K_{it+1},A_{it+1}\right)-\beta\Phi_2'\left(K_{it+2},K_{it+1}\right)-T^K_{it+1}\left(1-\beta\left(1-\delta\right)\right)\right. \\
\left.-\Phi_1'\left(K_{it+1},K_{it}\right)=0\right.
\end{aligned}
\tag{5}
$$

where the subscript indicates the position of the variable of differentiation within the associated parentheses. This equation states that in equilibrium, the total (expected) benefits of an additional unit of capital in $t+1$ in terms of increase in profit and reduction in future investment costs must be exactly equal to the total (expected) costs in the form of an increase in adjustment costs.

Log-linearizing Equation (5), in the steady state with an undistorted equilibrium ($T^K=0$ and setting $K_{it+1}=K_{it}$) the law of motion of the (log of) capital will be:

$$
k_{it+1}\left(\left(1+\beta\right)\xi+1-\alpha\right)=E_{it}\left[a_{it+1}+\tau_{it+1}\right]+\beta\xi E_{it}\left[k_{it+2}\right]+\xi k_{it} \tag{6}
$$

where ξ is a rescaled version of the parameter governing the severity of the adjustment costs, while τ is a (decreasing) function of T^K, i.e., higher values of τ imply lower firm-specific costs of capital.

The distortions τ are assumed to be the sum of three components:

$$
\tau_{it}=\gamma a_{it}+\chi_i+\epsilon_{it} \tag{7}
$$

with one being proportional to the firm's productivity (γa_{it}), one firm specific ($\chi_i\sim N\left(0,\sigma^2_\chi\right)$) and one transitory ($\epsilon_{it}\sim N\left(0,\sigma^2_\epsilon\right)$).[7] The magnitude of each of these forces is captured respectively by γ, σ^2_χ and σ^2_ϵ, which are three of the parameters the model estimates.

[6]We use the same notation as in the original paper, where: $G=\left(1-\alpha_2\right)\left(\frac{\alpha_2}{W}\right)^{\frac{\alpha_2}{1-\alpha_2}}Y^{\frac{1}{1-\theta}\frac{1}{1-\alpha_2}}$, $\alpha=\frac{\alpha_1}{1-\alpha_2}$ and $A_{it}=\hat{A}_{it}^{\frac{1}{1-\alpha_2}}$.The expectation operator reflects the uncertainty faced by farms whose productivity is potentially subject to idiosyncratic shocks in each period.

[7]Since higher levels of τ indicate lower costs of capital, $\gamma<0$ indicates that more productive farms face higher costs of accumulating capital.

Similar to the distortions, (log) productivity is itself a stochastic process, described by the equation:

$$a_{it} = \rho a_{it-1} + \mu_{it} \tag{8}$$

where $\mu_{it} \sim N\left(0, \sigma_\mu^2\right)$. However, farms receive a (noisy) signal of their future productivity:

$$s_{it+1} = \mu_{it+1} + e_{it+1} \tag{9}$$

where $e_{it+1} \sim N\left(0, \sigma_e^2\right)$, whose precision depends on the variance of the distribution of the noise e.

Therefore, the conditional expectation on future productivity levels is given by:

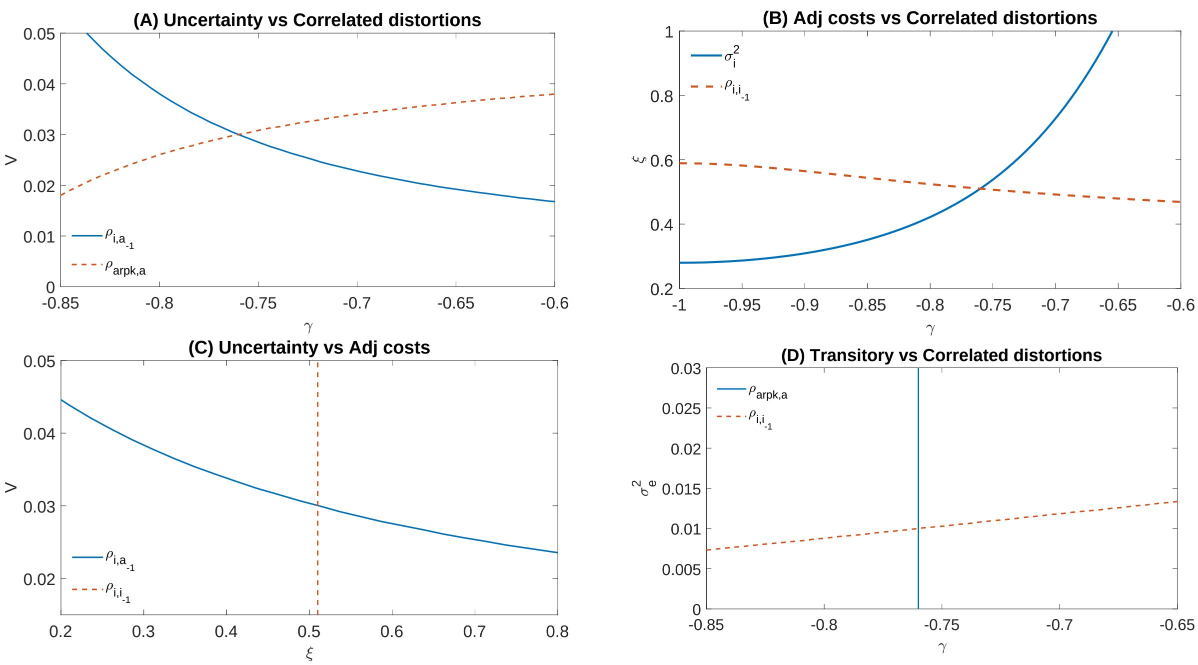
$$E_{it}\left[a_{it+1}\right] = \rho a_{it} + \frac{V}{\sigma_e^2} \tag{10}$$

where $V = \left(\frac{1}{\sigma_\mu^2} + \frac{1}{\sigma_e^2}\right)^{-1}$ with variance V. Therefore, the contributions to the dispersion of *arpk* of each of the components, namely adjustment costs, uncertainty, and correlated, transitory and fixed distortions, are effectively summarized, respectively, by the five parameters ξ, V, γ, σ_e^2, σ_χ^2.

Following DV, we estimate these parameters by matching a set of empirical moments describing the correlation and autocorrelation of capital, productivity and investment that can be expressed as a complex function of these parameters using a non-linear solver. As shown by DV, this approach avoids the biases that would arise in targeting one single moment or a moment pair, approaches adopted in previous studies in the related literature. Instead, we target jointly 5 different moments: the correlation between investment and past productivity shocks, $\rho_{i,a_{-1}}$, the autocorrelation of investments, $\rho_{i,i_{-1}}$, the correlation between farm productivity and *arpk*, $\rho_{arpk,a}$, the variance in investment, σ_i^2 and finally the dispersion of *arpk*, σ_{arpk}^2. Figure 1 illustrates this methodology by plotting the pairwise isomoment curves and illustrating the resulting parameter estimates for the case of Ireland. Each isomoment corresponds to the range of values for the parameter that is consistent with the empirical moment in focus.

The intuition behind this methodology is better explained by examining the moments in

Figure 1: Example of method of moments (Ireland)



a pairwise manner. For example, the impact of uncertainty and correlated distortions can be disentangled by examining $\rho_{i,a_{-1}}$ and σ^2_{arpk}. In fact, although they both have the same qualitative -positive- impact on the variance of the *arpk*, they affect $\rho_{i,a_{-1}}$, in opposite ways. Intuitively, higher uncertainty (due to either higher variance in innovation μ or in the signal e) leads farms to base their investment decisions more on past productivity shocks thus increasing $\rho_{i,a_{-1}}$. On the other hand, higher levels of correlated distortions (lower γ), would *ceteris paribus* reduce the sensitivity of investment to past productivity shocks (as they increase the cost of capital for the farm) and so would reduce $\rho_{i,a_{-1}}$. Thus, matching both empirical moments allows us to identify V and γ. Panel A of Figure 1 illustrates how the combination of $\rho_{i,a_{-1}}$ and σ^2_{arpk} can be used to identify V and γ.

In a similar way, the impact of correlated distortions can be separated out by considering the two empirical moments $\rho_{i,i_{-1}}$ and σ^2_i (see panel B of Figure 1). Specifically, both correlated distortions and adjustment costs reduce (all other factor fixed) the variance of investments. Intuitively, when correlated distortions are high, farms are less willing to invest following a positive productivity shock as capital has become more expensive as a result of the change in productivity and vice-versa; this reduces farms' responsiveness to productivity shocks and in turn the dispersion of investment. High investment costs have the same impact as they increase the cost of adjusting the amount of capital operated. On the other hand, the two forces have an opposing impact on the autocorrelation of investment as higher (quadratic) adjustment costs encourage firms to smooth investments over successive periods (increasing $\rho_{i,i_{-1}}$) while in the case of correlated distortions past investments (following positive productivity shocks) make future capital more expensive, reducing $\rho_{i,i_{-1}}$.

Uncertainty/informational frictions and adjustment costs can be separately identified considering that they both increase the correlation between current investment and past productivity shocks (the former because farms rely more heavily on past productivity realization to predict future outcomes, and the latter because investment following productivity shocks are smoothed over the years) but, as explained above, only adjustment costs affect $\rho_{i,i_{-1}}$ (see panel C of Figure 1).

Finally, the impact of correlated and transitory distortions can be disentangled by considering that while they both reduce the autocorrelation of investments (and so the positively sloped iso-moment curve for $\rho_{i,i_{-1}}$), only correlated distortions affect $\rho_{arpk,a}$, whose iso-moment curve is thus vertical. This is depicted in Panel D of Figure 1.

In our analysis, we estimate the five moments separately for each EU15 country using the method of moments which involves minimizing the equally weighted distance between the model and the data value for the five empirical moments of interest. The results are presented and discussed in section 4.

3 Data

The data for our empirical analysis come from the Farm Accountancy Data Network (FADN) dataset. The dataset consists of micro level annual data on farm income, production and characteristics for each country in the EU. The sample is constructed to be representative of the population of commercial farms in the EU and is technically organized as a revolving panel. In this paper, we focus on farms in the EU15 countries from 2001 to 2010.[8]

The sample reflects the sectoral composition of the agricultural activities in each country. In particular, for the scope of this analysis, farms are divided into eight groups depending on their main activity, namely field crops, horticulture, wine production, other permanent crops, milk production, other grazing livestock, granivores and a residual category including mixed, non-specialized farms. The sample size and the distribution of farming activities across countries are shown in Table 1.

[8]The list of countries and country codes are provided in Table A1.

Table 1: Sample size and farm type distribution by country

	Field crops	Horticulture	Wine	Permanent crops	Milk	Other grazing livestock	Granivores	Mixed	N
AUT	0.16	0.00	0.04	0.02	0.43	0.10	0.13	0.12	13,611
BEL	0.09	0.14	0.00	0.06	0.22	0.19	0.10	0.19	8,730
DEU	0.18	0.07	0.05	0.02	0.30	0.05	0.12	0.21	46,144
DNK	0.18	0.13	0.00	0.02	0.26	0.01	0.28	0.12	7,995
ESP	0.28	0.11	0.07	0.15	0.14	0.15	0.06	0.04	52,583
FIN	0.11	0.13	0.00	0.00	0.60	0.02	0.09	0.04	3,522
FRA	0.24	0.05	0.15	0.04	0.18	0.15	0.04	0.13	45,846
GBR	0.22	0.06	0.00	0.02	0.31	0.26	0.05	0.08	25,690
GRC	0.43	0.03	0.06	0.28	0.00	0.12	0.00	0.08	24,417
IRL	0.04	0.00	0.00	0.00	0.51	0.38	0.00	0.06	5,385
ITA	0.28	0.08	0.11	0.20	0.12	0.11	0.03	0.06	70,004
LUX	0.01	0.00	0.07	0.00	0.52	0.29	0.00	0.12	2,886
NLD	0.15	0.30	0.00	0.04	0.28	0.04	0.14	0.04	9,876
POR	0.14	0.09	0.12	0.12	0.24	0.20	0.01	0.07	12,017
SWE	0.21	0.00	0.00	0.00	0.48	0.07	0.14	0.10	4,662
Total	0.24	0.08	0.07	0.10	0.21	0.13	0.06	0.10	333,368

Source: Authors' calculation based on FADN data.

After dropping observations with missing data and trimming the three percent extreme values of the empirical moments of interest, we are left with a sample of over 300,000 farm/year observations between 2002 and 2010 spread across the 15 EU countries and the eight broad farm activity types.[9] Unsurprisingly, there is a lot of cross country variation in the composition of the agricultural sector, reflecting the variety of agro-climatic conditions and geographical differences across countries in the sample. In order to account for this, the target empirical moments are generated using variations from country, year and farm activity type averages.

The main variables of interest are the inputs used in production and the value of the agricultural output. The quantity of labour employed is directly available in the FADN dataset, which reports the total amount of paid and unpaid hours worked on the farm in Annual Working Units (AWU). We assume that paid and unpaid workers are equally productive and generate labour input by summing them together. Similarly, farm-specific value added is directly available in the data. It is defined as the total value of farm output minus the cost of intermediate inputs used in production and intermediate consumption. The data also include the total amount of subsidies received by farms. As shown in Table 2, subsidies

[9] Observations from 2001 were used to generate lags for 2002 but were dropped from the analysis as empirical moments using lags and changes were not defined.

represent a substantial source of income for European farms. The vast majority of them are awarded using EU funds according to the rules established by European directives. They are distributed by the member states, who have some autonomy in the distribution of funds. In some instances they can also directly distribute subsidies using their own budget. For the purpose of this paper, we will sum up all subsidies received by farms. However, we will use the distinction between coupled and decoupled subsidies in section 4 to estimate the impact of the 2005 CAP reform.

Obtaining the value of capital is slightly more challenging. We define a farm's capital as the value of its fixed assets, including the land operated in agricultural production. However, while the book value of other fixed assets (buildings, machinery and breeding livestock) is readily available in the data, the value of the land operated is not and only the acreage is available. In order to aggregate land and other inputs, we compute a region and farm type specific land price based on the rental prices observed in the sample itself and following the methodology in Rizov et al. (2013) to convert rents into value.[10]

The values of these variables for the median farm in each country are summarized in Table 2. Similar to the pattern reflected in Table 1, there is a lot of cross-country heterogeneity in farm size, profitability, and labour and capital intensity. These differences reflect both the differences in the type of activity farms are engaged in and country specific idiosyncrasies. For example, the median farm in Greece is less than 7 hectares in size, while in the UK and Denmark where agricultural production is concentrated in land intensive sectors like milk production and grazing livestock, the median farm is more than 100 hectares. Similarly, there is a wide variation in land prices across countries. The median price of a hectare of agricultural land in the Netherlands is nearly three times higher than Italy and Germany (2nd and 3rd country in this ranking) and 15 times higher than in Finland and France.[11] Finally, the table shows that subsidies represent a non-trivial share of the income received by farmers, although there is significant variation across countries.

[10] More specifically, regions are smaller geographical areas defined in the FADN dataset. There is a total of 105 regions in the EU15 countries. While smaller countries, like Luxemburg and Belgium are composed of one single region, France and Italy are made up of 22 and 21 regions respectively. Land prices are estimated for each farm activity type and region pair as long as there are at least 100 rental price observations in the subsample. In cases where less than 100 observations are recorded, the price is estimated at the regional, or (in cases where there is less than 100 observations for the region available) farm type, level.

[11] Our estimates of land prices are in line with Eurostat estimates https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=apri_lprc&lang=en.

Table 2: Descriptive statistics median farm by country

	Operated land (ha)	Land price (€'000 per ha)	Other assets (€'000)	Labour (AWU)	Value added (€'000)	Subsidies (€'000)
AUT	30.84	3.04	227.93	1.67	27.59	18.46
BEL	42.14	19.30	194.74	1.80	68.56	15.76
DEU	58.23	20.37	174.27	1.80	142.81	39.69
ESP	23.00	4.77	27.98	1.36	24.39	5.70
FIN	50.18	3.95	173.13	2.14	24.60	49.49
FRA	75.91	3.83	145.73	2.00	48.34	24.50
GBR	102.99	10.37	170.89	2.05	47.03	29.10
GRC	6.70	11.38	17.19	1.31	11.75	4.62
IRL	50.47	18.48	130.81	1.33	25.01	18.18
ITA	12.43	22.10	58.86	1.44	22.33	3.24
LUX	83.01	9.71	375.33	1.60	51.05	40.43
NLD	23.60	61.78	355.27	2.14	129.11	5.67
POR	12.10	4.21	24.23	1.60	9.75	4.04
SWE	75.35	4.32	223.61	1.62	32.42	22.68

Source: Authors' calculation based on FADN data. Operated land is expressed in hectares, while land prices are expressed in thousands of Euros per hectare. Other assets, value added and subsidies are in thousands of euros and labour is expressed in Annual Working Units (AWU). All monetary values are adjusted using Eurostat deflators for agricultural outputs and inputs.

4 Results

In this section, we present the empirical results of the paper. We start by presenting and discussing the target moments obtained from the FADN data without and with subsidies included in value added. We then present the parameter estimates and the resulting estimated impact on capital dispersion and aggregate total factor productivity of each contributing component: adjustment costs, uncertainty, and correlated, transitory and firm-specific distortions. We also show how the case of EU agriculture compares with the estimates of DV for the US and China. Finally, we use our results to estimate the productivity losses due to distortions brought about by subsidies before and after the implementation of the 2005 CAP reform that decoupled subsidies from farm production.

4.1 Empirical moments

The target moments necessary to estimate the parameters to decompose and identify the sources of capital misallocation are estimated for each country based on the FADN dataset described in section 3. In terms of model parametrization, we use the same elasticity of substitution $\theta = 6$, discount factor $\beta = 0.95$ and depreciation rate $\delta = 0.10$ as in DV. Unlike DV, who rely on external sources (Bai et al. 2006; Cooper and Haltiwanger 2006) to estimate the capital and labour shares and fix them at the country level (in the benchmark analysis), we compute these shares separately for each country and sector (using the eight main farm types listed in Table 1). Given that the elasticity of capital is different for each country and sector, the parameter for α for each country is set at the weighted average of the capital share using sector (farm activity type) specific value added as weights.

These moments are estimated separately for each of the EU 15 countries. We include year and type of farm fixed effects (interacted) to eliminate time or sectoral trends and drop the three percent extreme observations for each moment.[12] Productivity is obtained as the difference between (log) value added and (log) capital multiplied by the factor α while arpk is obtained as (log) value added minus the (log) of capital. ρ and σ^2_μ are estimated directly by regressing productivity a on it's lag.

In order to study the impact of subsidies on capital dispersion, we estimate two different versions of the model. The first does not include subsidies in the value added measure, and so will reflect the farms' actual productivity. In the second, we include subsidies in the measure of value added and so this reflects the actual returns obtained by farmers and the one they consider when making investment and production decisions. Comparing the results from the two different specifications will allow us to assess the role played by subsidies in determining the capital allocation across heterogeneous farms and whether the 2005 CAP reform had any effect on it.

The estimated empirical moments are shown in Table 3. Reassuringly, they are comparable across countries indicating that, although there are some differences across countries, the process of capital accumulation in the farming sector and the resulting outcomes are broadly similar across the EU15. However, it is worth pointing out that some countries display a much higher dispersion in *arpk*; notably, Spain, Portugal, Italy and Greece report the higher levels (ranging from 1.11 to 0.96), nearly twice as large as countries like Austria, Belgium and Germany (0.43, 0.42 and 0.58 respectively).

Interestingly, when we add subsidies to the measure of value added and re-estimate the empirical moments, we find that they explain a large share of the *arpk* dispersion, implying that the monetary returns to capital actually experienced by farms (i.e. returns taking

[12] This trimming strategy is the same as DV. The results are robust to more and less conservative choices.

Table 3: Empirical moments of EU15 countries

		α	ρ	σ^2_μ	$\rho_{i,\alpha-1}$	$\rho_{i,\imath-1}$	$\rho_{arpk,a}$	σ^2_i	σ^2_{arpk}
AUT	No subs	0.70	0.81	0.16	0.03	-0.36	0.93	0.01	0.43
	Subs	0.70	0.86	0.05	0.02	-0.36	0.89	0.01	0.17
BEL	No subs	0.66	0.81	0.13	0.02	-0.30	0.89	0.02	0.42
	Subs	0.66	0.83	0.07	0.03	-0.30	0.84	0.02	0.27
DEU	No subs	0.67	0.83	0.20	-0.01	-0.27	0.88	0.01	0.58
	Subs	0.67	0.91	0.07	-0.01	-0.27	0.80	0.01	0.34
DNK	No subs	0.56	0.89	0.18	0.00	-0.33	0.75	0.04	0.51
	Subs	0.56	0.92	0.09	0.00	-0.33	0.68	0.04	0.31
ESP	No subs	0.59	0.74	0.37	0.03	-0.33	0.91	0.03	1.11
	Subs	0.59	0.78	0.20	0.04	-0.33	0.87	0.03	0.74
FIN	No Subs	0.65	0.69	0.37	0.02	-0.25	0.92	0.01	0.66
	Subs	0.65	0.83	0.04	0.05	-0.25	0.75	0.01	0.15
FRA	No Subs	0.61	0.79	0.21	0.06	-0.24	0.92	0.02	0.60
	Subs	0.61	0.87	0.07	0.08	-0.24	0.80	0.02	0.29
GBR	No subs	0.65	0.77	0.33	-0.03	-0.29	0.91	0.01	0.89
	Subs	0.65	0.89	0.08	-0.03	-0.29	0.79	0.01	0.41
GRC	No subs	0.61	0.78	0.31	-0.01	-0.43	0.94	0.04	0.90
	Subs	0.61	0.81	0.12	-0.02	-0.43	0.90	0.04	0.45
IRL	No subs	0.79	0.70	0.36	0.09	-0.32	0.97	0.02	0.62
	Subs	0.79	0.85	0.05	0.26	-0.32	0.92	0.02	0.15
ITA	No Subs	0.60	0.82	0.27	0.02	-0.33	0.90	0.04	0.96
	Subs	0.60	0.86	0.16	0.03	-0.33	0.84	0.04	0.68
LUX	No Subs	0.72	0.81	0.14	0.03	-0.40	0.94	0.01	0.36
	Subs	0.72	0.84	0.04	0.07	-0.40	0.83	0.01	0.10
NLD	No Subs	0.59	0.85	0.19	0.01	-0.31	0.82	0.04	0.74
	Subs	0.59	0.86	0.15	0.00	-0.31	0.80	0.04	0.64
POR	No Subs	0.65	0.72	0.48	0.00	-0.34	0.93	0.05	1.11
	Subs	0.65	0.79	0.20	0.02	-0.34	0.89	0.05	0.61
SWE	No Subs	0.68	0.73	0.44	0.03	-0.31	0.92	0.02	0.83
	Subs	0.68	0.81	0.11	0.02	-0.31	0.86	0.02	0.29

Source: Authors' calculation based on FADN data.

subsidies into account) are less dispersed than the actual capital productivity. This suggests that less productive farms receive larger levels of support.

In terms of the other moments, the two that are affected most by the inclusion of the subsidies in the measure of value added are the variance in the innovation shocks, σ^2_μ, and the correlation between the *arpk* and farm productivity which are both markedly reduced in every country. Intuitively, this indicates that subsidies reduce the uncertainty in the monetary returns of farming and increase the monetary returns of less productive farms.

Table 4 provides a comparison of the estimated moments (which we aggregate using the agricultural GDP of each country in 2005) with the ones obtained by DV for China and the US, as well as for the agricultural, fishery and forestry sector in the US, which is arguably more directly comparable to the context of our analysis.[13] When subsidies are not accounted for, productivity is much more variable than in the comparator cases. Moreover, the correlation between current investments and past productivity shocks ($\rho_{i,a_{-1}}$) appears to be nearly zero, whereas it takes on positive values in both China and the US. The autocorrelation of investment ($\rho_{i,i_{-1}}$), at -0.31, is between the values that DV find for China (-0.36) and the US (-0.30), while the correlation between productivity and *arpk* ($\rho_{arpk,a}$) is higher than in either country but is similar to that found for US agriculture. The variance of investments (σ_i^2) is also lower than in China and the US but is similar to US agriculture.

Table 4: Comparison of empirical moments

	α	ρ	σ_μ^2	$\rho_{i,\alpha_{-1}}$	$\rho_{i,1_{-1}}$	$\rho_{arpk,a}$	σ_i^2	σ_{arpk}^2
EU15 (no subs)	0.62	0.79	0.28	0.02	-0.31	0.90	0.03	0.82
EU15 (subs)	0.62	0.85	0.12	0.03	-0.31	0.83	0.03	0.50
China	0.62	0.91	0.15	0.29	-0.36	0.76	0.14	0.92
US	0.71	0.93	0.08	0.13	-0.30	0.55	0.06	0.45
US (agriculture)	0.77	0.92	0.11	0.13	-0.37	0.92	0.03	0.61

Source: Authors' calculations based on FADN data (first two rows) and empirical moments from David and Venkateswaran (2019) (last three rows). The EU figures are aggregated using the size of the agricultural sector (in GDP) of each country in 2005 as weights (see Table A1 for weights used).

As anticipated, including the subsidies in the measure of value added reduces the volatility in innovation shocks as well as the correlation between productivity and arpk. Including subsidies also brings our estimates of the empirical moments more in line with those of DV for China and the US, especially those obtained for the US agricultural sector. All the target moments are indeed remarkably similar, with the sole exception of $\rho_{i,a_{-1}}$, which is much smaller in our case.

[13]More specifically, the results for China are based on industrial (manufacturing, mining and utilities) firms with sales above $600,000 between 1998 and 2009, while the ones for the US are based on publicly traded firms from Compustat North America (including firms operating in every sector). The figures on US agriculture are taken from DV's online appendix and are obtained using observations for firms operating in Agriculture, Forestry and Fishing from the same Compustat database.

4.1.1 Parameter estimates and decomposition of *arpk* variance

As explained in section 2, each of the parameters of interest can be expressed as a complex function of the five empirical moments discussed so far, which allows us to estimate them by matching the empirical moments in the calibrated model. The five parameters of interest are ξ, V, γ, σ_ϵ^2 and σ_χ^2 and describe, respectively, the severity of adjustment costs, uncertainty and informational frictions, correlated distortions, transitory distortions and fixed distortions.

The main advantage of this methodology is that the parameters are estimated jointly to match a broad set of empirical moments and therefore allow a more credible decomposition of the capital productivity dispersion. For policy purposes, it is of particular interest to disentangle the so-called "efficient" component – which includes adjustment costs and uncertainty/informational frictions – from the potentially policy-induced distortions.[14]

By comparing the parameter estimates obtained using the moments calculated using the actual value added with those calculated using the value added plus the subsidies, we can study directly the extent to which subsidies contribute to each component of the *arpk* dispersion. The estimated parameters are shown in Table 5 for each country and for both specifications of the model, while the comparison with the DV estimates for China and the US are shown in Table 6. Our estimates are quite in line with the parameters obtained by DV for US agriculture with slightly lower adjustment costs but more pronounced firm-specific and correlated distortions. The latter component is particularly large for EU agriculture, indicating the existence of (potentially policy-induced) distortions which favour relatively less productive farms in accessing and accumulating agricultural capital.

The parameter γ is in fact much larger in magnitude than in China and the US, although markedly similar to the corresponding US estimate when considering only the agricultural sector. This is not surprising as the estimate of γ depends crucially on the observed autocorrelation of productivity and *arpk* (which is typically very high in our sample) and (negatively) on the responsiveness of investment to lagged productivity shocks $\rho_{i,a_{-1}}$, which is particularly low in our case. Similarly, the lack of investment responsiveness (coupled with a rather high variance of the innovation shocks) points towards a large contribution of uncertainty

[14] Although this terminology is quite useful, it can be potentially misleading as capital dispersion due to adjustment costs and uncertainty is only "efficient" given the existing level of investment costs and informational frictions which are not necessarily sector specific and exogenous to policies. Similarly, not all the dispersion attributed to distortions is necessarily due to distortionary policies as they may reflect heterogeneity in technology and mark-ups. We address this possibility in section 6.

Table 5: Estimated parameters EU15 countries

		ξ	V	σ^2_χ	γ	σ^2_e
AUT	No Subs	0.60	0.06	-0.83	0.00	0.06
	Subs	0.60	0.02	-0.76	0.00	0.03
BEL	No Subs	0.43	0.06	-0.88	0.00	0.08
	Subs	0.95	0.03	-0.80	0.00	0.08
DEU	No Subs	1.84	0.06	-0.71	0.01	0.12
	Subs	0.69	0.02	-0.67	0.00	0.12
DNK	No Subs	0.81	0.07	-0.46	0.01	0.19
	Subs	0.72	0.03	-0.39	0.01	0.15
ESP	No Subs	0.48	0.18	-0.98	0.00	0.27
	Subs	0.61	0.09	-0.95	0.00	0.21
FIN	No Subs	0.75	0.16	-0.79	0.00	0.09
	Subs	0.64	0.03	-0.78	0.00	0.06
FRA	No Subs	0.74	0.09	-0.89	0.00	0.10
	Subs	1.02	0.03	-0.71	0.00	0.10
GBR	No Subs	0.60	0.13	-0.91	0.00	0.16
	Subs	0.55	0.03	-0.76	0.00	0.15
GRC	No Subs	0.10	0.16	-1.00	0.00	0.13
	Subs	0.60	0.05	-0.97	0.00	0.09
IRL	No Subs	0.80	0.17	-0.81	0.00	0.02
	Subs	0.51	0.03	-0.76	0.00	0.02
ITA	No Subs	0.33	0.12	-0.93	0.00	0.19
	Subs	0.30	0.08	-0.83	0.00	0.20
LUX	No Subs	1.05	0.05	-0.81	0.01	0.04
	Subs	1.02	0.02	-0.64	0.01	0.03
NLD	No Subs	0.43	0.08	-0.77	0.00	0.25
	Subs	0.42	0.06	-0.77	0.00	0.23
POR	No Subs	0.33	0.23	-0.94	0.00	0.18
	Subs	0.25	0.10	-0.90	0.00	0.14
SWE	No Subs	1.16	0.18	-0.74	0.01	0.10
	Subs	0.65	0.04	-0.72	0.00	0.07

Source: Authors' calculation based on FADN data.

and informational frictions, especially in the specification not including subsidies in value added.

As mentioned in the previous section, including the subsidies has a significant impact on σ^2_μ and $\rho_{arpk,a}$, which are both markedly reduced in every country. This affects the estimates of the parameters governing uncertainty/informational frictions, V, and the correlated distortions, γ, which are both smaller in the second specification. Intuitively, the smaller V indicates that farms are less subject to uncertainty/informational frictions than it appears

Table 6: Comparison of parameters

	ξ	V	σ_χ^2	γ	σ_e^2
EU15 (no subs)	0.65	0.12	-0.88	0.00	0.17
EU15 (subs)	0.61	0.05	-0.80	0.00	0.15
China	0.13	0.10	-0.70	0.00	0.41
US	1.38	0.03	-0.33	0.03	0.29
US (agriculture)	0.83	0.05	-0.78	0.01	0.09

Source: Authors' calculations based on FADN data (first two rows) and empirical moments from David and Venkateswaran (2019) (last three rows). The EU figures are aggregated using the size of the agricultural sector (in GDP) of each country in 2005 as weights (see Table A1 for weights used).

from the analysis of the value added net of subsidies and that their lack of responsiveness to productivity shocks reflects the fact that their investment decisions are based on their monetary returns which depend not only on (more variable and uncertain) actual productivity shocks but also and crucially on the predictable flow of subsidies.

The other parameter that is significantly affected by the inclusion of subsidies is γ, which in the aggregate analysis shrinks from 0.88 to 0.8. This suggests that part of the correlated distortions faced by farms are explained, and thus arguably driven, by the subsidies they receive. Practically, this shows that subsidies are benefiting to a larger extent less productive farms so that, when they are included in value added, the remaining correlated distortions appear less severe. We can therefore interpret the difference in the impact of correlated distortions (and of the other types of distortions) on the dispersion in *arpk* and total factor productivity between the first and the second specification as the magnitude of the impact of subsidies on capital misallocation and productivity.

We use the estimated parameters to examine the impact of each factor under analysis on the dispersion in *arpk* allowing us to identify the sources of the observed volatility in capital revenue productivity for each EU 15 country.[15] The results are presented in Table 7 and a graphical representation is provided by Figure 2. Interestingly, the lion's share of the dispersion in capital productivity is attributed to distortions rather than "efficient" factors

[15]Following the baseline specification of DV, we estimate the impact on productivity dispersion separately for each component fixing the others to zero. The sum of the effects are typically very close to the total dispersion. In order to compute percentages and carry out the decomposition, we re-scale the estimates to make them exactly add up to the observed σ^2_{arpk}.

(i.e. adjustment costs and uncertainty/informational frictions). This is in line DV's findings for the US and China.

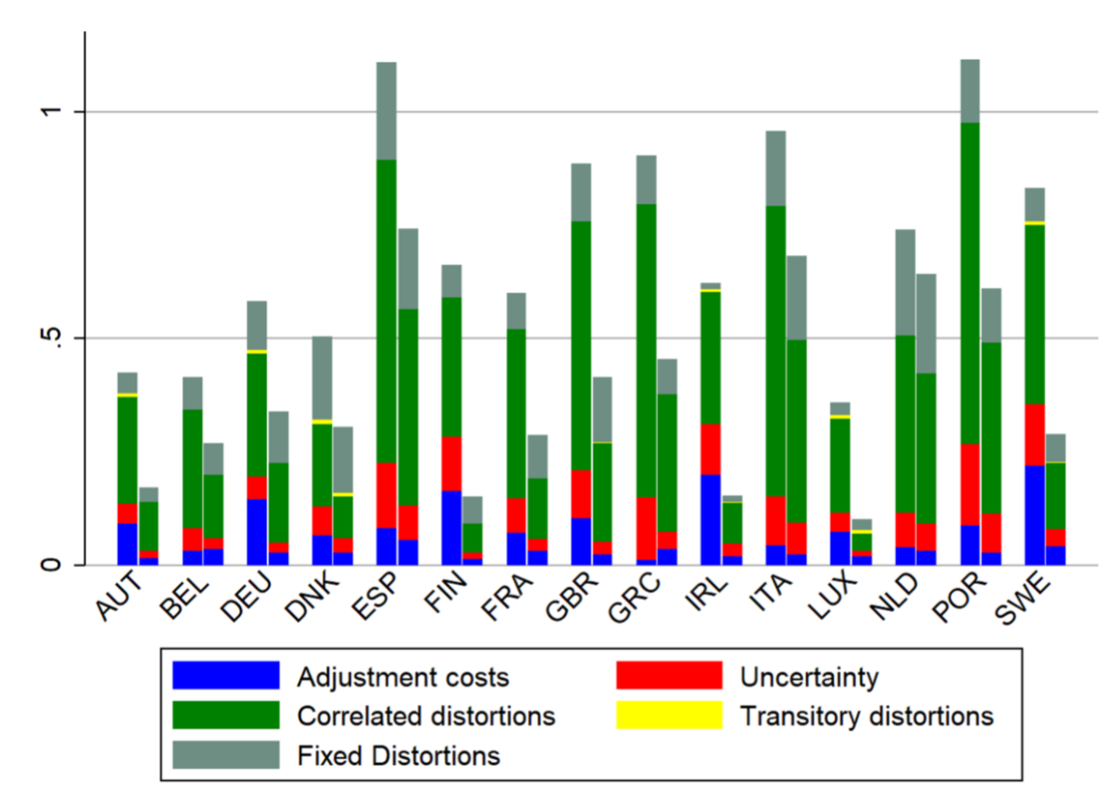
Table 7: Decomposition of σ^2_{arpk}

		Adjustment	Uncertainty	Correlated	Transitory	Fixed	Total
AUT	No Subs	0.09	0.05	0.24	0.01	0.05	0.43
	Subs	0.02	0.02	0.11	0.00	0.03	0.17
BEL	No Subs	0.03	0.05	0.26	0.00	0.07	0.42
	Subs	0.04	0.02	0.14	0.00	0.07	0.27
DEU	No Subs	0.14	0.05	0.27	0.01	0.11	0.58
	Subs	0.03	0.02	0.18	0.00	0.11	0.34
DNK	No Subs	0.07	0.06	0.18	0.01	0.18	0.51
	Subs	0.03	0.03	0.09	0.01	0.14	0.31
ESP	No Subs	0.08	0.14	0.67	0.00	0.22	1.11
	Subs	0.06	0.08	0.43	0.00	0.18	0.74
FIN	No Subs	0.16	0.12	0.31	0.00	0.07	0.66
	Subs	0.01	0.01	0.07	0.00	0.06	0.15
FRA	No Subs	0.07	0.08	0.37	0.00	0.08	0.60
	Subs	0.03	0.03	0.13	0.00	0.09	0.29
GBR	No Subs	0.10	0.11	0.55	0.00	0.13	0.89
	Subs	0.02	0.03	0.22	0.00	0.14	0.41
GRC	No Subs	0.01	0.14	0.65	0.00	0.11	0.90
	Subs	0.03	0.04	0.30	0.00	0.08	0.45
IRL	No Subs	0.20	0.11	0.29	0.01	0.01	0.62
	Subs	0.02	0.03	0.09	0.00	0.01	0.15
ITA	No Subs	0.04	0.11	0.64	0.00	0.17	0.96
	Subs	0.02	0.07	0.40	0.00	0.18	0.68
LUX	No Subs	0.07	0.04	0.21	0.01	0.03	0.36
	Subs	0.02	0.01	0.04	0.01	0.02	0.10
NLD	No Subs	0.04	0.08	0.39	0.00	0.23	0.74
	Subs	0.03	0.06	0.33	0.00	0.22	0.64
POR	No Subs	0.09	0.18	0.71	0.00	0.14	1.11
	Subs	0.03	0.08	0.38	0.00	0.12	0.61
SWE	No Subs	0.22	0.14	0.39	0.01	0.07	0.83
	Subs	0.04	0.04	0.15	0.00	0.06	0.29

Source: Authors' calculation based on FADN data.

In absolute terms, accounting for the subsidies reduces both the impact of the "efficient" components and the magnitude of the distortions. As discussed above, including subsidies in the specification allows us to estimate more realistic parameters for adjustment costs and uncertainty since it is based on the actual revenues farmers arguably base their investment decisions on. On the other hand, the difference in the estimated distortions can be interpreted

Figure 2: Decomposition of σ^2_{arpk} without and with subsidies



as the contribution of subsidies to the distortions themselves and can in turn be used to estimate their impact on total factor productivity. As shown in Figure 2, the subsidies seem to account for a relevant share of the correlated distortions while the severity of fixed distortions is left virtually unaffected.

Table 8: Percentage contribution to σ^2_{arpk}

	Adjustment	Uncertainty	Correlated	Transitory	Fixed
EU15 (no subs)	10.6%	12.3%	59.7%	0.3%	17.1%
EU15 (subs)	7.5%	9.4%	54.5%	0.2%	28.4%
China	1.3%	10.3%	47.4%	0.0%	44.4%
US	10.8%	7.3%	14.4%	6.3%	64.7%
US (agriculture)	10.0%	7.3%	67.3%	1.8%	13.6%

Source: Authors' calculations based on FADN data (first two rows) and empirical moments from David and Venkateswaran (2019) (last three rows). The EU figures are aggregated using the size of the agricultural sector (in GDP) of each country in 2005 as weights (see Table A1 for weights used).

Table 8 shows how our decomposition compares with the one estimated by DV for China and the US. Notably, we find that (regardless of the specification) correlated distortions play an important role and contribute a to a larger share of the dispersion than in China in relative terms. Reassuringly, the results are remarkably similar to those found for the US agriculture, fishery and forestry sector, which also exhibits high correlated distortions and comparable values for uncertainty and adjustment costs.

4.2 The impact of subsidies and the effect of decoupling on capital misallocation

As shown in Figure 2, there is a lot of heterogeneity within countries in the EU15, not only in the capital productivity dispersion but also in the extent to which this is explained by subsidies. For example, Finland and the Netherlands have a similar level of capital dispersion when subsidies are not accounted for, but adding subsidies to the value added measure reduces *arpk* dispersion in Finland by nearly 80 percent, but only by less than 15 percent in the Netherlands. As shown in Table 2, the two countries differ significantly in terms of the relative contribution of subsidies to farm profitability and this is likely to explain these differences in the impact of subsidies.

Tables 9 provides a more detailed picture of the structure and importance of subsidies in the 15 countries under analysis before and after the implementation of the 2005 CAP reform. It is clear that there are substantial differences in the contribution of subsidies to farm profits across countries: the share of profits due to subsidies in the Netherlands is only 6 percent and less than 20 percent in Spain and Italy while it exceeds 33 percent in France, Austria, Finland and Sweden.[16]

Similarly, there are differences in the implementation of the CAP reform, as member states were given some flexibility in deciding the timing and extent of the decoupling. In some instances (Denmark, Italy and the Netherlands), more than 90 percent of the subsidies received by the median farm after the CAP reform implementation were decoupled, while in Finland, Portugal and Australia decoupled payments accounted for 22, 33 and 41 percent only. These differences are driven by the different approaches member states adopted to implement the reform, with some countries opting for a full decoupling in each sector and others maintaining coupled subsidies for some areas and/or activities or implementing a slower transition towards full decoupling. Interestingly, the total contribution of subsidies to farm income remained

[16] Table A2 presents the same statistics by country, where the contribution of each farm is weighted by its value added.

Table 9: Subsidies and CAP reform (median farm)

	Implementation	Subsidies contribution to value added			Percentage decoupled subsidies	
		All	Before	After	Before	After
AUT	2005	0.36	0.36	0.36	0	0.41
BEL	2005	0.20	0.17	0.23	0	0.61
DEU	2005	0.31	0.29	0.31	0	0.84
DNK	2005	0.23	0.23	0.24	0	0.96
ESP	2006	0.17	0.17	0.17	0	0.68
FIN	2006	0.49	0.49	0.49	0	0.22
FRA	2006	0.35	0.35	0.35	0	0.72
GBR	2005	0.33	0.33	0.33	0	0.88
GRC	2006	0.26	0.25	0.27	0	0.80
IRL	2005	0.34	0.27	0.38	0	0.78
ITA	2005	0.17	0.20	0.14	0	0.92
LUX	2005	0.41	0.39	0.43	0	0.52
NLD	2007	0.06	0.04	0.11	0	0.95
POR	2005	0.25	0.21	0.28	0	0.30
SWE	2005	0.39	0.41	0.38	0	0.66

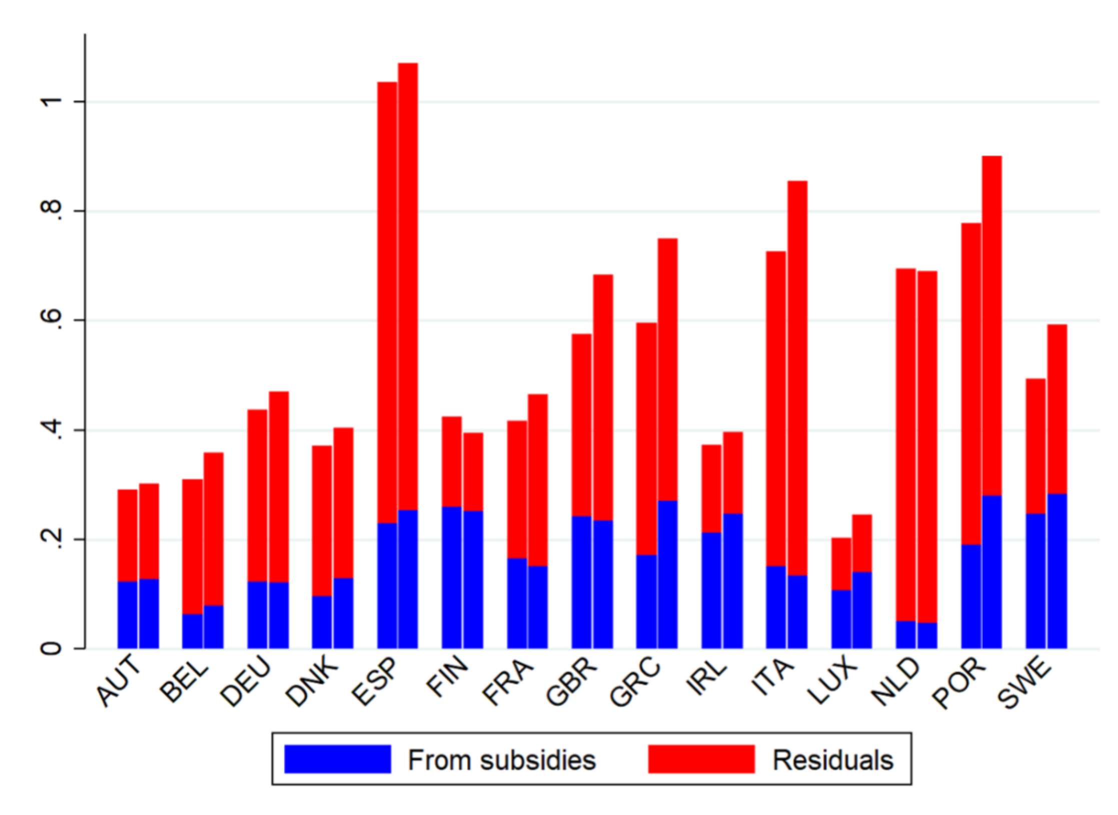
Source: Authors' calculation based on FADN data.

virtually unaffected in most countries. This is hardly surprising as the main objective of the decoupling reform was to change the production incentives of farmers without affecting the income support component.

Figure 3 plots the level of capital dispersion for each country before and after the date of the CAP reform implementation (which can differ across member states, as shown in Tables 9 and A2) and the share of dispersion accounted for by subsidies. The figures suggest that capital dispersion has increased in nearly every country (with the sole exception of Finland and the Netherlands) and that the share mechanically explained by subsidies (i.e. the variation in the revenue productivity of capital obtained by adding subsidies to the value added) has remained roughly the same.

The observed increase in the productivity dispersion can be due to a number of factors independent from the decoupling reform. In order to understand better the extent to which it can be attributed to the CAP reform, it is useful to look separately at the contribution of "efficient" factors (adjustment costs and uncertainty) and distortions. Figures A1 and A2 show the level of capital dispersion for each country before and after the date of the CAP reform implementation attributed respectively to the "efficient" factors and the distortions and indicating the share of variation accounted for by subsidies.

Figure 3: Decomposition of σ^2_{arpk} before and after decoupling



As argued above, not considering subsidies when studying the investment decisions of farmers can lead to an overstatement of the adjustment costs and informational frictions faced by farms as their lack of responsiveness to productivity shocks is due to the mitigating effect of subsidies on revenue, which reduces the variability in the actual profitability of farms. In light of this, only the "residual" impact on capital dispersion (i.e. the one estimated when adding subsidies to value added when estimating the target moments) can actually be attributed to such frictions. As far as the distortions are concerned, the residual component indicates the share of capital dispersion due to farm-specific factors which are not driven by subsidies but by other policy or environmental constraints. Interestingly, from a visual inspection of Figure A2, it appears that most countries witnessed an increase in the distortions caused by subsidies following the implementation of the CAP reform.

As shown in DV, we can directly compute the impact of each source on total factor productivity, a, based on their contribution to the dispersion in $arpk$ as:

$$\frac{\partial a}{\partial \sigma^2_{arpk}} = -\frac{(\theta \hat{\alpha}_1 + \hat{\alpha}_2)\,\hat{\alpha}_1}{2} \tag{11}$$

We apply this formula (using country specific elasticities obtained as the weighted average of estimated sector elasticities, using the relative value added as weights) to compute the impact of each source of dispersion in *arpk* on total factor productivity. More specifically, we use the estimates from the model including subsidies to capture the impact of adjustment costs and uncertainty as this better reflects the actual conditions influence farmers' investment decisions, while the share of distortions caused by CAP subsidies is obtained by comparing the results obtained without adding subsidies to value added (returning the total distortions) and the one including subsidies in value added (returning the distortions that are not captured by subsidies).

The results are presented in Table 10. We find that adjustment costs reduce total factor productivity by 1.6 percent while uncertainty/informational frictions reduce it by 2.2 percent. Both of these estimates are between the estimates found for China and the US in DV and confirm that, although adjustment costs and uncertainty play a role in shaping investment decisions of farms, they do not result in particularly high aggregate productivity losses. Interestingly, there does not seem to be a large difference in their impact on total factor productivity in the period before and after the CAP reform. More specifically, countries experienced a slight reduction in the severity of the impact of adjustment costs and a small increase in the impact of uncertainty and informational frictions.

Table 10: Impact of misallocation on total factor productivity

	"Efficient" components		Distortions		Total
	Adjustment	Uncertainty	Correlated	Fixed	
All					
Δa	-0.016	-0.022	-0.211	-0.058	-0.303
of which subsidies			-0.096	-0.001	-0.097
Before decoupling					
Δa	-0.019	-0.020	-0.180	-0.057	-0.278
of which subsidies			-0.079	-0.006	-0.085
After decoupling					
Δa	-0.014	-0.023	-0.227	-0.059	-0.325
of which subsidies			-0.109	0.000	-0.108

Source: Authors' calculations based on FADN data. The EU figures are aggregated using the size of the agricultural sector (in GDP) of each country in 2005 as weights (see Table A1 for weights used).

Distortions are more detrimental to productivity than adjustment costs and uncertainty/informational frictions.[17] Overall, we estimate that they reduce TFP by nearly 27 percent. This estimate also lies between DV's estimates for China (74) and the US (17). Most of these distortions take the form of correlated distortions, i.e. are associated with farm productivity. On the other hand, fixed distortion make up a small proportion of the overall distortions and transitory are practically zero. Overall, subsidies contribute to about one half of the correlated distortions and are estimated to reduce aggregate agricultural productivity by around 10 percent.

Interestingly, the impact of subsidies before and after the CAP reform has remained largely similar both in relative and in absolute terms. More specifically, we estimate that subsidies reduce TFP by 8.5 percent before the reform and by 10.8 percent afterwards, suggesting that, if anything, the post-decoupling structure of subsidies has an even more detrimental impact on the efficiency of resource distribution across heterogeneous farms. This is perhaps not too surprising, since while the reform decoupled subsidies from production, they are still linked to the possession and operation of agricultural land, and therefore still affect farmers' investment decisions. In particular, these subsidies are still awarded to relatively less productive farmers on the basis of the operated land, potentially discouraging them from dis-investing, making it more difficult for more productive farmers to scale up.

Needless to say, this exercise only focuses on the impact on aggregate productivity through the allocation of resources across existing farmers and so only evaluates the impact of the decoupling reform on this component. It may be, for example, that decoupled subsidies might have encouraged investments and so improved the average farm-level productivity or had some positive, non-financial consequences such as supplying environmental goods or supporting farming in less profitable areas where agricultural land would otherwise have been abandoned.

5 Subsidies and productivity: reduced form analysis

The analysis in section 4 shows that agricultural subsidies, before as well as after the decoupling, accounted for a relevant share of the correlated distortions identified in the decomposition of the dispersion in *arpk*. This suggests that the structure of subsidies provides some advantage to relatively less productive establishments and potentially encourages them to

[17] We do not present the figures for transitory distortions as their impact on both capital dispersion and total factor productivity is negligible. They are available on request.

operate a larger than efficient share of the factors of production.

We use our micro-level data to test this hypothesis directly through a reduced form regression taking the form:

$$\frac{\text{subsidies}}{\text{value added}}_{ijct} = \beta_0 + \beta_1 a_{ijct} + X'_{ijct}\gamma + \nu_j + \kappa_c + \tau_t + e_{ijct} \tag{12}$$

where the percentage contribution of subsidies to farm income is regressed on the (log) of farm productivity, a set of farm-specific controls X, and farm activity type (j), country (c) and year (t) fixed effects. The estimate of the coefficient β_1 will indicate the elasticity of the level of subsidization of the farm with respect to farm productivity. If the coefficient is not statistically different from zero, we cannot reject the hypothesis that subsidies are neutral and do not advantage less productive farms, if instead it is less than zero, it would confirm that subsidies are relatively more beneficial to less productive establishments.

In a similar way, we can directly test whether the implementation of the decoupling reform had any impact on this elasticity by estimating the same equation as in (12), but adding a dummy variable, D, indicating periods where the CAP reform was implemented in country c and year t and it's interaction with farm-specific productivity:

$$\frac{\text{subsidies}}{\text{value added}}_{ijct} = \beta_0 + \beta_1 a_{ijct} + \beta_2 D_{ct} + \beta_3 D_{ct} \times a_{ijct} + X'_{ijct}\gamma + \nu_j + \kappa_c + \tau_t + e_{ijct} \tag{13}$$

By estimating this regression, it is possible to assess whether the decoupling reform changed the average level of subsidization (by checking the sign and significance of β_2), as well as if it affected the extent to which subsidies favour less productive farms (β_3). Intuitively, a positive estimate of the coefficient on the interaction term would indicate that decoupling reduced the relative subsidization of less productive farmers.

The estimates of equations 12 and 13 based on all farms in our sample are shown in Table 11. The main explanatory variable is the (log) of farm productivity, which we used to estimate the target moments and is constructed as outlined in section 4. We acknowledge that temporary shocks in productivity (directly affecting farm output in a given year) could mechanically affect the ratio of subsidization, and so in columns 3, 4 and 6 we use the median productivity of farms across the years they were included in the sample as the main explanatory variable. In columns 1 and 3 no additional controls are included, while in the remaining specifications we also include the (log) capital and labour inputs.

Table 11: Subsidies and productivity

	Dependent Variable: Contribution of subsidies to farm income (%)					
	(1)	(2)	(3)	(4)	(5)	(6)
Productivity (log)	-0.137***	-0.147***	-0.104***	-0.089***	-0.154***	-0.096***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Decoupling					0.007	0.007
					(0.01)	(0.01)
Interaction					0.012	0.011
					(0.01)	(0.01)
Capital and Labour	No	Yes	No	Yes	Yes	Yes
Median productivity	No	No	Yes	Yes	No	Yes
R^2	0.65	0.67	0.46	0.50	0.68	0.50
N	333,368	333,368	333,368	333,368	333,368	333,368

Source: Authors' calculations based on FADN data. All regressions include farm type, year and country fixed effects. Standard errors are clustered at the country, year and farm type levels. *** p $\leq$ 0.01,** p $\leq$ 0.05, * p $\leq$ 0.1. Decoupling is a country and year specific dummy variable taking value 1 when the country has implemented the decoupling reform and Interaction is the interaction term between Decoupling and the (log) productivity of the farm. Capital and labour indicates whether farm labour and capital (in logs) are included in the regression as controls, and Median productivity indicates specifications where the median productivity of the farm is used as the measure of productivity.

As expected, regardless of the specification considered, β_1 is estimated to be negative and statistically significant at every conventional confidence level, suggesting that the subsidy scheme favours less productive farms. The point estimates are similar across specifications ranging from -0.15 to -0.09, indicating that more productive farms are relatively less subsidized (as captured by the contribution of subsidies to total income). Unsurprisingly, the point estimates as well as the R^2 are lower when using the median farm productivity as the main explanatory variable, indicating that these results are partly driven by temporary shocks affecting jointly productivity and output (i.e. the denominator of the dependent variable). Even though the magnitude is lower, the relationship still holds for the median productivity level indicating the presence of a more structural link.

Finally, we fail to find any significant impact of the decoupling reform either on the level of subsidization or on the relationship between subsidies and productivity. This result is consistent with the fact that we did not find any effect of the reform on the efficiency of the capital distribution across farms (Table 10).[18]

6 Heterogeneity in mark-ups and production technology

It is possible that part of the observed dispersion in capital productivity is due to the structure imposed by the underlying structural model. As in DV, we consider how much of the dispersion could be explained by heterogeneity in mark-ups or differences in the production technology actually used by farms operating within the same sector. In the baseline model, the aggregation of farm production (representing the demand side of the economy) is obtained through a standard CES function resulting in equal mark-ups across farms in equilibrium. Similarly, all farms in a given sector are assumed to produce output using a common Cobb-Douglas production function. Imposing this simplified structure can lead to an overstatement of the actual dispersion in capital productivity as the resulting *arpk* includes heterogeneous mark-ups and production elasticities. This artificially increases the variation in *arpk* across farms.

Following DV, we exploit De Loecker and Warzynski (2012)'s intuition that (as long as the elasticity of material inputs is constant across farms), the mark-up of a cost minimizing firm is inversely proportional to the share of materials in revenue. The dispersion in mark-ups can thus be inferred directly from the variation in the share of materials in revenue which is typically readily available in firm-level data. In our case, we define this share as one minus the ratio of value added to the total value of farm output. As for the other empirical moments, we compute this variance separately for different farm activity types and years for every country.

Computing the variance in production elasticities within sectors is empirically more complicated. Following DV, we can obtain an upper bound for this variance as:

$$\sigma^2 \left(\log \hat{\alpha}_{it}\right) \leq \frac{\sigma^2_{\widetilde{arpk}} \sigma^2_{\widetilde{arpn}} - cov\left(\widetilde{arpk}, \widetilde{arpn}\right)^2}{2\frac{\bar{\alpha}}{\zeta - \bar{\alpha}} cov\left(\widetilde{arpk}, \widetilde{arpn}\right) + \left(\frac{\bar{\alpha}}{\zeta - \bar{\alpha}}\right)^2 \sigma^2_{\widetilde{arpk}} + \sigma^2_{\widetilde{arpn}}} \tag{14}$$

[18] We estimate a similar set of regressions where the dependent variable is the total (log) of subsidies received by farms rather than their contribution to farm revenue. The results are shown in Table A3 and are fully in line with our conclusions on the link between productivity and subsidies.

where ζ is the average revenue share of materials and $\bar{\alpha}$ is the average capital elasticity (that is empirically equal to the elasticity $\hat{\alpha}_1$ computed for the previous analysis) and $\tilde{arpk}$ and $\tilde{arpn}$ are the average revenue product of capital and labour, respectively, adjusted for the mark-up. [19] Intuitively, if the marginal revenue of capital and labour tend not to move together, it means that firms are operating with different levels of capital and labour intensities, possibly indicating heterogeneity in their production processes. This can of course also be the result of some capital or labour specific distortions affecting the input mix of farms; the upper bound in Equation 14 is computed assuming that labour and capital distortions are perfectly correlated and as such all the existing variation in the input mix is due to differences in technology.

The moments of interest are presented in Table 12, along with the resulting percentage contribution to the dispersion in *arpk* of heterogeneity in mark ups and production functions. Table 13 compares the aggregate findings with the results from DV for China and the US.

It is clear that, similar to the case of China and the US, differences in technology play an important role in determining the observed dispersion in *arpk*. In our case, the upper bound indicates differences in the technology adopted could explain up to one-third of the dispersion. The relative homogeneity in mark-ups is not surprising as it plausibly reflects the high substitutability of the output produced by farms. The heterogeneity in technology is instead rather marked and in line with the figures for China and the US.

Conceptually, these components are likely to be captured as fixed distortions in the decomposition presented in section 4. Indeed, there seems to be a strong correlation between the share of *arpk* dispersion explained by fixed distortions and the variance in mark-ups and technology; a univariate cross country regression returns a coefficient (elasticity) of 0.57, significant at the 5 percent confidence level. [20] Figure 4 provides a graphical depiction of the positive relationship between the share of *dispersion* that the model attributes to fixed farm-specific factors and the share that can be linked empirically to heterogeneity in mark-ups and production technology. We can conclude from this that while these factors could explain part of the observed dispersion in *arpk*, they do not explain all and the part that they do

[19] More specifically, they are obtained as the difference of the (log) revenue productivity of capital/labour minus the (log) mark-up obtained as the inverse of the firm-specific material share of revenue.

[20] Interestingly, the share attributed to mark-ups and heterogeneous production technology is consistently higher than the share attributed to fixed distortions, but this realistically reflects the fact that the former is an upper bound.

Table 12: Dispersion in technology and mark-ups

	$cov(\widetilde{arpk},\widetilde{arpn})$	$\sigma^2_{\widetilde{arpk}}$	$\sigma^2_{\widetilde{arpn}}$	$\sigma^2_{\hat{\alpha}}$	σ^2_{Mup}	Total	Percentage Contribution
AUT	0.19	0.31	0.34	0.11	0.02	0.13	0.31
BEL	0.17	0.36	0.3	0.14	0.02	0.16	0.39
DEU	0.26	0.48	0.41	0.16	0.01	0.17	0.3
DNK	0.2	0.41	0.26	0.11	0.01	0.13	0.26
ESP	0.3	0.91	0.52	0.37	0.03	0.4	0.36
FIN	0.36	0.51	0.56	0.15	0.01	0.16	0.25
FRA	0.21	0.48	0.36	0.18	0.02	0.2	0.33
GBR	0.39	0.74	0.52	0.21	0.02	0.23	0.26
GRC	0.3	0.67	0.58	0.29	0.03	0.32	0.36
IRL	0.44	0.46	0.67	0.1	0.02	0.11	0.19
ITA	0.32	0.79	0.67	0.36	0.03	0.39	0.41
LUX	0.22	0.26	0.32	0.06	0.01	0.07	0.21
NDL	0.2	0.66	0.34	0.27	0.02	0.28	0.38
POR	0.53	0.92	0.8	0.29	0.04	0.33	0.30
SWE	0.48	0.66	0.72	0.18	0.01	0.19	0.23

Source: Authors' calculation based on FADN data. The last column indicates the percentage contribution of mark ups and heterogeneity in elasticity of production to *arpk* dispersion. The contribution of variance in elasticity is an upper bound.

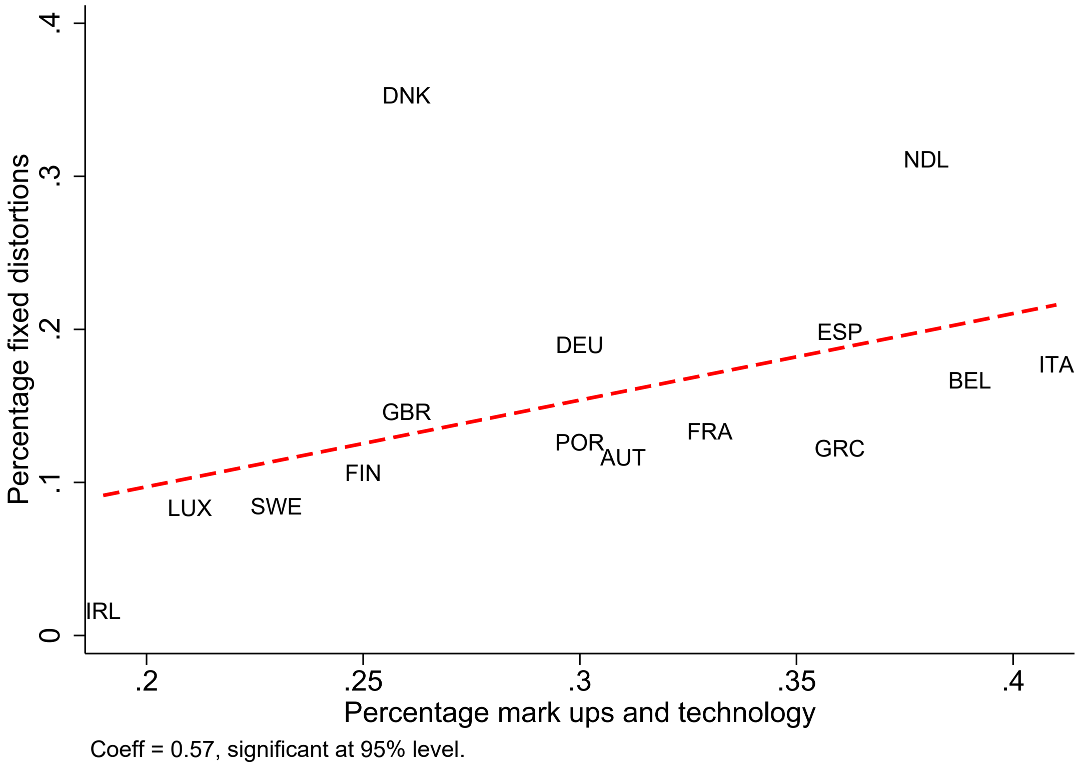
Table 13: Comparison of dispersion in mark-ups and technology

	Mark ups		Technology	
	Dispersion	Contribution	Dispersion	Contribution
EU 15	0.02	2.6%	0.26	31.5%
China	0.05	3.8%	0.30	23.1%
US	0.06	13.6%	0.18	44.4%

Source: Authors' calculations based on FADN data (first row) and David and Venkateswaran (2019) (last two rows). The EU figures are aggregated using the size of the agricultural sector (in GDP) of each country in 2005 as weights (see Table A1).

explain relates to fixed distortions rather than correlated distortions.

Figure 4: Fixed distortions and heterogeneous technology/mark-ups



7 Conclusion

In this paper, we have provided new evidence on the nature and extent of resource misallocation for the EU agricultural sector. We focussed on capital misallocation and used the recent methodology developed by DV to quantify the impact of resource misallocation on productivity and to disentangle the main contributing factors with a particular focus on how government subsidies. While government supports for the agricultural sector are motivated on grounds other than efficiency, including food security, the provision of public goods relating to the environment and spatial equity in the form of rural development supports, knowing the impact on productivity is important for making informed policy choices. In this paper, we quantify the lost productivity associated with subsidies through the capital misallocation channel.

We find evidence that capital misallocation led to a 30 percent loss in aggregate productivity in the sector during the period 2001 to 2010. Most notably, a large proportion of this, around one third, can be attributed to government subsidies. This is equivalent to a 10 percent loss in productivity. Given that for the period of our analysis total gross value added of the sector amounted to €1,632 this is an economically meaningful loss. Moreover, we find evidence that the reform of the CAP, which decoupled subsidies from production with the aim of eliminating distortionary effects on productivity, made no material difference to the extent of capital misallocation associated with subsidies.

This is the first paper, to our knowledge to provide estimates of this kind for the agricultural sector, and so our results provide an important benchmark for other studies of other sectors of the economy, such as the manufacturing sector, and also the agricultural sector in other country or regional contexts. Moreover, the large contribution of subsidies to misallocation and associated productivity losses provides new insights on their distortionary effect that are important for policy makers considering the reform of such policies for agriculture but also for other subsidised sectors of the economy.

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Appendix

Table A1: Codes, Countries and weights for aggregation

Code	Country	Weight
AUT	Austria	2.01%
BEL	Belgium	1.62%
DEU	Germany	10.59%
DNK	Denmark	1.91%
ESP	Spain	18.53%
FIN	Finland	2.13%
FRA	France	17.98%
GBR	Great Britain	6.24%
GRC	Greece	6.69%
IRL	Ireland	0.96%
ITA	Italy	19.73%
LUX	Luxemburg	0.06%
NDL	Netherlands	6.34%
POR	Portugal	3.05%
SWE	Sweden	2.15%

Source: Weights are based on the absolute value of agricultural production in 2005.

Table A2: Subsidies and CAP reform (adjusted for value added)

		Subsidies contribution to value added			Percentage decoupled subsidies	
	Implementation	All	Before	After	Before	After
AUT	2005	0.32	0.32	0.32	0	0.42
BEL	2005	0.17	0.17	0.18	0	0.49
DEU	2005	0.30	0.30	0.30	0	0.80
DNK	2005	0.18	0.17	0.19	0	0.83
ESP	2006	0.17	0.17	0.17	0	0.62
FIN	2006	0.43	0.44	0.43	0	0.19
FRA	2006	0.25	0.25	0.25	0	0.60
GBR	2005	0.23	0.23	0.24	0	0.83
GRC	2006	0.23	0.22	0.24	0	0.73
IRL	2005	0.27	0.23	0.32	0	0.82
ITA	2005	0.15	0.16	0.14	0	0.78
LUX	2005	0.36	0.35	0.37	0	0.51
NLD	2007	0.07	0.05	0.08	0.08	0.60
POR	2005	0.24	0.22	0.25	0	0.39
SWE	2005	0.33	0.34	0.32	0	0.63

Source: Authors' calculation based on FADN data.

Table A3: Subsidies and productivity (level)

	Dependent Variable: Subsidies (log)					
	(1)	(2)	(3)	(4)	(5)	(6)
Productivity (log)	-0.206***	-0.306***	-0.194***	-0.335***	-0.342***	-0.280***
	(0.05)	(0.05)	(0.06)	(0.05)	(0.07)	(0.04)
Decoupling					0.110	0.127
					(0.14)	(0.14)
Interaction					0.055	-0.081
					(0.09)	(0.09)
Capital and Labour	No	Yes	No	Yes	Yes	Yes
Median productivity	No	No	Yes	Yes	No	Yes
R^2	0.45	0.55	0.45	0.55	0.55	0.55
N	333,368	333,368	333,368	333,368	333,368	333,368

Source: Authors' calculations based on FADN data. All regressions include farm type, year and country fixed effects. Standard errors are clustered at the country, year and farm type levels. *** $p \leq 0.01$,** $p \leq 0.05$, * $p \leq 0.1$. Decoupling is a country and year specific dummy variable taking value 1 when the country has implemented the decoupling reform and Interaction is the interaction term between Decoupling and the (log) productivity of the farm. Capital and labour indicates whether farm labour and capital (in logs) are included in the regression as controls, and Median productivity indicates specifications where the median productivity of the farm is used as the measure of productivity.

Figure A1: Decomposition of σ^2_{arpk} before and after decoupling (adjustment costs and uncertainty)

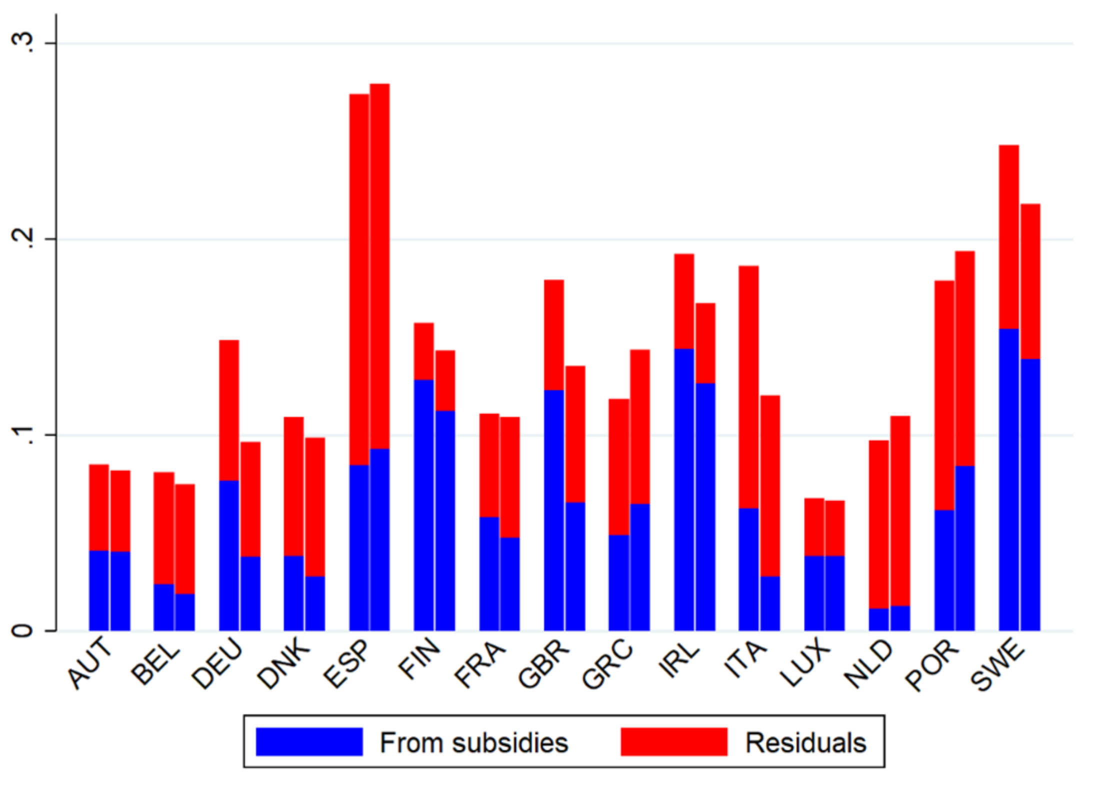

Figure A2: Decomposition of σ^2_{arpk} before and after decoupling (distortions)