Distributional Effects of CAP Subsidies: Micro Evidence from the EU

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European Commission (DG Joint Research Centre)

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Abstract

In this paper we estimate the income distributional effects of the common agricultural policy (CAP) for farmers and landowners. First, we theoretically analyse the level of farmers' and landowners' gains from coupled and decoupled payments. Second, using a unique farm level panel data set from the FADN for the period 1995-2007 we employ the fixed effects, the Heckman selection bias and the GMM estimators to estimate income distributional effects of CAP subsidies. The results do not confirm the theoretical hypothesis that landowners benefit a large share of the CAP subsidies. According to our estimates, farmers gain between 60% to 95%, 80% to 178% and 86% to 90% of the total value of coupled crop/animal, coupled RDP and decupled payments, respectively. The CAP subsidies are only marginally capitalised in land rents. Our results suggest that rental rates are more responsive to structural variables and show a strong time dependency, suggesting the presence of rigidities in the EU rental markets, which constraint the adjustment of land rents to market signals and thus reduce landowners' gains from the CAP.

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1. Introduction

The EU agricultural sector receives more than 50 billion Euros (ca. 45% of the EU budget) through the CAP subsidies per year. There is an ongoing debate among policy makers and scientific community about the actual beneficiaries of the CAP subsidies (or as referred to "income distributional effects of subsides"). Even though farmers are the primary recipients of the CAP subsidies, various factors may lead to a situation where farmers benefit only part of the subsidies or to a situation where farmers do not benefit from the CAP subsidies at all. Besides farmers, also other agricultural market participants may partly or fully capture the CAP subsidies. Particularly, this might be the case of landowners, consumers, and input suppliers. For example, studies from the US show that landowners capture a substantial share of subsidies (e.g. Goodwin, Mishra and Ortalo-Magné 2005; Kirwan 2005; Lence and Mishra 2003).

Theoretical studies show that depending on the type of subsidies and formal and informal institutions and market distortions, agricultural subsidies may or may not benefit farmers. Floyd (1965) was among the first who developed a conceptual model to analyse the income distributional effects of agricultural subsidies. The subsequent theoretical literature extended Floyd's model with the objective to identify how different types of agricultural policies (e.g. direct payments, export subsidies, decoupled subsidies, market price intervention) and other factors (e.g. demand and supply elasticities, credit markets, imperfect competition, market structure) affect the distributional effects of subsidies (Alston and James 2002; de Gorter and Meilke 1989; Gardner 1983; Guyomard, Mouël, and Gohin 2004; Salhofer 1996; Ciaian and Swinnen 2009).

The empirical evidence on distributional effects of farm subsidies is considerably scarcer. Two types of approaches have been followed in empirical literature. First, econometric studies try to estimate the distributional effects of subsidies. The vast majority of these studies estimate the capitalisation rate of subsidies into land values (i.e. landowners' policy rents) in North America (e.g. Goodwin and Ortalo-Magné 1992; Gardner 2002; Lence and Mishra 2003; Roberts, Kirwan, and Hopkins 2003; Kirwan 2005). There are only few studies on the income distributional effects of the CAP in the EU (Duvivier, Gaspart and de Frahan 2005;

Patton et al. 2008; Kilian et al. 2008).[1] The other strand of empirical literature applies partial equilibrium (PE) or general equilibrium (CGE) models to simulate the distributional effects of agricultural subsidies (e.g. Dewbre, Anton and Thompson 2001; Gohin and Moschini 2006; Hubbard (1995); OECD 2000; Salhofer and Schmid 2004). Although PE and CGE models can capture complex interlinkages present in the agricultural markets, the simulated effects heavily depend on calibrated or arbitrary assumed elasticities. As a result, the confidence interval of these studies is rather big.

The objective of this study is to assess the distributional effects of the CAP subsidies in the EU. First we theoretically analyse the distributional effects of the CAP subsidies for coupled crop and animal payments, coupled Rural Development Programme (RDP) (investment support, environmental payments, Less Favoured Area (LFA) payments) and decoupled payments. These subsidies cover most of the CAP support (around 75% of the total CAP expenditures). Our main contribution to the literature is to empirically estimate how benefits of different types of the CAP subsidies are distributed between farmers and landowners. Employing a unique farm level Farm Accountancy Data Network (FADN) panel data for the period 1995-2007 we are able to empirically estimate the distributional effects by controlling for unobserved heterogeneity.

2. Theoretical framework

There is extensive theoretical literature on the distributional effects of agricultural subsidies. Most of these studies apply partial equilibrium models either by modelling a representative farm or by considering the supply-demand market interactions (e.g. Floyd 1965; Alston and James 2002; de Gorter and Meilke 1989; Gardner 1983; Guyomard, Mouël, and Gohin 2004; Salhofer 1996; Ciaian and Swinnen 2006, 2009).

In line with the first approach, in this paper we employ a stylised partial equilibrium model with perfect markets, whereby the representative farm's non-increasing to scale production technology, $f(A,Z)$, where, *f*, the quantity of the final product, is assumed to be a function of two inputs (land, A, and non-land input, Z, (e.g. labour)) with $f_i > 0$, $f_{ii} < 0$, $f_{ij} > 0$,[2] for i, $j = A$ and Z. For simplicity, the entire land is assumed to be owned by landowners, which rent it to farms.[3] The representative farm's profits are given as follows:

[1] With few exceptions (Dewbre and Mishra 2007; Henningsen, Kumbhakar and Lien 2009), the econometric estimates on farmers' benefits from subsidies are non-existent.

[2] f_i and f_{ij}, f_{ii} are first and second derivatives of the production function with respect to its arguments, respectively.

[3] This distinction between landowners and farmers is convenient for our theoretical explanation but is not essential for the derived results, because with perfect markets agents are indifferent between renting and owning

(1) $\prod = pf(A,Z) - rA - wZ$

where p is the price of the final product, r is rental price of land, and w is price of non-land input.

We analyse two types of CAP subsidies: (i) coupled direct payments and coupled RDP measures, and (ii) decoupled direct payments granted to the EU farmers under the CAP. The coupled direct payments and the coupled RDP measures include crop area direct payments, animal direct payments, investment support, LFA payments, and environmental payments. The coupled direct payments are available to farmers in all EU Member States (MS), though they were significantly reduced with the introduction of the SPS in 2005. The decoupled CAP payments consist of the Single Payment Scheme (SPS), and the Single Area Payment Scheme (SAPS). The SPS was introduced by the 2003 CAP reform and is implemented mainly in the Old MS starting from 2005. The SAPS is implemented in the New MS.

2.1. Coupled CAP payments

The coupled direct payments change farm profit function (1) as follows:

(2) $\prod = (p + s_Q) f(A,Z) - (r - s_A)A - (w - s_Z)Z$

The crop coupled direct payments include payments such as compensatory area payments for cereals, oilseeds and protein crops, area payment to rice, etc. They are directly coupled to land and can be modelled as an area subsidy, s_A, linked to land (e.g. Dewbre et al. 2001; Kilian and Salhofer 2008). The coupled animal direct payments include various types of subsidies such as suckler cow premium, beef premium, slaughter premium, ewe premium, etc. These subsidies are either output (animal) type of payments, s_Q, (e.g. beef premium, slaughter premium) or subsidies linked to non-land input, s_Z, (e.g. suckler cow premium, ewe premium), which particularly affect the stock of breeding livestock.

Besides the crop and animal coupled direct payments, farmers receive also Rural Development Programme (RDP) payments (also known as the "second pillar" CAP policies). We study three types of RDP payments: the investment support, the LFA and environmental payments. Under the investment support programme farmers can obtain a grant to partly finance the costs of capital purchases. The investment support can be modelled as a non-land (capital) input subsidy, s_Z, because it reduces the non-land input costs. The LFA is an area based payment to farmers located in less productive regions. Similar to the crop area payments, it can be modelled as an area subsidy, s_A. The environmental payments are granted

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land either with or without subsidies. The landownership affects only the overall farmers' gain/loss form subsidies through their effect on the rental income from land.

for a range of farm activities aimed at improving environment on the farm. These payments cover additional costs and farm income foregone resulting from these activities. The environmental payments affect in particular farm input use, because they are conditional on the adoption of environmentally friendly production practices, such as input use reduction, organic farming, intensification of livestock, conversion of arable land to grassland, rotation measures, and support of biodiversity (European Commission 2005). These payments can be modelled as land or/and non-land input subsidies, s_A, s_Z, because they affect all inputs, but may not alter farm production level and/or farm income. For example, if the environmental payments cover exactly the additional costs, then their marginal impact on farm behaviour is zero. [4]

With decoupled subsidies farm and market equilibrium conditions are given as follows:

(3) $(p+s_Q)f_A = r - s_A$ and $(p+s_Q)f_Z = w - s_Z$

(4) $f = D(p)$

(5) $A = S^A(r)$

(6) $Z = S^Z(w)$

where D is output demand and S^A and S^Z are supply functions of land and non-land inputs, respectively, with $\partial D/\partial p = D_p \leq 0$, $S_r^A \geq 0$ and $S_w^Z \geq 0$.

Equations (3) are farm marginal equilibrium conditions derived from maximisation of the profit function (2). They determine the farm input demands. Equations (4), (5) and (6) are market clearing conditions for output, land, and non-land input, respectively.

Farm's profit may be altered by subsidies ($d\Pi/ds_i$) for two reasons: first, because farms are recipients of the subsidies; and second, because subsidies may affect agricultural output prices (dp/ds_i), and input prices (i.e. land, dr/ds_i and non-land input dw/ds_i). Landowner's income is affected if subsidies affect land rental prices (dr/ds_i). Totally differentiating the equilibrium conditions (3) – (6) and solving for dp/ds_i, dr/ds_i, dw/ds_i, and $d\Pi/ds_i$ (for i = A, Z, Q), respectively, yields comparative static results, which are summarised in Table 1.

According to the comparative static results reported in Table 1, the income distributional effects of coupled subsidies largely depend on input supply and output demand elasticities. The elasticities determine the price adjustments resulting from the subsidy induced input supply and output demand changes. Inelastic demand and supply lead to large adjustments in prices, implying that subsidies may be leaked from farms to other market participants by

[4] Implicitly it follows that the actual value of environmental payments could be positive, zero or negative depending on the size of additional costs induced by the payments.

reducing the price paid by consumers or/and increasing the prices received by input suppliers. In the reverse case of elastic demand and supplies, the price response to subsidies is small and farmers will likely be the main subsidy beneficiaries.

The *output subsidy*, s_Q, (column 2 in Table 1) generates gains to landowners through its capitalisation into land rents ($dr/ds_i > 0$). The gain is decreasing in land supply elasticity, S_r^A, and increasing in output demand and non-land input supply elasticities, D_p and S_w^Z, respectively. In empirical studies the land supply elasticity is usually found to be rather low, mostly due to natural constraints. Given that the land supply elasticity is rather low,[5] landowners may potentially benefit a substantial share of output subsidies (more than non-land input suppliers).[6] However, landowners do not benefit the full amount of output subsidies, as usually it is shared with other market participants. Landowners may benefit full value of output subsidies only in an extreme case of fixed land supply and fixed non-land input and output prices (i.e. with inelastic land supply and infinitely elastic output demand and non-land input supply, respectively). Farmers' gains from an output subsidy depend on the extent they are dissipated to landowners (dr/ds_i), non-land suppliers (dw/ds_i) and consumers (dp/ds_i), which are largely dependent on the input supply and output demand elasticities, respectively (column 2 in Table 1). For example, high output demand and input supply elasticities imply that prices are inelastic to output and input quantity adjustments. This would imply that in the presence of high elasticities, if the output subsidy induces a change in the output and input quantities, the price effects would be minimal and a substantial share of subsidies would benefit farmers.[7]

The *land subsidy* (s_A) likely benefit landowners. Due to the fact that the land subsidy is targeted on land, it stimulates farm land demand and in combination with inelastic land supply it might be capitalised into higher land rents thus creating leakages of policy rents to landowners. In a corner solution, when the land supply is fixed, the land subsidy is fully capitalised into land rents (column 3 in Table 1). The impact of land subsidy on farm income is ambiguous. Similarly to output subsidy, it depends on the extent it is dissipated to landowners (dr/ds_i), non-land suppliers (dw/ds_i) and consumers (dp/ds_i). An important determinant of farm gains is output demand elasticity. With inelastic output demand farms will likely loose, whereas with elastic output demand farms will likely gain. This is because

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[5] Based on an extensive literature review Salhofer (2001) concludes that a plausible range of land supply elasticity for the EU is between 0.1 and 0.4. Similarly, Abler (2001) finds a plausible range between 0.2 and 0.6 for the US, Canada and Mexico.

[6] Supply elasticities of non-land inputs vary widely between 0.1 and 3 (Balcombe and Prakash 2000; Floyd 1965; OECD 2000; Thijssen 1988), because it covers a wide range of inputs (e.g. fertilisers, fuel, labour), which have various reactions to prices. In relative terms the supply elasticity of non-land inputs is bigger than the supply elasticity of land implying lower subsidy gains for non-land input suppliers than for landowners.

[7] Note that farms would benefit full amount of output subsidies only in an extreme case with perfectly elastic output demand and input supplies.

the productivity gain induced by land subsidy is more than offset by output price decrease in the former case compared to the latter case. Generally, given that the major part of land subsidies are likely dissipated to landowners (because of inelastic land supply), farmers' policy benefits/losses from the land subsidy will be minor.

The *non-land input subsidy* (s_Z) has an ambiguous impact on incomes for both landowners and farmers. The subsidy reduces the output price because it cuts the marginal costs of production and hence boosts farm output. The size of the output price reduction determines the policy gains to landowners and farmers. With inelastic output demand landowners and farmers will likely loose, whereas with elastic output demand they will likely gain. The subsidy gains of landowners decrease and of farmers increase in land supply elasticity. The subsidy gains of both landowners and farmers increase in the non-land supply elasticity.

In summary, the coupled subsidies may result in different policy gains to landowners and farmers. Farmers' gains from subsidies depend on the extent the subsidies affect input and output prices. In the case the output subsidy farmers gain while in the case of input subsidies they may gain or lose. Landowners will likely benefit from output subsidy and land subsidy (because of inelastic land supply). The non-land input subsidy could either confer benefits or impose costs to landowners.

2.2. Decoupled CAP payments

The CAP implements two types of decoupled direct payments: the SPS and the SAPS. The SPS was introduced by the 2003 CAP reform mainly in Old MS. The SAPS is implemented in most New MS in 2004.

The SAPS is a payment decoupled from production and it is granted to farmers on per hectare basis, however it is coupled to land use and hence can be modelled as a land subsidy s_A (in equation (2)). As a result, the impact of the SAPS on landowners' and farmers' incomes has the same effect as the land subsidy impacts discussed above (column 3 in Table 1), whereby landowners are likely the main beneficiaries of SAPS due to the inelastic land supply (Ciaian and Swinnen 2006).

The distributional effects of the SPS are different. Under the SPS, farm benefits depend on the number of entitlements and eligible hectares (s)he possesses. More precisely, the entitlement is an asset owned by farmers. However, the entitlements can be activated only if they are accompanied by an equal number of eligible hectares.[8]

[8] See Ciaian, Kancs and Swinnen (2008) for more details on the SPS implementation.

Kilian and Salhofer (2008), Courleux, et al. (2008) and Ciaian, Kancs and Swinnen (2008) have derived the income distributional effects of the SPS. They show that the degree to which the SPSs benefit landowners or farmers crucially depends on the ratio of entitlements to eligible land: i.e. the land capitalisation of the SPS is increasing in the number of entitlements. As long as the number of eligible hectares used by farm in the absence of the SPS application exceeds the number of entitlements (deficit entitlements), the SPS benefit farms because it does not distort land markets. In the opposite case, when the number of entitlements exceeds the number of hectares (surplus entitlements), the SPS will alter farms' land marginal condition. In this case the higher is the number of entitlements, the higher is the impact of the SPS on land market, and the higher is the capitalisation into land rental prices. If the number of entitlements is sufficiently high, then at the margin the SPS creates an equivalent effect as the coupled land subsidy, s_A (Courleux, et al. 2008).[9]

In summary, with perfect markets the main part of the SAPS is likely channelled to landowners through capitalisation into land rental prices. The distributional effects of the SPS are similar to the SAPS if the number of entitlements is in surplus relative to the eligible area. In the case of deficiency entitlements relative to the eligible area, the SPS fully benefit farmers.

2.3. Other factors affecting the income distributional effects of the CAP

In the theoretical analysis above we assumed perfect input and output markets. However, in reality rural markets are affected by many other factors, the two most important of which are accompanying policy measures and land market institutions and regulations.

The income distributional effects of subsidies depend particularly on *accompanying policy measures.* In the real world agricultural support policies are combined in policy programmes involving multiple instruments implemented in the same time, none of which can be considered isolated from the others. For example, both coupled and decoupled CAP payments are conditional on the fulfilment of cross-compliance requirements. Farm failure to respect these conditions can lead to a reduction or a complete termination of the CAP payments.[10] The conditionality of the CAP payments may mitigate their effects on land rents and farm profits due to the fact that the eligibly for subsidy may require farmers to incur certain costs.

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[9] This is the case when the SPS leads to the same equilibrium level of farm land use as an equivalent land subsidy. For more on how the implementation details of the SPS affect incomes of farmers and landowners see Kilian and Salhofer (2008), Courleux, et al. (2008) and Ciaian, Kancs and Swinnen (2008).

[10] Before the 2003 CAP reform, the cross-compliance policies had environmental focus. Farmers were expected to comply with environmental protection requirements as a condition for benefiting from the CAP support. The 2003 CAP reform made cross-compliance compulsory and extended the coverage of requirements in the fields of environment, public, animal and plant health and animal welfare.

The distributional effects of subsidies can be affected also by *market institutions and regulations*. The rental market regulations in the EU include e.g. rental price restrictions (minimum/maximum price) and regulations on the duration of rental contracts (Ciaian, Kancs and Swinnen 2010)**.** The rental price restrictions are in general formal imposed by government, whereas the duration of rental contracts can be regulated through both formal governmental interventions and/or through informal rural market institutions. The minimum rental prices reduce land demand if the unregulated market price is lower than the regulated price. In contrast, the maximum rental prices reduce land supply, if the unregulated market price is higher than the price ceiling. Of particular importance for the CAP is the maximum price intervention. The potential capitalisation of the CAP into land rents will be reduced in the presence of a rental price ceiling and thus will facilitate higher transfers of the CAP rents toward farms. An important implication for the rental price adjustments has also the duration of rental contracts. *Ceteris paribus*, long-term rental contracts for agricultural land will adjust less to external changes than short-term contracts. According to Ciaian, Kancs and Swinnen (2010), the key determinants of rental contract duration in the EU are social norms (e.g. in Greece), governmental regulations (e.g. there is a minimum of 9 years in Belgium and France, 6 years in the Netherlands and 5 in Spain), and market institutions (e.g. Germany, Italy, Sweden). Moreover, in several countries (e.g. France) even the renewal of rental contracts is regulated. The implications of the rental contract duration on the CAP capitalisation are likely more significant than the rental price regulations, because they are more widespread in the EU (Ciaian, Kancs and Swinnen 2010).

3. Econometric specification

Solving the farm maximisation problem (equations (3)-(4)) and accounting for the SPS subsidies, farm income (profit) and land rents depend on the output price (*p*), the non-land input price (*w*), farm output (*f*) and decoupled and coupled subsidies (*e* and s_i for *i*=*Q*, *A*, *Z*) suggesting the following econometric models:

(7) $$r_{jt} = \alpha_0 + \alpha_s s_{ijt} + \alpha_e e_{jt} + \alpha_1 p_{jt} + \alpha_2 w_{jt} + \alpha_3 f_{jt} + \alpha_4 X_{jt} + \eta_{jt}$$

(8) $$\Pi_{jt} = \delta_0 + \delta_s s_{ijt} + \delta_e e_{jt} + \delta_1 p_{jt} + \delta_2 w_{jt} + \delta_3 r\_adj_{jt} + \delta_4 f_{jt} + \delta_5 X_{jt} + \varepsilon_{jt}$$

where subscripts *i*, *j*, *t* stand for the type of coupled subsidies (*i*=*Q*, *A*,*Z*), farm and time, respectively; and X_{jt} is a vector of observable covariates such as farm characteristics, regional, and time variables. As usual, η_{jt} and ε_{jt} are the residuals.[11]

[11] The definition of the rest of the variables is the same as in the theoretical section.

The main interest in our study are parameters α_s and α_e in rental equation, and δ_s and δ_e in profit equation. These parameters indicate the income distributional effects of subsidies: i.e. the policy rents of landowners (α_s, α_e) and farmers (δ_s, δ_e) per 1 Euro of coupled and decoupled CAP payments.

The estimation of equations (7) and (8) is subject to several econometric issues. We identify three key issues: omitted variable bias, selection bias and endogeneity. Without addressing these issues it is impossible to obtain consistent estimates of the incidence of agricultural subsidies on farmland rental rates. In order, to control for these econometric issues we estimate three econometric models: the fixed effects model, the Heckman selection bias model and the generalised method of moment (GMM) model.

Omitted variable bias

Equations (7) and (8) contain the key variables determining the incidence of agricultural subsidies. In addition to these included explanatory variables, there are also unobservable farm characteristics, e.g. farmer ability, which affect land rental price and net farm income, and in the same time are correlated with explanatory variables in equations (7) and (8). Ignoring the unobserved farm heterogeneity would cause omitted variable bias.

The panel structure of the FADN data allows us to control for the omitted variable bias. By employing properties of the panel data, the unobserved heterogeneity component that remains fixed over time can be controlled for thus eliminating or reducing considerably the omitted variable bias.

In order to control for unobserved permanent farm-level characteristics, we follow Kirwan (2005) and estimate *fixed effects model*, which yields:

(9) $$r_{jt} = \alpha_0 + b_j + \alpha_s s_{ijt} + \alpha_e e_{jt} + \alpha_1 p_{jt} + \alpha_2 w_{jt} + \alpha_3 f_{jt} + \alpha_4 X_{jt} + \eta_{jt}$$

(10) $$\Pi_{jt} = \delta_0 + d_j + \delta_s s_{ijt} + \delta_e e_{jt} + \delta_1 p_{jt} + \delta_2 w_{jt} + \delta_3 r\_adj_{jt} + \delta_4 f_{jt} + \delta_5 X_{jt} + \varepsilon_{jt}$$

where b_j and d_j are fixed effects for farm j, which capture time-unvarying farm-specific characteristics. These fixed effects reflect farm heterogeneity, such as different technologies for different farms, different managerial skills or other unobservable fixed farm specific characteristics.

Selection bias

A significant number of farms in the FADN dataset do not rent any land. Because of missing left hand side variables, these farms are excluded from our sample. To control for the selection bias related to farms' rental market participation decisions, we employ the *Heckman's sample selection model* (Heckman 1979).

One may expect that more dynamic farms and/or those with limited own land resources may be more inclined to participate on rental markets compared to less dynamic, part-time and/or subsistence farms. Farms with zero rentals will drop out from equation (7), as their land rental prices do not exist. If the farm rental decision is non-random, then the standard estimation approach would result in biased estimates. To control for the potential sample selection bias, we follow Heckman (1979) and adopt a two stage estimation approach. In the first stage, we examine the determinants of farms' decision to rent agricultural land using a Probit model.[12] In the second stage, we estimate the rental equation (7) in first differences. The selection bias is controlled for through inclusion of the Inverse Mills Ratio (IMR) computed in the first stage.[13] This yields an empirically estimable Heckman's sample selection model, which controls for time-unvarying farm specific effects:

$$(11) \qquad \Delta r_{jt} = \alpha_s \Delta s_{ijt} + \alpha_e \Delta e_{jt} + \alpha_1 \Delta p_{jt} + \alpha_2 \Delta w_{jt} + \alpha_3 \Delta f_{jt} + \alpha_4 \Delta X_{jt} + \alpha_4 \text{IMR}_{jt} + \Delta \eta_{jt}$$

Although, the FADN sampling strategy is representative and methodologically consistent, theoretically, the estimation of equations (7) and (8) could also suffer from attrition bias. The FADN is an unbalanced panel, where every year 5 to 20 percent of farms are dropped from the sample. Farms are excluded either because of the FADN sampling strategy of regular annual replacement of observations and/or because of other reasons (voluntary drop-out, exit from farming). If some groups of farms drop out from the sample more frequently than others, then the standard estimators would yield biased results. Therefore, we test also for the attrition bias. We find no significant impact on the estimated coefficients.[14]

Endogeneity

Three sources of endogeneity might bias our estimates. If subsidies were assigned to farms randomly, then parameters α_s and α_e in the rental equation and parameters δ_s and δ_e in the profit equation would measure the share of each extra subsidy Euro per hectare reflected in higher rental rates. In reality, however, subsidies s_{ijt} and e_{jt} are not assigned randomly to farms. For example, the coupled animal and crop subsidies depend on regional and farm level productivities. The coupled subsidies are allocated to each MS based on regional productivities (e.g. regional reference yield). At farm level the size of subsidies depends on the MS subsidy size (i.e. regional productivity) and on the farms' crop choice (e.g. supported versus non-supported crops). Similar holds for the SAPS in the new MS. Although, the SAPS

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[12] The dependent variable h_j is a dichotomous (1, 0) variable indicating whether the *j*-th farm rented land or not.

[13] If IMR is significant in the second stage, it suggests there is significant bias in the initial model. However, one potential limitation of the Heckman method is that if the Heckman in the selection model is not well-specified, the IMR may be weaker than expected and the Heckman method may have limited power to detect bias. As a result, a second factor to examine following the addition of the IMR variable into the initial specification models is whether or not there have been significant changes in any of the parameter estimates.

[14] The results are available upon request from the authors.

is not based on farm productivities directly, it is nevertheless correlated with the pre-accession average country/regional productivities, because the base for the CAP application in new MS was the average production level and intensity in the pre-accession period. This implies that the SAPS is exogenous at farm level within each new MS but endogenous between the new MS. The decoupled SPS payments depend on the past coupled payments and on the average country/regional productivities, because the value of the SPS was set based on regional productivities or/and farm past level of subsidies. The RDP (investment support, environmental payments) are allocated to farmers based on project submission. Only those farms which submit and have a successful project are granted the support. Hence the RDP is non-random because farms self-select to participate and only those with the best projects (likely the more productive farms) are granted the RDP support. This structure of coupled and decoupled CAP subsidies implies that they are endogenous variables reflecting the characteristics of country/regions' land and farmer's behaviour. Hence, subsidies are not assigned randomly, which implies that subsidy payments are correlated with the error term. As a result, the resulting standard OLS estimates of (α_s, α_e) and (δ_s, δ_e) may be biased.

A further source of endogeneity is simultaneity bias arising from adjustments in farmer behaviour due to subsidy payments. The support programmes typically encourage more input use and production of supported commodities than in absence of subsidies. If subsidies were removed, the relative input and output market prices would change. Therefore, the subsidies and prices are (partially) co-determined. A regression approach which does not control for price changes would overestimate or underestimate the subsidy effects depending on the direction of price changes.

Finally, market prices and subsidy payments are subject to a expectation error. The difference between the actual and the expected market prices/subsidies is the expectation error, which is part of the composite error term potentially causing unreliable estimates. Farm decisions are based on a combination of the current and pre-harvesting information. The expectation error is less problematic for subsidies in the short-medium run, because they are set beforehand[15] and in general are known to farmers. However, some uncertainty may exist particularly with respect to coupled subsidies (e.g. crop payments), because they are subject to downward correction at farm level, if the sum of all farm application for subsidies exceeds the national ceilings. A further source of expectation error is uncertainty about the future CAP reforms. However, this error is less problematic for profits and rents, because they tend to be determined based on yearly market adjustments.[16]

These endogeneity problems may lead to biased estimates not only for subsidies but also for output and input prices. To address this source of endogeneity, we employ the Arellano and

[15] The CAP is adopted within multiannual programming frameworks.

[16] For example as opposed to land prices which incorporate present value of the future land rents.

Bond (1991) robust two-step GMM estimator. Arellano and Bond (1991) have shown that lagged endogenous variables are valid instrument in panel data setting. This allows us to use lagged levels of the endogenous variables as instruments (additionally to exogenous variables), after the equation has been first-differenced to eliminate the farm specific effects. The GMM estimator is particularly suitable for datasets with a large number of cross-sections and few periods and it requires that there is no autocorrelation. The FADN dataset matches these requirements, because it is a panel data and contains a very large number of farm-level observations relative to the period covered. Given that the robust two-step GMM standard errors can be severely downward biased, we use the Windmeijer (2005) bias-corrected robust variances.

4. Data and variable construction

The main source of the data used in the empirical analysis is the Farm Accountancy Data Network (FADN), which is compiled and maintained by the European Commission. The FADN is a European system of sample surveys that take place each year and collect structural and accountancy data on the farms. In total there is information about 150 variables on farm structure, yield, output, costs, subsidies and taxes, income, balance sheet, and financial indicators. Sample sizes vary from country to country (roughly between 500 and 20 000 observations, while most countries have about 1 500-10 000) representing a population of around 5,000,000 farms, covering approximately 90% of the total utilised agricultural area and accounting for more than 90% of the total agricultural production. The aggregate FADN data are publicly available. However, farm-level data are confidential and, for the purposes of this study, accessed under a special agreement.

To our knowledge, the FADN is the only source of micro-economic data that is harmonised (the bookkeeping principles are the same across all EU Member States) and is representative of the commercial agricultural holdings in the whole EU. Farms are selected to take part in the survey on the basis of sampling plans established at the level of each region in the EU. The survey does not, however, cover all the agricultural holdings in the Union, but only those which are of a size allowing them to rank as commercial holdings.

The FADN data is a panel dataset, which means that farms that stay in the sample over consecutive years can be traced over time using a unique identifier. In this study we use panel data for 1995-2007 covering all EU MS except Romania and Bulgaria. Romania and Bulgaria were excluded from the sample, because for these countries the data were available only for one year (2007).

The description of constructed variables is presented in Table 2. The dependent variable in equation (7) (r_{jt}) - *land rental price* - is constructed from the FADN data by dividing the total amount of rent paid for farm land and rental charges with the total utilised agricultural area (UAA) rented by the holder under a tenancy agreement for a period of at least one year. The dependent profit variable in equation (8) (Π_{jt}) – *net farm income* – is calculated by subtracting taxes, variable expenses (intermediate, land, labour) and fixed costs (depreciation and interest payments) from the total farm revenues (output and subsidies). We estimate equation (8) per hectare, which means that we divide the obtained net farm income with the utilised agricultural area.

Similarly, all subsidy variables (*coupled crop area payments*, *coupled animal payments*, *decoupled payments* (SPS and SAPS), *investment support*, *environmental payments* and *LFA*) (e and s_i for i=Q, A, Z) are constructed from the FADN data and are calculated on per-hectare basis. Every agricultural producer in the FADN survey is asked to report both the total subsidies received as well as to specify the amount by major subsidy types. To account for taxes and other types of subsidies, we construct variable *other subsidies* by subtracting taxes from rest of the farm payments not included in the above payment categories.

Also the output and input control variables in equations (7) and (8) (w_{jt}, r_adj_{jt}, f_{jt}) are constructed from the FADN data. To account for the output and input price adjustments we include *market return*, *wage*, *other inputs* and *adjusted rental price* (only for income equation (8)). The market return variable is constructed by dividing the total farm output by the total utilised agricultural area. The wage variable is constructed as a weighted average of the regional mean wage and farm specific wage. The variable other inputs includes crop/animal-specific inputs (seeds and seedlings, fertilisers, crop protection products, feed, other specific costs), overheads, depreciation and interest costs. It is constructed as a weighted average of the sectoral/regional mean and farm specific value and it is divided by the UAA. Similarly, the adjusted rental price is a weighted average of the regional/sectoral rate and farm specific rent. We utilise weighted input costs (i.e. wage, other inputs and rents) of the regional/sectoral mean and farm-specific values in order to control for three factors: regional opportunity values of inputs, measurement error potentially present at farm level data[17] as well as farm specific effects (e.g. labour skill differences, land quality at farm, farm specific technology).

The covariates matrix, X_{jt}, includes other explanatory variables, which affect land rents and farm income. The *land rented ratio* and *labour own ratio* are included in equations to control for potential differences in incentives between own and rented/hired land/labour as well as to account for higher cost level of farms using rented/hired land/labour. Additionally, in order to account for differences in rental contracts, we construct variable *sharecropped land* by dividing farm area under share cropping by the UAA. A variable capturing the economic size (*farm size*) of farms is also available from the FADN data. The economic size of farms is

[17] For example, regional averages were utilised for farms with missing wage, rental price and other costs data (because of zero labour hiring and zero land renting).

expressed in European size units. To account for non-agricultural pressures on agricultural sector, we include agricultural area per capita (*land per capita*). In order to account for the various technological, sectoral and regional covariates, we include variables accounting for effects such as irrigated land, area under glass, fallow land, credit and capital availability and sectoral, regional and time dummies (for more details see Table 2). In general, the dummy variables capture unobserved heterogeneities, which represent common characteristics for all farms but which may differ between regions, such as informal and formal rural institutions, differences in climatic conditions, and market imperfections.

Variables used in the GMM regressions are structured in endogenous and exogenous and are summarised in Table 3.[18] To reduce the endogeneity problem between various types of subsidies and to reduce the number of instruments, we merge the subsidy types into four main groups: *RDP (investment support*, *environmental payments*, *LFA*), *coupled payments* (*crop area payments*, *animal payments*) *decoupled payments* (*SPS*, *SAPS*), *other subsidies* (the rest of subsidies minus taxes). To account for the dynamic adjustment of rents and farm income, we create lagged dependent (2 lags) and lagged explanatory (0 and 1) variables. For all endogenous variables, we use the first lag as an instrument alongside the exogenous variables and lagged dependent variables. The choice of lags for instruments was selected by checking the validity of different sets of instruments.

5. Empirical results

5.1. Main findings

We estimate the incidence of agricultural subsidies on farmland rental rates in three alternative models: the fixed effects model, the Heckman sample selection model and the first difference GMM model. Table 4 reports the fixed effects panel data estimates in levels, where the dependent variables are net farm income (columns 1-3) and land rental price (columns 4-6). Additional to the complete income and rental equation specification in columns 1 and 4, we add lag dependent variable in specifications 3 and 4 and, following Dewbre and Mishra (2007), we exclude variables potentially causing multicollinearity in specification 2 and 5.

Generally, the farm income models yield significantly ‘better’ estimates than the rental price models. For example, most of the estimated coefficients have the expected sign in the income equation, and market returns have a positive and significant impact on farm income whereas inputs costs reduce farm income (columns 1-3). This is not the case for the rental equation,

[18] The agricultural employment is relatively low in the overall EU employment (around 2-5%) implying that farms are likely price taker on the labour market and hence the wage rate is most likely exogenous for individual farms.

where input variables are either statistically insignificant or they have a positive sign although, according to our expectations, market returns increase land rents (columns 4-6).

Both the income and land rent coefficients weakly increase with *farm size*, which may reflect the presence of economies of scale. The land abundance variable (*land per capita*) is positive and significant for income equation but not for the rental equation. The *rented land ratio* reduces both income and land rents. Profits are affected because of lower incentive associated with the use of rented land and because of higher costs of farms relying on rented land as opposed to farms owning land. Rental rates might decrease because of lower incentive associated with the use of rented land. *Sharecropped land ratio* has a positive sign but is not statistically significant in most of the estimated models. Own labour (*labour own ratio*) increases farm profits because of cost reducing effect. Contrary to our expectations, own labour reduces land rents as, due to incentive differences between family and hired labour, one would expect the opposite sign (e.g. Pollak 1985; Allen and Lueck 1998). The coefficient associated with the *output livestock ratio* is statistically insignificant. Higher farm own consumption reduces farm income and land rents, which possibly is because of smaller market orientation of farms producing for self-consumption. The *liabilities-to-assets ratio* increase income and land rants, which may indicate the presence of farm credit constraint.

All estimated models suggest that subsidies significantly influence farm income (columns 1-3, Table 4). The estimates are relatively stable across the models except for the coupled crop and animal payments, which suggest their correlation with the excluded variables in specification 2, such as market returns and input prices (column 2 in Table 4). As discussed in the previous section, the regional and farm level productivities represent a strong determinant of coupled CAP subsidies. Our estimates imply that the net farm income increases between 0.77 EUR and 1.65 EUR for each subsidy EUR[19]. Surprisingly, the estimated subsidy coefficients are particularly high for LFA and coupled crop area payments for farm income. According to the theoretical predictions, both should be capitalised into land rents and benefit landowners instead of farmers. As expected the *decoupled payment* estimates (between 0.89 and 0.92) are slightly higher than the estimates for coupled crop/animal payments and the investment support (between 0.60 and 0.90). In contrast, the *environmental payments* generate slightly higher farm income effect (between 0.85 and 1.00) compared to decoupled payments, which is contrary to the theoretical expectations. These results may suggest that they do not induce farm behavioural effects, e.g. additional costs.

Although, the estimates of the income distributional effects of subsidies reported in Table 4 are rather high, they are consistent with other studies. For example, Henningsen, Kumbhakar and Lien (2009) report that the intermediate input subsidies have a negative impact on

[19] The subsidy farm income effect higher than 1.00 may be caused by the interaction of subsidies with the farm credit constraint leading to productivity upgrade and hence higher farm income (Ciaian and Swinnen 2009).

farmers' income in Norway (i.e. -0.39), while output subsidies and decoupled payments fully benefit farmers (1.02 and 1.00, respectively). The estimates of Dewbre and Mishra (2007) for US range between 0.96 and 0.97 for decoupled payments and between 0.50 and 0.83 for coupled payments.

Regarding the land rental price equation, the estimates of subsidy effects are statistically significant for roughly half of the variables, but their values are relatively low (less than 0.05), implying that subsidies are not an important determinant of land rents (columns 4-6, Table 4).[20] These findings contradict the empirical studies from the US, which find that the capitalisation rate for coupled and decoupled subsidies is between 20-100%.[21] Among the possible explanations behind the relatively low estimates could be strict rental market regulations in the EU, and identification issues. In addition, the rental costs in the FADN data include not only farm land rents, but also rents for buildings and other rental charges. Although, we made an attempt to correct for this data issue,[22] the data may still contain a measurement error bias.

Table 5 reports the Heckman first-difference estimates for rental equation, which controls for the rental market participation bias. The coefficient of the *Inverse Mills Ratio,* which tests the impact of rental market participation bias, fails to be significant and parameter estimates of subsidies are to a large extent consistent with the fixed effects estimates reported in Table 4, which confirms that the CAP subsidies are capitalised into land rents at a low rate.

The GMM estimates are shown in Table 6.[23] As usual, we start with diagnostic tests. We employ the Arellano-Bond statistics to test for serial dependence of errors. The tests indicate strong evidence against the null hypothesis of zero autocorrelation in the first-differenced errors at order 1 but confirm no autocorrelation in the first-differenced errors at order 2 in both the rental and income equations. Serial correlation of order higher than 1 would imply misspecification of the model. The test for the validity of instruments performs better for the

[20] Table 7 and Table 8 report fixed effect estimates for selected MS. The results are largely consistent with the EU level estimates where CAP subsidies generate a substantial policy gain to farmers but not to landowners.

[21] The empirical findings from the studies on land capitalisation of agricultural subsidies can be summarised as follows: (i) Landowners do benefit from all type of subsidies, both coupled and decoupled. (ii) Land capitalisation of *coupled* subsidies (based on US studies) varies between 20% and (more than) 100%. (iii) Land capitalisation of *decoupled* subsidies (based on US studies) varies between 20% and 90%. (iv) Subsidies and market returns show similar level of the land capitalisation rate. The land capitalisation of the market returns is between 20% and 80%. (v) The impact of coupled subsidies is lower than the theory predicts: land rents/prices do not appear to capture the full value of coupled subsidies, at least in the short to medium run, but they do capture a substantive amount of subsidy payments. (vi) The impact of decoupled subsidies is stronger than expected from the theory. This can be explained, for example, by the conditionality of the support on other policy measures (Goodwin, Mishra and Ortalo-Magné 2003, 2005; Lence and Mishra 2003; Roberts, Kirwan, and Hopkins 2003; Kirwan 2005; Barnard, et al. 1997; Taylor and Brester 2005).

[22] For example by excluding high value rents which may represents rental for buildings.

[23] The variables employed in GMM are summarised in Table 3.

income equation than for the rental equation. The Sargan test statistics indicates that we cannot reject the null hypothesis that the over-identifying restrictions are valid for the income equation. However, for the rental price equation, the test rejects the null hypothesis, implying that instruments may be correlated with the residuals and thus fail to fulfil the exogeneity condition. The Sargan test rejection may be also a result of heteroskedasticity. Arellano and Bond (1991) found tendency for this test to be under-rejected in the presence of heteroskedasticity. To account for heteroskedasticity, we follow Windmeijer (2005) and use robust standard errors.

Generally, the GMM results reported in Table 6 are fairly consistent with the fixed effects results reported in Table 4 for the income equation (columns 1 and 2). The consistency is particularly strong in terms of sign for all parameters and of magnitude for parameters corresponding to subsidies, market return and input prices. The rental equation shows significant changes in the sign, magnitude and significance level for all parameters compared to the fixed effects results (columns 3 and 4). These results confirm that the rental equation does not respond well to variables predicted by the theory. The majority of the estimated coefficients corresponding to subsidies, market return and input prices are not significant. A strong determinant of rents appears to be lagged values of rents, indicating the rigidity of rental markets potentially induced by rental price regulations and long durations of rental contracts. In the presence of rental price thresholds and long durations of rental contracts, land rents do not adjust to market signals but tend to stay unchanged over time, which may lead to a lagged dependency between rents. Additionally, rents are responsive to control variables such as *farm size*, *land rented ratio*, *output livestock ratio*, indicating that the farm structural differences are strong determinants of rental rates.

According to the results reported in Table 6, a substantial share of the CAP payments benefit farms (columns 1 and 2). Relative to the fixed effects results (Table 4), the *RDP* and *coupled payments* tend to generate higher gains to farmers whereas *decoupled payments* induce slightly lower benefits if lagged effects are not taken into account (model 1). Accounting for the lagged dependencies (model 2), the contemporaneous farm income effect of subsidies is reduced, and the lagged coefficients of subsidies are not statistically significant. The estimates in Table 6 indicate that farmers benefit between 0.81 to 0.95 EUR, 0.81 to 0.86 EUR and more than 1.00 EUR for each payment EUR of coupled, decupled and RDP payments, respectively (columns 1 and 2). For the rental equation most of the coefficients measuring the subsidy capitalisation into land rents are statistically not significant (Table 6, columns 3 and 4).

5.2. Identification issues and limitations

The estimated results reported in Table 4 to Table 6 show that capitalization of the CAP subsidies into land rents is inconsistent with the theoretical predictions saying that a substantial share of all types of CAP subsidies benefit landowners (see the theoretical section 2). Two issues may yield these results: governmental regulations and rental market institutions, and identification problem.

The extensive governmental regulations and rental market institutions (minimum/maximum price; long-term rental contracts) in the EU may prevent land rents to adjust to policy changes. A study of Ciaian, Kancs and Swinnen (2010) reports the presence of important rental market regulations including rental price restrictions (minimum/maximum price) and the regulations on the duration of rental contracts**.** The rental price restrictions are in general imposed by government whereas the duration of rental contracts can be implemented by both formal governmental interventions and/or through informal rural market institutions. According to Ciaian, Kancs and Swinnen (2010),[24] several MS implement minimum or maximum rental prices such as Belgium, France, Greece and the Netherlands. These price interventions (particularly the maximum price) may reduce the transmission of subsidies into land rents. An even more important implication on the rental price adjustments has the long-term duration of rental contracts because, according to Ciaian, Kancs and Swinnen (2010), they tend to be more widespread than rental price regulations. For example, several countries have the average duration of rental contracts longer than 5 years (Belgium, Finland, France, Germany, Netherlands, and Spain). In Italy the average duration is 2 to 5 years for arable crops and 5 to 10 years for fruit crops (Ciaian, Kancs and Swinnen 2010). The long-term duration of rental contracts makes rental markets stickier and the time lag for the adjustment to policy changes takes a longer time period.

An important shortcoming of the FADN rental data is that it does not contain any information about the farm rental contracts and rental market regulations (e.g. contract type, contract duration, maximum rental price), which would allow to control for the rental market institutions. For example, to control for the rental contract duration, Patton et al. (2008) exclude from their sample in Northern Ireland all farms with the duration of contracts longer than one year and find (contrary to our empirical finding) high coupled subsidy capitalisation into land rents (between 0.40 and 1.20). Similarly, Kilian et al (2008) consider a variable measuring the share of newly signed rental contracts in order to estimate the difference in land capitalisation rate between the SPS and the pervious coupled subsidies in Bavaria (Germany). Their estimates indicate that the SPS is capitalised by additional 15% to 19% above the previous coupled subsidies. However, since Kilian et al (2008) use a cross-section data, they are not able to control for unobserved farm specific effects.

[24] The study of Ciaian, Kancs and Swinnen (2010) cover 11 MS.

Particularly the rental price estimates may suffer from identification problems. If the law of one (rental) price holds, then the cross-sectional variation in rental price in each region/MS is independent of the subsidy variation at farm level, whereas the time variation in rental price, which may be induced by change in the subsidies, will be captured by regional/time dummies, or other region/country specific variables. This is because the equilibrium market rental price adjustments are determined by overall marginal and not by the farm specific marginal change of subsidies. In other words, the law of one price implies that the variation in land rents is not farm-specific but the rental prices tend to respond to policy or market changes at the same rate for all farms in a given region/MS. For farm income estimates this is less of a problem, because profits are farm specific and are determined by both farm and region specific variables (including subsidies).

6. Conclusions

In this paper we estimate the distributional effects of the CAP subsidies between farmers and landowners. First, we theoretically analyse the farmers' and landowners' benefits from different types of CAP subsidies: coupled direct payments (crop area payments, animal payments); coupled RDP measures (investment support, LFA, and environmental payments); and decoupled direct payments (SPS and SAPS) granted to EU farmers under the present CAP. In empirical analysis we use the FADN farm level panel data for the period 1995-2007 to estimate the incidence of agricultural subsidies on farmland rental rates and farm income.

According to the theoretical results, the ranking of income distributional effects between farmers and landowners depends on the type of the CAP payments. However, in well functioning markets, landowners are found to benefit a large share of all types of CAP subsidies through their capitalisation into land rents. This is due to inelastic land supply, which does not allow adjustments in land supply. The only channel of land market adjustment is rental price, when subsidies induce stronger competition for agricultural inputs. In particular, landowners are expected to gain proportionally more from CAP subsidies linked to land (e.g. crop area payments, LFA) than farmers (and other market agents), because land subsidies directly stimulate land market and because of inelastic land supply. Farmers and landowners are expected to share the benefit (losses) from output subsidies and non-land input subsidies (e.g. investment support, environmental payments). However, because of inelastic land supply, landowners may also benefit a substantial share of non-land input and output subsidies. Theoretically, the decoupled subsidies are expected to have a mixed impact on incomes of landowners and farmers. They may result in high capitalisation rates leading in such a way to considerable leakage of policy gains to landowners. This is the case of the SAPS and, if entitlements are surplus relative to the eligible area, also the case of the SPS. In this case both the SAPS and the SPS create similar market incentives as land based subsidies.

However, as long as the number of eligible area exceeds the number of entitlements, the SPS benefit farmers.

We employ the fixed effects, the Heckman sample selection model and the GMM estimators to estimate the distributional effects of CAP subsidies. The empirical results do not confirm the theoretical predictions, whereby landowners benefit a large proportion of the CAP subsidies. In contrast, our estimates suggest that farmers benefit the major share of all types of CAP subsidies (RDP, coupled and decupled payments). According to our results, farmers gain more than 60% of CAP payments, i.e. they gain 60% to 95%, 86% to 90% and 80% to 178% of coupled, decupled and RDP payments, respectively. Our estimates are relatively robust with respect to different specifications and estimation approaches.

In contrast, landowners are found to benefit only marginally from subsidies; the coefficient estimates are either statistically not significant or their magnitudes are close to zero. These estimates could change, if, for example, improved rental contract data becomes available (e.g. duration of rental contract; presence of new contracts). Further, our results suggest that farmland rental rates are more responsive to structural variables (farm size, farm specialisation, importance of renting) than to variables predicted by the theory (market returns, input prices, subsidies). Additionally, the empirical results confirm a strong time dependency between the land rents (i.e. current rental rates depend on the lagged rents), suggesting that the presence of rigidities on the EU rental markets (rental price regulations and prevalence of long duration of rental contracts) may considerably constrain the rental price adjustments and thus reduce the landowners gains from subsidies relative to farmers. At the same time, the dependency of rental price on structural variables may indicate the identification problem of the farm level variation of subsidies on land rents. This is because, if the law of one (rental) price holds, the cross-sectional and the time variation in rental price in each region/MS is independent of the subsidy variation at farm level but it is likely correlated and captured by the time and/or region/country specific dummy variables.

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Table 1. Transfer efficiency of coupled subsidies

(1)	**Output subsidy (s_Q)** (2)	**Land subsidy (s_A)** (3)	**Non-land input subsidy (s_Z)** (4)
$\frac{dr}{ds_i}$	$\frac{\left[p_s f_{ZZ} f_A - \frac{f_A}{S_w^Z} - f_Z p_s f_{AZ}\right]\frac{D_p}{S_r^A}}{U} > 0$	$\frac{\left[\frac{f_Z f_Z}{p_s f_{ZZ}} - \frac{D_p}{p_s f_{ZZ} S_w^Z} + D_p\right]\frac{p_s f_{ZZ}}{S_r^A}}{U} > 0$	$\frac{-\left[\frac{f_Z f_A}{p_s f_{AZ}} + D_p\right]\frac{p_s f_{AZ}}{S_r^A}}{U} <> 0$
$\frac{d\Pi}{ds_i}$	$\frac{d\prod}{ds_Q} = f\left[1+\frac{dp}{ds_Q}\right] - A\frac{dr}{ds_Q} - Z\frac{dw}{ds_Q} > 0$	$f\frac{dp}{ds_A} + A\left[1-\frac{dr}{ds_A}\right] - Z\frac{dw}{ds_A} <> 0$	$f\frac{dp}{ds_Z} - A\frac{dr}{ds_Z} + Z\left[1-\frac{dw}{ds_Z}\right] <> 0$
$\frac{dp}{ds_i}$	$\frac{\left[p_s f_{ZZ} - \frac{1}{S_w^Z} - p_s\frac{f_Z}{f_A} f_{AZ}\right] f_A{}^2 + \left[p_s f_{AA} - \frac{1}{S_r^A} - p_s \frac{f_A}{f_Z} f_{ZA}\right] f_Z{}^2}{U} < 0$	$\frac{f_A\left[p_s f_{ZZ} - \frac{1}{S_w^Z}\right] - f_Z p_s f_{ZA}}{U} < 0$	$\frac{f_Z\left[p_s f_{AA} - \frac{1}{S_r^A}\right] - f_A p_s f_{AZ}}{U} < 0$
$\frac{dw}{ds_i}$	$\frac{\left[p_s f_{AA} f_Z - \frac{f_Z}{S_r^A} - f_A p_s f_{ZA}\right]\frac{D_p}{S_w^Z}}{U} > 0$	$\frac{-\left[\frac{f_Z f_A}{p_s f_{ZA}} + D_p\right]\frac{p_s f_{ZA}}{S_w^Z}}{U} <> 0$	$\frac{\left[\frac{f_A f_A}{p_s f_{AA}} - \frac{D_p}{p_s f_{AA} S_r^A} + D_p\right]\frac{p_s f_{AA}}{S_w^Z}}{U} > 0$

Note: $U = D_p\left[f_A\frac{f_Z}{D_p} + p_s f_{AZ}\right]^2 - \left[f_A\frac{f_A}{D_p} + p_s f_{AA} - \frac{1}{S_r^A}\right]\left[f_Z\frac{f_Z}{D_p} - \frac{1}{S_w^Z} + p_s f_{ZZ}\right]D_p$; $p_s = p + s_Q$. For non-increasing return to scale production function it follows that $f_{ZZ} f_{AA} \geq f_{AZ} f_{AZ}$ implying $U_A > 0$.

Table 2. Description of variables

Variable name	Description
Dependent variables	
Land rental price	Total value of rent paid for farm land and buildings and rental charges divided with the UAA rented by the holder under a tenancy agreement for a period of at least one year
Net farm income	Total farm revenues (output and subsidies) minus taxies, variable expenses (intermediate, land, labour) depreciation, and interest payments. The obtained value is divided with UAA to obtain hectare value of farm income
Explanatory variables	
Coupled crop area payments	Hectare value of all farm subsidies on crops, including compensatory payments/area payments and set-aside premiums
Coupled animal payments	Hectare value of all farm subsidies on livestock and livestock products
Decoupled payments	Hectare value of SPS and SAPS
Investment support	Hectare value of subsidies on investments
Environmental payments	Hectare value of environmental subsidies; including part of the measures of the article 69 of Regulation 1782/2003
LFA	Hectare value of LFA subsidies
Other subsidies	Hectare value of other coupled and RDP not included in the above subsidy categories minus taxes
Market return	Hectare value of total output of crops and crop products, livestock and livestock products and of other output
Adjusted rental price	Weighted average of the regional/sectoral mean rent and farm specific rent. The regional mean rent is averaged by NUTS 2 and output specialisation. The farm rent is calculated by dividing rent paid for farm land and buildings and rental charges with total rented area.
Wage	Weighted average of the regional mean wage and farm specific wage. The regional mean wage is averaged over NUTS 2. The farm wage is calculated by dividing wages and social security charges by total hired labour.
Other inputs	Weighted average of the regional/sectoral mean and farm specific value of other inputs. The regional mean value of other inputs is averaged by NUTS 2 and output specialisation. The farm rent is hectare value of crop/animal-specific inputs (seeds and seedlings, fertilisers, crop protection products, feed, other specific costs), overheads, depreciation and interest costs.
Land rented ratio	Ratio of rented area to UAA
Labour own ratio	Ratio of unpaid input to total labour
Sharecropped land	Ratio of sharecropped land to UAA
Farm size	Economic size of holding expressed in European size units (ESU)
Land per capita	Ratio of total agricultural area to total population at MS level
Irrigated land ratio	Ratio of irrigated land to UAA
Glass land ratio	Ratio of the area under glass or plastic land to UAA
Fallow land ratio	Ratio of fallow and set-aside land to UAA
Woodland ratio	Ratio of woodland area to UAA
Output livestock ratio	Ratio of total livestock output to total farm output
Own-consumption ratio	Ratio of farmhouse consumption and farm use to total output
Liabilities-to-assets ratio	Ratio of total liabilities to total farm assets
Farm product stock	Stock of agricultural products divided by UAA
Investment	Gross Investment divided by UAA
Building-machinery per ha	Value of Buildings and machinery divided by UAA
Lu	Total livestock units
List of dummy variables	
Year, sector, country, LFA region and their interaction terms.	

Note: All variable are calculated from the FADN data except for the variable *land per capita* which uses agricultural land from the FAOSTAT and total population from the UN National Accounts Main Aggregates Database.

Table 3. Variables used in the GMM estimation

	Variable name	Lags
Dependent variable		
	Land rental price	2
	Net farm income	2
Endogenous variables		
	RDP	0 and 1
	Coupled payments	0 and 1
	Decoupled payments	0 and 1
	Other subsidies	0 and 1
	Market return	0 and 1
	Adjusted rental price	0 and 1
	Other inputs	0 and 1
	Building-machinery per ha	1
	Farm product stock	0 and 1
	Investment	1
Exogenous variables		
	Wage, Farm size, Land per capita, Land rented ratio, Sharecropped land ratio, Labour own ratio, Output livestock ratio, Own-consumption ratio, Liabilities-to-assets ratio, and other dummies for sector, country, and their interaction terms.	0

Table 4. Fixed effects estimates of net farm income and land rental price for EU

	Net farm income			Land rental price		
	(1)	(2)	(3)	(4)	(5)	(6)
Investment support	0.866***	0.805***	0.861***	0.00998**	0.0113***	0.0149***
Environmental payments	0.969***	1.006***	0.947***	0.00713	0.0110**	0.00655
LFA	1.213***	1.264***	1.197***	0.0421***	0.0497***	0.0412***
Coupled crop area payments	0.912***	0.593***	0.904***	0.00252	-0.00152	0.00163
Coupled animal payments	0.832***	0.773***	0.815***	0.00787**	0.00864***	-0.000149
Decoupled payments	0.920***	0.889***	0.908***	-0.0181***	-0.0175***	-0.0161***
Other subsidies	1.639***	1.005***	1.567***	-0.00161	-0.00605	-0.00517
Market return	0.881***		0.879***	0.00751***		0.00741***
Wage	-0.00929***		-0.00923***	0.000514***		0.000295***
Adjusted rental price	-0.0822***		-0.0811***			
Other inputs	-1.046***		-1.031***	-0.000371		0.000622
Net farm income(-1)			-0.0133***			
Land rental price(-1)						0.153***
Farm size	0.159**	0.0980	0.123	0.0182**	0.0161*	0.00866
Land per capita	253.4**	2,013***	566.6***	4.126	47.08	-59.85
Land rented ratio	-33.53***	-277.5***	-26.56**	-142.2***	-148.1***	-144.8***
Sharecropped land ratio	73.09	96.49	137.7***	25.13	17.00	36.70
Labour own ratio	1,159***	462.6***	1,074***	-18.40***	-21.95***	-15.04***
Output livestock ratio	-13.04	-13.92	-8.820	0.0906	0.467	0.0964
Own-consumption ratio	-153.6***	-906.6***	-144.2***	-1.695	-5.380***	-3.055*
Liabilities-to-assets ratio	0.00156***	0.00892***	0.000990***	9.199***	8.122***	9.464***
Constant	-23,459**	-133,508***	-10,625	-4,261*	-5,417**	-4,941**
Observations	675719	677501	498882	434261	435393	319714
R-squared	0.834	0.032	0.840	0.046	0.039	0.074
Number of idn	177151	177262	131325	114103	114177	84030

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: for the sake of conciseness not all variables are reported

Table 5. Heckman first difference estimates of land rental price for EU

	Land rental price
Investment support	0.00879***
Environmental payments	0.00715**
LFA	0.0299***
Coupled crop area payments	0.00785***
Coupled animal payments	0.00990***
Decoupled payments	-0.00763***
Other subsidies	-0.000645
Market return	0.00602***
Wage	0.000350***
Adjusted rental price	
Other inputs	0.00172***
Farm size	0.00220
Land per capita	81.23***
Land rented ratio	-194.5***
Sharecropped land	11.88
Labour own ratio	-14.68***
Output livestock ratio	0.734
Own-consumption ratio	-4.545**
Liabilities_ass_ratiod1	8.466***
Inverse Mills Ratio (IMR)	0.868
Constant	-103.9
Observations	557048

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Note: for the sake of conciseness not all variables are reported

Table 6. Arellano and Bond estimates of farm income and land rental price for EU

	Net farm income		Land rental price	
	(1)	(2)	(3)	(4)
RDP	1.782***	1.328***	-0.101**	-0.0577
RDP(-1)		-0.264	-	0.0145
Coupled payments	0.950***	0.815***	-0.0176	-0.0212
Coupled payments(-1)		0.158	-	0.0129
Decoupled payments	0.864***	0.812***	-0.0131	-0.0188
Decoupled payments(-1)		0.123	-	0.0134
Other subsidies	1.275**	0.953	-0.00184	0.125
Other subsidies(-1)		0.755	-	0.0302
Market return	0.972***	0.914***	-0.00303	0.00322
Market return(-1)	-	0.101		-0.00237
Wage	-0.00310***	-0.00251*	-0.000362*	-0.000264
Wage(-1)	-	-0.00262*	-	0.000434**
Adjusted rental price	-0.0517	0.174	-	-
Adjusted rental price(-1)	-	-0.442	-	-
Other inputs	-0.901***	-0.890***	0.00499	0.00171
Other inputs(-1)	-	-0.296**	-	0.0146
Net farm income(-1)	0.0285*	-0.0707	-	-
Net farm income(-2)	0.00975	0.0137	-	-
Land rental price(-1)	-	-	0.470***	0.484***
Land rental price(-2)	-	-	0.116***	0.118***
Farm size	0.338	0.289	-0.0394*	-0.0460*
Land per capita	1,388***	1,333***	-51.53	-48.17
Land rented ratio	587.9***	488.5**	-640.0***	-638.9***
Sharecropped land ratio	281.1***	343.9***	-118.8**	-107.8**
Labour own ratio	2,352***	2,420***	13.85	27.49
Output livestock ratio	-121.4***	-104.1**	17.70***	14.72**
Own-consumption ratio	-302.4***	-358.4***	-17.28*	-16.21
Liabilities-to-assets ratio	21.61	-207.0	10.34	22.05
Constant	-48,542***	-61,651***	6,179	8,002*
Observations	116920	116431	76584	76362
Number of idn	47345	47291	30347	30321
Sargan test (Prob > chi2)	0.1312	0.1880	0.0000	0.0000
Arellano-Bond autocorrelation test				
AR(1) (Prob > z)	0.0000	0.0001	0.0000	0.0000
AR(2) (Prob > z)	0.5214	0.4949	0.1108	0.1133

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Note: Estimates are based on the period 2000-2007; For the sake of conciseness not all variables are reported

Table 7. Fixed effects net farm income estimates for selected MS

	Belgium (1)	Poland (2)	Germany (3)	Spain (4)	France (5)	Italy (6)	Netherlands (7)	UK (8)	Sweden (9)	Hungary (10)	Ireland (11)
Investment support	0.925***	1.312***	0.824***	0.924***	0.937***	0.649***	0.499	0.984***	0.703***	1.135***	0.996***
Environmental payments	0.950***	0.944***	1.062***	0.728***	0.998***	0.958***	0.00407	0.963***	0.797***	0.988***	0.994***
LFA	-0.303	0.811***	1.145***	1.211***	1.165***	1.234***	-	0.684***	1.117***	1.255**	1.037***
Coupled crop area payments	0.920***	0.995***	1.024***	0.890***	0.820***	0.952***	0.435	0.780***	0.877***	0.448	0.896***
Coupled animal payments	0.707***	14.41**	0.874***	0.769***	0.846***	0.993***	0.359	0.839***	0.769***	0.785***	0.996***
Decoupled payments	0.840***	0.842**	0.908***	0.551***	0.849***	0.972***	1.608***	0.776***	0.407***	1.383***	0.960***
Other subsidies	0.840***	0.973***	1.437***	2.883***	1.180***	1.782***	1.959***	0.875***	0.996***	0.806***	0.978***
Market return	0.827***	0.933***	0.859***	0.908***	0.759***	0.944***	0.705***	0.718***	0.737***	0.841***	0.966***
Wage	-0.00790***	-0.0246***	-0.00728***	-0.0140***	-0.0105***	-0.0154***	-0.00822**	-0.00455***	-0.00347***	-0.0154***	-0.00373***
Adjusted rental price	-0.532**	-0.153**	-0.517***	0.0945***	-0.553***	0.0370	-0.698***	-0.193***	-0.372***	-1.016***	-0.360***
Other inputs	-0.718***	-1.458***	-1.134***	-1.190***	-1.012***	-1.333***	-0.716***	-0.790***	-0.954***	-0.855***	-1.720***
Farm size	2.168**	0.00484	0.219***	0.574	0.245	0.0479	1.240	-0.174***	-0.0196	0.0874	0.139
Land rented ratio	110.7	14.97	-217.7***	73.93*	-51.73**	-73.27***	112.4	60.72**	-37.17**	32.45	-221.5***
Sharecropped land	-	53.69***	-	-537.1*	173.3	-141.9*	-812.3	100.6	632.8***	-	-
Labour own ratio	1,851***	348.9***	642.7***	1,633***	760.6***	1,735***	2,412***	481.6***	521.9***	221.9***	411.1***
Output livestock ratio	-248.2**	-33.49***	-92.22***	-87.63***	5.135**	-51.57**	-967.8**	-71.73***	-70.53***	-11.45	9.476***
Own-consumption ratio	-1,652***	-136.6***	-369.5***	-186.0***	-338.0***	-135.3***	-880.2	-441.5***	-277.8***	-228.7***	3.096
Liabilities-to-assets ratio	-291.8***	-85.69***	-135.1***	-355.9***	-155.6***	-242.1***	-932.2**	-149.0***	-125.5***	-32.67	-140.7***
Constant	-106,497**	37,026**	-208,561***	4,910	36,707***	-28,271***	254,710**	-33,555	31,089**	29,387	278,398***
Observations	12057	40933	68585	86153	79137	167378	9633	32972	9268	6067	13991
R-squared	0.849	0.902	0.760	0.828	0.768	0.913	0.729	0.737	0.775	0.830	0.932
Number of idn	2570	14214	14456	18771	15309	56318	2296	8722	1879	2123	3358

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: for the sake of conciseness not all variables are reported

Table 8. Fixed effects land rental price estimates for selected MS

	Belgium (1)	Poland (2)	Germany (3)	Spain (4)	France (5)	Italy (6)	Netherlands (7)	UK (8)	Sweden (9)	Hungary (10)	Ireland (11)
Investment support	0.0416	-0.00685	-0.00920	-0.0104	0.00483	0.0380***	0.359***	0.0334	-0.139	0.00978	0.0745**
Environmental payments	-0.0649	-0.0158	-0.00754	-0.0439	-0.00749	0.0141	0.0616	0.0440	0.0370	0.109**	0.0611*
LFA	-0.0478	0.0617***	-0.00118	0.120***	-0.0252	0.0299*	-	0.171**	-0.117**	0.413	-0.0566
Coupled crop area payments	0.000661	0.108*	-0.0470***	0.00526	-0.0344***	-0.000991	-0.0442	0.0542*	0.0273	0.0584	0.165**
Coupled animal payments	0.0187	-	-0.0422***	0.0232*	-0.0207***	0.0111	0.0296	0.00114	0.0146	-0.0751	-0.0287
Decoupled payments	-0.0399	0.318**	-0.0630***	-0.00606	0.0443***	0.00516	0.122*	-0.0193	-0.00123	-0.0839	-0.109***
Other subsidies	0.00161	0.000794	-0.0111	0.0502**	-0.0326***	-0.0180***	0.0127	-0.0994**	0.00206	-0.0407	-0.00504
Market return	0.00312**	-0.00259	0.00704***	0.00174	0.00654***	0.000653	-0.000945	0.0195***	0.00234	0.000235	0.0301**
Wage	0.000781*	-7.63e-05	0.000122	0.00109***	0.000193	-0.00116**	-0.000336	-3.75e-05	0.000389	0.00178	-0.00115
Other inputs	-0.00157	-0.00337	-0.00214	-0.00136	0.000772	0.00219	-0.00393	0.00600	-0.00459	-0.00115	0.0211
Farm size	0.127	0.0799*	-0.0410***	-0.0945	-0.0695	-0.0164	0.221**	0.0870**	0.128	0.0370	0.626
Land rented ratio	-41.54**	-74.34***	-120.6***	-191.9***	-139.8***	-227.9***	-374.6***	-357.7***	-135.6***	-36.71**	-254.7***
Sharecropped land	-	-	-	172.6**	247.2*	-	3,095***	455.9	-133.0	-	-
Labour own ratio	-46.47*	-10.04	-0.801	-37.02***	-23.24***	-20.38	25.12	-31.54*	15.99	9.821	49.80
Output livestock ratio	-9.733	2.865	32.71***	-9.990	-0.232*	11.61	56.63	11.48	6.019	-0.245	-5.661
Own-consumption ratio	62.64	-1.193	18.74*	-3.386	5.143	-10.63	-4.144	32.54	3.994	-20.70**	-5.342
Liabilities-to-assets ratio	36.53***	-6.804	38.29***	-19.27	1.083	-1.716	-38.75	4.640	-4.696	8.154*	-109.9
Constant	21,874**	-1,456	1,118	-4,191	25,434***	-7,705***	-8,608	8,043	-4,835	-31,021***	187,427
Observations	9408	15558	51607	26645	60654	55023	5658	14735	5494	2628	5126
R-squared	0.041	0.076	0.061	0.057	0.108	0.044	0.072	0.145	0.093	0.221	0.219
Number of idn	2249	7010	11012	6264	11985	19651	1473	4374	1244	1158	1297

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: for the sake of conciseness not all variables are reported