Comparative Analysis of Factor Markets for Agriculture across the Member States

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Drivers of agricultural capital productivity in selected EU member states

ABSTRACT

The aim of this Working Paper is to provide an empirical analysis of the marginal return on working capital and fixed capital in agriculture, based on data gathered by the Farm Accountancy Data Network from seven EU member states. Particular emphasis is placed on the detection of credit market imperfections. The key idea is to provide farm group-specific estimates of the shadow price of capital, and to use these to analyse the drivers of on-farm capital use in European agriculture. Based on Cobb Douglas estimates of farm-type specific production functions, we find that working capital is typically used in more than economically optimal quantities and often displays negative marginal returns across countries and farm types. This is less often the case with regard to fixed capital, but it is only in a small set of sectors where access to fixed capital appears severely constrained. These sectors include field crop and mixed farms in Denmark, dairy farms in East Germany, as well as mixed farms in Italy and the UK. The relationship between farm financial indicators and the estimated shadow prices of capital varies considerably across countries and sectors. Among the farms with a high shadow price for fixed capital in Denmark, high debt levels and little owned land tended to induce more intensive capital use, which may reflect the liberal Danish banking system. In East Germany, Italy and the UK, high debt levels made farmers more tightly capital constrained. Hence, in the latter group of countries, more traditional mechanisms of capital allocation based on debt capacity seemed to be at work. As a general conclusion, EU agriculture appears to be characterised by overcapitalisation rather than by credit constraints.

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Martin Petrick and Mathias Kloss*

Factor Markets Working Paper No. 30/September 2012

1. Introduction

In recent decades, the assessment of capital productivity in European agriculture has increasingly become a matter of controversy. The conventional wisdom is that capital productivity at least in Western European agriculture is lower than in other sectors of the economy and lower than the return on financial assets (Henrichsmeyer and Witzke, 1991, p. 387; Guan et al., 2006; Guan et al., 2009). Yet a survey of estimates of marginal capital productivity up to the 1990s showed widely varying outcomes (Witzke, 1993, p. 59). More recent studies on Central and East European (CEE) agriculture prior to EU accession found high marginal returns on capital, much above typical lending rates (Petrick, 2004a, b; Sarris et al., 2004). Based on bookkeeping data similar to those used in this study, Ciaian et al. (2011) argue that more intensive credit use boosted farm productivity in the CEE countries.

The literature has come up with a number of explanations for these divergent findings. An excess utilisation of capital consistent with low partial productivities may be due to non-pecuniary benefits (tractors as prestige objects) or the wish to provide safeguards against production risk (use of insurance contracts, precautionary investment in powerful machinery to mitigate production peaks; Witzke, 1993, p. 157). Aurbacher et al. (2011) have recently shown that farmers locked in small agricultural structures may be unable to coordinate on machinery sharing and thus may hold inefficiently high stocks of machinery.

A second line of literature has argued that high levels of marginal capital productivity are a result of constrained access to capital. If farmers are facing borrowing constraints, they may not be able to build up a capital stock that equates on-farm return on capital with the going market interest rate. This argument has played an important role in the modernisation of CEE and East German agriculture, which was assumed to be subject to notable credit market imperfections (Swinnen and Gow, 1999; Hüttel et al., 2010). In the light of recent financial turmoil in Europe, access to capital and the possibility of credit rationing have become important for agriculture throughout the EU (Pietola et al., 2011). This reinforces earlier concerns about the impact of agricultural finance structures in different member states (Benjamin and Phimister, 2002).

Against this background, this contribution empirically analyses the marginal return on capital in agriculture, based on individual farm data from seven EU member states. Particular emphasis is placed on the detection of credit market imperfections. The aim of the empirical study is to provide an updated set of capital productivity estimates for selected European countries. Furthermore, we come up with new evidence concerning the prevalence of credit rationing in the agricultural sectors of these countries. The key idea is to give farm

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group-specific estimates of the shadow interest rate, and to use these to analyse the drivers of on-farm capital use in EU agriculture.

In the following section we present a microeconomic model to provide a conceptual framework for the further analysis. We then discuss a number of issues in empirical implementation and summarise our empirical strategy. After introducing the database we explain the formation of subgroups. The results are presented in the penultimate section and are detailed in the appendix. The final section concludes.

2. A simple model of the credit-constrained farm

Assume a farmer maximises profit subject to a credit constraint. There is one output and one variable factor of production, which needs upfront financing and is thus fully credit funded. Revenue is used to repay debt and interest. Profit is then defined as revenue minus the costs of the input (Petrick, 2003):

$$\underset{x}{Max}\pi = pf(x,z) - (1+r)x, \text{ subject to} \tag{1}$$

$$K - x \geq 0, \tag{2}$$

where π is profit, f the production function, x variable input use, z other fixed inputs, r the market interest rate, p the output price and K the credit limit. f is monotonically increasing and concave in x and z. All prices are normalised by the input price. Solving this optimisation problem through the Lagrange method yields the following: from $L = pf(x,z) - (1+r)x + \eta(K-x)$ with $x > 0$ and assuming that (2) is binding, we have the first-order condition $\partial L / \partial x = p\partial f / \partial x - (1+r+\eta) = 0$. η is the Lagrange multiplier. Rearranging leads to

$$p\partial f / \partial x = 1 + r^* > 1 + r, \text{ with } r^* \equiv r + \eta. \tag{3}$$

We define r^* as the shadow price of capital on the farm; it represents the willingness to pay for credit. The marginal value product of the credit-financed input is thus equal to one plus the shadow price of capital. With a more severe credit constraint, the decision price for input use is increasing and input use is reduced. If there are several cooperating inputs on the farm and there are no other market imperfections, production and profit fall as a result of credit rationing. Public transfers or subsidy payments have the opposite effect. If household and production spheres of the farm compete for liquid funds, allocation decisions are no longer separable. Supply and demand equations can then only be derived from a fully specified household model (see Petrick, 2004a, b). A corresponding profit function of the credit-constrained farm household can be written as

$$\pi = \pi(p, r, z, z^h, K), \tag{4}$$

with z^h a vector of fixed household characteristics. In (4), K assumes the role of a fixed factor if the credit limit is binding, and

$$\partial \pi / \partial K = r^* \tag{5}$$

provides another measure of the shadow interest rate.

The above model serves as a useful motivation for measuring capital productivity and capital market imperfections in agriculture. Market imperfections exist if (2) is binding, that is not all profitable farm operations can be performed and there is an excess demand for liquid funds. The market imperfection may be due to unsolved problems of financial intermediation, for example arising from asymmetric information or divergent views by the farmer and the credit supplier about uncertain farming outcomes (Swinnen and Gow, 1999;

Barry and Robison, 2001; Curtiss, 2012). The severity of this market imperfection is directly reflected in the level of r^*.

Having established this measure of capital market imperfection, we hypothesise that certain financial and management characteristics of the farm can explain the severity of this constraint. Holding constant the influence of other factors, a positive effect of farm indebtedness is consistent with the view that more leveraged farms face restrictions on capital markets that prevent them from driving down their capital productivities. A negative effect may imply the presence of excess borrowing beyond economically rational returns, and thus also an inefficiency of agricultural capital markets. A negative impact of the level of farm assets, such as land, signals the importance of collateral, as farms less endowed with land may be less able to make use of mortgage credit. Corporate farms are assumed to be less attractive clients for lenders, as they are often subject to liability restrictions. Finally, we posit that older farmers have a longer credit history and therefore better credit access (Barry et al., 2000). They may also be more experienced and better endowed with wealth than younger operators. Beyond a certain age, however, a lack of relevant training and uncertainties concerning the farm successor may also make borrowing more difficult.

3. Issues in empirical implementation

A consistent measure of r^* provides a useful starting point for analysing the drivers of capital use and the determinants of capital market imperfections. Farm-individual predictions of the shadow interest rate allow comparisons of capital use among different types of farms in various regional settings. Furthermore, their determinants can be analysed in a second-stage regression, using other farm characteristics as explanatory variables. Even so, there are two basic issues in measuring r^* empirically:

1) *Primal vs. dual estimation.* Estimation could be based on the primal model (3) or the dual model (5). Data requirements for the two approaches are different: (3) requires the specification of a production function, with appropriate measurement of outputs and inputs, while (5) requires data on profits, prices and fixed factors, including the credit limit.

2) *How to measure the* a priori *credit rationing status.* Note that (5) is only defined for a binding credit constraint, i.e. equality in (2). Yet *K* is usually unobserved, so whether the constraint is binding for a given farm is hard to determine. While all relevant variables are principally observed for estimating (3), *x* is endogenous if the credit constraint is not binding.

Previous studies have used both primal and dual approaches and a variety of techniques to measure the credit rationing status (cf. Petrick, 2005, for a survey). Carter and Wiebe (1990) and Petrick (2003) are examples of the primal approach, based on a production function estimation. On the other hand, Feder et al. (1990), Sial and Carter (1996) and Petrick (2004a) implicitly or explicitly use the dual approach.[1] Blancard et al. (2006) identify "financial inefficiency" (as an indicator of credit rationing) by measuring the distance between an unconstrained profit function and the credit-constrained profit function, following the non-parametric approach to frontier profit by Färe et al. (1990). A key issue in choosing among the approaches is data availability. Except for Blancard et al. (2006), all studies worked with cross-sectional data in which price variation was negligible or assumed to be absent. Estimation thus focused on specifying an appropriate set of variable and/or fixed production factors and the credit limit.

This leads to the fundamental problem of how to measure the credit rationing status of a single farm. Following the model above, information on the level of both *x* and *K* is required

[1] Feder et al. (1990) and Sial and Carter (1996) base their analysis on an output supply equation. Petrick (2004a) derives this equation from a liquidity surplus function of the farm household.

to determine whether (2) is binding. As liquidity is highly fungible, particularly the latter is notoriously difficult to measure. In the literature, there have been three broad approaches to deal with this issue:

a) Missing information about *K*, a first group of studies assumes that all farms (Carter and Wiebe, 1990) or all borrowers (Sial and Carter, 1996) are credit constrained and that observed input expenditures are equal to the credit limit. This is also the assumption made by Färe et al. (1990) and Blancard et al. (2006). Of course, there may be borrowers who took some credit, but not up to their limit, so this assumption may lead to misspecification of models and an overestimation of the prevalence of credit rationing.

b) A second group uses direct elicitation of credit constraints to overcome the previous weakness. In specifically designed questionnaires, potential and actual borrowers are asked whether they perceive their credit ration as binding. Building on pioneering work by Feder et al. (1990) and others, this approach was used by Petrick (2003) and (2004a) in the context of a shadow price analysis for Poland.[2]

c) Without the information necessary for approach (b), a third approach uses other observable criteria to group the data into *a priori* credit constrained and unconstrained farms. This approach has been especially widespread in the investment literature (cf. Petrick, 2005). Typical criteria are high vs. low debt, tenanted vs. owned (Benjamin and Phimister, 2002), asset levels of farms, their debt-to-asset ratio and the age of the operator.

For the present study, the data available from the Farm Accountancy Data Network (FADN) cover a panel of farm-individual data from selected European countries. These data are rich in farm characteristics, factor use, output and financial statements, including balance sheet data. They are less detailed in price data and they have no specific information on credit rationing status. As a main interest is in the drivers and impacts of capital use, a production function approach is used in the following analysis.

As summarised by Griliches and Mairesse (1998), estimating production functions from micro data involves a number of econometric challenges. Individual farm output may be affected by unobserved characteristics of the farm. These characteristics may be owing to "management bias" as introduced to the literature by Mundlak (1961) or reflect socio-demographic or geographical characteristics of the farm that are constant over time. For example, soil fertility, the management ability of farmers and technology are supposed to be correlated with inputs. If panel data are available as in our case, the typical way to eliminate the influence of these factors is to use a fixed-effects or "within groups" estimator (Greene, 2008, p. 191). This will also eliminate the influence of fixed factors captured in *z* (equation 1).

While the entire spectrum of flexible functional forms is available for estimating the production function, the Cobb Douglas model is often used as a convenient starting point for empirical analysis (e.g. by Carter and Wiebe, 1990 and Petrick, 2003). Even so, it imposes a lot of structure on the data, including homogeneity and strong separability of factors (Chambers, 1988). The testing of more flexible functional forms may thus be desirable. We experimented with a translog formulation, which combined with the fixed effects approach did not yield satisfying results. Most interaction terms were poorly identified and the parameters led to widely varying shadow prices. We therefore resorted to the traditional Cobb Douglas model and combined it with a procedure of group-wise time demeaning, thereby eliminating fixed effects. We leave more flexible functional forms for future research, for example using the control function approach of Olley and Pakes (1996) and its recent modifications.

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[2] This approach continues to be refined in the development economics literature (Boucher et al., 2009).

The parameters of the production functions are used to calculate farm-individual (net) shadow prices of fixed and working capital according to subgroups following equation (3). This means we have multiplied the estimated production elasticities from the production function of the relevant farm subgroup with the average capital productivity of each farm in that group, subtracted one and expressed the result as a percentage. We then pool the shadow prices for high debt and low debt farms and use a second-stage ordinary least squares (OLS) regression to analyse the determinants of these shadow prices. We include the debt-to-asset ratio per farm, the amount of owned land as a source of collateral, the legal form and the age of the manager as regressors.

The following analysis thus proceeds in four steps:

1) Subgroups of farms are formed based on country, farm type and *a priori* credit rationing status.

2) Cobb Douglas production functions for the subgroups are estimated, allowing for varying technology parameters in each subgroup.

3) Based on the estimated production elasticities, shadow prices of fixed and working capital are calculated.

4) The drivers of capital productivity are analysed in a second-stage regression of shadow prices, separately for countries, farm types and fixed vs. working capital.

4. Database

The FADN provides a farm level data set that holds accountancy data for 25 of the 27 EU member states. Each year about 80,000 farms are sampled. They represent a population of about 5,000,000 farms in the member states. In each member state a liaison agency is responsible for the data collection and transmission, which consists of about 1,000 variables including structural, economic and financial data. To represent the heterogeneity of farms, a stratified sample is obtained. The stratification criteria are region, economic size and type of farming.

The farm universe consists of all farms with more than one hectare or those with less than one hectare that provide the market with a specified amount of output. From this universe all non-commercial farms are excluded in order to arrive at the field of observation. To be classified as a commercial farm, a farm must exceed a certain economic size. It is measured in economic size units (ESU). One ESU represents a certain amount in euros and is periodically adjusted for inflation. To determine the economic size of farms, the concept of standard gross margin is used. In addition, farms are classified by type of farming.

The raw data provided by FADN was arranged in a way that panel data estimators can be applied. For every country and sector in the study, we created a panel data set covering the years from 2001 up to 2008. For Poland and Slovakia, the first year of data is 2004. Therefore, these panels only cover five years. A small number of duplicates in the data were dropped.[3]

The variables and their measurement are readily available in the codebooks provided by FADN. Output is measured as the total farm output in euros. Labour is measured by the time worked in hours by total labour input on the farm, including both hired and family labour. The total utilised agricultural area is our land input in ha. It includes owned and rented land, and land in sharecropping.
A persistent issue in estimating production functions has been the specification of the capital variable. Typically, some simple measures of input quantities (such as fertilisers or pesticides) and machinery use (such as fuel expenses or tractor hours) are used in the cross-sectional studies. More sophisticated approaches use inventory methods to estimate real

[3] Duplicates likely arise from the fact that farms run legally separate operations in several regions.

capital service flows, by making assumptions about depreciation and capital rental rates (Andersen et al., 2011). In this study, the material or working capital input is proxied by total intermediate consumption in euros. It consists of total specific costs and overheads arising from production in the accounting year. Among others, it includes feed, fuel, lubricants, water, electricity and seed. Fixed capital inputs are approximated by depreciation of capital assets estimated at replacement value in euros. This variable includes plantations of permanent crops, farm buildings and fixed equipment, land improvements, machinery, equipment and forest plantations. Cows are measured in livestock units (LU) per farm, following the standard FADN conversion rates.

The determinants of capital use are measured as follows. The debt-to-asset ratio is calculated by the total liabilities divided by total assets. Owned land is constructed by subtracting the utilised area of rented land from the total utilised area. Corporate is an indicator variable that takes on the value of one if the observed farm is a corporation (i.e. neither a family nor a partnership farm). Lastly, we include the age of the farm manager in years. Table 1 summarises the variable definitions and gives the actual FADN codes.

Table 1. Selection of variables

FADN code	Variable description
Outputs	
SE131	Total output (€)
Inputs	
SE011	Labour input (hours)
SE025	Total utilised agricultural area (ha)
SE275	Total intermediate consumption (€) = working capital
SE360	Depreciation (€) = fixed capital
SE085	Dairy cows (livestock units; in dairy and mixed farms)
Determinants of shadow prices	
SE485/SE436	Debt-to-asset ratio
SE025-SE030	Owned land (ha)
A18	Corporate farm (1/0)
C01YR	Age of manager (years)

Source: FADN data.

All monetary values are deflated to real values in 2005 prices using respective price indices. The information was extracted from the Eurostat online database and merged with the panels. Output was deflated by the agricultural output price index. Fixed capital was deflated by the agricultural input price index for goods and services contributing to agricultural investment, and working capital by the agricultural input price index for goods and services currently consumed in agriculture.

Outliers were identified on the basis of the average, fixed capital productivity per farm (real SE131/real SE360). Observations were dropped for the production function estimation if their value was beyond the median ± 1.5 the interquartile range. For the shadow price regression, outliers in the dependent variable were dropped using the same criterion.

5. Selection of farm and country subgroups

As the FADN data do not contain any specific information about the credit rationing status of farms, the formation of subsamples based on suitable indicators available in the data was a crucial step in the analysis (approach (c) above). Subgroups were drawn according to three criteria:

1) member state,
2) farm type, and
3) *a priori* credit rationing status.

Different member states reflect different structural and political conditions as well as different banking systems. Stratification according to farm type is desirable to make farms comparable and to justify the assumption of a homogenous production technology implicit in the production function estimates. The credit rationing status shall facilitate the interpretation of diverging returns on capital as outlined above.

The member states selected for the study include major agricultural producers as well as diverse agricultural finance structures (Table 2). The spectrum is from large-scale (often corporate) farms in East Germany and Slovakia to medium-sized commercial farms in Denmark, France and the UK, and down to small family farms in West Germany, Italy and Poland. Not less diverse, agricultural finance systems vary from highly competitive and liberal in Denmark and the UK to the typical cooperative banking sectors in Germany and France, as well as a specialised sector bank in Slovakia and a generally low penetration of capital in Italy and Poland. As East and West Germany are structurally so distinct, we treat them separately in the following analysis. East Germany contains the five states Mecklenburg-West Pomerania, Brandenburg, Saxony-Anhalt, Thuringia and Saxony. West Germany contains all other states except Berlin and Bremen, which are not represented in the FADN data.

Table 2. Selection of countries

Country	**Agricultural structure (as represented in the data)**	**Agricultural finance**
Denmark (DK)	Medium-scale farms, highly commercialised	Liberal lending; high investment and financial leverage in agriculture
France (FR)	Medium-scale family farms	Centralised, cooperative banking sector; preferential lending rates for agriculture
Germany East (DEE) and West (DEW)	Small- to medium-scale family farms (West); large corporate farms (East)	Mixed cooperative, savings and commercial banks; lower debt capacity in the East
Italy (IT)	Small-scale family farms	Very low financial leverage
Poland (PL)	Small-scale family farms	Cooperative banking sector, emerging commercial banks, preferential lending rates, low investment levels
Slovakia (SK)	Large corporate farms	Specialised agricultural bank, low investment levels
United Kingdom (UK)	Medium-scale farms, highly commercialised	Lending primarily by non-specialised commercial banks; traditionally a focus on overdraft loans

Sources: Authors based on Pietola et al. (2011); Benjamin and Phimister (2002); European Commission (2010); FADN data.

Our farm type classification follows the TF8 scheme of the FADN and includes three dominant farm types:

- field crops (TF1),
- specialised dairy farms (TF5), and
- mixed farms (TF8).

While the first two represent specialised and fairly homogeneous production technologies, the third type was included for its quantitative importance in many member states.

For the *a priori* classification into credit constrained and unconstrained farms, we followed Bierlen & Featherstone (1998) and Benjamin & Phimister (2002) in using the debt-to-asset ratio as a separation criterion. For each farm in the sample, we calculated the average debt-to-asset ratio over the years the farm was included in the sample. If this value was below the median debt-to-asset ratio in the respective country/farm type subsample, the farm with all its years of observation was classified as 'low debt' or *a priori* unconstrained, or otherwise as 'high debt' or constrained. For the calculation of the median, only farms with a non-zero debt-to-asset ratio were considered. This led to much bigger unconstrained subsamples in Italy and Poland, as many farms have zero debt in these countries.

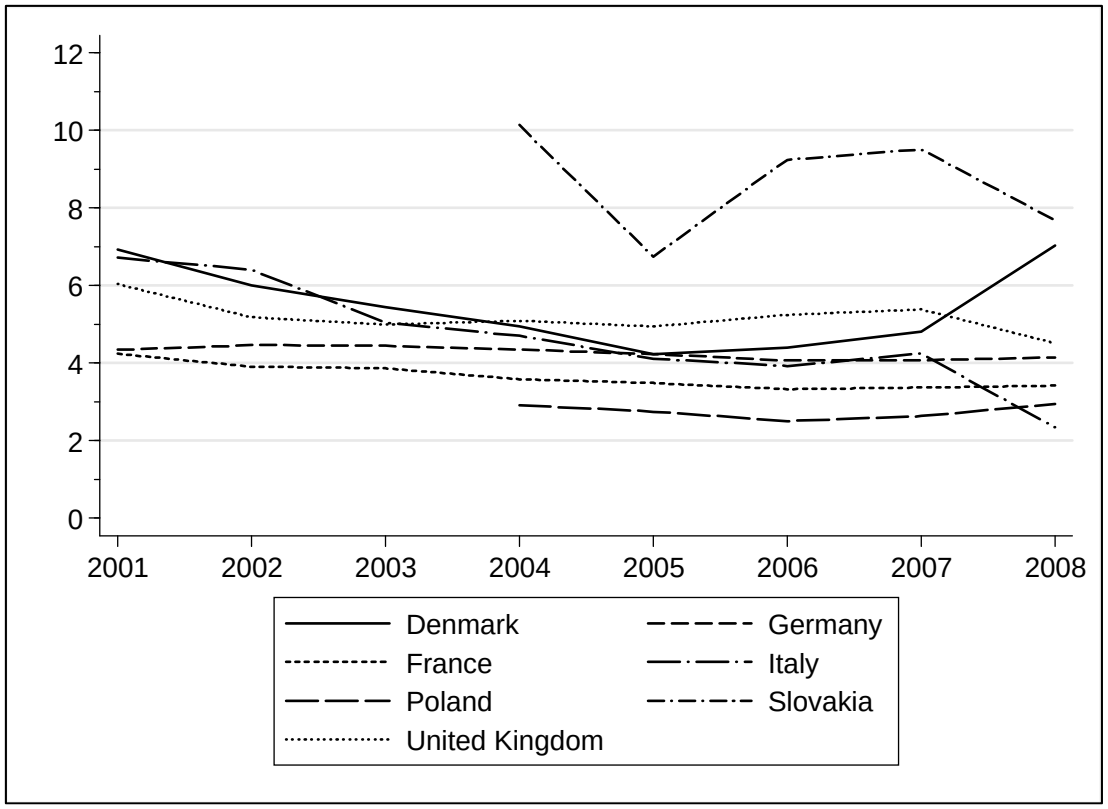
6. Results

In the following discussion, the main results concerning the potential presence of capital constraints and the drivers of marginal capital productivity are presented, separated by capital and farm type. Detailed results by country are compiled in the appendix of this paper. The latter includes distributional charts of shadow prices, descriptive statistics of all variables, estimates of the production function parameters by subgroup, as well as mean comparison tests and regression tables of shadow prices.

The upper part of each of the following tables summarises the main results concerning the presence of capital market imperfections. It starts with a statement about whether the production function estimation could at all identify the capital elasticity with sufficient statistical precision. If an elasticity could not be identified, all of the following statements suffer from a severe methodological caveat, as the empirical basis for these statements is very weak. Columns to which this caveat applies appear in pale letters. The second row asks whether the shadow price of capital on the *a priori* credit constrained, high-debt farms is significantly higher than that on low-debt farms. This statement is based on the t-tests reported in the appendix. If the answer is yes this outcome supports the view that highly leveraged farms are more tightly capital constrained, as they cannot equalise their marginal capital productivity with the low-debt farms. It is thus the first evidence of a credit market imperfection. The third row states whether the estimated shadow prices were excessively higher than typical interest rates on agricultural loan markets. Such loan rates were compiled recently by Pietola et al. (2011) and are reproduced in Figure 1. Our table statements are based on simple numerical comparisons between these interest rates and the internal shadow prices of farms.

The lower section of each table summarises the outcomes of the shadow price regressions. For age, we included a quadratic term to capture the potential non-linearities outlined above. Significantly positive or negative coefficients are indicated by + and –, while "0" denotes a non-significant effect. Due to lack of data, some variables could not be included for some groups, and are thus marked by "n.a." (not applicable).

Figure 1. Agricultural loan rates in EU member countries (%)



Note: Loan rates represent interest payments weighted by outstanding loans and are thus averages over all loan categories.

Source: Authors based on aggregate FADN data on the website of the European Commission, DG for Agriculture and Rural Development (http://ec.europa.eu/agriculture/rica/database/database_en.cfm).

6.1 Fixed capital

Table 3 to Table 5 summarise the results with regard to fixed capital on field crops, dairy and mixed farms, respectively. The fixed capital elasticity is commonly identified by the production function in all country subgroups, with the exception of East German field crops, Polish and Slovak dairy and Slovak mixed farms. The Polish and Slovak samples contain fewer years than the other countries, which may have contributed to the poor identification of the capital variable. In 12 out of 24 cases was the mean shadow price of fixed capital higher for high-debt farms than for low-debt farms. This is usefully illustrated by the combined histograms of high-debt and low-debt farms in the appendix, which show the distribution of shadow prices per farm group. In cases where high-debt farms display higher shadow prices than low-debt farms, the red distributions (constrained) peak further to the right than the white ones (unconstrained).

Despite this evidence in favour of debt effects on shadow prices, only in five cases were the calculated shadow prices excessively higher than typical interest rates. This finding applies to Danish field crops, East German dairy farms, and Danish, Italian and British mixed farms. In addition, the distributions of shadow prices for Slovak and British field crop farms display a notable tail to the right, indicating that at least a subsample of farms is constrained. It thus appears that credit rationing is an issue only in some specific sectors and countries, whereas in a majority of cases marginal returns on capital in agriculture are quite low. In many of the subsamples where we found no excessive levels of shadow prices this marginal return was actually highly negative (see the tables in the appendix).

Table 3. Field crop farms, fixed capital

	DK	FR	DEE	DEW	IT	PL	SK	UK
Capital elasticity identified	yes	yes	no	yes	low debt only	yes	low debt only	yes
Mean shadow price high debt > low debt	no	yes	yes	yes	no	yes	no	yes
Excessive average shadow price level	yes	no	no	no	no	no	no	no
Effect on shadow price								
Debt-to-asset ratio	–	+	+	+	–	+	–	+
Owned land (ha)	+	–	+	0	+	+	0	–
Corporate farm (1/0)	+	0	–	n.a.	+	–	–	+
Age of manager	–	–	–	–	+	+	n.a.	–
Age square	+	0	+	0	–	–	n.a.	+

Source: Authors' estimations based on FADN data.

Among the five groups with excessive shadow prices for fixed capital, only the UK displays the expected positive relationship between debt-to-asset and shadow price and a negative coefficient on owned land. In the other cases, owned land has a positive sign, while the debt-to-asset sign varies. It seems they deserve a differentiated interpretation, as these farmers operate in rather diverse contexts. In the two Danish groups of field crops and mixed farms, farms with a higher debt-to-asset ratio and less owned land show lower shadow prices of fixed capital, and thus appear less constrained. This is consistent with liberal lending policies in the past, which led to high capital inflows regardless of the availability of collateral. The direction of causality between shadow prices and debt levels deserves further scrutiny in this case.

The rather distinct cases of large East German dairy farms and relatively small Italian mixed farms experience higher shadow prices if the debt-to-asset ratio is also high. This outcome is more in line with the view that high indebtedness makes capital access more difficult. As land ownership by operators is less widespread in East Germany, land may be less relevant as collateral, which in turn may explain the positive sign of the land variable in this case.

Table 4. Dairy farms, fixed capital

	DK	FR	DEE	DEW	IT	PL	SK	UK
Capital elasticity identified	low debt only	yes	high debt only	yes	yes	no	no	high debt only
Mean shadow price high debt > low debt	no	no	yes	yes	no	no	yes	yes
Excessive average shadow price level	no	no	yes	no	no	no	no	no
Effect on shadow price								
Debt-to-asset ratio	–	–	+	+	–	+	+	+
Owned land (ha)	–	–	+	+	+	+	0	0
Corporate farm (1/0)	0	0	0	n.a.	+	n.a.	0	0
Age of manager	0	–	0	–	0	0	n.a.	+
Age square	0	–	0	+	0	0	n.a.	–

Source: Authors' estimations based on FADN data.

In all groups with excessive shadow prices of fixed capital, the corporate farms display higher shadow prices (or no effect in East German dairy farms). This is consistent with the presumption that liability regulations constrain the capital access of corporate farms. On the other hand, the influence of the age of the manager appears to be small, most frequently it is not statistically different from zero.

Throughout the tables, the sign of the debt-to-asset ratio confirms the outcome of the mean comparison between high-debt and low-debt farms in the upper part of the tables.

Among the farm groups with very low (usually negative) shadow rates, capital market imperfections in the classical sense of limited credit access appear to be less relevant in general. It is thus questionable whether the reported financial indicators contribute much to understanding these low rates. One of the apparent regularities is that in France and West Germany the shadow prices of fixed capital are typically the lower the older the farm manager, regardless of farm type. In both countries, this may be an indication of excess capital use for other than purely economic reasons, such as prestige or strong risk aversion, which could be more pronounced among the older farmers.

Table 5. Mixed farms, fixed capital

	DK	**FR**	**DEE**	**DEW**	**IT**	**PL**	**SK**	**UK**
Capital elasticity identified	yes	yes	low debt only	yes	yes	yes	no	yes
Mean shadow price high debt > low debt	no	yes	no	no	yes	yes	no	yes
Excessive average shadow price level	yes	no	no	no	yes	no	no	yes
Effect on shadow price								
Debt-to-asset ratio	–	+	–	+	+	+	–	+
Owned land (ha)	+	–	0	+	+	+	–	–
Corporate farm (1/0)	+	0	+	n.a.	+	–	–	+
Age of manager	0	0	0	–	0	+	n.a.	+
Age square	0	0	0	+	+	–	n.a.	–

Source: Authors' estimations based on FADN data.

6.2 Working capital

The working capital estimates in Table 6 to Table 8 almost all identified the capital elasticity. This is expected, as the within-group variation in working capital is typically higher than in fixed capital. In the minority of cases (10) is the mean shadow price of working capital higher for high-debt farms than for low-debt farms. Credit constraints may thus be less binding for working capital than for fixed capital. The latter presumption is forcefully supported by the finding that shadow price levels were excessive in only one case (Danish mixed farms). Some farms in the shadow price distributions of Danish, French and Italian field crop and West German dairy farms appear constrained. However, most shadow prices were negative on average.

Table 6. Field crop farms, working capital

	DK	FR	DEE	DEW	IT	PL	SK	UK
Capital elasticity identified	yes	yes	yes	yes	yes	yes	yes	yes
Mean shadow price high debt > low debt	yes	no	yes	yes	no	no	no	no
Excessive average shadow price level	no	no	no	no	low debt only	no	no	no
Effect on shadow price								
Debt-to-asset ratio	–	–	+	+	–	–	–	–
Owned land (ha)	+	–	+	–	–	–	+	+
Corporate farm (1/0)	+	0	–	n.a.	+	0	+	0
Age of manager	+	0	0	0	+	+	n.a.	+
Age square	0	0	0	0	–	–	n.a.	–

Source: Authors' estimations based on FADN data.

Debt-to-asset ratios often have a negative impact on shadow rates, while the effect of owned land varies quite a bit. Taken together, this is an indication that factors other than borrowing constraints drive the low values of working capital productivity. The age of the manager seems to have an effect on shadow rates less often than for fixed capital, and the same applies to the corporate structure of the farm.

Table 7. Dairy farms, working capital

	DK	FR	DEE	DEW	IT	PL	SK	UK
Capital elasticity identified	yes	yes	yes	yes	yes	yes	low debt only	yes
Mean shadow price high debt > low debt	yes	no	yes	yes	no	yes	no	yes
Excessive average shadow price level	no	no	no	no	no	no	no	no
Effect on shadow price								
Debt-to-asset ratio	–	–	+	+	–	+	–	0
Owned land (ha)	+	–	+	–	–	0	0	+
Corporate farm (1/0)	0	0	0	n.a.	0	n.a.	0	0
Age of manager	+	–	+	0	–	+	n.a.	+
Age square	–	+	–	+	+	–	n.a.	–

Source: Authors' estimations based on FADN data.

Table 8. Mixed farms, working capital

	DK	FR	DEE	DEW	IT	PL	SK	UK
Capital elasticity identified	yes	yes	yes	yes	yes	yes	yes	yes
Mean shadow price high debt > low debt	no	no	yes	yes	no	no	no	no
Excessive average shadow price level	yes	no	no	no	no	no	no	no
Effect on shadow price								
Debt-to-asset ratio	+	–	+	+	–	–	–	–
Owned land (ha)	+	–	+	+	–	–	0	0
Corporate farm (1/0)	0	–	–	n.a.	+	0	+	0
Age of manager	0	0	0	+	0	0	n.a.	0
Age square	0	0	0	+	0	0	n.a.	0

Source: Authors' estimations based on FADN data.

7. Conclusions

Our empirical analysis of marginal capital productivity in the agricultural sector of seven EU member states has produced the following main insights. First, working capital is typically used in more than economically optimal quantities and displays commonly negative marginal returns across countries and farm types. This is less often the case with fixed capital, but it is only a small set of sectors where access to fixed capital appears severely constrained. These sectors include field crop and mixed farms in Denmark, dairy farms in East Germany, as well as mixed farms in Italy and the UK.

Second, the relationship between farm financial indicators and the estimated shadow prices of capital varies considerably across countries and sectors. Among the farms with a high shadow price for fixed capital in Denmark, high debt levels and little owned land tended to induce more intensive capital use. The latter may be an indicator of the liberal Danish banking system. In East Germany, Italy and the UK, high debt levels made farmers more tightly capital constrained if their shadow rates indicated some constrained capital access in the first place. Hence, in the latter group of countries, more traditional mechanisms of capital allocation based on debt capacity seemed to be at work.

With these exceptions in mind, EU farmers typically do not face serious constraints in accessing capital. Based on our findings, it seems fair to say that (economically) excessive capital use is the rule. In France and West Germany, marginal returns to fixed capital are particularly low on farms with older operators, which may indicate non-pecuniary benefits from capital use or a risk-averse accumulation of capital stocks to mitigate production peaks. As a general conclusion, EU agriculture appears to be dominated more by overcapitalisation than by credit constraints. This statement is broadly in line with other recent studies of capital use in individual European countries (Aurbacher et al., 2011; Guan et al., 2009). It also holds for the two new member states in our sample, Poland and Slovakia, and thus qualifies the finding of Ciaian et al. (2011), according to which credit use increased farm productivity in the new member states. Yet our findings are less robust for these two cases due to a smaller sample size and problems with identification in the production function estimations.

One policy conclusion is apparent from the findings presented in this study. Capital subsidies have been part of the Common Agricultural Policy for a long time and are also provided by many national governments. If EU farmers typically use too much capital, with regard to both fixed and working capital, there is little economic justification for such subsidies, and future policy reforms should aim at downsizing their importance.

We conclude with some limitations of our findings and suggestions for further research. The previous results are subject to the assumptions that provided the basis for the empirical analysis. For example, the assumption of a Cobb Douglas technology in the production function estimates is rather rigid. Among other restrictions, it rules out multiple equilibria of locally optimal capital use. It thus may conceal traps associated with low asset levels, in which capital returns are low although capital use is also low. Such circumstances may, for example, be present in countries dominated by small and less commercially oriented farms, such as Italy or Poland. As our attempt to combine more flexible functional forms with a fixed effects regression was not successful, this also calls for alternative estimation approaches. For example, a control function approach to account for unobserved heterogeneity may be more appropriate for modelling flexible production technologies.

Our relatively simple conceptual framework does not explicitly account for the dynamic and risk-related considerations of the decision-makers. More complex models may provide more differentiated insights into the allocation patterns of fixed capital in particular.

Taking the finding of a widespread excess of capitalisation in agriculture for granted, there is a need to better understand the drivers behind this outcome. Such an analysis should look at both the demand side and the supply side of agricultural capital markets (Kataria et al., 2012). The motives and strategies of farm managers to invest in capital require a more careful evaluation. Imperfections in the arrangements of machinery sharing provide an interesting avenue of further research (Aurbacher et al., 2011) and the role of agricultural subsidies should be investigated further (Ciaian and Pokrivcak, 2011). Moreover, there is a definite need for a more detailed examination of the manifold institutional environments in the agricultural banking sectors in Europe.

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Appendix: Results by selected member states

Denmark

France

Germany (East)

Germany (West)

Italy

Poland

Slovakia

United Kingdom

Denmark

Figure A1. Shadow prices of fixed capital

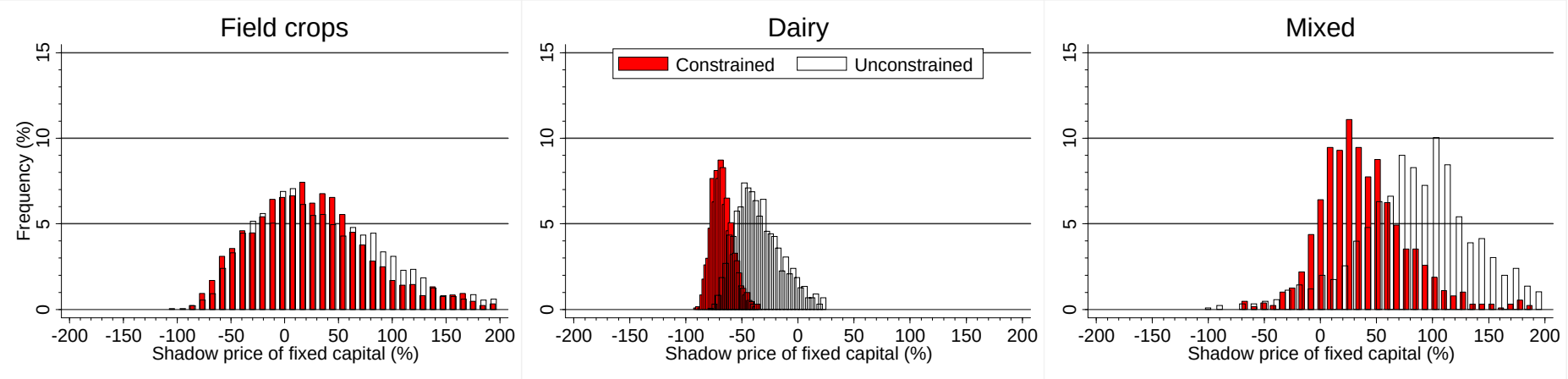

Figure A2. Shadow prices of working capital

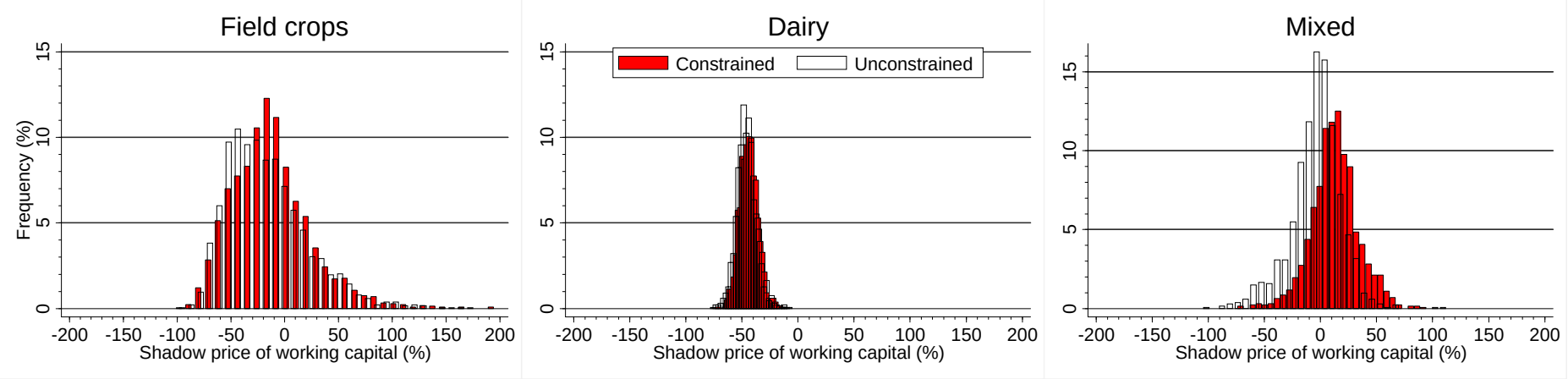

Table A1. Denmark: Descriptive statistics and mean comparison of shadow prices

	Field crops				***Dairy***				***Mixed***			
	Low debt		*High debt*		*Low debt*		*High debt*		*Low debt*		*High debt*	
	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean
Output (ths €)	1881	145.10	2140	273.61	1334	330.82	1300	476.45	1327	449.56	1279	650.36
Labour (ths hours)	1881	2.28	2140	3.53	1334	4.53	1300	5.30	1327	4.42	1279	6.00
Land (ha)	1881	96.89	2140	152.42	1334	103.81	1300	136.40	1327	133.87	1279	183.24
Working capital (ths €)	1881	86.70	2140	167.26	1334	208.05	1300	302.52	1327	316.72	1279	461.64
Fixed capital (ths €)	1881	23.96	2140	42.44	1334	42.50	1300	61.54	1327	61.65	1279	87.64
Cows (LU)	--	--	--	--	1334	100.27	1300	139.59	1327	12.23	1279	11.85
Debt-to-asset ratio	1881	0.23	2140	0.63	1334	0.47	1300	0.80	1327	0.44	1279	0.79
Owned land (ha)	1881	72.36	2140	94.02	1334	79.37	1300	97.59	1327	98.32	1279	121.51
Corporate farm (1/0)	1881	0.03	2140	0.05	1334	0.04	1300	0.07	1327	0.04	1279	0.05
Age of manager (years)	1881	48.73	2140	57.28	1334	55.37	1300	61.86	1327	53.73	1279	59.99
Shadow price of fixed capital (%)	1881	37.06	2140	25.72	1334	-35.07	1300	-67.26	1327	92.88	1279	38.01
p(high debt>low debt)		>0.999				>0.999				>0.999		
p(high debt<low debt)		<0.001				<0.001				<0.001		
Shadow price of working capital (%)	1881	-16.27	2140	-12.93	1334	-45.81	1300	-43.73	1327	-3.95	1279	12.72
p(high debt>low debt)		0.002				<0.001				<0.001		
p(high debt<low debt)		0.998				>0.999				>0.999		

Notes: LU=livestock units. P-values based on two-sample t-test for paired data.

Table A2. Denmark: Production elasticities based on production function estimates (Cobb Douglas fixed effects)

	Field crops		***Dairy***		***Mixed***	
	Low debt	*High debt*	*Low debt*	*High debt*	*Low debt*	*High debt*
Labour	0.31	0.27	0.13	0.06	0.08	0.11
Land	0.18	0.14	0.07	0.01#	-0.03#	0.01#
Working capital	0.57	0.58	0.35	0.36	0.72	0.83
Fixed capital	0.23	0.20	0.08#	0.04#	0.27	0.18
Cows	--	--	0.43	0.43	0.01#	< 0.01#
No. of observations	1881	2140	1334	1300	1327	1279
No. of farms	722	863	473	446	589	534

Notes: All estimates based on group-demeaned variables (fixed effects regression). Year dummies are included but results not shown. All coefficients are significant at least at the 5% level except when marked with #, based on standard errors robust to clustering in groups.

Table A3. Determinants of shadow prices (pooled OLS)

	Fixed capital						**Working capital**					
	Field crops		*Dairy*		*Mixed*		*Field crops*		*Dairy*		*Mixed*	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Debt-to-asset ratio	-19.75***	3.97	-51.16***	1.73	-82.18***	5.40	-9.63***	2.47	-1.79**	0.79	16.48***	2.11
Owned land (ha)	0.04***	0.01	-0.05***	0.01	0.04***	0.01	0.07***	0.01	0.03***	0.00	0.09***	0.01
Corporate farm (1/0)	20.96***	4.78	-0.72	1.72	21.70***	4.83	18.15***	3.32	0.57	0.75	2.25	1.94
Age of manager	-1.56**	0.62	0.02	0.43	0.72	1.18	0.72**	0.37	0.50***	0.16	0.60	0.44
Age square	0.02***	0.01	<0.01	<0.01	-0.01	0.01	<0.01	<0.01	>-0.01**	<0.01	<0.01	<0.01
R^2	0.093		0.429		0.166		0.123		0.164		0.223	
No. of observations	4022		2634		2607		4022		2634		2607	

*** (**, *) significant at the 1% (5%, 10%) level, based on heteroscedasticity robust standard errors

Notes: Year dummies and constant are included but results not shown. Outliers in dependent variable eliminated prior to estimation.

France

Figure A3. Shadow prices of fixed capital

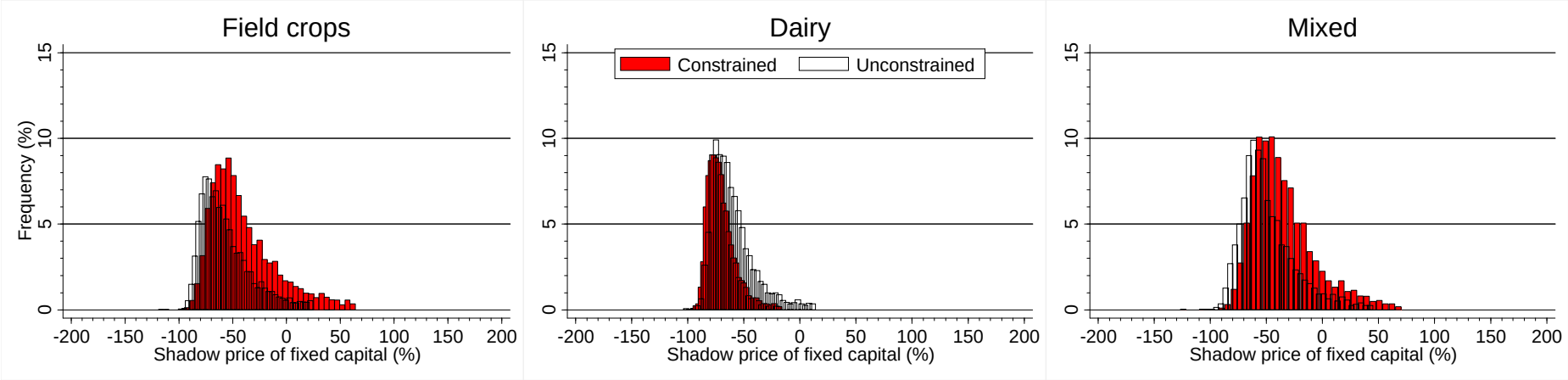

Figure A4. Shadow prices of working capital

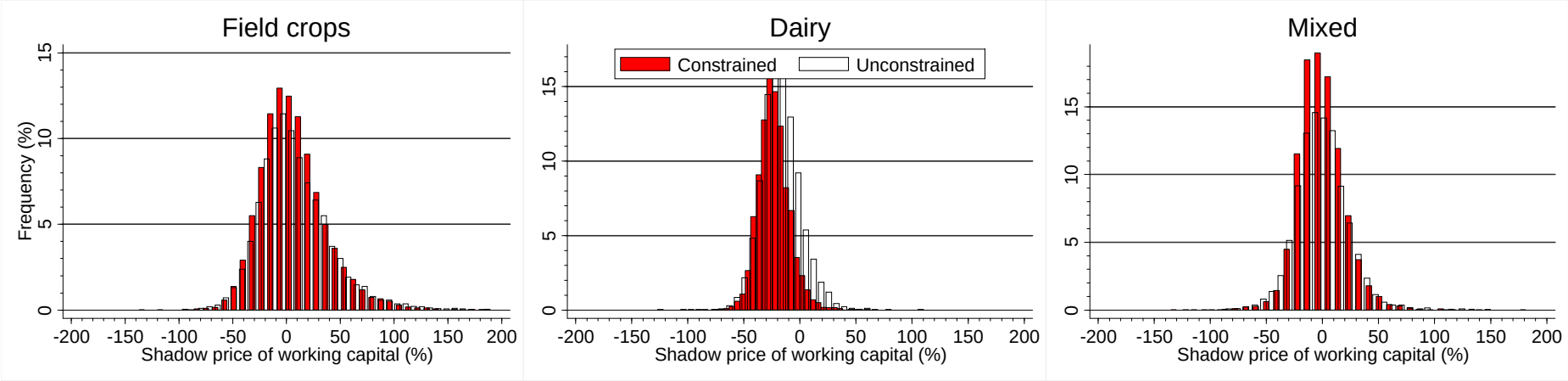

Table A4. France: Descriptive statistics and mean comparison of shadow prices

	Field crops				***Dairy***				***Mixed***			
	Low debt		*High debt*		*Low debt*		*High debt*		*Low debt*		*High debt*	
	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean
Output (ths €)	6704	125.67	6920	166.63	3418	101.55	3775	144.38	4034	153.39	3829	221.53
Labour (ths hours)	6704	2.89	6920	3.58	3418	2.83	3775	3.35	4034	3.31	3829	3.81
Land (ha)	6704	120.56	6920	143.34	3418	72.91	3775	87.70	4034	112.79	3829	126.80
Working capital (ths €)	6704	83.54	6920	112.49	3418	65.31	3775	97.42	4034	108.67	3829	162.41
Fixed capital (ths €)	6704	29.43	6920	36.31	3418	23.82	3775	31.51	4034	33.45	3829	44.31
Cows (LU)	--	--	--	--	3418	42.35	3775	53.71	4034	24.48	3829	35.53
Debt-to-asset ratio	6701	0.24	6919	0.61	3418	0.20	3775	0.50	4025	0.28	3829	0.59
Owned land (ha)	6704	18.59	6920	9.92	3418	13.36	3775	6.75	4034	13.76	3829	6.61
Corporate farm (1/0)	6704	0.00	6920	0.01	3418	0.00	3775	0.00	4034	0.00	3829	0.00
Age of manager (years)	6691	55.50	6903	58.36	3409	57.37	3757	60.37	4009	57.50	3808	60.51
Shadow price of fixed capital (%)	6704	-56.34	6920	-40.24	3418	-60.32	3775	-69.87	4034	-48.59	3829	-34.80
p(high debt>low debt)		<0.001				>0.999				<0.001		
p(high debt<low debt)		>0.999				<0.001				>0.999		
Shadow price of working capital (%)	6704	8.17	6920	5.79	3418	-16.76	3775	-23.14	4034	-0.28	3829	-1.42
p(high debt>low debt)		>0.999				>0.999				0.989		
p(high debt<low debt)		<0.001				<0.001				0.011		

Notes: LU=livestock units. P-values based on two-sample t-test for paired data.

Table A5. France: Production elasticities based on production function estimates (Cobb Douglas fixed effects)

	Field crops		***Dairy***		***Mixed***	
	Low debt	*High debt*	*Low debt*	*High debt*	*Low debt*	*High debt*
Labour	0.11	0.11	0.06	0.05	0.07	0.06
Land	0.16	0.04#	0.03#	0.13	0.12	0.02#
Working capital	0.73	0.72	0.53	0.51	0.72	0.71
Fixed capital	0.09	0.11	0.08	0.06	0.10	0.12
Cows	--	--	0.33	0.26	0.02	0.02
No. of observations	6704	6920	3418	3775	4034	3829
No. of farms	1502	1580	838	1049	1087	1026

Notes: All estimates based on group-demeaned variables (fixed effects regression). Year dummies are included but results not shown. All coefficients are significant at least at the 5% level except when marked with #, based on standard errors robust to clustering in groups.

Table A6. Determinants of shadow prices (pooled OLS)

	Fixed capital						**Working capital**					
	Field crops		***Dairy***		***Mixed***		***Field crops***		***Dairy***		***Mixed***	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Debt-to-asset ratio	19.11***	1.18	-15.16***	1.05	28.14***	1.60	-11.59***	0.94	-18.11***	0.96	-12.33***	1.24
Owned land (ha)	-0.08***	0.01	-0.06***	0.01	-0.11***	0.01	-0.13***	0.01	-0.07***	0.01	-0.18***	0.01
Corporate farm (1/0)	-0.27	3.07	0.54	4.18	5.99	7.10	0.49	3.07	-8.57	5.32	-14.50*	7.67
Age of manager	-0.65***	0.22	-1.61***	0.25	-0.36	0.40	0.21	0.26	-1.05***	0.23	-0.29	0.36
Age square	<0.01	<0.01	>-0.01***	<0.01	>-0.01	<0.01	>-0.01	<0.01	0.01***	<0.01	<0.01	0.00
R^2	0.081		0.067		0.070		0.113		0.086		0.077	
No. of observations	13592		7168		7821		13592		7168		7821	

*** (**, *) significant at the 1% (5%, 10%) level, based on heteroscedasticity robust standard errors

Notes: Year dummies and constant are included but results not shown. Outliers in dependent variable eliminated prior to estimation.

Germany (East)

Figure A5. Shadow prices of fixed capital

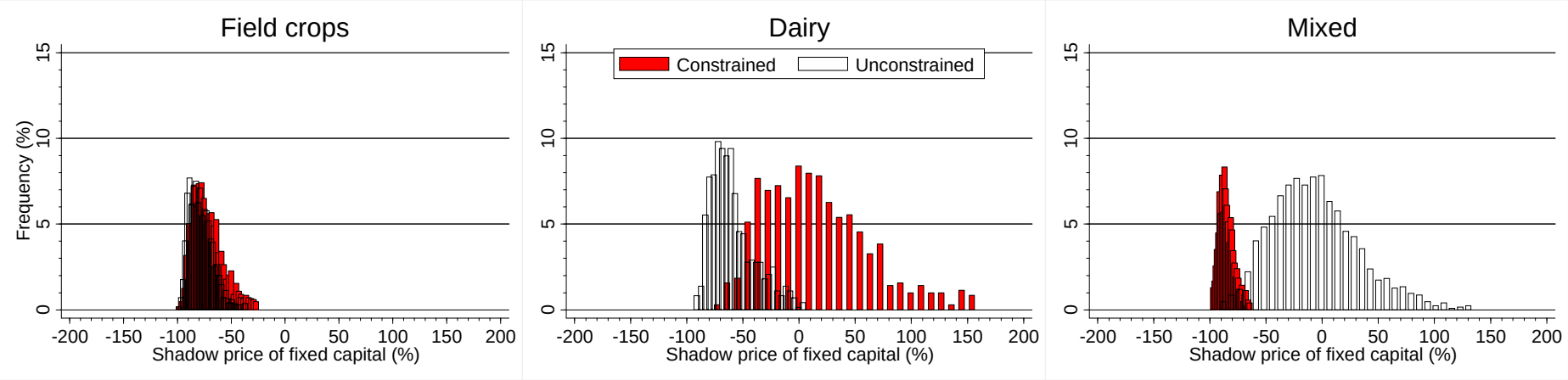

Figure A6. Shadow prices of working capital

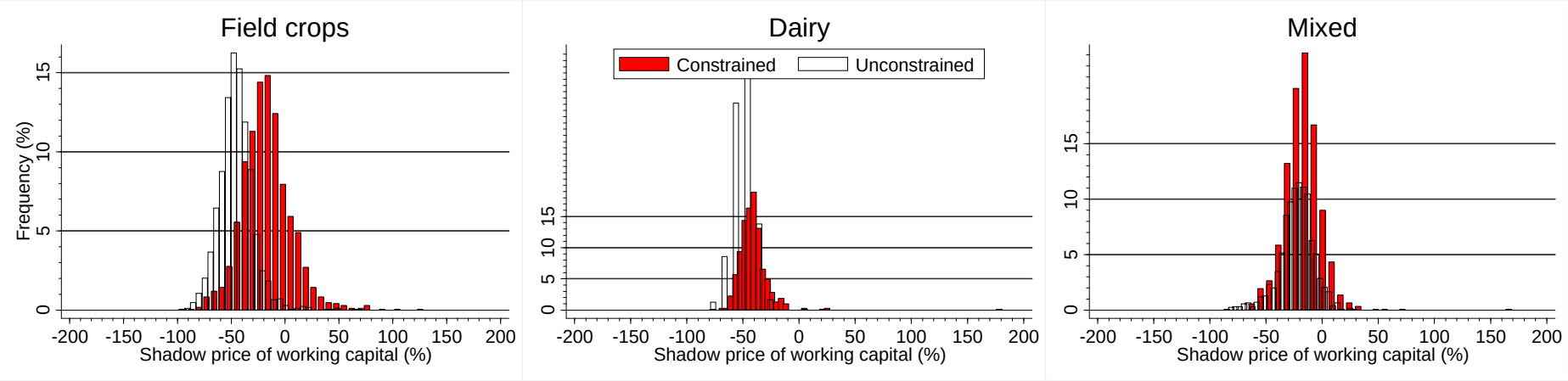

Table A7. Germany (East): Descriptive statistics and mean comparison of shadow prices

	Field crops				***Dairy***				***Mixed***			
	Low debt		*High debt*		*Low debt*		*High debt*		*Low debt*		*High debt*	
	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean
Output (ths €)	1692	851.00	1673	552.20	723	880.03	703	487.29	1264	1658.68	1247	841.78
Labour (ths hours)	1692	24.13	1673	15.49	723	29.68	703	12.22	1264	50.26	1247	24.45
Land (ha)	1692	713.71	1673	574.64	723	428.98	703	259.66	1264	1052.61	1247	616.57
Working capital (ths €)	1692	596.33	1673	413.83	723	604.69	703	340.58	1264	1178.69	1247	627.13
Fixed capital (ths €)	1692	130.18	1673	86.35	723	120.94	703	68.21	1264	238.96	1247	119.79
Cows (LU)	--	--	--	--	723	236.53	703	159.77	1264	268.30	1247	153.79
Debt-to-asset ratio	1692	0.19	1673	0.67	723	0.24	703	0.73	1264	0.19	1247	0.61
Owned land (ha)	1692	90.23	1673	76.35	723	51.65	703	42.13	1264	126.98	1247	67.86
Corporate farm (1/0)	1692	0.29	1673	0.16	723	0.28	703	0.07	1264	0.60	1247	0.28
Age of manager (years)	1079	53.37	1320	57.31	510	54.87	610	55.77	458	53.79	834	55.27
Shadow price of fixed capital (%)	1692	-77.79	1673	-71.33	723	-59.04	703	15.05	1264	-6.34	1247	-85.03
p(high debt>low debt)		<0.001				<0.001				1.000		
p(high debt<low debt)		1.000				1.000				<0.001		
Shadow price of working capital (%)	1692	-45.09	1673	-17.29	723	-49.26	703	-41.42	1264	-22.92	1247	-17.45
p(high debt>low debt)		<0.001				<0.001				<0.001		
p(high debt<low debt)		>0.999				>0.999				>0.999		

Notes: LU=livestock units. P-values based on two-sample t-test for paired data.

Table A8. Germany (East): Production elasticities based on production function estimates (Cobb Douglas fixed effects)

	Field crops		***Dairy***		***Mixed***	
	Low debt	*High debt*	*Low debt*	*High debt*	*Low debt*	*High debt*
Labour	0.17#	0.12	0.04#	0.04#	0.08#	0.01#
Land	0.41	0.23	0.17	-0.06	0.10#	0.19
Working capital	0.41	0.64	0.35	0.41	0.58	0.62
Fixed capital	0.04#	0.05#	0.07#	0.17	0.15	0.02#
Cows	--	--	0.47	0.34	<0.01#	0.01
No. of observations	1692	1673	723	703	1264	1247
No. of farms	402	382	185	183	335	343

Notes: All estimates based on group-demeaned variables (fixed effects regression). Year dummies are included but results not shown. All coefficients are significant at least at the 5% level except when marked with #, based on standard errors robust to clustering in groups.

Table A9. Determinants of shadow prices (pooled OLS)

	Fixed capital						**Working capital**					
	Field crops		*Dairy*		*Mixed*		*Field crops*		*Dairy*		*Mixed*	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Debt-to-asset ratio	10.92***	0.70	107.97***	3.88	-56.05***	2.78	22.58***	1.92	6.37***	1.33	10.33***	1.53
Owned land (ha)	0.03***	<0.01	0.06*	0.04	-0.01	0.02	0.05***	0.01	0.03***	0.01	0.03**	0.01
Corporate farm (1/0)	-10.35***	1.23	1.69	2.98	34.65**	17.24	-6.60***	2.00	-0.78	3.03	-11.48***	3.41
Age of manager	-0.55**	0.23	-0.02	1.01	-0.56	0.74	0.19	0.42	0.93***	0.34	-0.74	0.51
Age square	0.01**	<0.01	>-0.01	0.01	<0.01	0.01	<0.01	<0.01	-0.01**	<0.01	0.01	<0.01
R^2	0.191		0.444		0.310		0.199		0.068		0.071	
No. of observations	2399		1120		1292		2399		1120		1292	

*** (**, *) significant at the 1% (5%, 10%) level, based on heteroscedasticity robust standard errors

Notes: Year dummies and constant are included but results not shown. Outliers in dependent variable eliminated prior to estimation.

Germany (West)

Figure A7. Shadow prices of fixed capital

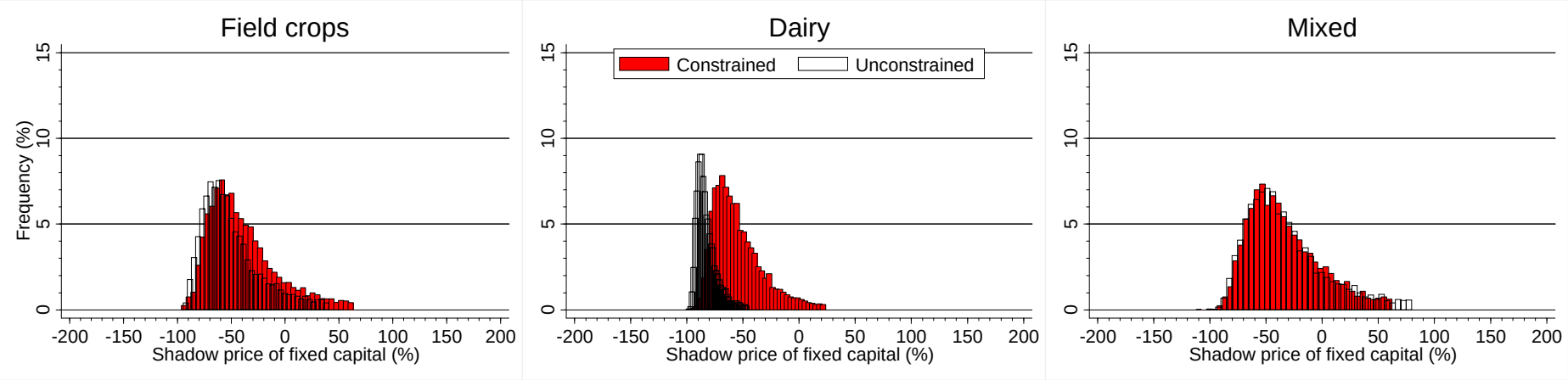

Figure A8. Shadow prices of working capital

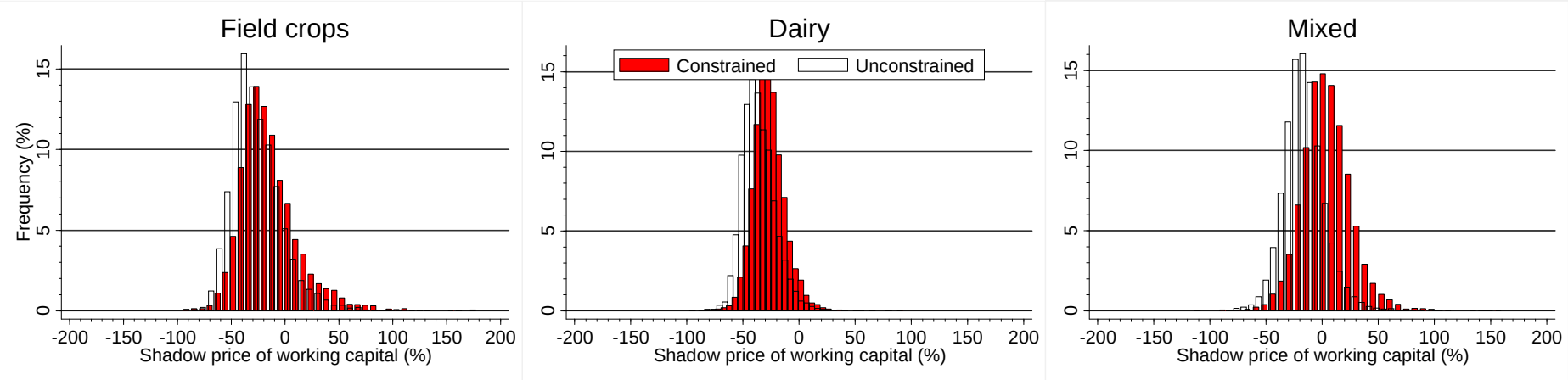

Table A10. Germany (West): Descriptive statistics and mean comparison of shadow prices

	Field crops				***Dairy***				***Mixed***			
	Low debt		*High debt*		*Low debt*		*High debt*		*Low debt*		*High debt*	
	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean
Output (ths €)	3968	118.69	4355	183.26	5568	100.97	5674	168.13	4917	130.25	5249	195.41
Labour (ths hours)	3968	3.75	4355	4.88	5568	3.47	5674	4.16	4917	3.43	5249	4.11
Land (ha)	3968	75.27	4355	101.43	5568	45.68	5674	73.37	4917	57.13	5249	78.74
Working capital (ths €)	3968	75.15	4355	119.94	5568	62.80	5674	107.98	4917	97.44	5249	149.33
Fixed capital (ths €)	3968	20.42	4355	28.71	5568	18.53	5674	26.48	4917	20.56	5249	28.12
Cows (LU)	3968	0.50	4355	1.34	5568	36.94	5674	60.19	4917	10.56	5249	13.24
Debt-to-asset ratio	3968	0.03	4355	0.32	5568	0.05	5674	0.29	4917	0.04	5249	0.32
Owned land (ha)	3968	34.53	4355	25.13	5568	22.56	5674	22.25	4917	25.86	5249	22.98
Corporate farm (1/0)	3968	0.00	4355	0.00	5568	0.00	5674	0.00	4917	0.00	5249	0.00
Age of manager (years)	3860	54.20	4208	56.56	5514	55.36	5598	58.76	4858	55.44	5172	57.97
Shadow price of fixed capital (%)	3968	-49.76	4355	-39.40	5568	-82.20	5674	-54.42	4917	-32.54	5249	-33.17
p(high debt>low debt)		<0.001				<0.001				0.828		
p(high debt<low debt)		>0.999				>0.999				0.172		
Shadow price of working capital (%)	3968	-26.44	4355	-15.07	5568	-36.04	5674	-26.97	4917	-16.34	5249	3.76
p(high debt>low debt)		<0.001				<0.001				<0.001		
p(high debt<low debt)		>0.999				>0.999				>0.999		

Notes: LU=livestock units. P-values based on two-sample t-test for paired data.

Table A11. Germany (West): Production elasticities based on production function estimates (Cobb Douglas fixed effects)

	Field crops		***Dairy***		***Mixed***	
	Low debt	*High debt*	*Low debt*	*High debt*	*Low debt*	*High debt*
Labour	0.08	0.09	0.04	0.03	0.02#	0.04#
Land	0.25	0.23	0.10	0.05	0.15	0.11
Working capital	0.47	0.56	0.39	0.46	0.63	0.80
Fixed capital	0.07	0.09	0.03	0.06	0.09	0.08
Cows	--	--	0.33	0.26	0.02	0.01
No. of observations	3942	4381	5471	5771	4863	5303
No. of farms	933	1099	1005	1081	1295	1447

Notes: All estimates based on group-demeaned variables (fixed effects regression). Year dummies are included but results not shown. All coefficients are significant at least at the 5% level except when marked with #, based on standard errors robust to clustering in groups.

Table A12. Determinants of shadow prices (pooled OLS)

	Fixed capital						**Working capital**					
	Field crops		*Dairy*		*Mixed*		*Field crops*		*Dairy*		*Mixed*	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Debt-to-asset ratio	16.53***	1.69	57.87***	4.02	11.48***	1.41	2.23*	1.16	9.05***	1.22	18.17***	2.01
Owned land (ha)	< 0.01	0.01	0.13***	0.01	0.05**	0.02	-0.07***	0.01	-0.01*	0.01	0.07***	0.01
Corporate farm (1/0)	--		--		--		--		--		--	
Age of manager	-0.57**	0.28	-0.63***	0.18	-0.66**	0.31	-0.20	0.27	-0.08	0.14	0.64***	0.21
Age square	< 0.01	< 0.01	0.01***	< 0.01	< 0.01**	< 0.01	< 0.01	< 0.01	< 0.01*	< 0.01	< 0.01**	< 0.01
R^2	0.049		0.240		0.027		0.019		0.047		0.080	
No. of observations	8086		11112		10032		8086		11112		10032	

*** (**, *) significant at the 1% (5%, 10%) level, based on heteroscedasticity robust standard errors

Notes: Year dummies and constant are included but results not shown. Outliers in dependent variable eliminated prior to estimation.

Italy

Figure A9. Shadow prices of fixed capital

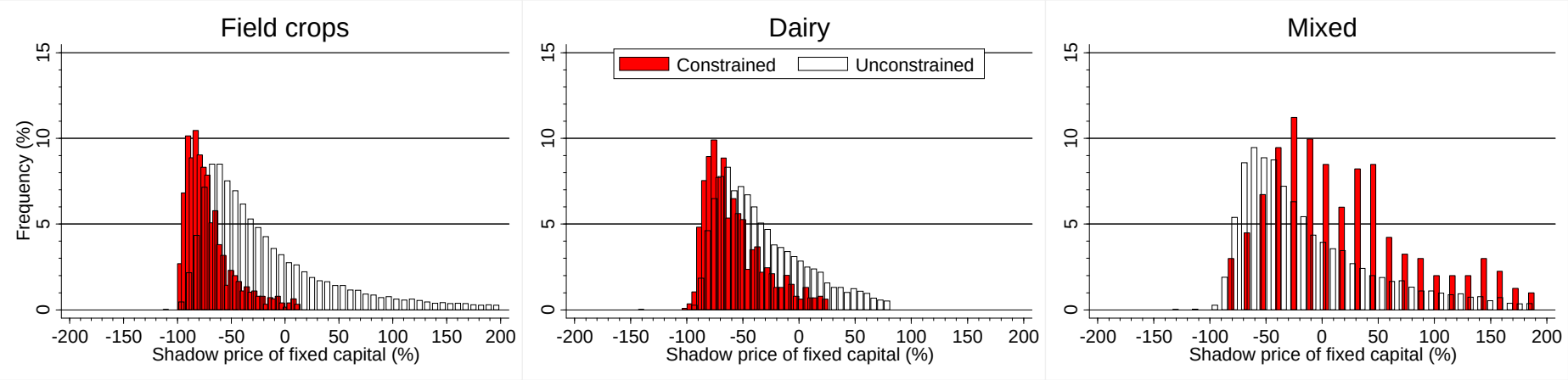

Figure A10. Shadow prices of working capital

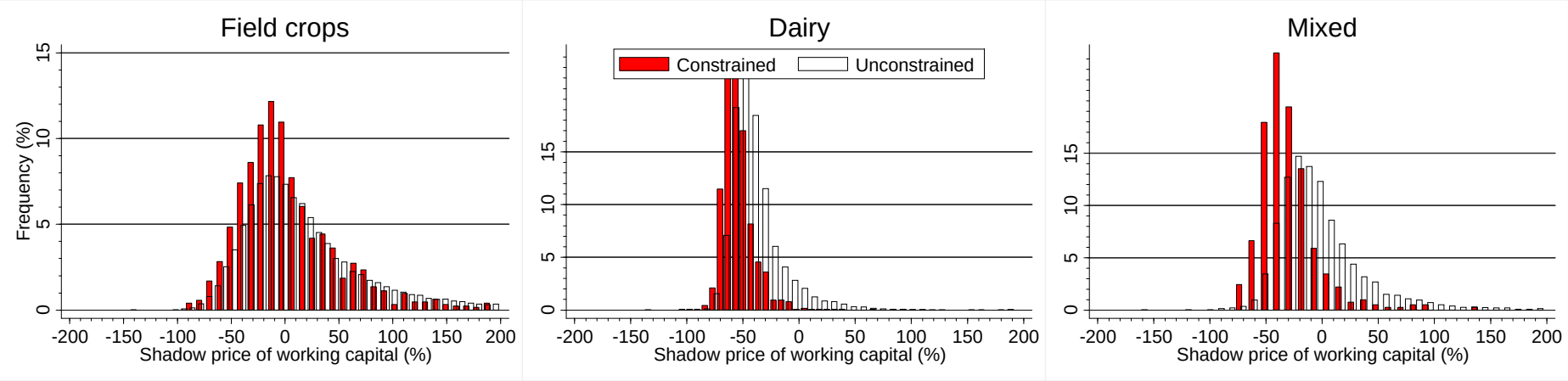

Table A13. Italy: Descriptive statistics and mean comparison of shadow prices

	Field crops				***Dairy***				***Mixed***			
	Low debt		*High debt*		*Low debt*		*High debt*		*Low debt*		*High debt*	
	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean
Output (ths €)	29135	55.93	1261	125.06	6700	152.42	1139	216.41	6176	83.91	411	168.39
Labour (ths hours)	29135	3.52	1261	5.97	6700	5.28	1139	6.56	6176	4.21	411	6.81
Land (ha)	29135	38.93	1261	65.21	6700	37.50	1139	50.05	6176	38.98	411	75.46
Working capital (ths €)	29135	26.91	1261	60.04	6700	84.29	1139	128.06	6176	44.94	411	92.62
Fixed capital (ths €)	29135	10.10	1261	22.18	6700	17.79	1139	27.20	6176	11.73	411	22.11
Cows (LU)	--	--	--	--	6700	47.38	1139	63.55	6176	9.09	411	18.70
Debt-to-asset ratio	29135	0.00	1261	0.18	6700	0.00	1139	0.14	6176	0.00	411	0.14
Owned land (ha)	29135	24.63	1261	33.18	6700	13.43	1139	14.42	6176	21.80	411	24.41
Corporate farm (1/0)	29135	0.07	1261	0.10	6700	0.05	1139	0.07	6176	0.05	411	0.06
Age of manager (years)	28822	50.85	1245	58.56	6674	54.63	1132	58.28	6128	53.70	409	58.76
Shadow price of fixed capital (%)	29135	-17.95	1261	-70.75	6700	-33.65	1139	-57.13	6176	-12.58	411	22.83
p(high debt>low debt)		>0.999				>0.999				<0.001		
p(high debt<low debt)		<0.001				<0.001				>0.999		
Shadow price of working capital (%)	29135	24.87	1261	6.57	6700	-37.49	1139	-54.61	6176	0.09	411	-28.32
p(high debt>low debt)		>0.999				>0.999				>0.999		
p(high debt<low debt)		<0.001				<0.001				<0.001		

Notes: LU=livestock units. P-values based on two-sample t-test for paired data.

Table A14. Italy: Production elasticities based on production function estimates (Cobb Douglas fixed effects)

	Field crops		***Dairy***		***Mixed***	
	Low debt	*High debt*	*Low debt*	*High debt*	*Low debt*	*High debt*
Labour	0.12	0.17	0.05	0.05#	0.08	-0.01#
Land	0.23	0.19	0.06	0.07#	0.19	0.41
Working capital	0.50	0.46	0.30	0.25	0.46	0.34
Fixed capital	0.14	0.05#	0.08	0.05	0.12	0.17
Cows	--	--	0.30	0.49	0.02	-0.03#
No. of observations	29135	1261	6700	1139	6176	411
No. of farms	10157	436	2682	425	2981	181

Notes: All estimates based on group-demeaned variables (fixed effects regression). Year dummies are included but results not shown. All coefficients are significant at least at the 5% level except when marked with #, based on standard errors robust to clustering in groups.

Table A15. Determinants of shadow prices (pooled OLS)

	Fixed capital						Working capital					
	Field crops		*Dairy*		*Mixed*		*Field crops*		*Dairy*		*Mixed*	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Debt-to-asset ratio	-80.07***	20.97	-81.24***	5.77	139.51***	19.34	-27.25***	7.86	-62.93***	4.30	-93.86***	10.59
Owned land (ha)	0.03***	0.01	0.16***	0.02	0.09***	0.02	-0.08***	0.01	-0.03***	0.01	-0.06***	0.01
Corporate farm (1/0)	27.40***	1.71	14.57***	2.10	32.58***	4.37	8.82***	2.36	2.21	1.40	12.37***	3.58
Age of manager	0.30***	0.03	-0.11	0.21	-0.59	0.37	0.08**	0.04	-0.43***	0.16	0.18	0.25
Age square	>-0.01***	<0.01	<0.01	<0.01	0.01**	<0.01	>-0.01***	<0.01	<0.01***	<0.01	>-0.01	<0.01
R^2	0.038		0.063		0.051		0.018		0.071		0.039	
No. of observations	30068		7808		6540		30068		7808		6540	

*** (**, *) significant at the 1% (5%, 10%) level, based on heteroscedasticity robust standard errors

Notes: Year dummies and constant are included but results not shown. Outliers in dependent variable eliminated prior to estimation.

Poland

Figure A11. Shadow prices of fixed capital

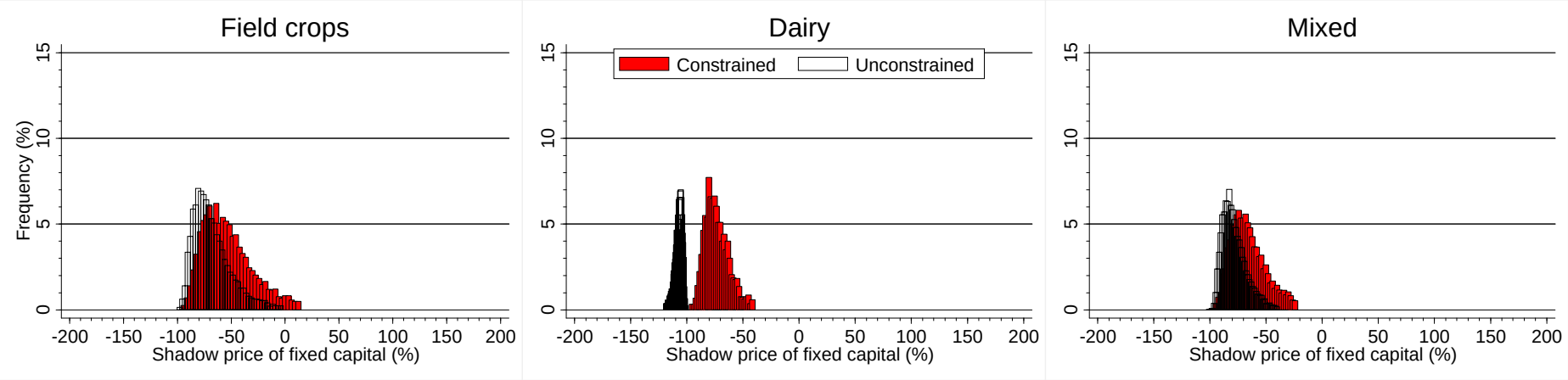

Figure A12. Shadow prices of working capital

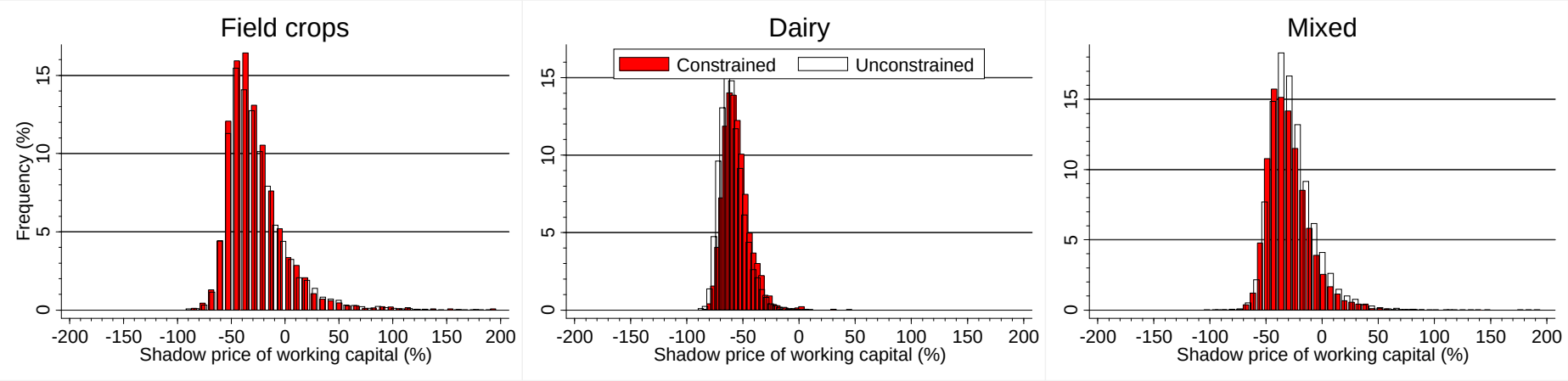

Table A16. Poland: Descriptive statistics and mean comparison of shadow prices

	Field crops				***Dairy***				***Mixed***			
	Low debt		*High debt*		*Low debt*		*High debt*		*Low debt*		*High debt*	
	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean
Output (ths €)	8802	28.28	4287	84.80	3929	27.42	2198	50.80	15042	20.97	6606	54.92
Labour (ths hours)	8802	4.41	4287	6.34	3929	4.15	2198	4.72	15042	3.86	6606	5.03
Land (ha)	8802	34.06	4287	113.39	3929	21.50	2198	36.06	15042	20.23	6606	49.46
Working capital (ths €)	8802	16.83	4287	56.68	3929	14.96	2198	27.93	15042	13.85	6606	37.43
Fixed capital (ths €)	8802	5.12	4287	12.29	3929	4.18	2198	7.05	15042	3.49	6606	7.26
Cows (LU)	8802	0.96	4287	1.67	3929	16.52	2198	27.58	15042	4.12	6606	7.99
Debt-to-asset ratio	8802	0.03	4287	0.27	3929	0.03	2198	0.21	15042	0.02	6606	0.17
Owned land (ha)	8802	22.04	4287	53.64	3929	16.32	2198	23.84	15042	15.34	6606	30.63
Corporate farm (1/0)	8802	0.00	4287	0.04	3929	0.00	2198	0.00	15042	0.00	6606	0.01
Age of manager (years)	8721	62.30	4119	65.92	3909	63.26	2185	66.53	14937	62.39	6531	65.87
Shadow price of fixed capital (%)	8802	-67.77	4287	-53.24	3929	-107.47	2198	-73.00	15042	-78.03	6606	-65.61
p(high debt>low debt)		<0.001				<0.001				<0.001		
p(high debt<low debt)		1.000				>0.999				>0.999		
Shadow price of working capital (%)	8802	-26.19	4287	-27.12	3929	-59.45	2198	-55.75	15042	-26.86	6606	-29.55
p(high debt>low debt)		0.942				<0.001				>0.999		
p(high debt<low debt)		0.057				>0.999				<0.001		

Notes: LU=livestock units. P-values based on two-sample t-test for paired data.

Table A17. Poland: Production elasticities based on production function estimates (Cobb Douglas fixed effects)

	Field crops		***Dairy***		***Mixed***	
	Low debt	*High debt*	*Low debt*	*High debt*	*Low debt*	*High debt*
Labour	0.17	0.11	0.01#	0.05#	0.08	0.07
Land	0.28	0.35	0.13	0.13	0.26	0.26
Working capital	0.41	0.41	0.22	0.23	0.47	0.44
Fixed capital	0.06	0.06	-0.01#	0.03#	0.03	0.04
Cows	--	--	0.45	0.52	0.01	0.01
No. of observations	8802	4287	3929	2198	15042	6606
No. of farms	3129	1357	1478	840	4976	2218

Notes: All estimates based on group-demeaned variables (fixed effects regression). Year dummies are included but results not shown. All coefficients are significant at least at the 5% level except when marked with #, based on standard errors robust to clustering in groups.

Table A18. Determinants of shadow prices (pooled OLS)

	Fixed capital						**Working capital**					
	Field crops		*Dairy*		*Mixed*		*Field crops*		*Dairy*		*Mixed*	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Debt-to-asset ratio	30.64***	1.73	97.24***	2.23	40.35***	1.27	-4.49**	1.85	11.93***	1.42	-5.87***	1.45
Owned land (ha)	0.07***	0.01	0.12***	0.01	0.11***	0.01	-0.05***	0.01	0.01	0.01	-0.02**	0.01
Corporate farm (1/0)	-48.34***	4.28	--	--	-71.30***	2.46	-6.35	14.29	--	--	0.53	2.16
Age of manager	0.82***	0.22	0.12	0.18	0.31***	0.10	1.20***	0.36	0.75***	0.17	0.34	0.26
Age square	-0.01***	<0.01	0.00	0.00	>-0.01***	<0.01	-0.01***	<0.01	-0.01***	<0.01	>-0.01	<0.01
R^2	0.113		0.473		0.161		0.017		0.061		0.066	
No. of observations	12840		6094		21470		12840		6094		21470	

*** (**, *) significant at the 1% (5%, 10%) level, based on heteroscedasticity robust standard errors.

Notes: Year dummies and constant are included but results not shown. Outliers in dependent variable eliminated prior to estimation.

Slovakia

Figure A13. Shadow prices of fixed capital

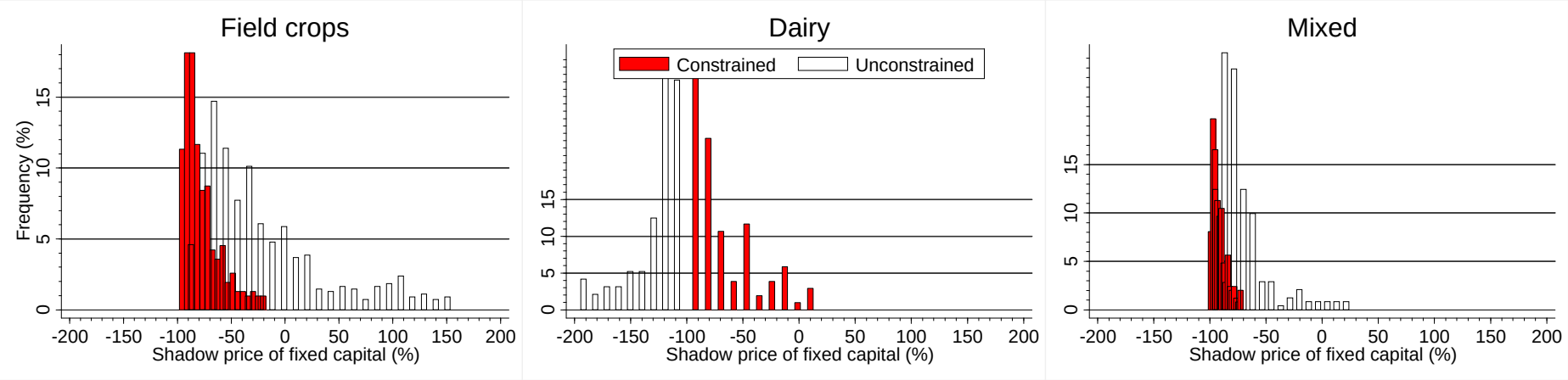

Figure A14. Shadow prices of working capital

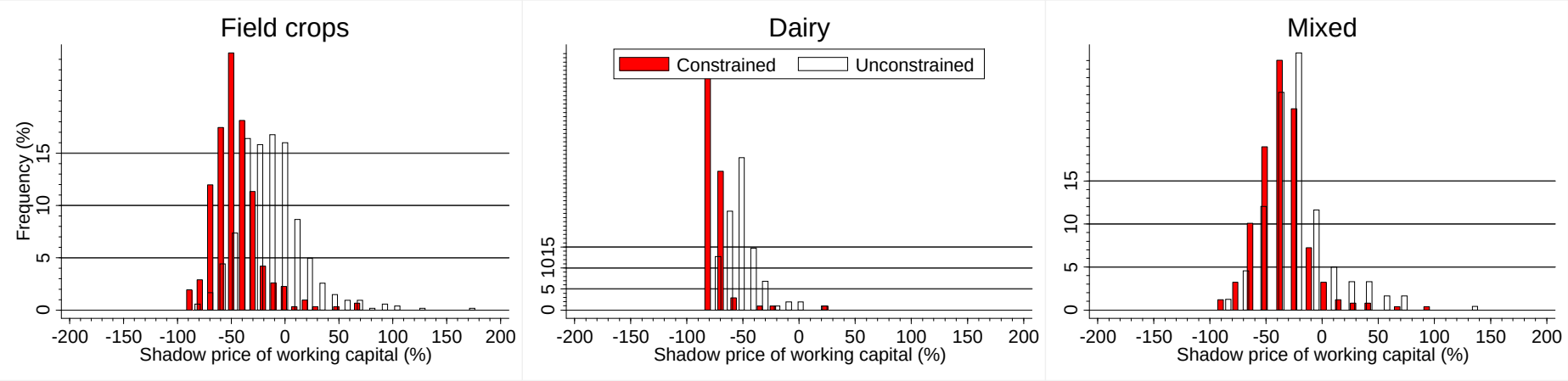

Table A19. Slovakia: Descriptive statistics and mean comparison of shadow prices

	Field crops				***Dairy***				***Mixed***			
	Low debt		*High debt*		*Low debt*		*High debt*		*Low debt*		*High debt*	
	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean
Output (ths €)	544	693.41	309	476.81	102	878.04	100	779.23	241	1443.35	248	1225.84
Labour (ths hours)	544	50.39	309	29.18	102	100.16	100	76.75	241	128.16	248	103.34
Land (ha)	544	808.62	309	695.42	102	1386.26	100	1192.32	241	1578.63	248	1533.82
Working capital (ths €)	544	493.03	309	365.34	102	684.23	100	581.84	241	1057.92	248	953.91
Fixed capital (ths €)	544	151.01	309	85.21	102	399.37	100	273.89	241	385.61	248	316.82
Cows (LU)					102	294.77	100	248.26	241	258.46	248	227.30
Debt-to-asset ratio	544	0.04	309	0.27	102	0.04	100	0.19	241	0.02	248	0.15
Owned land (ha)	544	33.00	309	32.93	102	17.43	100	17.33	241	29.96	248	64.40
Corporate farm (1/0)	544	0.47	309	0.23	102	0.95	100	0.84	241	0.88	248	0.88
Age of manager (years)	289	55.13	238	58.24	6	57.50	16	57.25	28	55.11	31	55.61
Shadow price of fixed capital (%)	544	-21.97	309	-77.49	102	-132.72	100	-69.94	241	-73.07	248	-91.64
p(high debt>low debt)		>0.999				<0.001				>0.999		
p(high debt<low debt)		<0.001				>0.999				<0.001		
Shadow price of working capital (%)	544	-11.99	309	-45.85	102	-50.05	100	-75.40	241	-21.32	248	-36.14
p(high debt>low debt)		>0.999				>0.999				>0.999		
p(high debt<low debt)		<0.001				<0.001				<0.001		

Notes: LU=livestock units. P-values based on two-sample t-test for paired data.

Table A20. Slovakia: Production elasticities based on production function estimates (Cobb Douglas fixed effects)

	Field crops		***Dairy***		***Mixed***	
	Low debt	*High debt*	*Low debt*	*High debt*	*Low debt*	*High debt*
Labour	0.08#	0.19	0.16#	-0.14#	0.21#	0.16#
Land	0.08#	0.35	0.16#	-0.53#	-0.12#	0.20#
Working capital	0.66	0.41	0.38	0.20#	0.60	0.51
Fixed capital	0.10	0.03#	-0.08#	0.05#	0.05#	0.01#
Cows	--	--	-0.20#	0.89	<0.01#	-0.01#
No. of observations	544	309	102	100	241	248
No. of farms	194	98	41	39	103	104

Notes: All estimates based on group-demeaned variables (fixed effects regression). Year dummies are included but results not shown. All coefficients are significant at least at the 5% level except when marked with #, based on standard errors robust to clustering in groups.

Table A21. Determinants of shadow prices (pooled OLS)

	Fixed capital						**Working capital**					
	Field crops		*Dairy*		*Mixed*		*Field crops*		*Dairy*		*Mixed*	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Debt-to-asset ratio	-102.65***	10.11	117.76***	14.74	-40.51***	6.23	-60.32***	5.14	-34.74***	6.78	-28.63***	10.12
Owned land (ha)	-0.01	0.01	0.04	0.03	>-0.01***	0.00	0.01**	0.01	0.02	0.03	0.01	0.01
Corporate farm (1/0)	-9.53***	3.52	-8.05	12.58	-14.48***	4.08	5.39**	2.12	4.61	4.77	13.94***	3.55
Age of manager	--	--	--	--	--	--	--	--	--	--	--	--
Age square	--	--	--	--	--	--	--	--	--	--	--	--
R^2	0.129		0.241		0.153		0.167		0.142		0.118	
No. of observations	853		202		489		853		202		489	

*** (**, *) significant at the 1% (5%, 10%) level, based on heteroscedasticity robust standard errors

Notes: Year dummies and constant are included but results not shown. Outliers in dependent variable eliminated prior to estimation.

United Kingdom

Figure A15. Shadow prices of fixed capital

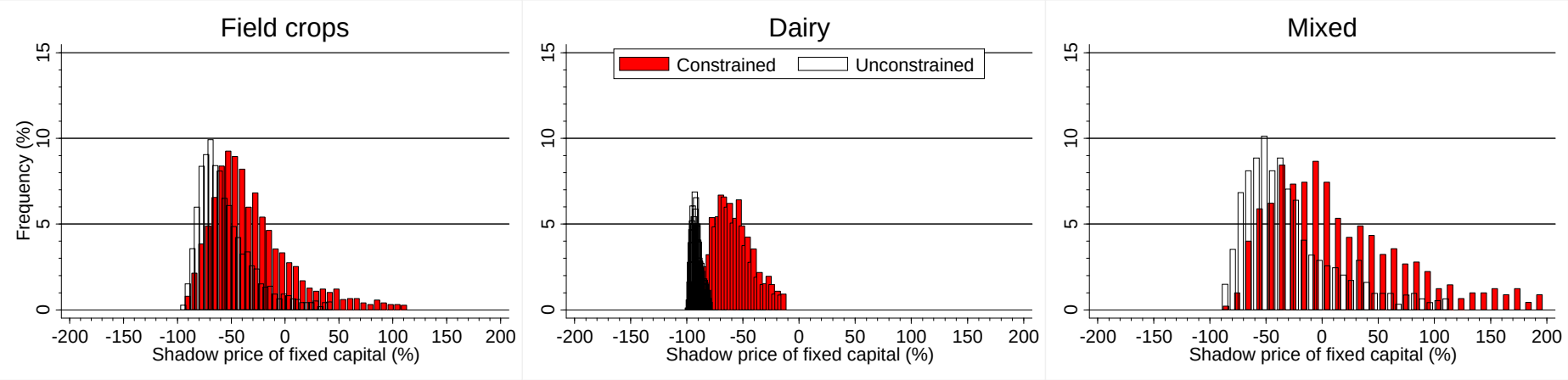

Figure A16. Shadow prices of working capital

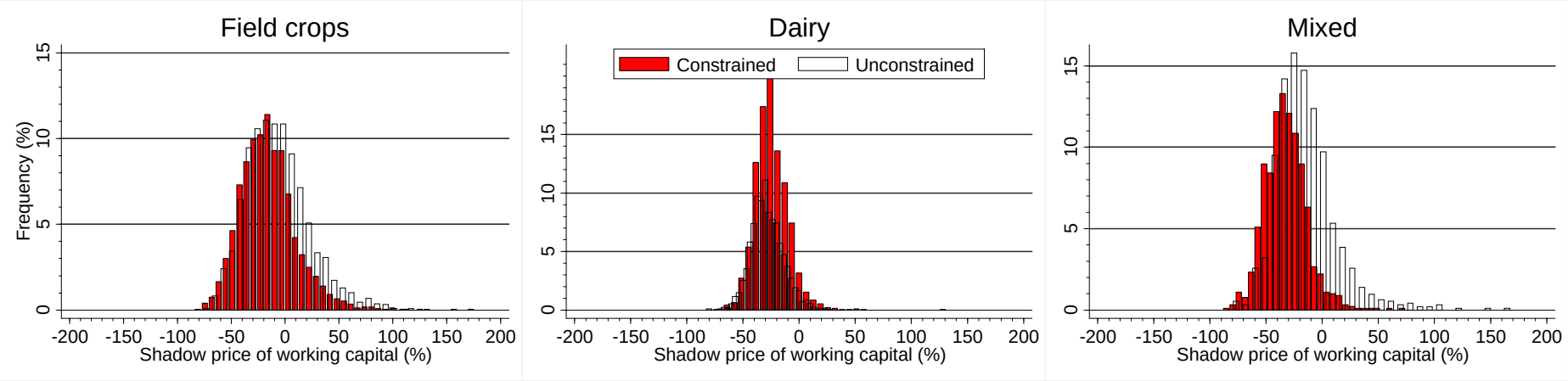

Table A22. United Kingdom: Descriptive statistics and mean comparison of shadow prices

	Field crops				***Dairy***				***Mixed***			
	Low debt		*High debt*		*Low debt*		*High debt*		*Low debt*		*High debt*	
	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean
Output (ths €)	2185	219.86	2289	297.22	2096	202.15	1838	301.93	937	170.26	902	246.81
Labour (ths hours)	2185	5.38	2289	7.05	2096	5.69	1838	6.72	937	5.55	902	6.43
Land (ha)	2185	206.75	2289	251.20	2096	87.45	1838	114.96	937	154.65	902	200.70
Working capital (ths €)	2185	147.80	2289	208.18	2096	130.10	1838	206.70	937	129.41	902	199.83
Fixed capital (ths €)	2185	36.98	2289	48.05	2096	24.81	1838	32.52	937	26.39	902	33.01
Cows (LU)	2185	0.81	2289	0.90	2096	88.93	1838	129.12	937	13.17	902	28.37
Debt-to-asset ratio	2185	0.03	2288	0.26	2096	0.03	1838	0.28	937	0.03	902	0.26
Owned land (ha)	2185	159.37	2289	117.28	2096	63.94	1838	67.46	937	97.75	902	97.16
Corporate farm (1/0)	2185	0.08	2289	0.09	2096	0.01	1838	0.02	937	0.04	902	0.04
Age of manager (years)	2185	242.79	2289	227.97	2096	167.99	1838	213.24	937	154.77	902	209.39
Shadow price of fixed capital (%)	2185	-54.84	2289	-30.63	2096	-91.10	1838	-57.88	937	-28.24	902	14.97
p(high debt>low debt)		<0.001				<0.001				<0.001		
p(high debt<low debt)		>0.999				>0.999				>0.999		
Shadow price of working capital (%)	2185	-6.66	2289	-15.73	2096	-28.33	1838	-24.56	937	-14.38	902	-32.45
p(high debt>low debt)		>0.999				<0.001				>0.999		
p(high debt<low debt)		<0.001				>0.999				<0.001		

Notes: LU=livestock units. P-values based on two-sample t-test for paired data.

Table A23. United Kingdom: Production elasticities based on production function estimates (Cobb Douglas fixed effects)

	Field crops		***Dairy***		***Mixed***	
	Low debt	*High debt*	*Low debt*	*High debt*	*Low debt*	*High debt*
Labour	0.09	0.18	0.09	0.11	0.24	0.10#
Land	0.27	0.18	0.06#	0.07	0.02#	0.33
Working capital	0.67	0.61	0.47	0.51	0.67	0.57
Fixed capital	0.07	0.10	0.01#	0.04	0.10	0.14
Cows	--	--	0.48	0.39	0.03#	0.01#
No. of observations	2185	2289	2096	1838	937	902
No. of farms	559	615	482	466	305	309

Notes: All estimates based on group-demeaned variables (fixed effects regression). Year dummies are included but results not shown. All coefficients are significant at least at the 5% level except when marked with #, based on standard errors robust to clustering in groups.

Table A24. Determinants of shadow prices (pooled OLS)

	Fixed capital						**Working capital**					
	Field crops		*Dairy*		*Mixed*		*Field crops*		*Dairy*		*Mixed*	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Debt-to-asset ratio	44.62***	2.98	66.76***	2.61	91.66***	11.56	-14.86***	1.77	0.29	1.40	-33.55***	3.13
Owned land (ha)	-0.02***	<0.01	<0.01	0.01	-0.05***	0.01	0.01***	0.00	0.01*	<0.01	>-0.01	<0.01
Corporate farm (1/0)	9.74***	1.99	0.23	2.21	16.65**	7.06	1.43	1.59	2.30	1.47	4.69	2.90
Age of manager	-0.11*	0.05	0.11***	0.02	0.23*	0.12	0.22***	0.04	0.07***	0.02	0.05	0.06
Age square	<0.01**	0.00	>-0.01***	<0.01	>-0.01*	<0.01	>-0.01***	<0.01	>-0.01***	<0.01	>-0.01	<0.01
R^2	0.119		0.371		0.118		0.136		0.024		0.078	
No. of observations	4473		3934		1839		4473		3934		1839	

*** (**, *) significant at the 1% (5%, 10%) level, based on heteroscedasticity robust standard errors

Notes: Year dummies and constant are included but results not shown. Outliers in dependent variable eliminated prior to estimation.

Comparative Analysis of Factor Markets for Agriculture across the Member States

245123-FP7-KBBE-2009-3

The Factor Markets project in a nutshell

Title	Comparative Analysis of Factor Markets for Agriculture across the Member States
Funding scheme	Collaborative Project (CP) / Small or medium scale focused research project
Coordinator	CEPS, Prof. Johan F.M. Swinnen
Duration	01/09/2010 – 31/08/2013 (36 months)
Short description	Well functioning factor markets are a crucial condition for the competitiveness and growth of agriculture and for rural development. At the same time, the functioning of the factor markets themselves are influenced by changes in agriculture and the rural economy, and in EU policies. Member state regulations and institutions affecting land, labour, and capital markets may cause important heterogeneity in the factor markets, which may have important effects on the functioning of the factor markets and on the interactions between factor markets and EU policies. The general objective of the FACTOR MARKETS project is to analyse the functioning of factor markets for agriculture in the EU-27, including the Candidate Countries. The FACTOR MARKETS project will compare the different markets, their institutional framework and their impact on agricultural development and structural change, as well as their impact on rural economies, for the Member States, Candidate Countries and the EU as a whole. The FACTOR MARKETS project will focus on capital, labour and land markets. The results of this study will contribute to a better understanding of the fundamental economic factors affecting EU agriculture, thus allowing better targeting of policies to improve the competitiveness of the sector.
Contact e-mail	info@factormarkets.eu
Website	www.factormarkets.eu
Partners	17 (13 countries)
EU funding	1,979,023 €
EC Scientific officer	Dr. Hans-Jörg Lutzeyer