OECD-FLA Network Project ‚Drivers of Farm Performance‘

Project Part II - Outline 06/20

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intro

- OECD FLA network project phase II
- project aims

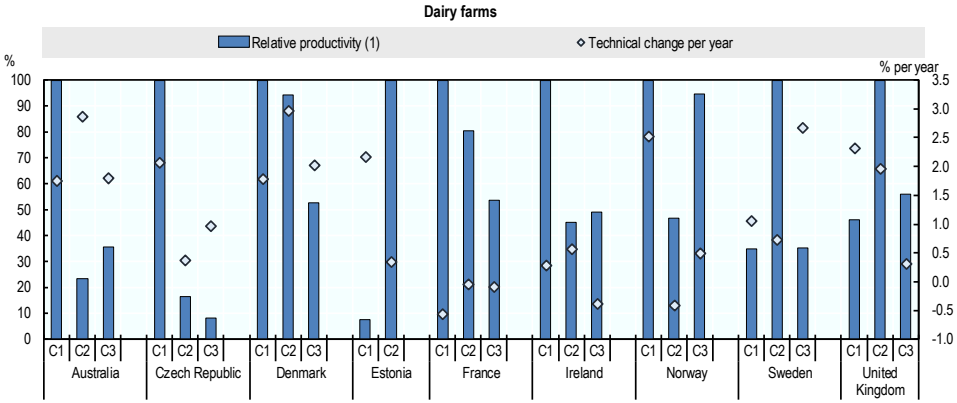
  (i) the identification, description and evaluation of essential *characteristics of farms* and their respective *technologies in each class* (stage 1)

  (ii) the systematic analysis of farms' *class membership over time*, its dynamics and potential significant *class switching patterns* (stage 2)

  (iii) the evaluation of significant *drivers for class membership patterns* with a strong focus on the *potential effect of policy measures* (stage 3)

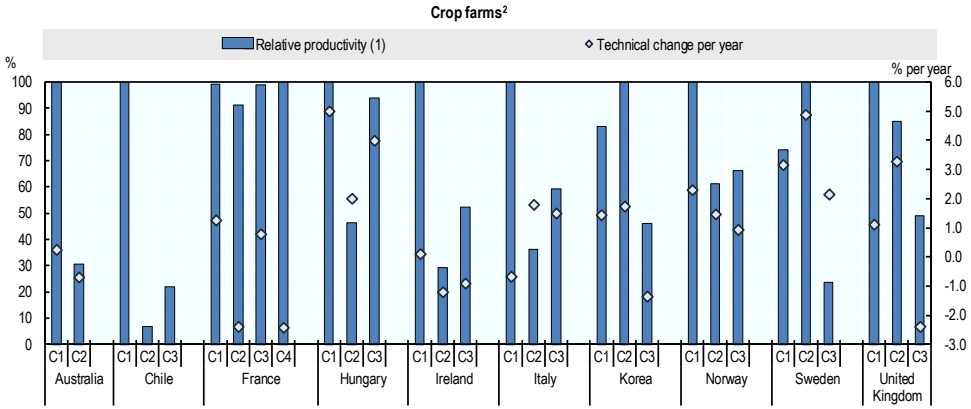
  (iv) the identification of *effective and efficient policy measures* to increase the probability of farms' switching to more productive, sustainable and innovative technologies (stage 3)

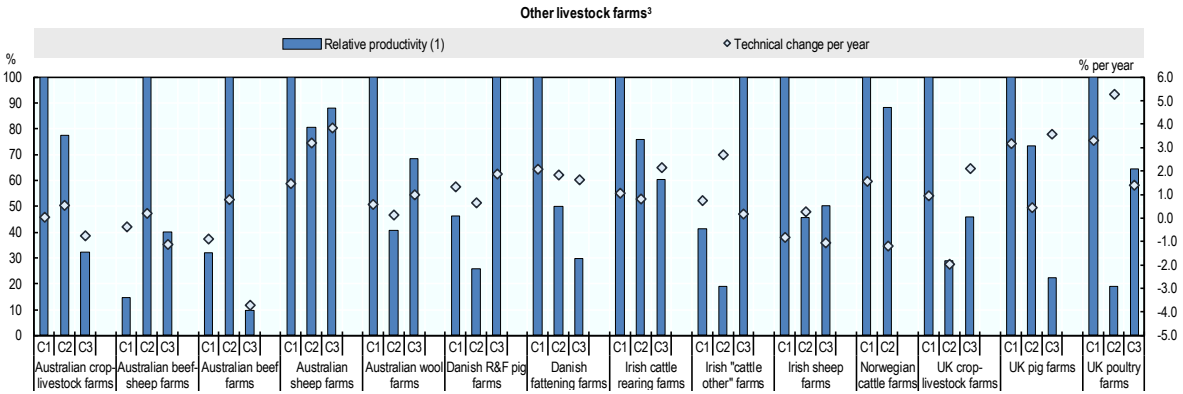
- proposed analyses will be exemplary applied on representative country cases and policies/schemes



Project Phase I

Relative productivity and technical change across case studies, by farm type, country and technology classes





stage 1 - class characteristics

- to identify high and low performing farms to efficiently design and effectively target sectoral policies with respect to economic performance, environmental sustainability and innovativeness

- we summarise core production technology and other characteristics as well as performance indices' scores per class at the beginning, the mid point and the end of the respective period considered (i.e. at t=1, t=n/2, and t=n)

- by means of descriptive statistics (mean, minimum, maximum, standard deviation, quantiles' values per class etc.)
- by means of a multinomial logit for a cross-sectional setting (model 1)

stage 2 - class dynamics

- dynamics in farms' class membership over the time period considered
- initiating and supporting farms' switch to a more productive class is a primary policy goal, potential trade-offs and/or synergies between economic and environmental performances are to be considered
- what type of farms are actually switching to more productive and/or more sustainable and/or more innovative classes?
- what type of farms are actually maintaining these higher performance levels over time given sector and country specifics as well as potential external shocks?
- 3 analytical steps …

stage 2

step I

- we statistically summarize the characteristics of farms that switch to a different class during the respective time period considered on a yearly basis (i.e. from one year t to the next year t+1)
- we build groups for "*positive switchers*" (i.e. farms that switch to a more productive class from one year t to the next year t+1), for *"negative switchers"* (i.e. farms that switch to a less productive class), and for "*non-switchers*" (i.e. farms that stay in the same class)

step II

- we identify and statistically summarize the characteristics of farms that *switch to a more productive class and manage to remain in this* class for a certain time or even improve further
- we analyse the sub-sample of switching farms that are *part of the sample for at least three years in a row* during the respective time period considered

step III

- estimation of the *propensity to switch* to a more productive class in the respective time period (model 2)
- relative *probability of staying at the higher performance level* (i.e. in the same productive class) or even improving further (i.e. a switch to an even more productive class from year t+1 to year t+2) (model 3)

stage 2

- *"permanent improvers"*

  farms that switch to a more productive class from one year to the next year and remain there also in the subsequent year or improve even further

- *"occasional improvers"*

  farms that switch to a more productive class from one year to the next year but then fall back to a less productive class again

Table 2. Class Switching Scenarios

time point	year t	year t+1	year t+2
group I "permanent improvers"			
class membership	1	2	3
	1	2	2
	1	3	3
	2	3	3
group II "occasional improvers"			
class membership	1	2	1
	1	3	2
	1	3	1
	2	3	2
	2	3	1

Note: class 1= least productive, class 2 = medium productive, and class 3 = most productive.

stages 1 & 2

Table 1. Country and farm coverage - Phase II, stages 1 and 2

	Crop farms	Rice farms	Small-scale fruit farms	Dairy farms	Cattle farms[1]	Pig farms	Poultry farms	Sheep farms	Wool farms	Mixed crop-livestock farms	Mixed beef-sheep farms
Australia	X			X	X			X	X	X	X
Chile			X								
Czech Republic				X							
Denmark				X		X[2]					
Estonia				X							
France	X			X							
Hungary	X										
Ireland	X			X	X[3]			X			
Italy	X										
Korea		X									
Norway	X			X	X						
Sweden	X			X							
United Kingdom	X[4]			X		X	X			X	
Number of cases	8	1	1	9	4	3	1	2	1	2	1

33 farm case studies in total, 14 selected phase II, stages 1 & 2
Note: 1. Also called beef farms. 2. Pig fattening farms and pig rearing and fattening farms. 3. Cattle rearing farms and cattle finishing farms. 4. Cereal farms.
Crosses indicate the farm case studies (farm types and countries) included in the report phase I. Light green indicates the farm cases proposed to be studies in phase II.

stage 3 - policy effects I EU

- The design of a modern agricultural policy framework is a complex task and requires the integration of existing knowledge and empirical evidence of the effects of previous policy programmes.
- The multilateral policy framework of the CAP gives empirical researchers the opportunity to study the effects of different agricultural policy measures at farm-level by making use of econometric methods for causal inference.
- Many econometric causal inference approaches exist: The difference-in-difference (DID) strategy in combination with matching is well-suited for the European policy case and the farm-level data at hand.

DID matching approach basic idea:

compare treatment and control groups in terms of outcome changes over time relative to the outcomes observed for a pre-intervention baseline

- The matching procedure (e.g. propensity score matching) for the baseline data makes certain that the comparison group is similar to the treatment group before applying double differences to the matched sample (i.e. with-without policy treatment and before-after policy treatment) (model 4)
- Each case study should provide an in-depth assessment of a specific policy and depending on the primary goal of the respective measure, the DID outcome variable(s) might change.
- To capture the effects on different dimensions of farm performance, beside the productivity level and productivity class membership indicator, also the various performance indices' scores are considered at farm level.

stage 3 - policy effects analysis I EU cases

Policy Case 1 - Dairy farming subsidies in Czech Republic

Policy Case 2 - CAP Pillar I implementation differences

Policy Case 3 - Small Farmer Scheme implementation

Policy Case 4 - Regional Development Programmes

Policy Case 1 - Dairy farming subsidies in Czech Republic

- Two crucial subsidies promoting dairy farming in the Czech Republic are studied:
  - introduced in 2010 at a national level, payments were granted per cow in order to strengthen the competitiveness of Czech dairy farms ("specific market support measure in the dairy sector" based on EC Regulation 1233/2009 focusing specific market support measures in the milk and milk products sector);
  - also introduced in 2010 at a national level, payments were granted per cow ("payment for cows kept under the dairy market (dairy cows)" based on EC Regulation Art.68 of the NR (EC) No 73/2009.

- Since all Czech dairy farmers equally profited from these payments, a control group for the proposed DID setting does not exist at a national level. At EU level, though, dairy farmers in countries such as Poland, Slovakia or the Baltic states face agricultural, natural and socio-economic structures that are quite similar to the ones in the Czech Republic as well as share similar institutional and policy experiences by Soviet influenced policy regimes until 1991 and have equally been affected by the EU's CAP since their countries joined the European Union in 2004.
- Given data availability, a control group will be selected from a sample of Estonian dairy farms (model 4.1)

Policy Case 2 - CAP Pillar I implementation differences

- This second empirical case study investigates the effects of a well-known, trade-related policy reform aiming at reducing agricultural production surpluses through limiting the incentives to produce: decoupling.
- This policy measure essentially aims at breaking the linkages between farm income-support schemes and farmers' production decisions. Numerous previous work on the topic exists and is methodically very diverse, however, most of the more robust contributions nevertheless lack a counterfactual approach.

- The 2003 CAP reform, which decoupled payments from production, was implemented in all member states of the EU from 2004 onwards. However, not all member states put the policy into practice to the same extent. Especially in France, the share of remaining coupled support was kept higher compared to other countries.
- The effect of a variation in the remaining share of coupled subsidies on farm productivity, technical change, resource allocation, innovativeness and sustainability can thus be studied comparing the performance of French farms to the performance of farms in the UK, where decoupling was implemented more stringently. The different outcomes can be compared to a scenario without decoupling based on literature findings (model 4.2)

Policy Case 3 - Small Farmer Scheme implementation

- The third empirical case study aims to assess the impact of the EU small farmer scheme on farms' productivity and other performance. Introduced in the course of the 2013 CAP reform, this specific support scheme had three main objectives:

  (1) enhancing the competitiveness of small farms,

  (2) lowering the administrative burden for small farms when accessing CAP aids, and

  (3) contributing to the vitality and dynamics of rural areas.

  The scheme is optional for member states and not all of them finally opted for its implementation.

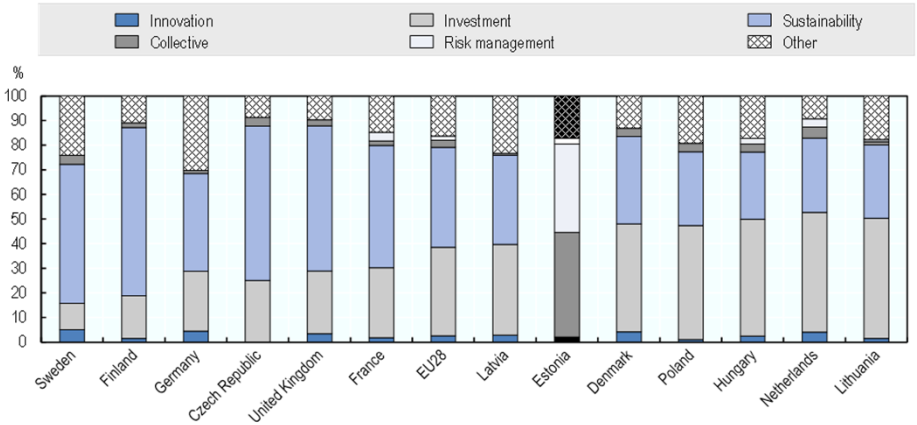
- This scenario allows to identify treatment and control farms in different member states and to apply the DID method if sufficient similarities between these farms can be detected. Countries to be considered for our analyses include (1) Eastern European countries like Hungary (treatment) and the Czech Republic (control). (2) Italian and French farms etc. (model 4.3)

- The main outcome variables of interest will be linked to the scheme's competitiveness objective (i.e. economic performance and innovativeness). Also, the environmental performance of treated and untreated small farms shall be studied in order to contribute to the ongoing discussion whether small (family) farms are a more environmentally sustainable form of agricultural production than what is commonly perceived as large, corporate farming.

Policy Case 4 - Regional Development Programmes

- The EU's rural development policy helps the rural areas of the EU to meet the wide range of challenges and opportunities in terms of economic, environmental and social development. Known as the "second pillar" of the Common Agricultural Policy (CAP), it has been revised for the period 2014-2020 through the process of wider CAP reform.
- Each EU member state sets national priorities by formulating a tailored Rural Development Plan (RDP 2014-2020) including measures related to innovation, sustainability, collective action/cooperation, and risk management. Thus, while the European Commission, approves, and monitors RDPs, decisions regarding the selection of projects and the granting of payments are handled at national or regional levels.
- Previous rural development programming periods focused on similar areas: *Rural Development Programme 2007-13* and *Rural Development Programme 2000-06.*

Figure 1 - RDP 2014-20 choices by selected EU member states (EC 2015)



Policy Case 4 - Regional Development Programmes

- The described variety of regional policy mixes over time and space allows to identify and quantitatively evaluate the impact on farms' performances controlling for farm and farming characteristics:
  - E.g. the empirical analysis could focus on priority 2 of the RDP 14-20 ("Enhancing the competitiveness of all types of agriculture and enhancing farm viability") which corresponds to axis 1 of the RDP 07-13 ("improving the competitiveness of the agricultural and forestry sector") and axis 1 in the RDP 00-06 ("improving competitiveness of farming and forestry"),
  - E.g. crop farms in Italy, France, UK, Denmark, Hungary, and Sweden for the 3 RDP programming periods 00-06, 07-13, and 14-20.

- Assuming that the regional policy measures affect the individual farms in different ways these policy effects can then be studied by comparing the outcomes of treatment and control groups for each country over different programming periods following the DID framework outlined above (model 4.4)
- Alternatively, assuming that the regional policy measures affect the farms more or less in the same way (i.e. common trend assumption) these policy effects can be analysed by using the pooled sample of countries over all programming periods and applying a regression based framework following e.g. a dynamic panel data (DPD) approach (model 5)

stage 3 - policy effects analysis II Australia

Policy Case 5 - Dairy Industry

Policy Case 6 - Cropping Industry

Policy Case 7 - Sheep Industry

stage 3 - policy effects II Australia

- Studying the effects of deregulation in the Australian agricultural sectors is highly relevant given that the country's support for agricultural producers is one of the lowest in the OECD while at the same time Australia shows very competitive farm businesses.
- The largest country in Oceania has started to deregulate its agricultural sector in the 1970s, anticipating the rise of market liberalism in other countries and sectors. In 2020, the level of support to agriculture is therefore far below the level of support in EU countries. Studying the impact of liberalisation on Australian agriculture can thus provide timely guidance for those countries exploring deregulation now or in the future.

- In Australia, national agricultural policy affects all farmers of the same sector, meaning that a quasi-experimental method like DID cannot be applied for studying the effects of policy changes as no counterfactuals can be observed.
- In order to examine the causality between deregulation reforms and farm/sector performance we propose a three-step procedure:
  - First, we use farm-level data to generate estimates for economic and other performances at the farm- as well as the sector-level. To capture the effects on different dimensions of farm performance, beside the productivity level and productivity class membership indicator, also the various performance indices' scores are considered at farm level.
  - Second, we apply dynamic panel methods to study the impacts of various policy measures on these respective outcomes (model 6)
  - Finally, we aim to apply a structural break analysis at the sector-(or class-)level time series (model 7)

Policy Case 5 - Australian Dairy Industry

- The Australian dairy industry provides a well-studied example of the positive impact of liberalisation on industry productivity and dairy output supply (Sheng et al. 2019).
- Agricultural policy frameworks in Australia tend to be applied broadly at a national level and presumably impact farms in a similar way. However, there is some evidence to suggest that the effect of resource reallocation on dairy farms proceeding the removal of milk price support in 2000 differed at farm level and by region.
- Although the policy framework to deregulate Australian dairy was applied in a uniform way, its impact appeared to differ depending on the location and type of dairy farm (i.e. seasonal versus year-round production).
- However, little is known about the actual impact on specific farm performance and behaviour. The responses of dairy farm classes to policy change and other major technological or environmental transitions are unknown from an empirical perspective, yet potentially provide important insights.

Policy Case 5 - Australian Dairy Industry ..

- Before the introduction of a market based mechanism for the milk price in July 2000, the level of dairy industry assistance was about 51% compared to about 6% assistance for agricultural industries in Australia on average.
- By 2008, the Australian dairy industry was fully deregulated. In the years 2002/03, 2006/07 and 2012/13 severe droughts significantly impacted dairy output and profits. By 2010/11 experts report a significant uptake of automated technology in the dairy sector. Finally, also the introduction of soil testing technology in the years 2010/11 led to a more effective fertiliser use on Australian dairy farms.

- To evaluate the causality/correlation between deregulation reforms and dairy farm/sector performance we follow the procedure as outlined above:
  - We use the estimates for different dimensions of farm performance produced in the 1st phase of the project. Therefore, beside the productivity level and productivity class membership indicator, also the various performance indices' scores are considered at dairy farm level (see phase I reports).
  - Then we apply dynamic panel methods to study the impacts of various dairy policy measures on these respective outcomes (models 6.1 and 7.1)

stage 3

Policy Case 6/7 - Australian Cropping Industry / Sheep Industry

- We plan to conduct a similar empirical analyses as outlined before for the cropping and/or sheep sector.
- Cropping is the largest agricultural industry in Australia and owes it success to innovation/technology/scale/structural adjustment measures over time.
- The sheep industry is of interest as the wool price dynamics (collapse) as a consequence of sector deregulation measures (similar to the dairy deregulation) resulted in major structural change.

Thank you.

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Policy Case 1 - Dairy farming subsidies in Czech Republic

First Draft Results

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Balancing covariates between Czech and Estonian farms before treatment through Propensity Score Matching to identify suitable treatment and control groups

Farms are matched based on the propensity score with a matching algorithm.

The propensity score is estimated using a logistic regression:

$$P(T = 1|X_1, \dots, X_n) = \frac{\exp(\beta_0 + \beta_1 X_1 + \cdots + \beta_n X_n)}{1 + \exp(\beta_0 + \beta_1 X_1 + \cdots + \beta_n X_n)}$$

T defines treatment, X observed covariates

Estimating the effect of the Czech special aid for the dairy sector
(implemented under Art.68 of the NR (EC) no 73/2009 Coll, introduced in 2010)

via Difference-in-Difference (control group EST)

Program impact is estimated as follows:

$$DD = E(Y_1^T - Y_0^T \mid T_1 = 1) - E(Y_1^C - Y_0^C \mid T_1 = 0)$$

Y_t^T and Y_t^C are the respective outcomes for program beneficiaries and nontreated units in time t (before and after treatment)

Estimating equation for i treatment and control units:

$$Y_{it} = \alpha + DDT_i t + \beta T_i + \delta t_i + \varepsilon_{it}$$

Propensity Score Matching results (pre-treatment year 2009)

Parameter estimates of logit model:

Variables	Estimate	z
ln land	0.400**	2.09
ln labour_ha	1.774***	3.22
ln assets_ha	1.916***	3.76
ln dairy_cow_density	-0.561	-0.49
ln milk_sales_ha	0.935	1.05
ln age	-1.663	-1.35
LFA_category	-1.166	-1.47
feed_cow	-0.001**	-2.14
Intercept	-23.361***	-2.56

Regression statistics	
Number of observations	169
LR chi2	83.93***

Unadjusted and adjusted means of selected variables:

Variable	(1) Potential treatments	(2) Potential controls	(3) Selected treatments	(4) Selected controls
labour_ha	93.103	59.665***	70.257	78.499
assets_ha	6709.6	3608.5***	5088.6	5636.5
dairy_cow_density	0.441	0.298***	0.357	0.366
LFA_category	0.794	0.934***	1.000	0.965
feed_cow	1696.5	1822.3	1822.5	1848
Number of observations	64	107	29	29

1:1 nearest neighbour matching, caliper (0.2), trimming

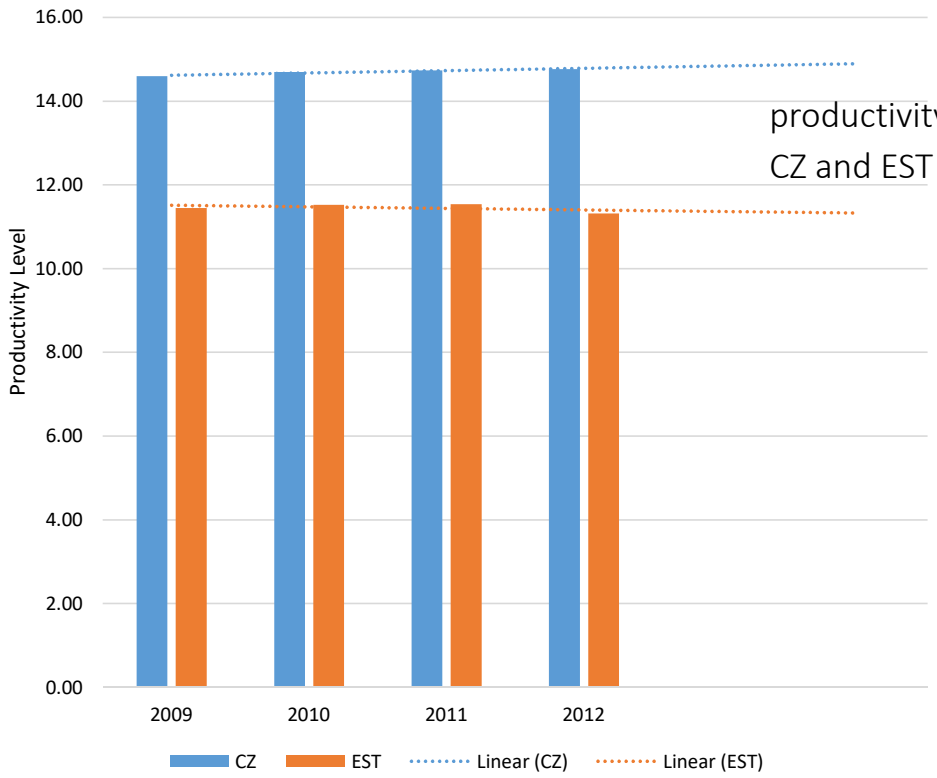
Difference-in-Difference estimation (09-12) for outcome variable *productivity*

	productivity level	S.Err.	|t|	P>|t|
2009				
EST	11.448			
CZ	14.600			
Diff (EST-CZ)	3.151	0.425	7.42	0.000***
2012				
EST	11.320			
CZ	14.769			
Diff (EST-CZ)	3.449	0.425	8.12	0.000***
Diff-in-Diff	0.297	0.600	0.50	0.621
Number of observations: 116				

Difference-in-Difference estimation (09-12) for outcome variable *class switches*

	class switch	S.Err.	|t|	P>|t|
2009				
EST	0.000			
CZ	0.000			
Diff (EST-CZ)	0.000	0.178	0.00	1.000
2012				
EST	0.276			
CZ	0.138			
Diff (EST-CZ)	-0.138	0.178	0.78	0.439
Diff-in-Diff	-0.138	0.251	0.55	0.584
Number of observations: 116				

Difference-in-Difference estimation (09-12) for outcome variable *productivity*



productivity development for matched CZ and EST farms, 2009-2012

insights | ongoing work

revision of estimations

- so far 09-12, we work on 09-15
- additional controls needed (received for Czech Rep, wait for Estonia)
- other farm performance effects: sustainability, innovation etc.

- trend for productivity increase in Czech dairy farming
- we hope to be able to confirm this for 09-15 and maybe also identify significant positive policy effect

problems

- low number of farm observations as we have to match for full period 09-15
- structure Cz-Est dairy sector considerably different, „land" not included as matching variable

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Project Ideas 21|22

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- farm labour structure development
  - characteristics (family/hired/seasonal/age/education/skills/off-farm/part-time etc.)
  - drivers for distributions over space & time
- farm labour productivity development
  - labor related technical change (non-neutral)
  - labour substitution effects (lab-capital, lab-land, etc.)
  - farm efficiency effects
  - policy effects | other exogenous shocks
- sustainable innovation and labour quality/skills
  - relative importance for propensity to innovate
  - effects on productivity - sustainability link
- method:
  - data driven quantitative and robust empirical evidence (statistical and econometric)
  - exploit farm level data and performance estimates further (based on FLA drivers project)
  - in different sectors and across countries
  - link farm performance estimates to labour productivity and skills levels
  - link farm indices scores to labour characteristics and productivity
  - investigate farm dynamics and labour issues

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Project Part II - Models Appendices

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stage 1

- relative probability of class membership P_{ij}
- marginal contribution of the individual characteristics

model 1 - multinomial logit for a cross-sectional setting

$$P_{ij} = \frac{exp(\alpha_j + X_i\beta_j)}{\sum_{k=1}^{J} xp(\alpha_k + X_i\beta_k)} \qquad [1]$$

P_{ij} is the probability of class membership for farm i, α_j denotes the specific constant term of class membership j (with j = class 1, class 2 and class 3, respectively), and X_i is a set of individual farm characteristics

stage 2

step III estimation of the propensity to switch to a more productive class in the respective time period

- relative probability P_{ij} of switching to a different class from year t to year t+1
- marginal contribution of the individual characteristics

model 2 - multinomial logit

$$P_{is} = \frac{exp(\alpha_s + X_i\beta_s)}{\sum_{m=1}^{S} xp(\alpha_m + X_i\beta_m)} \qquad [2]$$

P_{is} is the probability of a certain class switch for farm I from year t to t+1, α_s denotes the specific constant term of class switch s (with s = +1 for switch to more productive class, 0 for staying in the same class - i.e. no switch, -1 for switch to a less productive class, respectively), and X_i is a set of individual farm characteristics covering differences in characteristics from year t to year t+1, and levels as well as binary indicators for characteristics

stage 2

step III

- relative probability P_{ij} of staying at the higher performance level (i.e. in the same productive class) or even improving further (i.e. a switch to an even more productive class from year t+1 to year t+2)
- marginal contribution of the individual characteristics

model 3 - Heckman selection ordinal probit

$$y_i^* = X_i\beta_m + \varepsilon_i \qquad [3]$$

$$d_i^* = Z_i\gamma_m + v_i \qquad [4]$$

$$d_i = 1 \;\; if \;\; d_i^* > 0; \quad d_i = 0 \;\; otherwise \qquad [5]$$

$$y_i = y_i^* * d_i \qquad [6]$$

$$y_i \begin{cases} y_1 \;\; if \;\; -\infty < y_i^* \leq -2 & i.e. farm\ i\ switches\ class\ 3\ to\ class\ 1 \\ y_2 \;\; if \;\; -2 < y_i^* \leq -1 & i.e. farm\ i\ switches\ class\ 3\ to\ class\ 2, or\ class\ 2\ to\ class\ 1 \\ y_3 \;\; if \;\; -1 < y_i^* \leq 0 & i.e. farm\ i\ does\ not\ switch\ classes \\ y_4 \;\; if \;\; 0 < y_i^* \leq \infty & i.e. farm\ i\ switches\ class\ 2\ to\ class\ 3 \end{cases} \qquad [7]$$

model 4 - estimation of the average policy program impact

- a two-period setting where $t = 0$ refers to the period before program/policy and $t = 1$ to the period after program/policy implementation, letting Y_t^T and Y_t^C be the respective outcomes for a program beneficiary (T) and non-treated units (C) in time t

$$DID = E(Y_1^T - Y_0^T | T_1 = 1) - E\left(Y_1^C - Y_0^C | T_1 = 0\right) \qquad [8]$$

where $T_1 = 1$ denotes treatment or the presence of the program/policy change at $t = 1$, whereas $T_1 = 0$ denotes untreated areas, with baseline data one can thus estimate impacts by assuming that unobserved heterogeneity is time invariant and uncorrelated with the treatment over time

- within a regression framework the DID estimator can be expressed in its simplest form by the following equation:

$$Y_{it} = \alpha + \beta T_{i1} t + \rho T_{i1} + \gamma t + \varepsilon_{it} \qquad [9]$$

with the subscript i denoting the i-th farm and the subscript 1 denotes treatment or the presence of the program/policy change as discussed before; the coefficient β on the interaction between the program treatment variable T_{i1} and time $t = 1, \dots, T$ gives the average DID effect; this two-period model can be generalized with multiple time periods to a panel fixed-effects model including a range of time-varying covariates X_{it}

stage 3

model 4.1 - estimation of the average dairy subsidy effect in Czech Republic

- the two-period setting to exemplify the analytical approach as follows: $t = 2009$ refers to the period before the dairy cow related subsidies programs have been implemented whereas $t = 2010$ refers to the period after the programs' implementation, letting $Y_t^{Cz_dc}$ and $Y_t^{Est_ndc}$ be the respective outcomes for the Czech dairy farms benefiting from the programs (Cz_dc) and non-treated dairy farms in Estonia (Est_ndc) at time t. Hence, the DID method estimates the average Czech dairy cow subsidies' program impact as follows:

$$DID_{Cz_dc} = E\left(Y_{2010}^{Cz_dc} - Y_{2009}^{Cz_dc} \middle| T_{Cz_dc} = 1\right) - E\left(Y_{2010}^{Est_ndc} - Y_{2009}^{Est_ndc} \middle| T_{Cz_dc} = 0\right) \qquad [10]$$

where $T_{Cz_dc} = 1$ denotes treatment or the presence of the dairy cow related payment programs change at $t = 1$, whereas $T_{Cz_dc} = 0$ denotes untreated farms. Given the panel data availaibility at dairy farm level we are able to estimate farm performance impacts by assuming that unobserved heterogeneity over dairy farms is time invariant and uncorrelated with the dairy cow related subsidies treatment over time.

- within a regression framework the DID estimator can be expressed by the following equation:

$$Y_{it} = \alpha + \beta T_{iCz_dc} t + \rho T_{iCz_dc} + \gamma t + \varepsilon_{it} \qquad [11]$$

where the coefficient β on the interaction between the post-program treatment variable T_{iCz_dc} and time $t = 2005, \ldots, 2015$. gives the average cow subsidies related DID effect. We further generalize this two-period model by using multiple time periods applying a panel fixed-effects model including a range of time-varying covariates X_{it} related to farm and farmer characteristics. The applied matching procedure (i.e. propensity score matching) for the baseline data in t = 2009 makes certain that the dairy farm comparison group is similar to the dairy farm treatment group before applying double differences to the matched dairy farm sample (i.e. with-without dairy cow related subsidies treatment and before-after dairy cow related subsidies treatment). As outcome variable Y_{it} we apply various farm productivity and other farm performance related indices uncluding also class membership and class switching indicators based on the results produced in phase I of this project.

stage 3

model 4.2 - estimation of CAP I implementation effects

- the two-period setting to exemplify the analytical approach as follows: $t = 2003$ refers to the period before the CAP reform has been implemented whereas $t = 2004$ refers to the period after the reform's implementation. $Y_t^{UK_cpI}$ and $Y_t^{F_gpI}$ be the respective outcomes for the UK crop farms after the complete reform (UK_cpI) and crop farms in France after gradual reform (F_gpI) at time t. Hence, the DID method estimates the average UK reform program impact as follows:

$$DID_{UK_cpI} = E\left(Y_{2004}^{UK_cpI} - Y_{2003}^{UK_cpI} \middle| T_{UK_cpI} = 1\right) - E\left(Y_{2004}^{F_gpI} - Y_{2003}^{F_gpI} \middle| T_{UK_cpI} = 0\right) \qquad [12]$$

where $T_{UK_cpI} = 1$ denotes treatment or the presence of the complete CAP reform implementation at $t = 2004$ or after, whereas $T_{UK_cpI} = 0$ denotes untreated farms. Given the panel data availaibility at crop farm level we are able to estimate farm performance impacts by assuming that unobserved heterogeneity over crop farms is time invariant and uncorrelated with the complete CAP pillar I reform treatment over time.

- within a regression framework the DID estimator can be expressed by the following equation:

$$Y_{it} = \alpha + \beta T_{iUK_cpI} t + \rho T_{iUK_cpI} + \gamma t + \varepsilon_{it} \qquad [13]$$

where the coefficient β on the interaction between the post-program treatment variable T_{iUK_cpI} and time $t = 1989, , \ldots, 2016$ gives the average reform related DID effect. We further generalize this two-period model by using multiple time periods applying a panel fixed-effects model including a range of time-varying covariates X_{it} related to farm and farmer characteristics. The applied matching procedure (i.e. propensity score matching) for the baseline data in t = 2003 makes certain that the crop farm comparison group is similar to the crop farm treatment group before applying double differences to the matched crop farm sample (i.e. with-without reform treatment and before-after reform treatment). As outcome variable Y_{it} we apply various farm productivity and other farm performance related indices uncluding also class membership and class switching indicators based on the results produced in phase I of this project.

stage 3

model 4.3 - estimation of SFS effects

- The effects of the Small Farmer Scheme (SFS) can be robustly identified by using the previously introduced two-period setting: $t = 2014$ refers to the period before the implementation of the scheme whereas $t = 2015$ refers to the period after the scheme's implementation. $Y_t^{Hu_sfs}$ and $Y_t^{Cz_nsfs}$ be the respective outcomes for the Hungarian small farms after the SFS implementation (Hu_sfs) and small farms in Czech Republic (Cz_nsfs) at time t. Hence, the DID method estimates the average Hungarian SFS implementation impact as follows:

$$DID_{Hu_sfs} = E\left(Y_{2015}^{Hu_sfs} - Y_{2014}^{Hu_sfs} \middle| T_{Hu_sfs} = 1\right) - E\left(Y_{2015}^{Cz_nsfs} - Y_{2014}^{Cz_nsfs} \middle| T_{Hu_sfs} = 0\right) \qquad [14]$$

where $T_{Hu_sfs} = 1$ denotes treatment or the presence of the SFS implementation $t = 2004$ or after, whereas $T_{Hu_sfs} = 0$ denotes untreated farms. Given the panel data availaibility at mall farm level we are able to estimate farm performance impacts by assuming that unobserved heterogeneity over small farms is time invariant and uncorrelated with the SFS treatment over time.

- within a regression framework the DID estimator can be expressed by the following equation:

$$Y_{it} = \alpha + \beta T_{iHu_sfs} t + \rho T_{iHu_sfs} + \gamma t + \varepsilon_{it} \qquad [15]$$

where the coefficient β on the interaction between the post-scheme treatment variable T_{iHu_sfs} and time $t = 2001, \ldots, 2015$ gives the average reform related DID effect. We further generalize this two-period model by using multiple time periods applying a panel fixed-effects model including a range of time-varying covariates X_{it} related to farm and farmer characteristics. The applied matching procedure (i.e. propensity score matching) for the baseline data in t = 2014 makes certain that the small farm comparison group is similar to the small farm treatment group before applying double differences to the matched small farm sample (i.e. with-without SFS treatment and before-after SFS treatment). As outcome variable Y_{it} we apply various farm productivity and other farm performance related indices uncluding also class membership and class switching indicators based on the results produced in phase I of this project.

stage 3

model 4.4 - estimation of regional policy impact

- the effects of the RDP priority 2/axis 1 measures can be robustly identified by using the previously introduced two-period setting: $t = 1999$ refers to the period before the implementation of the RDPs whereas $t = 2000$ refers to the period after the RDPs implementation. $Y_t^{It_p2a1}$ and $Y_t^{It_np2a1}$ are the respective outcomes for the Italian farms with the RDP priority 2/axis 1 implementation ($Y_t^{It_p2a1}$) and farms without ($Y_t^{It_np2a1}$) at time t. Hence, the DID method estimates the average Italian RDP priority 2/axis 1 measures' implementation impact as follows:

$$DID_{It_p2a1} = E\left(Y_{2000}^{It_p2a1} - Y_{1999}^{It_p2a1} \middle| T_{It_\mathrm{p2a1}} = 1\right) - E\left(Y_{2000}^{It_np2a1} - Y_{2014}^{It_np2a1} \middle| T_{It_\mathrm{p2a1}} = 0\right) \qquad [16]$$

where $T_{It_p2a1} = 1$ denotes treatment or the presence of the RDP priority 2/axis 1 implementation $t = 2000$ or after, whereas $T_{It_np2a1} = 0$ denotes untreated farms. Given the panel data availaibility at farm level we are able to estimate farm performance impacts by assuming that unobserved heterogeneity over farms is time invariant and uncorrelated with the RDP treatment over time.

- within a regression framework the DID estimator can be expressed by the following equation:

$$Y_{it} = \alpha + \beta T_{iIt_p2a1} t + \rho T_{iIt_p2a1} + \gamma t + \varepsilon_{it} \qquad [17]$$

where the coefficient β on the interaction between the post-scheme treatment variable T_{iIt_p2a1} and time $t = 1999, 2000, \ldots, 2016$ gives the average RDP measure related DID effect. We further generalize this two-period model by using multiple time periods applying a panel fixed-effects model including a range of time-varying covariates X_{it} related to farm and farmer characteristics. The applied matching procedure (i.e. propensity score matching) for the baseline data in t = 1999 makes certain that the farm comparison group is similar to the farm treatment group before applying double differences to the matched farm sample (i.e. with-without RDP priority 2/axis 1 treatment and before-after RDP priority 2/axis 1). As outcome variable Y_{it} we apply various farm productivity and other farm performance related indices uncluding also class membership and class switching indicators based on the results produced in phase I of this project.

model 5 - estimation of regional policy impact (alternative approach)

- An alternative approach to evaluate the policy effects of RDP priority 2/axis 1 measures would be to pool all relevant country samples over all programming periods (e.g. crop farms in Italy, France, UK, Denmark, Hungary, and Sweden for the 3 RDP programming periods 2000-2006, 2007-2013, and 2014-2020) and use a dynamic panel data approach. As the national and regional RDP measures show cross-effects/synergies with other policies a panel regression set-up seems appropriate to capture such effects and also control for potential biases.

- Taking possible endogeneity issues into account, we apply two dynamic Generalized Method of Moments (GMM) methods, namely the Difference Generalised Method of Moments (DIF-GMM) estimator attributed to Arellano and Bond (1991) and the System Generalised Method of Moments (SYS-GMM) estimator proposed by Arellano and Bover (1995) and Blundell and Bond (1998) to estimate the following equation:

$$Y_{it} = \beta X'_{it} + \delta Y_{i,t-1} + \alpha_t + u_{it} \qquad i = 1,2,\dots,N; t = 1,2,\dots,T \qquad [18]$$

with farm i being observed at time t, δ a scalar, α_t (unobserved) individual-specific effects, X'_{it} (explanatory variables, including RDP priority 2/axis 1 measures) $1\text{x}K$ and β $K\text{x}1$ and u_{it} following a one-way error component model $u_{it} = \mu_{it} + v_{it}$ with $\mu_{it} \sim IID(0, \sigma_\mu^2)$ and $v_{it} \sim IID(0, \sigma_v^2)$ being independent of each other and between them. Y_{it} refers to the performance variable at farm level. Additionally, we make use of the panel dynamic ordinary least square (DOLS) methodology developed by Kao and Chiang (2001). We test our models with novel econometric methods for heterogeneous slope coefficients across group members, non-stationarity and correlation across panel members (Bond and Eberhardt, 2009; Eberhardt and Teal, 2010; Pesaran, 2006; Pesaran and Smith, 1995).

model 6 - estimation of deregulation effects

taking possible endogeneity issues into account, we apply two dynamic Generalized Method of Moments (GMM) methods, namely the Difference Generalised Method of Moments (DIF-GMM) estimator attributed to Arellano and Bond (1991) and the System Generalised Method of Moments (SYS-GMM) estimator proposed by Arellano and Bover (1995) and Blundell and Bond (1998) to estimate the following equation:

$$Y_{it} = \beta X'_{it} + \delta Y_{i,t-1} + \alpha_t + u_{it} \qquad i = 1,2,\dots,N; t = 1,2,\dots,T \qquad [19]$$

with farm i being observed at time t, δ a scalar, α_t (unobserved) individual-specific effects, X'_{it} (explanatory variables, including farm subsidies) $1\text{x}K$ and β $K\text{x}1$ and u_{it} following a one-way error component model $u_{it} = \mu_{it} + v_{it}$ with $\mu_{it} \sim IID(0, \sigma_\mu^2)$ and $v_{it} \sim IID(0, \sigma_v^2)$ being independent of each other and between them. Y_{it} refers to the ecological and/or economic outcome variable

model 6.1 - estimation of dairy deregulation effects

Taking possible endogeneity issues into account, we apply two dynamic Generalized Method of Moments (GMM) methods, namely the Difference Generalised Method of Moments (DIF-GMM) estimator attributed to Arellano and Bond (1991) and the System Generalised Method of Moments (SYS-GMM) estimator proposed by Arellano and Bover (1995) and Blundell and Bond (1998) to estimate the following equation:

$$Y_{it} = \beta X'_{it} + \delta Y_{i,t-1} + \alpha_t + u_{it} \qquad i = 1,2,\dots,N; t = 1,2,\dots,T \qquad [21]$$

with dairy farm i being observed at time t, δ and β scalars of parameters to be estimated, α_t (unobserved) individual-specific effects, X'_{it} (explanatory variables, including dairy sector deregulation indicators for the period from the year 2000 onwards, the period from 2010 onwards, as well as drought related indicators for the years 2002, 2006 and 2012). u_{it} following a one-way error component model with $u_{it} = \mu_{it} + v_{it}$, $\mu_{it} \sim IID(0, \sigma_\mu^2)$ and $v_{it} \sim IID(0, \sigma_v^2)$ being independent of each other and between them. Y_{it} refers to the ecological and/or economic outcome variable of dairy farm i at time t.

model 7 - estimation of deregulation effects (2)

We apply a structural break analysis at the sector-(or class-) level time series following Andrews and Fair (1988), Hansen (1997) and Hansen (2001) in an additional effort to examine the causality between deregulation reforms and ecological/economic performance. In doing so, we examine whether there are significant trend changes in various aggregate farm performance measures, when controlling for other determinants of farm performance. The following equation underlies this approach

$$Y_t^k = \alpha^k + \rho^k T(t > \tau) + \gamma^k Z_t(l) + \epsilon_t^k \qquad [20]$$

in this equation, Y_t^k denotes the aggregate of k at time t, where k refers to sector-(or class-) level economic or other performance. T is the time trend, τ refers to reformed year and $Z_t(l)$ denotes a group of control variables, including climate conditions and prices

model 7.1 - estimation of dairy deregulation effects (2)

In addition we aim to apply a structural break analysis at the dairy sector-(or dairy farm class-)level time series (following model 7 outlined above) to quantitatively examine the causality/correlation between dairy deregulation reforms and ecological/economic performance. In doing so, we examine whether there are significant trend changes in various aggregate dairy farm performance measures, when controlling for other determinants of farm performance.

Consequently, the following equation is to be estimated

$$Y_t^k = \alpha^k + \rho^k T(t > \tau) + \gamma^k Z_t(l) + \epsilon_t^k \qquad [19]$$

where Y_t^k denotes the performance indicator at time t, where k refers to dairy sector-(or dairy farm class-)level economic or other performance. T is the time trend, τ refers to deregulation year and $Z_t(l)$ denotes a group of control variables, including climate conditions and prices.

Thank you.

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