The development of production costs in dairy farms using panel data

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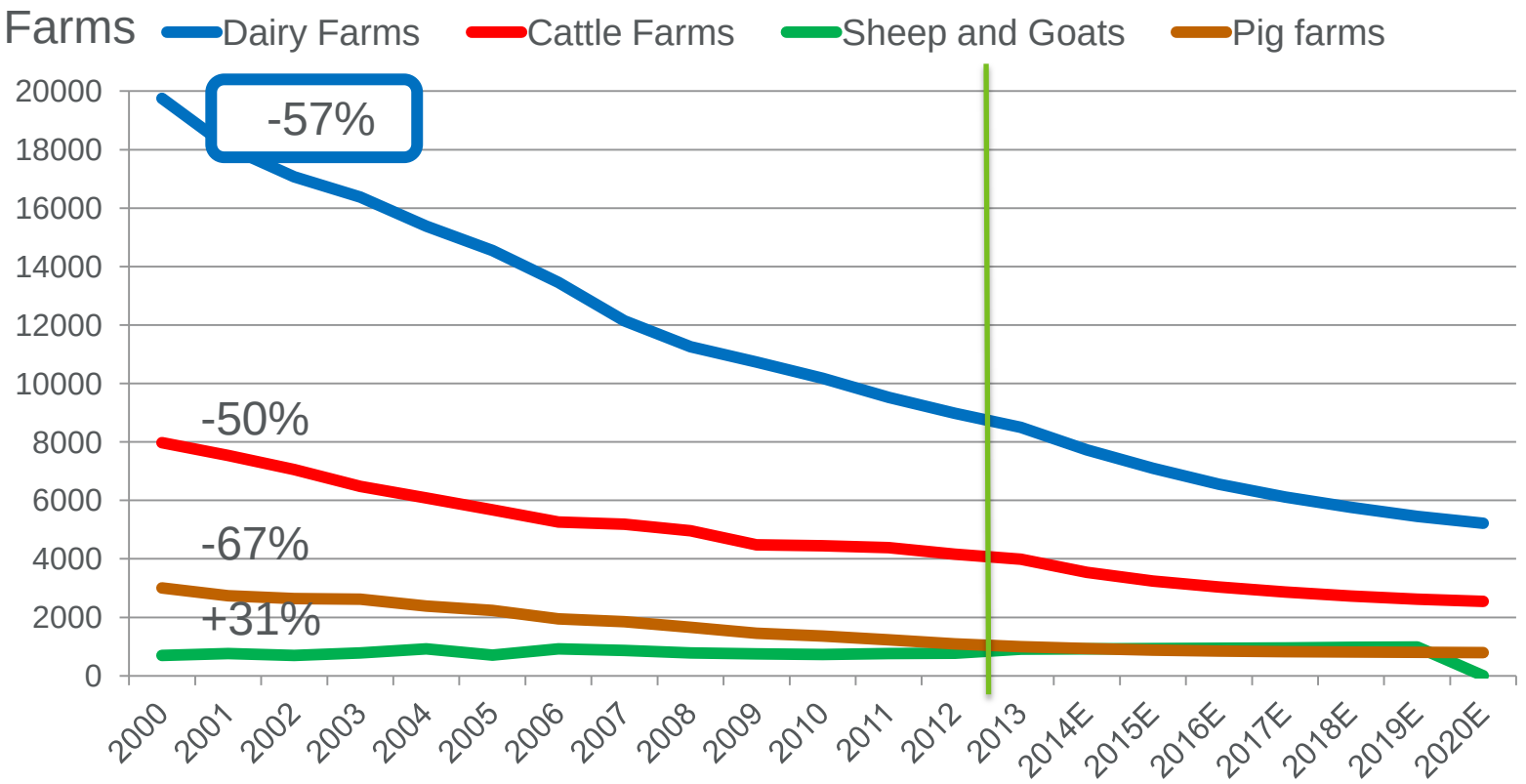
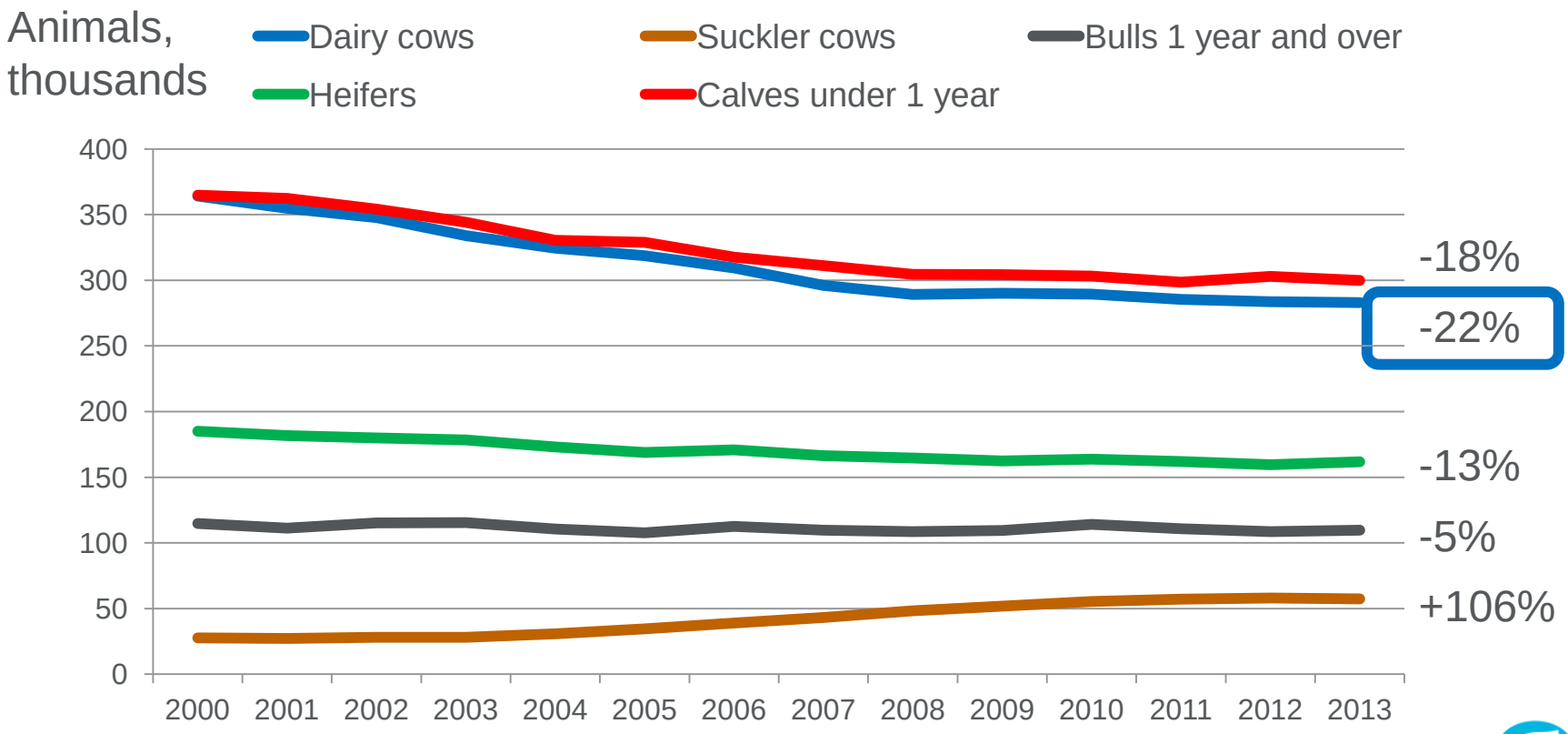
Contents

- Introduction
  - structural change and projections
  - number of cattle 2000–2013
  - development of costs
- Farm panel data
- Linear mixed model
- Model results

Introduction structural change and projections



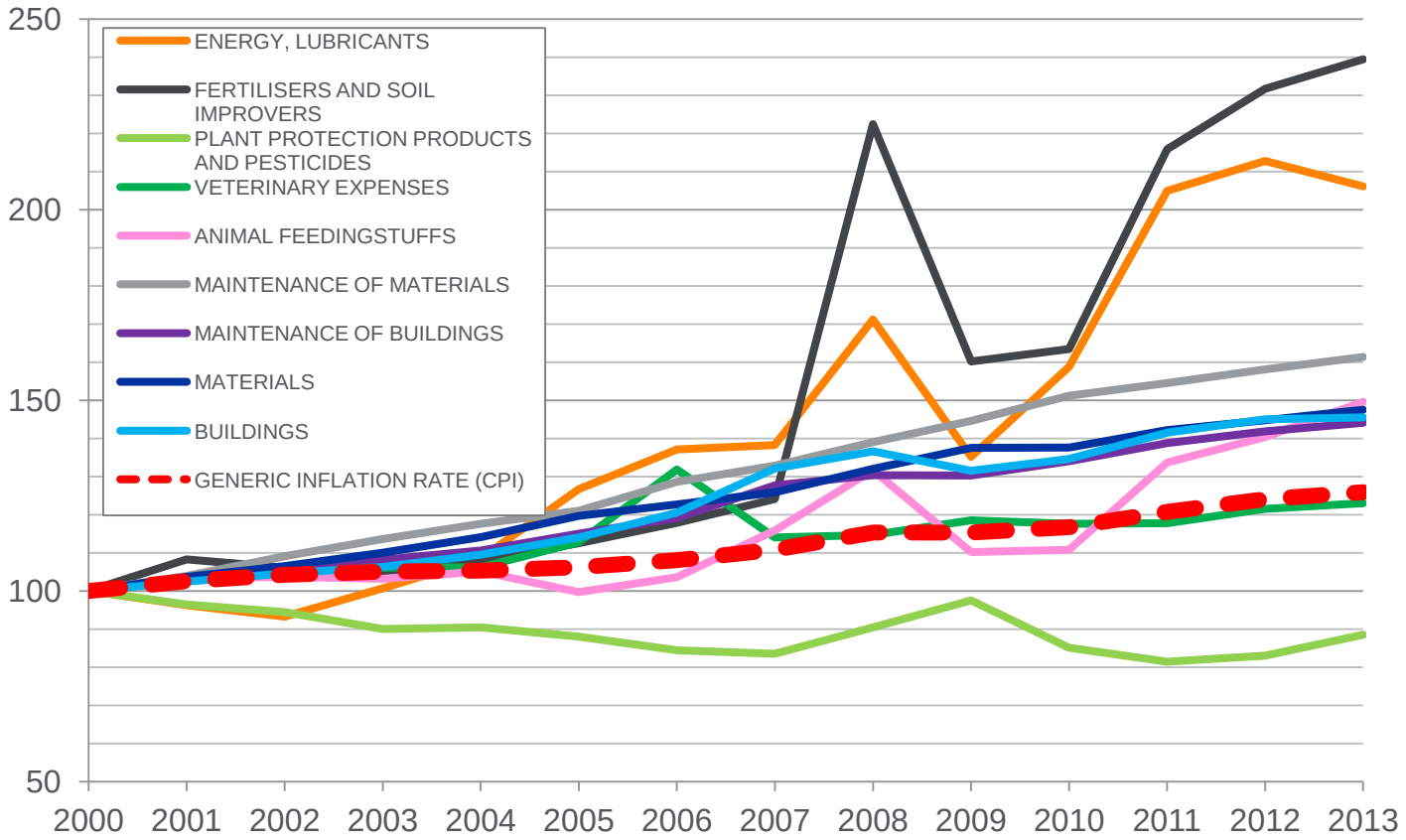
Introduction number of cattle 2000–2013



Introduction

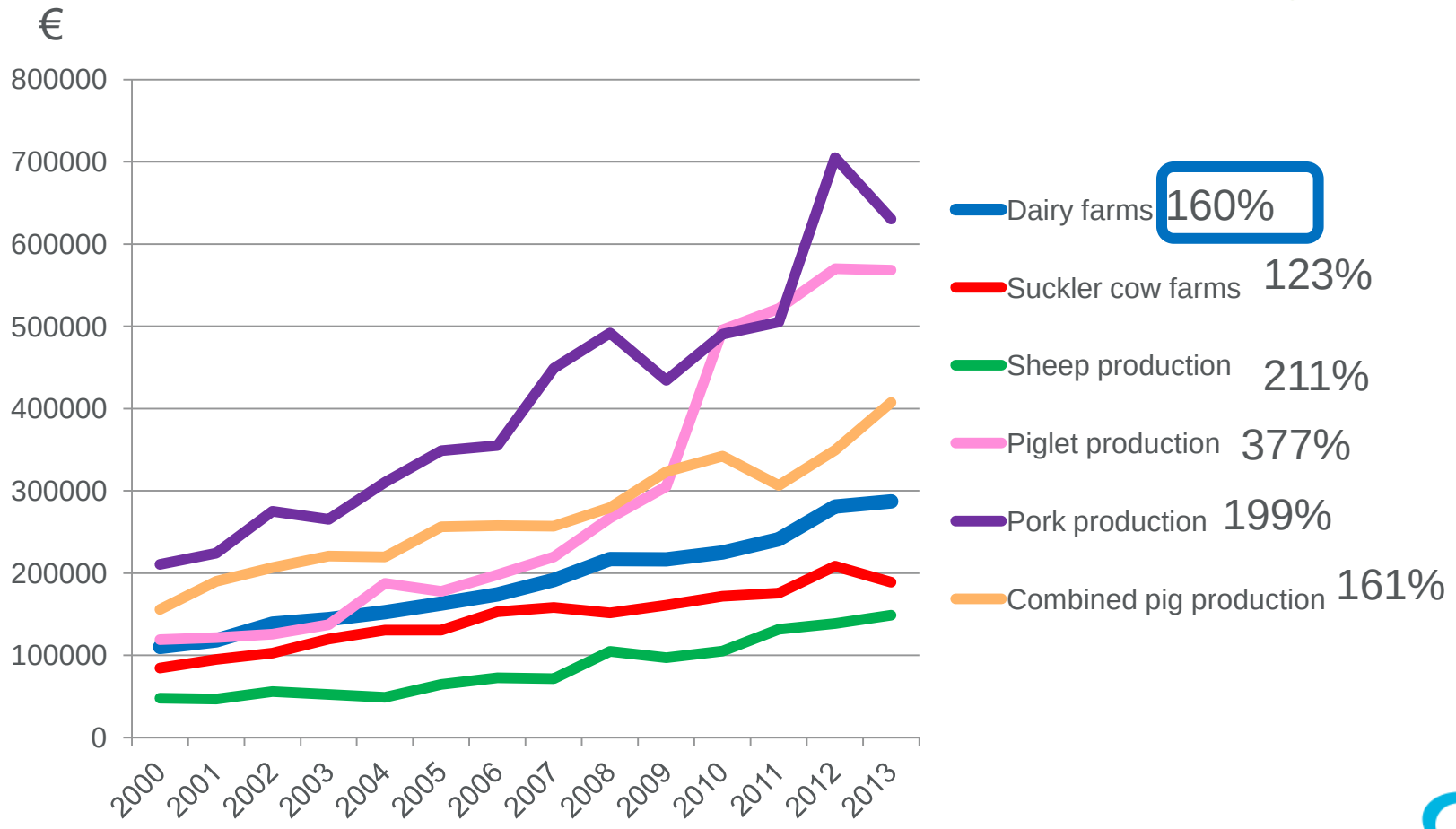
- The structure of agriculture has changed rapidly. Number of dairy farms has dropped by 57%, but the number of cows only by 22%.
- Average farm size has grown.
  - Farms have more animals and more arable land (hectares).
- The goal of this study was to study how the production costs in Finnish dairy farms have developed in 2000s taking into account farm-level information and time effect by observing the same farms for several years.
  - Farm-level information was location, economic size and number of cows.
  - Analyzed interindividual differences in intraindividual changes over time.

Introduction prices have increased in the 2000s



Data source: Statistics Finland.

Introduction production costs in animal farming




DATA:
dairy farms

Data farm level panel data 2000-2011

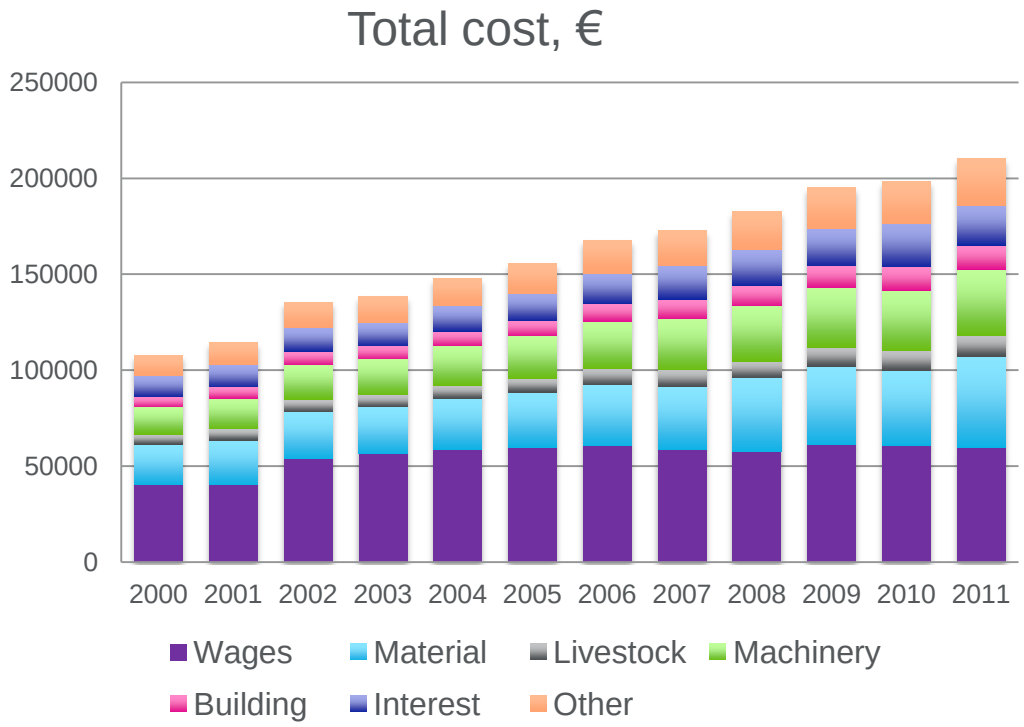
- Dairy farms participating in Luke profitability bookkeeping were studied for the years 2000–2011.
- The data set was formed as panel. Each farm was repeatedly measured in one year intervals.
- There were 4205 observations from 633 different farms and on average 350 different farms every year.
- Data set was unbalanced. This is due to the fact that it is voluntary to participate in Luke bookkeeping activities and, on the other hand, some farms had exited the business.

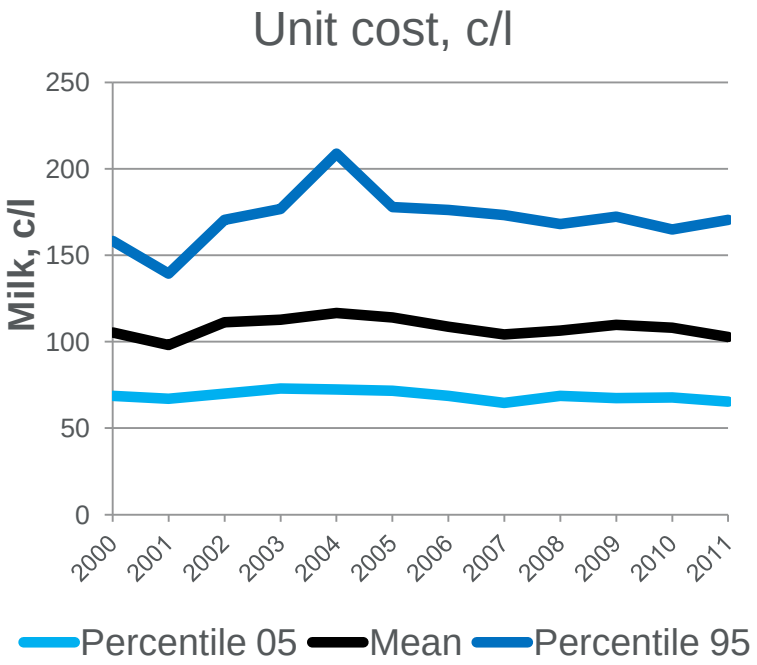
Data farm level panel data 2000-2011

- The unit production costs were studied (continuous variable).
- The total production cost is sum of following components: material, livestock, machinery, building, wages and interest costs.
- The production costs were deflated by using Consumer price indices year to 2011 prices (2000=100).
- The farm-level data were weighted with weight factors calculated individually for each farm for every year taking into account
  - the type of operations, economic size and location by support areas.
  - Weights were calibrated taking into account the total arable land in Finland.
- The unit costs of dairy farms were obtained by dividing the total production costs by the amount of produced milk (eurocent per litre).

Data farm level panel data 2000-2011

The development of average total and unit production costs in 2000—2011 deflated to 2011 prices and weighted results from Luke bookkeeping farms

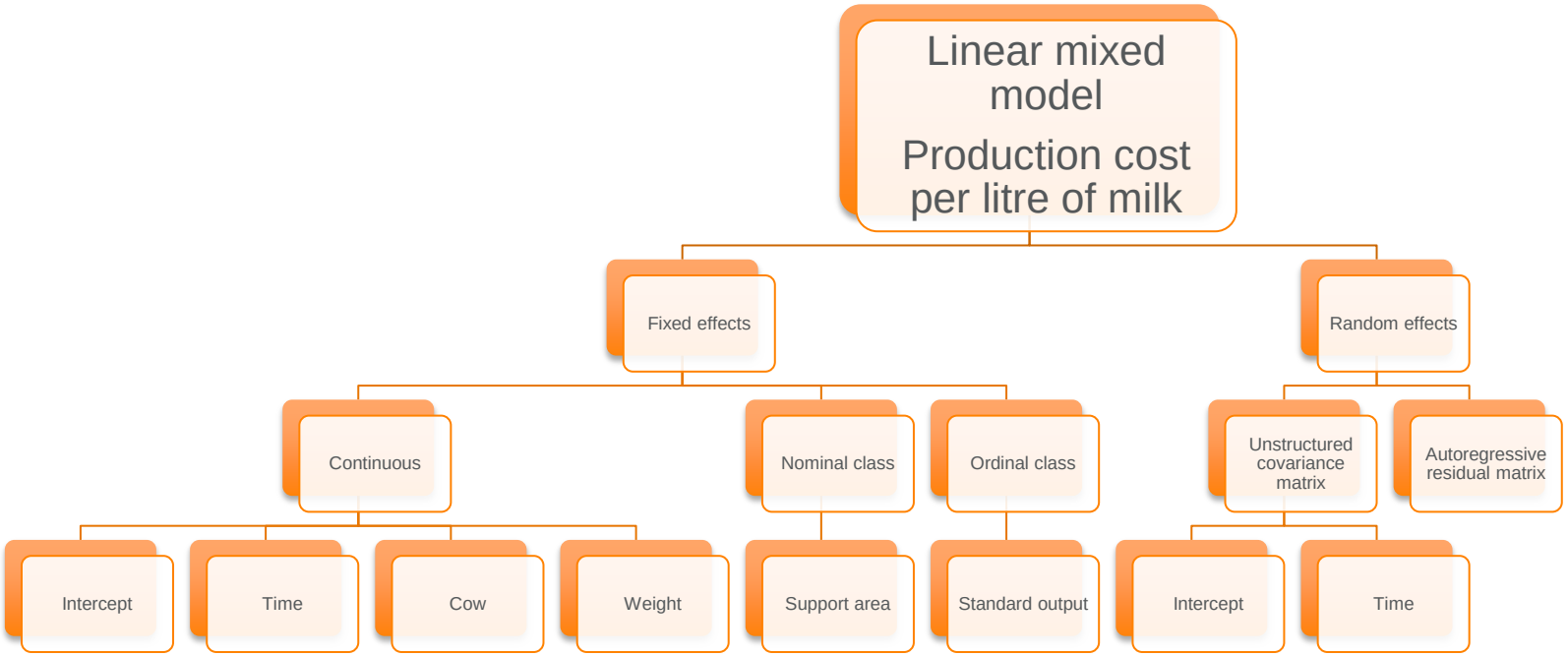




Total cost has increased over time meaning that prices have grown and dairy farms are larger. However, it seems that the unit cost has remained the same.


Model for
production costs

Model specification for unit cost



Data used, Luke profitability bookkeeping panel data.

Method linear mixed model

- A linear mixed model includes both fixed and random effects.
- The linear mixed model for an individual farm, ***i***, was defined as followed:

$$\begin{cases} \mathbf{y_i} = \underbrace{\mathbf{X_i}\boldsymbol{\beta}}_{\text{fixed}} + \underbrace{\mathbf{Z_i}\mathbf{b_i}}_{\text{random}} + \underbrace{\boldsymbol{\epsilon_i}}_{\text{random}} \\ \mathbf{b_i} \sim N(\mathbf{0}, \mathbf{D}) \\ \boldsymbol{\epsilon_i} \sim N(\mathbf{0}, \mathbf{R_i}) \\ \mathbf{b_1}, \ldots, \mathbf{b_n}, \boldsymbol{\epsilon_1}, \ldots, \boldsymbol{\epsilon_n} \text{ independent} \end{cases}$$

Method covariance structure for random effects

- Unstructured (UN) covariance structure was chosen for random effects in the model since it is suitable for longitudinal data.
- Random effects were defined over farm register number (observation unit i).
- The unstructured 2 × 2 covariance matrix for the random effects (intercept and time) is denoted as followed:

$$\mathbf{D} = \mathrm{Var}(\mathbf{b}_i) = \begin{pmatrix} \sigma^2_{b_0} & \sigma_{b_0,b_1} \\ \sigma_{b_0,b_1} & \sigma^2_{b_1} \end{pmatrix}$$

- where three parameters, b0 variance, b1 variance, b0 and b1 covariance, are denoted as UN(1,1), UN(2,2) and UN(2,1), respectively.

Method covariance structure for residual random effects

- For residual random effects first-order autoregressive (AR1) covariance structure was chosen because it is suitable for data containing sequential observations and correlations declining exponentially with time.
- The first-order autoregressive covariance matrix for residual is denoted:

$$\mathbf{R_i} = \mathrm{Var}(\boldsymbol{\epsilon_i}) = \begin{pmatrix} \sigma^2 & \sigma^2\rho & \dots & \sigma^2\rho^{n_i-1} \\ \sigma^2\rho & \sigma^2 & \dots & \sigma^2\rho^{n_i-2} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma^2\rho^{n_i-1} & \sigma^2\rho^{n_i-2} & \dots & \sigma^2 \end{pmatrix}$$

Results

Results of linear mixed model explaining the unit cost

Effect		Estimate	Std. error	Sig.	CI 95% Low	CI 95% Up
Intercept	a_0	135.303	3.120	<0.001	129.182	141.423
time	a_1	1.472	0.176	<0.001	1.125	1.818
cow	a_2	-0.710	0.045	<0.001	-0.797	-0.622
Standard output	a_3					
medium (50000-100000 €)		-20.025	1.869	<0.001	-23.689	-16.361
large (>100000 €)		-22.253	2.390	<0.001	-26.938	-17.567
small (0-50000 €)		0	0			
Support area	a_4					
A		-1.506	4.879	0.758	-11.089	8.077
B		7.385	3.623	0.042	0.268	14.503
C1		-0.921	3.195	0.773	-7.195	5.354
C2		-2.513	2.903	0.387	-8.215	3.189
C2P-C4		0	0			
weight	a_5	-0.011	0.013	0.390	-0.036	0.014
Covariance parameters						
UN (1,1)	σ^2_{b0}	342.126	57.962	<0.001	245.459	476.864
UN (2,1)	$\sigma_{b0,b1}$	5.231	6.890	0.448	-8.274	18.735
UN (2,2)	σ^2_{b1}	2.774	1.205	0.021	1.184	6.499
Residual						
AR1 diagonal	σ^2	435.630	27.519	<0.001	384.898	493.048
AR1 rho	ρ	0.493	0.032	<0.001	0.428	0.554
Observations		4205				
-2 Restricted Log Likelihood		37439				
Akaike's Information Criterion (AIC)		37449				
Schwarz's Bayesian Criterion (BIC)		37481				

Results

- Costs increase year-to-year.
- The unit cost decreased as the number of cows increased.
  - To compensate annual cost increase farms should be expanded with two cows every year.
- Small farms had higher unit cost and annual variation than medium-sized and large farms.
  - Finnish dairy farms have developed fast and the benefits of scale may not have yet been accomplished.
- The farm location by support areas explains only slightly the unit cost.
- Productions costs change at different pace between farms.

Unit cost of milk

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Unit cost	Dairy Farms											
	Milk											
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Production Cost EUR	**126309**	**134796**	**144792**	**163543**	**178032**	**190969**	**223385**	**234833**	**246679**	**268653**	**298286**	**313385**
Production volume, litre	**184154**	**189148**	**206169**	**230800**	**256422**	**283455**	**301808**	**326025**	**345209**	**365013**	**386805**	**408334**
Unit cost EUR/litre	**0,69**	**0,71**	**0,70**	**0,71**	**0,69**	**0,67**	**0,74**	**0,72**	**0,71**	**0,74**	**0,77**	**0,77**
Seed cost*100	0	0	0	0	0	0	0	0	0	0	0	0
Fertilizer*100	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0
Crop Protection	0	0	0	0	0	0	0	0	0	0	0	0
Crop Supplies	0	0	0	0	0	0	0	0	0	0	0	0
Drying	0	0	0	0	0	0	0	0	0	0	0	0
Forage costs paid	6,9	6,9	7,1	7	7,1	7,2	8,5	7,6	7,2	8,6	9,4	10,2
Forage costs of own fodder	12,7	13,8	13,7	13,7	14	12,1	14,2	14,6	14,3	14,2	16	15
Livestock costs	3	2,8	2,9	2,8	2,8	2,8	3	3,2	3,2	3,2	3,4	3,4
Livestock purchasing	0,2	0,1	0,2	0,2	0,3	0,3	0,2	0,1	0,2	0,1	0,1	0,1
Animal breeding	7,7	8,2	8	9,2	8	7,6	9	8,4	7,9	9,2	9,4	9,3
Fuel and lubricants	0,5	0,5	0,5	0,7	0,7	0,7	0,9	0,7	0,8	1	1,2	1,2
Electricity	1,1	1,3	1,2	1,1	1,1	1,2	1,3	1,4	1,5	1,7	1,7	1,6
Heating	0,1	0,2	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Repair of buildings	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3
Repair of machinery	2,5	2,7	2,8	2,7	2,9	3,1	3,5	3,5	3,8	4	4,3	4,7
Other expenditure	2,7	2,8	2,6	2,6	2,8	2,9	3,1	3,2	3,1	3,4	3,6	3,7
Insurance	1,9	1,9	1,9	1,9	1,8	1,8	1,8	1,9	2	2	2,1	2,2
Rents paid	0,1	0,1	0,1	0,1	0,1	0,1	0,2	0,2	0,2	0,2	0,2	0,2
Labour cost	19,8	20,1	19,3	18,3	16,6	15,2	14,9	14,8	14,5	13,6	13,5	13,3
Depreciation and interest of machinery	3,7	3,9	3,9	4,4	4,5	4,8	5,4	5	4,9	4,8	4,6	4,6
Depreciation and interest of buildings	3,6	3,8	3,7	3,9	4,3	5,1	5,4	5,1	5,4	5,2	5,2	5,2
Depreciation and interest of construction	0	0	0	0	0	0	0	0	0	0	0	0
Interest costs of other assets	1,5	1,5	1,5	1,4	1,4	1,5	1,6	1,4	1,6	1,4	1,5	1,2

Thank you!

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