

# Structural change of European dairy farms – A cross-regional analysis

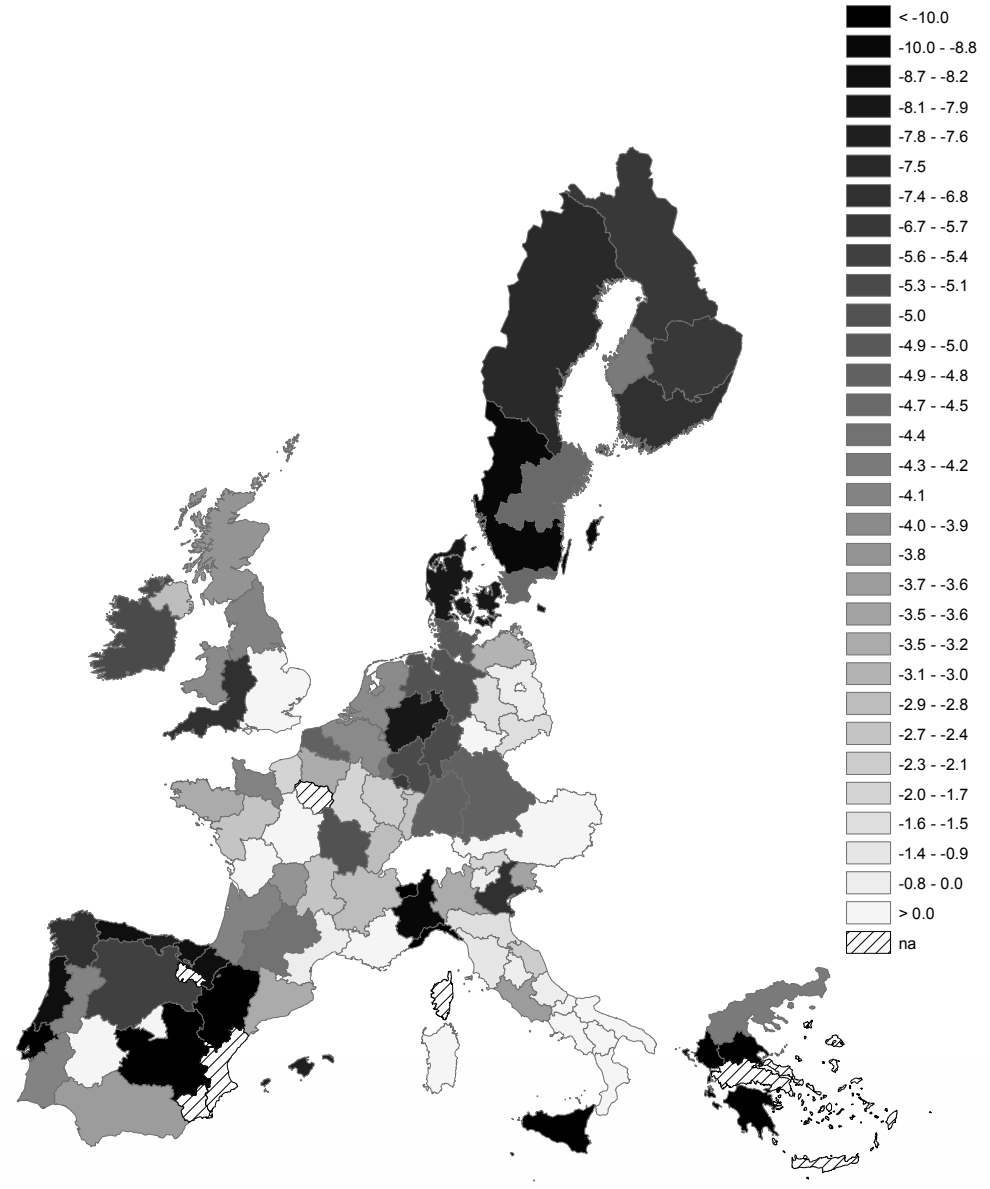
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# Background – Total farm numbers

- Data: Farm Accountancy Data Network (FADN)
- Average annual rate of change in EU15: -3.9%

Average annual change rate of dairy farms 1995-2005 [%]



## Background – size classes

Size class	Definition	Average annual change of farm numbers (%)	Standard deviation across the regions
SIZE1	< 20 cows	-10.5	9.5
SIZE2	20-39 cows	-3.9	7.1
SIZE3	40-79 cows	1.6	9.3
SIZE4	80-119 cows	4.4	8.3
SIZE5	≥ 120 cows	9.2	12.0

- Structural change: Change of the number of farms in different size classes
- Differences across regions
- What are the key exogenous factors explaining the differences in the regional development patterns?

# Markov chain approach

- Transition probability matrix

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1N} \\ p_{21} & p_{22} & \cdots & p_{2N} \\ \vdots & \vdots & \vdots & \vdots \\ p_{N1} & p_{N2} & \cdots & p_{NN} \end{bmatrix}$$

- Non-stationary Markov chain  $n_{jt} = \sum_{i=1} n_{it-1} P_{ijt}$

- Probability constraints:  $p_{ijt} \geq 0$  and  $\sum_j p_{ijt} = 1$

- Relation between transition probabilities and explanatory variables

$$p_{ijt} = f_{ij}(Z_t, \beta)$$

- 5 size classes + 1 artificial entry/exit class per region
  - SIZE1 (< 20 cows)
  - SIZE2 (20-39 cows)
  - SIZE3 (40-79 cows)
  - SIZE4 (80-119 cows)
  - SIZE5 ( $\geq$  120 cows)
- FADN data for EU15
  - Farms classified as ‘specialist milk’
  - 1995-2005
  - 94 FADN regions
  - Number of farms per size class (macro data)
  - Movements of sample farms (micro data)

## Step1: Transition probabilities

$$\min \left[ \sum_i \sum_j \sum_t p_{ijt} \ln(p_{ijt}/q_{ijt}) + \sum_m \sum_j \sum_t w_{mjt} \ln(w_{mjt}/u_{mjt}) \right]$$

$$\text{s.t.} \quad y_{jt} = \sum_i y_{it-1} p_{ijt} + \sum_m v_m w_{mjt} \quad \forall j, t$$

$$\sum_j p_{ijt} = 1, \quad \sum_m w_{mjt} = 1 \quad \text{and} \quad p_{ijt}, w_{mjt} \geq 0$$

- Generalised cross-entropy approach
- Minimises the difference between estimated probabilities and prior information
- Farm numbers (in shares): macro data
- Prior information: micro data

# Transition probability matrix

	SIZE1	SIZE2	SIZE3	SIZE4	SIZE5	EXIT
SIZE1	0.863	0.079	0.001	0.000	0.000	0.056
SD region	0.094	0.084	0.009	0.001	0.001	0.056
SD time	0.012	0.004	0.001	0.000	0.001	0.011
SIZE2	0.039	0.839	0.069	0.000	0.000	0.052
SD region	0.038	0.065	0.043	0.001	0.001	0.048
SD time	0.004	0.011	0.005	0.000	0.000	0.012
SIZE3	0.003	0.069	0.841	0.034	0.002	0.051
SD region	0.012	0.079	0.106	0.036	0.013	0.060
SD time	0.000	0.004	0.010	0.006	0.001	0.009
SIZE4	0.000	0.002	0.096	0.811	0.047	0.043
SD region	0.000	0.011	0.115	0.144	0.070	0.037
SD time	0.000	0.000	0.005	0.012	0.004	0.008
SIZE5	0.011	0.003	0.004	0.083	0.861	0.038
SD region	0.102	0.026	0.023	0.192	0.222	0.038
SD time	0.001	0.001	0.002	0.004	0.015	0.008
ENTRY	0.001	0.001	0.001	0.001	0.001	0.996
SD region	0.004	0.003	0.002	0.001	0.002	0.008
SD time	0.001	0.001	0.001	0.001	0.001	0.005

## Step 2: Regression analysis

Multinomial logit representation:

$$p_{ijrt} = \frac{\exp(\mathbf{z}_{irt} \boldsymbol{\beta}_{ij})}{1 + \sum_{k=1}^{s-1} \exp(\mathbf{z}_{irt} \boldsymbol{\beta}_{ik})}, \quad i = 1, \dots, s \quad j = 1, \dots, s-1$$

and

$$p_{isrt} = \frac{1}{1 + \sum_{k=1}^{s-1} \exp(\mathbf{z}_{irt} \boldsymbol{\beta}_{ik})}, \quad i = 1, \dots, s$$

Linearisation:

$$\ln\left(\frac{p_{ijrt}}{p_{ikrt}}\right) = \mathbf{z}_{irt} \boldsymbol{\beta}_{ij} \quad \text{for } i = 1, 2, \dots, s \quad \text{and} \\ j = 1, 2, \dots, s-1 \quad \text{and } k = s$$

- Effect of exogenous variables on transition probabilities → probability elasticities
- Probability elasticities: Effect of a 1% change in the  $l$ th explanatory variable on each transition probability



# Determinants and hypotheses

		Growth	Decline	Entry	Exit
Technology	Trend	+	-	-	+
	Milk yield (kg/cow)	+	-	0	-
Farm structure	Initial farm size (cows)	+/-	-	-	-
	Gini coefficient of dairy farms (index)	+	+	+	+
	Gini coefficient of the other farms (index)	+	+	+	+
	Stocking density (LU/forage ha)	+	-	+	-
Market conditions	Milk price over time (€/kg)	-	-	+	-
	Milk price across regions (€/kg)	-	-	+	-
	Milk price coefficient of variation (€/kg)	+/-	-	-	+
	Land rent (€/ha)	+	+	0	+
Natural resources	Share of grassland (%)	-	+	-	+
	Slope (%)	-	+	-	+
	Temperature sum (°C)	+/-	+/-	0	+/-
Social and demographical factors	Population density (population/km <sup>2</sup> )	+	-	0	-
	Population growth (%)	-	+	-	+
	Unemployment (%)	+/-	-	+	-
	Share of farmers > 55 years (%)	-	+	0	+

# Estimated coefficients

		Constant	Trend	Milk yield	Initial size	Gini dairy farms	Gini all farms	Stocking density	Milk price over time	Regional milk price	Milk price volatility	Land rent	Share of grassland	Slope	Temperature sum	Population density	Population growth	Unemployment	Age	R <sup>2</sup>
Own size	p11	11.943 ***	-0.041	-0.001 ***	0.030 ***	-2.173 *	-0.593	0.142 ***	4.518	-10.886 ***	3.743	0.000	-0.025 ***	0.115 ***	-0.286 *	0.002 **	-1.281 ***	0.198 ***	-0.055 ***	0.191
	p22	10.954 ***	-0.018	-0.001 ***	0.026 ***	-0.514	-3.010 **	0.200 ***	3.268	-7.798 **	2.539	0.000 ***	-0.030 ***	0.104 ***	-0.205 *	0.001 *	-0.054	0.108 ***	-0.029 ***	0.131
	p33	10.614 ***	0.025	-0.001 ***	0.027 ***	3.078 ***	-4.964 ***	0.158 ***	0.609	-8.609 ***	0.946	0.000 **	-0.035 ***	0.085 ***	-0.231 *	0.002 ***	-0.188	0.115 ***	-0.021 **	0.151
	p44	5.164 **	0.022	0.000	-0.015 **	-15.184 ***	12.286 ***	0.675 ***	1.522	-0.007	-27.158 ***	-0.001 ***	0.011	0.140 ***	-1.151 ***	0.002 **	-0.180	0.373 ***	0.036 ***	0.302
	p55	0.800	0.035	-0.001 ***	-0.009	-17.385 ***	16.932 ***	0.304 ***	0.167	45.776 ***	-76.935 ***	-0.001 ***	0.016	-0.023	-0.744 ***	-0.001	-0.359	0.048	-0.001	0.205
Entry	pe1	-17.283 ***	-0.086 ***	0.000	-0.001	0.007	-0.913	-0.044 *	2.711	3.229 **	0.000	0.000	-0.012 ***	0.054 ***	0.208 ***	-0.001 **	0.115	0.039 **	0.001	0.098
	pe2	-15.243 ***	-0.060 **	0.000	-0.003	-1.403 *	0.602	0.081 **	8.581 **	-0.576	-3.239	0.000	-0.004	0.043 ***	0.073	0.000	-0.339 *	0.031	0.010 *	0.060
	pe3	-17.070 ***	0.051 ***	0.000 **	-0.006 *	2.293 **	-0.371	-0.104 ***	4.076	-4.455 **	9.633 **	0.000	-0.002	0.040 **	0.206 **	0.001	0.018	0.040 *	-0.014 **	0.040
	pe4	-21.078 ***	0.131 ***	0.000 *	0.006	-2.896 **	0.913	-0.009	4.980	8.533 ***	-9.135 *	0.000	-0.002	0.048 **	-0.071	0.001 *	0.724 **	0.042	0.013	0.045
	pe5	-19.361 ***	0.219 ***	0.000	-0.006	-1.283	3.669 **	-0.013	7.154	-0.741	4.926	0.000 **	-0.001	0.008	0.052	0.001 **	0.376	0.084 **	-0.011	0.046
Growth	p12	0.170	-0.080 *	0.000	-0.038 ***	10.670 ***	0.500	-0.032	6.537	-5.323	-7.254	-0.002 ***	0.010	0.028	-0.282 *	0.003 ***	1.008 **	0.136 ***	-0.053 ***	0.130
	p13	-2.833	-0.013	-0.001 ***	0.026 ***	0.901	0.920	0.095 *	3.861	-9.737 **	17.088 **	0.000	-0.022 **	0.061 **	-0.430 **	0.000	-0.251	0.172 ***	-0.040 ***	0.122
	p14	-10.944 ***	0.002	0.000	0.037 ***	-3.253 **	-0.262	0.253 ***	6.380	-0.799	-5.915	0.000	-0.013	0.136 ***	-0.292 *	0.004 ***	-0.821 **	0.205 ***	-0.059 ***	0.151
	p15	-6.226 **	0.034	-0.001 ***	0.030 ***	-4.394 ***	3.236 *	0.203 ***	-1.818	-7.171 *	8.411	0.000	-0.026 ***	0.080 ***	-0.308 *	0.002 **	-1.131 ***	0.156 ***	-0.069 ***	0.152
	p23	6.998 ***	0.029	0.000 **	0.007	7.432 ***	-7.558 ***	0.205 ***	2.851	1.339	-18.105 **	0.000 **	-0.023 **	0.021	0.072	0.001 *	-0.789 **	-0.148 ***	-0.071 ***	0.115
	p24	-14.464 ***	0.058	0.000	0.034 ***	-2.599 *	-5.383 ***	0.160 ***	4.595	8.676 **	-15.517 **	0.000 **	-0.027 ***	0.187 ***	-0.121	0.002 ***	0.716 **	0.193 ***	-0.001	0.118
	p25	-7.438 ***	0.043	0.000 *	0.017 ***	-1.180	-1.458	0.241 ***	0.971	-12.594 ***	18.201 ***	0.000 *	-0.027 ***	0.124 ***	-0.161	0.001 *	-0.369	0.125 ***	-0.031 ***	0.081
	p34	-9.918 ***	0.104 **	0.001 ***	0.045 ***	18.920 ***	-7.253 ***	-0.297 ***	4.516	-10.444 **	-10.107	0.000	-0.029 ***	0.083 **	0.784 ***	0.002 **	-0.460	-0.175 ***	-0.069 ***	0.285
	p35	-10.548 ***	0.059	0.000	0.054 ***	-5.206 ***	-1.664	0.412 ***	0.548	-0.657	12.372 *	0.000 **	-0.050 ***	0.219	0.085	0.001	-1.613 ***	-0.161 ***	-0.024 **	0.171
	p45	-10.028 ***	0.023	0.002 ***	-0.027 ***	6.265 ***	11.045 ***	0.584 ***	0.004	-36.737 ***	28.195 ***	0.001 ***	0.020 *	0.266 ***	-1.405 ***	0.006 ***	-0.729 *	0.294 ***	0.003	0.257
Decline	p21	1.997	-0.013	-0.001 ***	-0.006	5.951 ***	-2.284	0.003	3.682	7.068 *	20.103 ***	-0.001 ***	0.007	0.002	-0.134	0.001	-0.002	-0.036	-0.092 ***	0.159
	p31	-6.833 ***	0.030	-0.001 **	0.014 **	8.062 ***	-3.150 *	-0.034	-0.871	3.930	-11.495 *	0.000 ***	-0.025 **	0.061 **	0.093	0.003 ***	0.157	-0.355 ***	0.034 **	0.170
	p32	0.335	0.008	0.000	0.042 ***	4.116 **	-12.498 ***	0.445 ***	1.307	4.267	-13.459 *	0.000	-0.007	0.126 ***	0.312 *	0.000	-0.316	-0.193 ***	-0.031 **	0.144
	p41	-14.128 ***	0.017	0.000	-0.017 ***	-14.633 ***	11.574 ***	0.665 ***	1.678	5.882 *	-37.262 ***	-0.001 ***	0.005	0.174 ***	-0.881 ***	0.002 **	-0.039	0.310 ***	0.048 ***	0.290
	p42	-13.297 ***	0.008	0.000	-0.019 ***	-11.433 ***	10.436 ***	0.556 ***	1.676	1.218	-37.259 ***	-0.001 ***	-0.002	0.382 ***	-1.480 ***	0.001 *	0.044	0.389 ***	0.070 ***	0.382
	p43	-20.364 ***	0.017	0.001 ***	0.030 ***	7.465 ***	-4.270 **	0.273 ***	1.075	18.262 ***	-64.172 ***	0.001 ***	0.108 ***	-0.034	0.435 **	0.004 ***	-0.807 **	0.160 ***	0.010	0.254
	p51	-1.085	0.037	-0.001 ***	-0.024 ***	-11.993 ***	11.541 ***	0.117 *	1.175	20.341 ***	-53.571 ***	-0.001 ***	-0.030 ***	-0.022	-0.149	-0.003 ***	-1.015 **	-0.076	0.005	0.214
	p52	-3.531	0.015	-0.002 ***	-0.005	-16.322 ***	13.067 ***	0.117 *	0.750	35.026 ***	-65.702 ***	-0.002 ***	-0.018 *	0.038	-0.896 ***	-0.005 ***	-0.645 *	-0.072	0.057 ***	0.267
	p53	-2.431	0.023	-0.002 ***	0.016 **	-22.114 ***	16.910 ***	0.294 ***	-0.011	24.655 ***	-45.773 ***	-0.002 ***	0.021 **	0.032	-0.912 ***	0.000	-0.303	-0.126 **	0.025 *	0.234
	p54	-0.649	0.021	0.000	-0.004	-16.906 ***	13.559 ***	0.340 ***	0.282	8.914 *	-18.066 **	-0.001 ***	0.004	-0.137 ***	-0.557 **	0.003 ***	-3.258 ***	-0.266 ***	0.034 **	0.167

\*\*\*:1%, \*\*:5%, \*:10% level of significance

- Most coefficients highly significant for many of the log-odds ratios
- Trend significant only for entry, milk price over time not significant at all
- R<sup>2</sup> for entry very low (0.058 on average), for the other transition probabilities on average 0.194

# Probability elasticities

		Constant	Trend	Milk yield	Initial size	Gini dairy farms	Gini all farms	Stocking density	Milk price over time	Regional milk price	Milk price volatility	Land rent	Share of grassland	Slope	Temperature sum	Population density	Population growth	Unemployment	Age
Own size	p11	1.636	0.003	-0.576	0.288	-0.340	-0.053	0.064	0.033	-0.342	0.053	0.059	-0.165	0.103	-0.063	-0.005	-0.097	0.130	-0.092
	p22	1.207	-0.021	-0.265	0.149	-0.267	0.056	0.056	0.059	-0.531	0.043	-0.001	-0.133	0.124	-0.125	0.004	0.014	0.236	0.084
	p33	2.046	-0.001	-0.842	-0.023	-0.154	0.139	0.000	-0.047	-0.436	0.074	-0.029	-0.149	0.008	-0.326	0.028	0.003	0.329	0.021
	p44	3.436	0.006	-1.338	-0.174	-1.230	0.905	0.161	0.058	-0.014	-0.043	-0.138	-0.384	0.107	-0.722	-0.041	0.023	0.326	0.125
	p55	0.197	0.012	-0.493	-0.032	-0.241	0.413	0.026	-0.004	1.632	-0.411	-0.044	0.078	0.034	-0.196	-0.059	0.055	0.261	-0.084
	pee	0.068	-0.002	-0.002	0.000	0.001	-0.001	0.000	-0.007	-0.001	0.000	0.000	0.001	-0.002	-0.002	-0.001	0.000	-0.002	0.000
Exit	p1e	-10.307	0.187	3.237	-0.926	0.328	0.206	-0.297	-1.439	3.205	-0.139	-0.018	0.764	-0.786	0.996	-0.313	0.288	-1.578	1.219
	p2e	-9.748	0.063	3.266	-0.886	-0.109	1.370	-0.451	-1.006	2.010	-0.087	0.221	0.987	-0.676	0.637	-0.153	0.030	-0.695	0.771
	p3e	-8.569	-0.114	2.381	-1.099	-1.099	2.307	-0.400	-0.245	2.369	0.025	0.141	1.147	-0.650	0.530	-0.236	0.059	-0.668	0.506
	p4e	-1.729	-0.091	0.107	0.436	3.433	-4.458	-1.554	-0.438	-0.011	1.348	0.209	-0.804	-0.970	3.550	-0.392	0.077	-2.896	-0.728
	p5e	-0.602	-0.146	3.952	0.336	5.098	-6.979	-0.746	-0.058	-13.284	3.530	0.576	-0.516	0.209	2.564	0.138	0.163	-0.151	-0.059
Entry	pe1	-17.215	-0.388	0.186	-0.047	0.003	-0.400	-0.110	0.877	1.051	-0.155	0.018	-0.446	0.414	0.769	-0.131	0.034	0.333	0.028
	pe2	-15.175	-0.271	-0.367	-0.139	-0.430	0.262	0.205	2.790	-0.189	-0.166	-0.007	-0.132	0.327	0.269	-0.041	-0.102	0.270	0.242
	pe3	-17.002	0.230	1.270	-0.247	0.705	-0.164	-0.263	1.321	-1.453	0.493	0.050	-0.076	0.307	0.763	0.095	0.005	0.344	-0.324
	pe4	-21.010	0.590	1.532	0.258	-0.889	0.397	-0.024	1.616	2.779	-0.468	0.006	-0.058	0.372	-0.267	0.191	0.217	0.357	0.315
	pe5	-19.293	0.985	0.644	-0.243	-0.393	1.600	-0.034	2.324	-0.243	0.252	0.166	-0.028	0.060	0.193	0.241	0.113	0.726	-0.266
Growth	p12	-10.137	-0.172	3.934	-2.457	3.604	0.424	-0.378	0.691	1.471	-0.510	-0.740	1.148	-0.570	-0.049	0.166	0.591	-0.404	-0.042
	p13	-13.140	0.126	-2.847	0.097	0.605	0.607	-0.057	-0.181	0.032	0.737	0.049	-0.060	-0.314	-0.598	-0.364	0.213	-0.092	0.269
	p14	-21.251	0.194	2.022	0.535	-0.671	0.091	0.345	0.640	2.945	-0.442	0.086	0.287	0.261	-0.088	0.253	0.041	0.197	-0.171
	p15	-16.533	0.340	-0.405	0.289	-1.022	1.619	0.218	-2.031	0.869	0.292	0.082	-0.194	-0.170	-0.147	-0.036	-0.052	-0.230	-0.425
	p23	-2.749	0.192	0.910	-0.602	2.173	-1.929	0.070	-0.077	2.446	-1.014	0.012	0.122	-0.515	0.906	0.074	-0.207	-1.972	-0.917
	p24	-24.211	0.324	3.445	0.476	-0.907	-0.980	-0.044	0.492	4.837	-0.882	0.026	-0.016	0.770	0.187	0.213	0.246	0.972	0.743
	p25	-17.185	0.257	1.615	-0.198	-0.472	0.734	0.162	-0.689	-2.094	0.845	0.064	-0.007	0.282	0.038	0.065	-0.081	0.386	0.029
	p34	-18.487	0.351	10.186	0.698	4.711	-0.860	-1.155	1.226	-1.034	-0.492	0.248	0.071	-0.011	3.440	0.076	-0.079	-2.182	-1.116
	p35	-19.117	0.152	2.492	1.062	-2.698	1.580	0.646	-0.067	2.155	0.659	-0.085	-0.732	1.037	0.846	-0.089	-0.426	-2.063	-0.052
	p45	-11.757	0.014	8.745	-0.633	5.357	0.363	-0.072	-0.436	-11.982	2.792	0.583	-0.060	1.080	-1.662	0.561	-0.142	-0.351	-0.649
Decline	p21	-7.750	0.004	-0.236	-1.110	1.718	0.373	-0.442	0.194	4.313	0.943	-0.436	1.266	-0.664	0.141	-0.045	0.030	-1.005	-1.416
	p31	-15.402	0.022	-0.669	-0.521	1.377	0.931	-0.485	-0.529	3.650	-0.563	-0.160	0.198	-0.181	0.874	0.213	0.106	-3.737	1.308
	p32	-8.234	-0.079	3.588	0.566	0.165	-3.149	0.730	0.181	3.759	-0.664	0.149	0.882	0.320	1.688	-0.302	-0.036	-2.335	-0.223
	p41	-15.856	-0.014	0.117	-0.232	-1.060	0.594	0.133	0.109	1.906	-0.561	-0.120	-0.631	0.368	0.280	-0.137	0.065	-0.218	0.403
	p42	-15.025	-0.054	1.017	-0.320	-0.078	0.098	-0.143	0.108	0.385	-0.561	-0.041	-0.884	1.971	-1.940	-0.173	0.090	0.464	0.920
	p43	-22.092	-0.017	6.757	1.636	5.726	-6.322	-0.860	-0.087	5.939	-1.939	0.599	3.246	-1.229	5.165	0.255	-0.166	-1.509	-0.499
	p51	-1.687	0.020	-4.148	-0.618	1.415	-1.941	-0.448	0.324	-6.656	0.786	-0.091	-1.636	0.041	2.010	-0.411	-0.142	-0.810	0.064
	p52	-4.134	-0.078	-4.804	0.151	0.086	-1.275	-0.449	0.186	-1.871	0.164	-0.116	-1.189	0.503	-0.759	-0.615	-0.031	-0.775	1.286
	p53	-3.034	-0.041	-4.939	0.964	-1.693	0.403	0.001	-0.062	-5.250	1.185	-0.284	0.278	0.457	-0.822	0.073	0.072	-1.240	0.524
	p54	-1.251	-0.054	4.040	0.193	-0.094	-1.060	0.117	0.034	-10.379	2.605	0.161	-0.376	-0.846	0.495	0.695	-0.817	-2.449	0.751



		Growth			Decline			Entry			Exit		
		Exp	Est		Exp	Est		Exp	Est		Exp	Est	
Technology	Trend	+	90	✓	-	70	✓	-	40		+	40	
	Milk yield	+	80	✓	-	50		0	80		-	0	
Farm structure	Farm size	+/-	40	✓	-	50		-	80	✓	-	60	✓
	Farm size heterogeneity (dairy)	+	50		+	60	✓	+	40		+	60	✓
	Farm size heterogeneity (all)	+	70	✓	+	50		+	60	✓	+	60	✓
	Stocking density	+	50		-	60	✓	+	20		-	100	✓
Market conditions	Milk price over time	-	60	✓	-	30		+	100	✓	-	100	✓
	Milk price across regions	-	30		-	40		+	40		-	40	
	Milk price volatility	+/-	50	✓	-	50		-	60	✓	+	60	✓
	Land rent	+	80	✓	+	30		0	80		+	80	✓
Natural resources	Share of grassland	-	60	✓	+	50		-	100	✓	+	60	✓
	Slope	-	50		+	60	✓	-	0		+	20	
	Temperature	+/-	50	✓	+/-	70		0	80		+/-	100	
Social and demographic factors	Population density	+	70	✓	-	60	✓	0	60		-	80	✓
	Population growth	-	60	✓	+	50		-	20		+	100	✓
	Unemployment	+/-	30		-	90	✓	+	100	✓	-	100	✓
	Age	-	70	✓	+	70	✓	0	60		+	60	✓

- Combination of micro and macro data
- EU15-wide cross-sectional analysis of dairy farm structural change
- Considerable cross-regional variance
- Overall, relevance of assumed key factors of structural change confirmed
- Results reveal complexity of structural change process