Modelling structural change in ex-ante policy impact analysis

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Abstract. Model-based ex-ante policy impact analyses are nowadays widely used in agricultural policy consulting. However, so far very few existing applications try to assess the impact on farm numbers and the re-allocation of resources between farms, and due to data availability, these studies generally use normative or ad-hoc decision rules on farm exits. In this paper, we fill this gap, combining an empirically-based estimation of profit-dependent farm exit probabilities with prospective modelling of farm adjustments and selected factor markets. This study combines farm-individual information from farm structural surveys for 1999, 2003 and 2007 and economic information from farm accountancy data for Germany. The estimated model explains farm exit probabilities depending on current and expected future profits, the expected development of competitors (e.g., neighbouring farms competing on the land market), and farm and regional structural characteristics influencing farms' strategic decision making. The econometric exit model is iteratively coupled to a representative farm group model for Germany, facilitating the ex-ante analysis of complex policy reforms. A first application on dairy market reform scenarios highlights the diverging impacts these may have on the developments of the number of dairy farms of different size or regions, and their income and output.

Keywords: Farm Model, Ex-ante Analysis, Structural Change.

1. Introduction

The use of models for ex-ante analysis of policy changes is widespread in the domain of agriculture. However, prospective farm level analyses are generally restricted to the modelling of adjustments with respect to the level of production activities, production intensity and the allocation of resources. Very few attempts have been made to model potential impact of future policy changes on farm numbers and the related re-allocation of resources between farms. This is partly due to the numerous challenges to modelling structural change (e.g., the complex and often strategic nature of respective decisions; the heterogeneity of farm(er)s; the interlinkages between farms; the complex interaction with policies; etc.), but also a consequence of limited data availability.

Most of the existing approaches to model future developments of farm numbers are based on Markov-Chain analyses (Zimmermann et al., 2009). Non-stationary models allow accounting for the influence of changes in exogenous variables. However, the potential for prospective policy analyses is limited by the generally rather aggregated level of the estimated model, ignoring regional specificity of structural change. Furthermore, all existing studies use only indirect proxies for changes in farm profitability, which limits the type of policy scenarios which can be analysed. In addition, the consistency of total use of fixed resources (e.g. land, quota) is not ensured.

Multi-agent models (e.g. Balmann et al., 1997; Happe, 2004) provide an interesting alternative, as they are well suited to capture the key factors of farm structural change in a bottom-up approach by accounting for heterogeneity and interaction between agents while at the same time allowing a detailed representation of farm business. However, at individual level personal traits are very important determinants for exit decisions, and respective data availability is very limited. Thus, in existing studies (e.g., Freeman, 2005; Kellermann et al., 2008) the decision rules for farm exit are generally based on ad-hoc / normative rules (e.g., a farm is assumed to exit if income falls below a certain normatively set level).

Only few attempts have been made to overcome some of these limitations by combining empirically-based estimates of the impact of economic parameters on structural change and a prospective modelling of farm performance. Henningsen et al. (2005) project farm income development under a Mid Term Review (MTR) scenario and use the results as inputs to an econometrically estimated farm succession model (Tietje, 2004), but do not consider land markets and respective interrelations. They found that

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although the MTR clearly reduces the incomes of several farm types, it does not significantly affect the rate of farm structural change. Hennessy and Rehman (2006) combine econometrically estimated models of entry-exit and off-farm labour allocation with prospective modelling of farm income development based on linear programming models. The modelling system was applied for an analysis of the impacts of the Mid Term Review of the CAP on Irish agriculture, and showed that farm numbers will decline more rapidly under decoupling relative to a baseline situation.

Against this background, the objective of this is paper is to develop and apply a model system which projects future structural change in agriculture under different policy or market scenarios. Specifically, the aim is to combine an empirically-based estimation of profit-dependent farm exit probabilities with a simulation model that provides prospective modelling of farm adjustments and land and quota markets, and to examine the effects that the endogenous modelling of structural change has on the results (e.g., production, income, etc.) of ex-ante policy impact analysis. We also want to explicitly evaluate how endogenously taking account for structural change alters results compared to a trend-based extrapolation of structural change.

The rest of the paper is structured as follows: First, a brief overview of the formulation and data used for the estimation of the exit model and the specification of the simulation model is given, followed by a description of the linkage between the two models. Using a baseline scenario, we evaluate the impact of endogenously taking account for structural change compared to a trend-based extrapolation of structural change. The effects of changes to the economic conditions on farm numbers are then illustrated for two dairy market scenarios. The paper ends with a discussion of results and future research implications.

2. Methods and data

2.1. The farm exit model

Structural change in agriculture is affected by a multitude of factors, e.g. technology, prices, human capital, off-farm income, demographics, market structure, or political environment. An overview and discussion of existing research is given in Boehlje (1990), Goddard et al. (1993) and Harrington and Reinsel (1995). Empirical studies of the importance of individual factors on the decision to exit farming highlight, that the impact of economic performance criteria strongly depends on farm and farmer characteristics (e.g., Sumner and Leiby, 1987; Bremmer et al., 2004; Weiss, 1999; Juvanicic, 2006; and the overview in Mann, 2003). There are two further important aspects which contribute to the challenge of understanding and projecting structural change in agriculture: Firstly, land is a key production factor, but is limited and immobile, and thus there is a close interdependency between a farmer's own decision to exit farming and those of her neighbours, giving rise to strategic elements in decision making (Margarian, 2010a). Secondly, sunk costs and the existence of status-quo rents can lead to a persistence of 'suboptimal' equilibria, a phenomenon known as path dependency (Balmann, 1995). Margarian (2010a) thus found that that initial regional farm structure is a key factor determining structural change.

In view of the findings of the literature, the aim was to specify an econometric model which takes into account farm and farmer characteristics and own and neighbouring farms' (future) economic performance while accounting for the regional specificity of structural change (Figure 1).

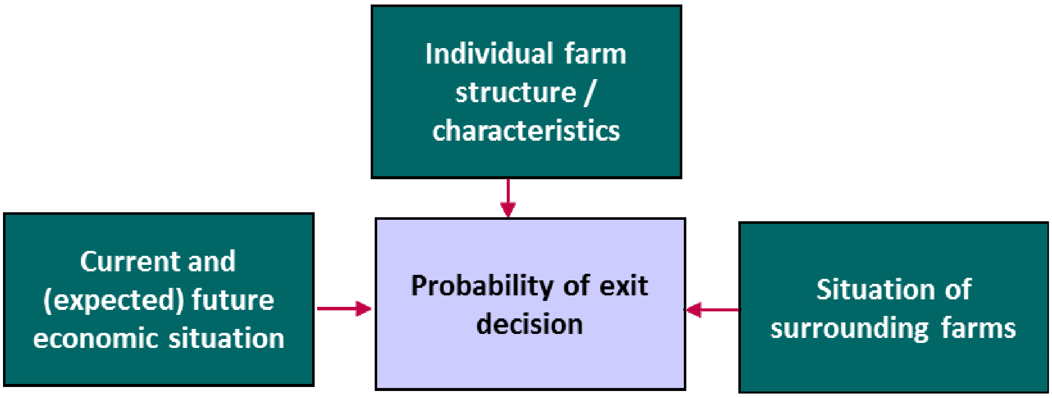


Figure 1. Determinants of farm exit decisions in the estimated exit model

The econometric estimation of profit-dependent farm exit probabilities is hampered by data availability. The farm accountancy data network (FADN), which provides extensive information on the economic performance of farms, is organized as a rotating panel, and does not allow determining whether a farm exits the survey due to the closing down of the farm or other reasons. The farm structural survey on the other hand provides information on farm exits but does not include information on the economic performance. Data protection rules prevent a linking of the data on single farm level (and thus, for example, the identification of exiting farms in FADN). Therefore, in a first step a detailed profit model was estimated based on German FADN data for the period 1998-2007. In this model, expected profits depend on farm structural characteristics such as resources (e.g., own and rented land, family and hired labour), animal numbers and cropping areas. Using this model, individual farm data from the farm structural surveys (FSS) from 1999, 2003 and 2007 for West Germany (575,000 observations) were then supplemented with estimated profits.

A logistic regression model (Equation 1) was then estimated, with the exit probability depending on

- current profits (profit level),
- expected profit development (allowing for asymmetric impact of positive and negative development) with fixed resources, and
- the development of regional profitability.

$$\ln\left(\frac{p}{1-p}\right) = logit(p) = X_{Type,Size,Region} =$$

$$\begin{aligned}
& C + CT_{Type} + CS_{Size} + CR_{Region} + CTS_{Type,Sizte} + CRS_{Region,Sizte} + CRT_{Region,Typ} \\
& + \left(\beta MGEW + \beta MGEWS_{Size} + \beta MGEWR_{Region}\right) \bullet MGEW \\
& + \left(\beta KGEW + \beta KGEWS_{Size} + \beta KGEWR_{Region}\right) \bullet KGEW \\
& + \left(\beta PGEW + \beta PGEWS_{Size} + \beta PGEWR_{Region} + \beta PGEWT_{Type}\right) \bullet PGEW \\
& + \left(\beta NGEW + \beta NGEWS_{Size} + \beta NGEWR_{Region} + \beta NGEWT_{Type}\right) \bullet NGEW
\end{aligned} \quad (1)$$

MGEW = profit level (difference to average farm profits)

KGEW = expected change in profits of neighbours (=average regional profits)

PGEW = expected change in profits (if positive; else 0)

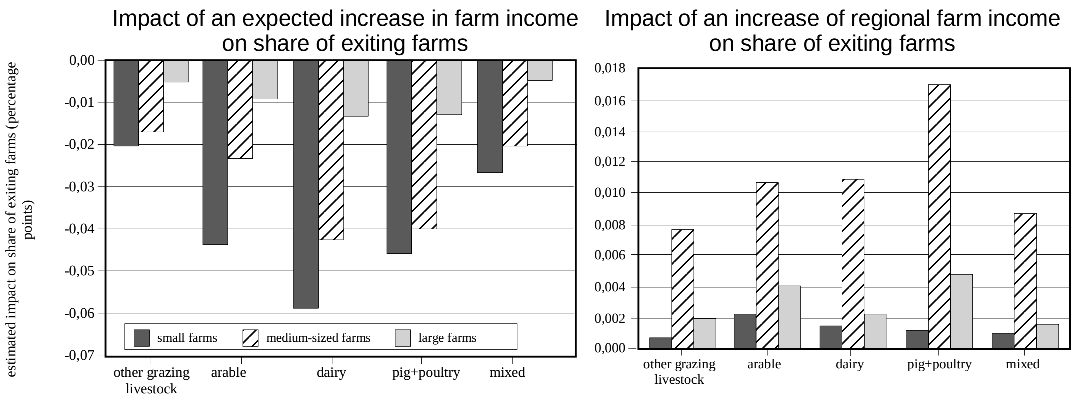
NGEW = expected change in profits (if negative; else 0)

The parameters are differentiated by region (42), farm type (4), and farm size (3), with the definitions of these characteristics aligned to those used in the farm model FARMIS. The reference farm for the estimation of the coefficients is a small dairy farm in region 1 (Schleswig-Holsteinische Marsch). The model has more than 600 estimated parameters[2], which reflects the complexity of structural change phenomena, but also raises significant challenges for the interpretation and condensation of results. ‘Expected profit developments’ here refers to the profits expected after a period of four years and were estimated at fixed resources, to reduce issues of endogeneity (profits are influenced by realised growth, growth realised depends on expected profits and thus probability to exit farming).

For the ex-ante exit model used in the modelling exercise, the share of farms which exit farming in a specific farm group defined by farm type, size and region can then be calculated as

$$Exit\,\mathrm{Pr}\,ob_{Type,Size,\mathrm{Re}gion} = \frac{e^{X_{Type,Size,\mathrm{Re}gion}}}{1+e^{X_{Type,Size,\mathrm{Re}gion}}} \qquad (2)$$

Due to the many interaction terms and the heterogeneity of regional results, the influence of changes of single exogenous variables on exit rates cannot easily be deduced from the estimated coefficients. Therefore, the impact of pre-defined isolated changes of profitability was calculated for all combinations of regions, farm sizes and farm types and compared to the results of the model with no changes in exogenous variables. Figure 2 provides an overview of the average impact on the share of exiting farms for an expected increase in farm income (of 10000 EUR/farm), and an expected increase in regional farm income (of 10000 EUR/farm). These results highlight that an expected increase of profits reduces the share of exiting farms, especially for small arable, dairy and pig & poultry farms. On the other hand, an increase of regional farm income increases the exit probability due to increased competition, especially for medium sized farms. However, the diversity of results across regions is often large.



Source: Margarian (2010b)

Figure 2: Illustration of the impact of selected changes in economic variables on farm exit rates

2.2. The farm and market models

Farm model FARMIS

FARMIS is a comparative-static process-analytical programming model for farm groups (Osterburg et al., 2001; Bertelsmeier, 2005; Offermann et al., 2005). Production is differentiated for 27 crop and 15 livestock activities. The matrix restrictions cover the areas of feeding (energy and nutrient requirements, calibrated feed rations), intermediate use of young livestock, fertilizer use (organic and mineral), labour (seasonally differentiated), crop rotations and political instruments (e.g., set-aside and quotas). The model specification is based on information from the German farm accountancy data network covering about 11,000 farms, supplemented by data from farm management manuals. Data from three consecutive accounting years is averaged to reduce the influence of yearly variations common in agriculture (e.g., due to weather conditions) on model specification and income levels. Key characteristics of FARMIS are: 1) the use of aggregation factors that allow for representation of the sectors’ production and income indicators; 2) input-output coefficients which are consistent with information from farm accounts; and 3) the use of a positive mathematical programming procedure to calibrate the model to the observed base

[2] The results of the estimation are documented in Margarian (2010b)

year levels. Prices are generally exogenous and are provided by market models. An exception to this applies to specific agricultural production factors, such as the milk quota, land, and young livestock, where (simplified) markets are modelled endogenously, allowing the derivation of respective equilibrium prices under different policy scenarios. FARMIS uses farm groups rather than single farms not only to ensure the confidentiality of individual farm data, but also to increase manageability and the robustness of the model system when dealing with data errors that may exist in individual cases. Homogenous farm groups are generated by the aggregation of single farm data. For this study, farms were stratified by region, type, and size, resulting in 467 farm groups which represent the western German agricultural sector.

In the current FARMIS implementation, farm exits are exogenous and the projection of farm numbers to the target year is based on an extrapolation of historical exit rates, which are derived from the FSS differentiated by region, farm type and farm size.

2.3. Linking the models

The basic idea for our approach is to use the simulation model FARMIS to estimate expected future profits, and to use the econometrically estimated exit model to determine profit-dependent exit rates (Figure 3). These exit rates can be implemented in the FARMIS model for the projection of the aggregation factors of the farm groups. As the exit model uses expected future profits at fixed resources as an exogenous variable, in a first step FARMIS accordingly needs to be run with farms' resources fixed at their current level, and then in a second step FARMIS is re-run with adjusted farm numbers to reallocate resources and determine new profits.

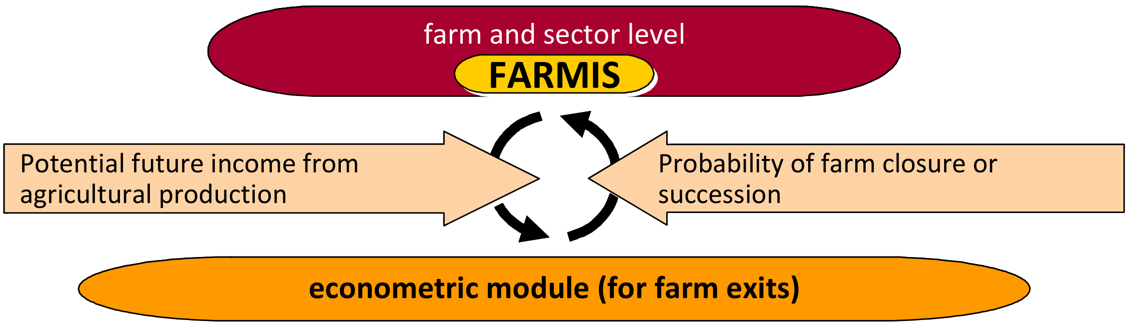


Figure 3. General approach to linking exit model and simulation model

As the exit rates are estimated for 4 year period and FARMIS is usually applied for a 10-15 year projection horizon, the application for policy impact analyses requires a repeated, iterative application of the two models, as illustrated in Figure 4. FARMIS thus provides the level of current farm profits, the expected change in farm income and the expected change in profits of neighbours, which all enter the exit model as exogenous variables, and allocates resources which are set 'free' by the exit of farms, the rate of which is determined by the exit model.

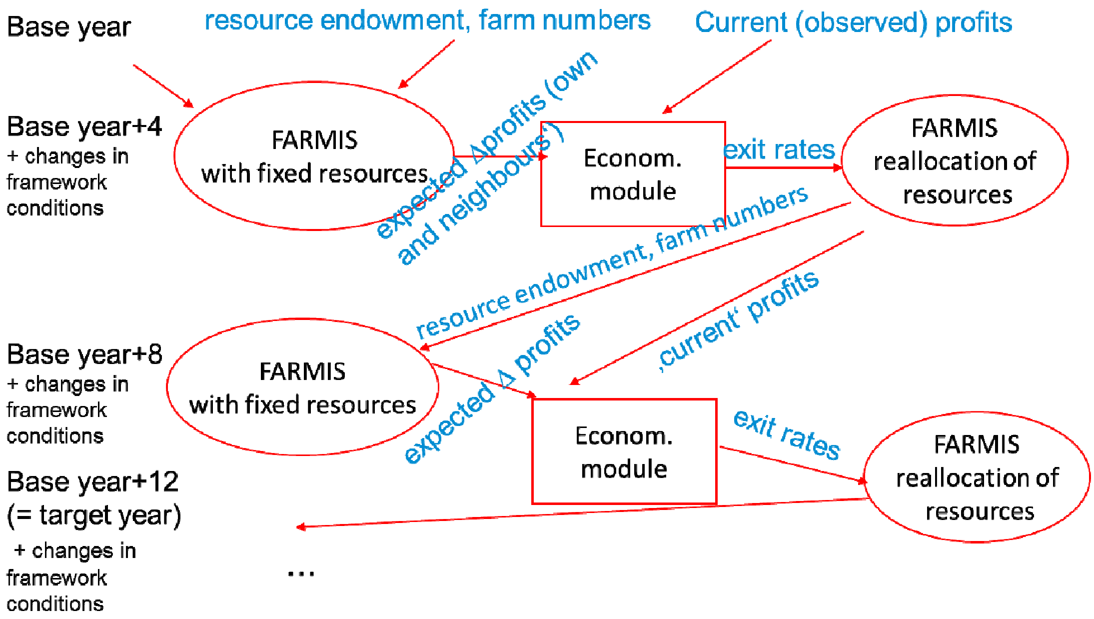


Figure 4. Iterative linking of exit model and simulation model

3. Impact of dairy market and policy scenarios on structural change

3.1. Scenarios

For this paper, scenarios are projected up to the year 2019, with the model base period being 2007 (average of the years 2006-2008). The 4-year projection horizon of the exit model thus implies three iterations of the combined modelling system for the years 2011, 2015, and 2019.

The baseline scenario is based on the Thünen Baseline (Offermann et al., 2012). The 2003 Reform and the Health Check of the CAP are fully implemented, which leads to regional flat rates for first pillar payments, and the milk quota scheme being abolished in 2015. Furthermore, the sugar market reform decided upon in 2005 is implemented and set-aside obligations are removed in 2008. For the farm modelling, prices and yields are exogenous and were determined by partial and general equilibrium models. The baseline scenario was also modelled for a model version with a trend-based projection of farm numbers to be able to determine the effect of endogenously accounting for farm exits on the results.

To analyse the impact of changes in the economic environment on farm numbers, two stylised simplified scenarios for dairy market were defined. The first scenario assumes a continuation of the quota scheme at base year levels, with prices being fixed to the values of the baseline scenario (which is clearly unrealistic but here the objective is not (yet) to provide policy impact analysis but rather to examine the principle effect of changes to selected exogenous variables). The second scenario assumes milk prices to be 16% higher than in the baseline.

3.2. Results

Impact of endogenous vs. trend-based projection of farm numbers

Table 1 provides an overview of the change in farm numbers in the baseline scenario compared to historical exit rates. Overall, structural change is projected to increase slightly, with farm numbers being 5% lower than under a trend-based projection. In terms of annual exit rates, the difference is comparatively small (annual decrease of farm numbers 2.6% compared to 2.2%). However, differences exist between farms of different types, regions and size. Exit rates are higher than historical values especially for arable and pig and poultry farms, farms in the southern regions of Germany, and smaller farms. According to the model results, the highest impact of the baseline scenario on farm exit rates is expected for small arable farms.

Table 1. Development of farm numbers in western Germany in the baseline scenario, endogenous versus trend-based projection of structural change

	Base year	Baseline		Difference
	2007	trend	endogenous	endog. to trend
All farms (western Germany)	200749	152950	145485	-5%
North	71954	55251	53987	-2%
South	101455	77122	70862	-8%
Centre	27340	20577	20636	0%
Arable	41137	24563	21508	-12%
Dairy	68667	55942	51899	-7%
Other grazing livestock	19632	13021	14201	9%
Mixed	44496	33461	33387	0%
Pig + Poultry	10839	9984	8511	-15%
Arable, < 50 ha	22234	9109	5573	-39%
Arable, 50 - 100 ha	9140	6844	7125	4%
Arable, > 100 ha	9764	8610	8809	2%
Dairy, < 30 cows	34096	24002	20481	-15%
Dairy, 30 - 60 cows	23652	21611	20764	-4%
Dairy, > 60 cows	10918	10329	10654	3%

As more farms exit the sector, the remaining farms can grow more (Table 2). On average, farm size in terms of arable area increases by 5%. The largest increase in average size is observed for the small arable farms, which however does not imply that the individual farms in this group grow strongly, but rather is a result of the fact that in this group especially the very small farms exit, thus increasing the average size of the group. The overall impact of the accelerated structural change on production and farm income is negligible for the baseline scenario, and results are almost identical to the model version with historical exit rates (e.g., difference <1% for cereal, milk, beef and pork production).

Table 2. Development of farm sizes in ha UAA in western Germany in the baseline scenario, endogenous versus trend-based projection of structural change

	Baseline		Difference
	trend	endogenous	endog. to trend
All farms (western Germany)	71	75	5%
North	90	92	2%
South	58	63	9%
Centre	70	70	0%
Arable	119	134	13%
Dairy	65	69	7%
Other grazing livestock	80	77	-4%
Mixed	79	80	1%
Pig + Poultry	47	53	13%
Arable, < 50 ha	51	72	40%
Arable, 50 - 100 ha	90	88	-2%
Arable,> 100 ha	215	211	-2%
Dairy, < 30 cows	36	41	13%
Dairy, 30 - 60 cows	66	68	3%
Dairy, > 60 cows	128	126	-2%

Impact of dairy market scenarios on farm numbers

The impact of the dairy market reform scenarios is identified by comparing results to those of the baseline scenario with endogenous structural change. Milk production is affected quite differently by the two scenarios: With higher milk prices, total milk production is increasing by 12%, while the continuation of the milk quota at 2007 levels reduces milk production by 13% compared to the baseline. Somewhat surprisingly, the impact on total number of dairy farms is almost identical, with dairy farm numbers being 4-5% higher than under baseline conditions. The total figure however masks significant differences at the more detailed level. Figure 5 illustrates the development of the numbers of small, medium and large dairy farms (farm size here relating to the number of dairy cows in the base year). The number of small farms decreases strongly under all three scenarios; however the number of smaller farms is higher in the dairy market scenarios than under the baseline scenario. Especially the continuation of the milk quota scheme seems to slow down the exit rates of smaller dairy farms. The positive impact of higher prices on the number of smaller dairy farms is reduced after the abolishment of the milk quota scheme in 2015. The number of medium-sized dairy farms is positively affected by both dairy scenarios, however in contrast to the smaller dairy farms, here the effect is largest for the scenario with higher milk prices. The number of larger dairy farms is actually lower that under the baseline scenario with a continuation of the quota scheme, as the overall limitation of milk production and the higher competition from small and medium-sized farms reduces the chances for growth and continuation. In contrast, higher milk prices with no limitation on sector output provide an opportunity especially for the larger dairy farms, whose number significantly increases compared to the baseline scenario.

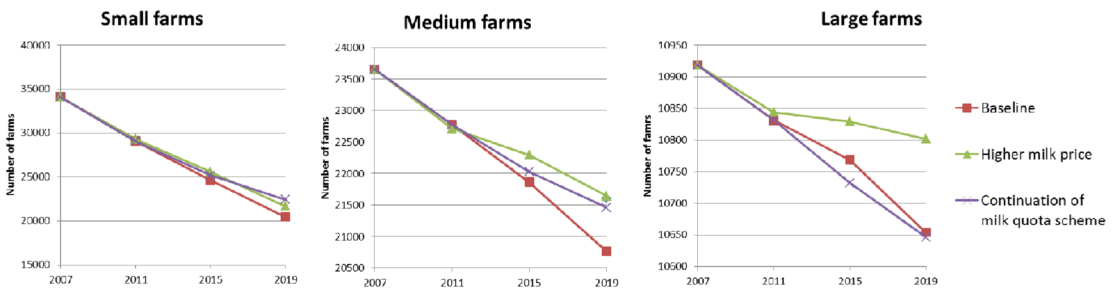


Figure 5. Impact of dairy market scenarios on farms numbers

4. Discussion and conclusions

For our modelling system, for the baseline scenario, the endogenous modelling of structural change has little impact on aggregated outcome but affects farm size distribution (depending on type, size, region) compared to a trend-based projection of farm numbers. The impacts may possibly be more pronounced for scenarios with larger changes compared to the base year, e.g. full liberalisation, and in this case endogenously accounting for structural change may affect results for total production. However, for very large changes of profitability of agricultural production which may not have been observed in the past, the estimated coefficients for the profit-dependent exit rates may not be valid any more (a general problem of all econometric approaches).

The evaluation of two stylised milk market scenarios reveals significant differences in the impact of policy or market changes on the number of dairy farms of different sizes. In the application presented here, product prices were exogenously fixed. A coupling to market models would enlarge the range of realistic, policy-relevant scenarios which could be analysed, e.g. the impact of quota schemes on structural change or the net effects of investment aid under a quota scheme on farm numbers.

For the econometric model, a logical next step would be a validation using 2011 FSS data. In addition, re-estimating the logit-model using the new data and including additional variables to account for the relation of the income level of the agricultural to the non-agricultural sectors may further improve results.

A big challenge remains the condensation and interpretation of the diverse and heterogeneous impacts of policies on regional structural change. Possibly a meta-analysis of model outcomes (see e.g. Happe, 2004; Margarian 2010b) may shed more light in this respect.

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