Flexibility of beef suckler cow systems under varying calf retention strategies

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Abstract

Beef suckler cow calf farms similarly to firms in other sectors of production operate in competitive and dynamically changing environments. In order to increase profitability and reduce uncertainty, beef suckler cow calf farmers may not be able to change radically their farm resources in the short-run; however they can decide on either retaining or not the ownership of calves. This decision brings changes to the herd size and composition, and ultimately defines the degree of farm's market integration. Flexibility is a measure of firm's competitive advantage which reflects its capacity to cope with uncertainty. In this paper two types of flexibility have been estimated, and its determinants have been identified for three cow calf systems. Namely, tactical flexibility indicates farmer's ability to vary output level in the medium-run, and operational flexibility reflects the ability to adjust product mix in the short-run. In these systems farmer's decision and time-length to retain their calves differs, thus farm's flexibility is examined in relation to varying calf retention decisions. Results indicate that calf to weaning farms who retain the ownership of their calves beyond weaning increase both tactical and operational flexibility. Adjustments in cattle marketing strategies increase the flexibility of all beef farms.

Keywords: Calf retention, cattle marketing strategies, flexibility, Modified Lilien Index, unbalanced panel data, Ireland

JEL classification: Q1, Q130

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1. Introduction

Beef production, similarly to other agricultural sectors in both Ireland and Europe, has undergone significant changes, since 1990s. In Ireland these changes have been mainly realized through the expansion of national suckler beef cow herd[1], the increased exit from farming and engagement in off-farm employment, and the increased importance of European Union's (EU) support payments (Binfield and Hennessy, 2001). The transformation of the Irish beef sector due to policy and economic growth factors was further challenged by the 1996 BSE (bovine spongiform encephalopathy) crisis in United Kingdom, and the Luxembourg Agreement which initiated the decoupling of all direct payments from agricultural production decisions from 2005 onwards.

The current targets set by the EU's Common Agricultural Policy (CAP) reform (2014-2020), the recent milk quota abolition (in March 2015), the volatile prices and weather conditions, and the fluctuating demand for beef in Irish markets since early 1990s (McCarthy *et al.*, 2003), require farmers to adopt flexible production technologies which will ensure the effective adjustment of their production systems and short-term targets, in order to reduce the uncertainty of market returns, remain profitable and competitive.

Beef suckler cow farms in Ireland similarly to France, United Kingdom, Spain and Portugal (Hocquette and Chatelliert, 2011) are an importance source of beef cattle in the beef supply chain[2] and the most widespread farm activity in Ireland (Crosson *et al.*, 2014). Nevertheless Irish beef suckler cow calf farms are characterized by low profitability[3] which could be partially attributed due to the inability to operate exclusively on cattle margins as do cattle backgrounders and finishers (Schroeder and Featherstone, 1990).

Calf retention beyond weaning and adoption of advanced marketing and value-added programs have received considerable attention by applied research (Pope *et al.*, 2011) and has been often suggested by extension specialists as a strategy for improved profitability, increased efficiency and reduced cattle price risk. The effect of calf retention decisions on farm's capacity to adapt to change has not received attention by research though. The first objective of this study is to assess farm's ability to remain competitive within a rapidly changing economic environment under varying calf retention strategies.

These strategies refer to the option to sell calves at weaning, retain them as post-weanlings (or stores), or maintain the ownership of the calves until the end of the cattle's finishing phase[4]. In

[1] The substantial increase in the number of suckler cows until 1998 was largely due to the MacSharry reform in 1992.

[2] Over half of all beef produced in Ireland is sourced from the beef suckler cow herd of 1.1 million cows (Finneran and Crosson, 2013).

[3] In 2010 the average family farm income for beef suckler cow calf systems was € 222 per hectare (Ashfield *et al.*, 2013).

[4] In Ireland, the finishing phase entails cattle of 15-30 months of age subject to input-output market prices, the breed and the gender of the animal.

order to evaluate the adaptability of beef suckler cow calf systems to changing conditions the concept of flexibility has been employed and measured, and its' determinants are further identified. Insights on farmers and systems ability to 'absorb perturbations' sourced by their operational environment might be useful not solely for the future development of risk-reduction policies and design of sustainable value-added beef systems, but also for farmers in order to understand which factors enhance (or weaken) farm household's long-term viability.

In the economics literature flexibility has been extensively studied as an explanation for the co-existence of large and small firms within the same industry (Weiss, 2001). Flexibility can be considered as a firm-specific resource or skill (Dreyer and Gronhaug, 2004). It is commonly inherent to small firms which due to flexible organization forms and production technologies demonstrate increased capacity to adjust to change, acquire new market information and exploit new opportunities resulting from changes in the economic environment. In contrast to larger more-static efficient firms which take advantage from scale economies and better access to credit, smaller firms remain competitive due to flexibility and effective cost management (Bosch and Blandon, 2011).

The notion of firm flexibility seems to have been first introduced in economics by Stigler (1939) (Carlsson, 1989), who argued that higher flexibility in firms is associated with a flatter average cost curve (Zeller and Robison, 1992). The concept of flexibility also triggered the interest of researchers from manufacturing, industrial organization and management science disciplines, and more recently the interest of agricultural systems modellers and scientists (cf., e.g., Sabatier *et al.*, 2015; Andrieu *et al.*, 2015; Boykin, 1967). To our knowledge in the agricultural economics literature, the works of Weiss (2001), Pieniadz *et al*. (2007), and Renner *et al.* (2014) are the only published studies that empirically measure farm flexibility and examine the effect of socio-economic and demographic factors on flexibility. Bosch and Blandon (2011) using the framework provided by *Activity Based Costing* analysed the influence of farm size in costs through product diversification (operational flexibility) and output adjustment (tactical flexibility) (Bosch and Blandon, (2011).

Besides the aforementioned quantitative studies on farm flexibility there are also the qualitative case studies of Ingrand *et al.* (2007), Astigarraga and Ingrand (2011), and Havet *et al.* (2014) who explored the capacity of suckler cattle farms to adapt to structural, environmental and market changes. These studies alongside the work of Nozieres *et al.*, (2011) illustrated how specific features of livestock production systems can provide buffer capacity and enhance the ability of farmers to adjust practises in the face of changing production conditions. A number of theoretical articles also provide interesting insights how flexibility can be conceptualized in the case of natural ecosystems and farm production systems in relation to other major concepts regarding the sensitivity of systems to perturbation; the concepts of *resilience* and *robustness* (cf., e.g., ten Napel *et al.*, 2011; Darnhofer *et al.*, 2010; Cowan *et al.*, 2013).

Building on the empirical work of Weiss (2001), the present study derives estimates for the short (operational)- and medium-term (tactical) flexibility of beef suckler cow calf systems over a 12 year period (2000-2011) and under varying calf retention strategies. Additionally, panel data model analysis has been employed in order to identify cattle marketing strategies, socio-demographic and production system-related factors which increase (or decrease) farm's flexibility. The incorporation of cattle marketing strategies, system-specific elements such as seasonality of production and calf rearing method in the model, aims to investigate the effect of marketing and production system adjustments on flexibility.

Insights on farmer's (and system's) ability to 'absorb perturbations' originated from their external operational environment are useful not only for the future development of risk-reduction policies and design of sustainable value-added beef systems, but also to assist farmers and farm advisers to understand which factors enhance (or weaken) farm household economic sustainability and long-term viability.

2. Background

Retention of calf ownership

Cow-calf producers face limited decisions until weaning, when farmers must decide if calves will be kept or sold. There is evidence from several studies that retaining ownership of calves beyond weaning may increase cow-calf producers' profitability (Pope et al. 2011) through weight gain which leads to increased cattle price, obtained valuable information on the post-weaning performance of cattle (White et al., 2007), reduced transaction costs, taking advantage of seasonal price fluctuation (Garoian *et al.*, 1990), and risk spreading from one beef enterprise to another and from one period of time to another (Davies et al., 1999). Adding vertical stages to calf production could be considered as a short-run decision, based on expected prices and forage availability, and consequently these vertical choices in cattle production offer flexibility to the farmer because they do not involve large investments in fixed capital (Whitson *et al.*, 1976).

Despite the potential benefits of calf's maintenance through stocker[5] or finishing stage, this decision involves increased feeding and marketing risk. Consequently the decision for calf retained ownership depends, among other farm-specific factors, on farmer's risk aversion, cash flow and labour constraints (Popp et al., 1999), degree of diversification in farm enterprise (Pope et al., 2011), expectations on future input and output prices (Lambert, 1989), and on-farm forage availability.

Irish beef production systems

In Ireland calves are sourced from both dairy and beef suckler cow herds. The common calving season is spring, and beef suckler cows rear their own calves until weaning at the end of the first grazing season (O'Donovan et al., 2011). A large proportion of weaned beef cattle will be sold in livestock marts although some farmers will decide to keep the weanlings during the winter (in-house feeding) and place them on the pasture in the next spring. At the age of 12 months or more, the majority of these cattle will be sold as stores (also referred as post-weanlings or feeder cattle) to fattening operations where they will enter the finishing phase fed with high-energy diets. A smaller number of beef farmers will keep stores in the farm until slaughter.

[5] This stage of the commercial life cycle of cattle is also known as back-grounding or feeder phase.

The effect of market integration or the retained calf ownership decision on the flexibility of each system is not easy to foresee. For example suckler cow-calf producers who retain calves until slaughter are mainly farmers with larger herds and land area, while calf to weaning and calf to store operations are considered to be more marginal operations (Araji, 1976). Results from empirical farm flexibility literature indicate a negative relationship between size of the farm and flexibility (Weiss, 2001; Renner *et al.*, 2014; Pieniadz *et al*., 2007; Bosch and Blandon, 2011). Therefore contrary to calf to weaning and calf to store farms, the calf to finish farms would be expected to be more inflexible. On the other hand integrated farms due to a longer production cycle might be more capable to adjust their output mix (operational flexibility) through live weight adjustments according to market demand and forage yield (Mosnier et al., 2009). It is more likely that annual changes in cattle herd composition, beef cattle marketing choices and features of the production system such as, seasonality of production (winter, summer or both) and calf's rearing method will also play important role on farms flexibility.

Irish beef systems can be considered as low input cost systems since cattle's diet mainly consists of grazed and ensiled grass (Crosson et al., 2006). This reflects the major advantage of Ireland over other European countries to produce between 12 and 16 tonnes of grass dry matter over a long growing season (O'Donovan et al., 2011). It is expected that the availability of grazing grass and home-produced dry and ensiled feed, will increase farm's flexibility when price of concentrate feed increases.

Table 1. Financial performance of beef suckler cow farms (2000-2011 mean values*)

Type of system	**Cattle gross output (/livestock unit)**	**Cattle direct costs (/livestock unit)**	**Family farm income (/UAA**)**	**Farm size-UAA (hectares)**	**Cattle livestock units**
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)
Calf to weaning (*n*=1994)	535.7 (174.5)	283.8 (136.4)	330.4 (303.4)	32.5 (33.1)	23.4 (14.7)
Calf to store (*n*=3525)	542.9 (188.3)	300.4 (137.8)	462.1 (430.6)	33.7 (21.8)	29.8 (20.1)
Calf to finish (*n*=1062)	559.2 (186.9)	295.5 (153.2)	465.3 (356.2)	54.7 (36.6)	62.1 (40.7)
All systems (*n*=12117)	542.2 (202.2)	298.2 (143.1)	438.6 (406.4)	37.8 (31.7)	34.5 (29.9)

* Population weighted to 13855 observations.

** Utilized agricultural area

Table 1 presents figures regarding the financial performance of beef suckler cow farms in our sample during the years 2000-2011. Average gross output is higher for calf to finish farms while direct cost per livestock unit is lower in calf to weaning farms. Calf to store farms' performance with respect to gross output and direct costs is almost identical to the average performance of all beef farms in the sample. The size of calf to finish farms in terms of total cattle livestock units and utilized agricultural area (UAA) is much higher from the sample mean and all other beef suckler cow farms.

Furthermore the analysis of flexibility in an agricultural context, should take into account a number of other features of the farm household such as family demographics, education, off-farm employment, which may affect flexibility in combination/or not with the structural characteristics of the farm enterprise. The dual character of farm household as an entrepreneurial unit and a team of utility-maximizing agents (family members), differentiates most of farm enterprises in Ireland and other European countries from firms. Traditionally, Irish families own and exclusively operate their farm enterprises regardless of their size or operating scale. However most of these farms are small- to medium sized farms with more than one third being classified as economically vulnerable, and another third as viable (Duesberg et al., 2014). As it was mentioned before, beef farms in comparison to other grass-based enterprises have been characterized by low profitability and over recent years have faced significant variations in beef, fertilizer and concentrate feed prices (Ashfield et al., 2013). The survival of Irish farm households despite income vulnerability and input/output price variations renders Ireland a challenging case study for analysing the competitiveness through flexibility of beef suckler cow farms.

Classification of cattle marketing strategies

Beef cattle farms have been classified into eight types of farms according to the proportion of certain classes in total numbers of purchased and sold cattle (Table 2).

Table 2. Classification of cattle marketing strategies

Cattle marketing strategy	Animals entering the cattle farm (from January to December)	Animals leaving the cattle farm (from January to December)
1. Calf to weaning (C-W)	> 50% of animals entering the farm as calves (sum of the number of purchased calves plus the number calves born in the beef farm)	> 50% of animals leaving the farm (sold) as weanlings
2. Calf to store (C-S)	> 50% of animals entering the farm as calves (sum of the number of purchased calves plus the number calves born in the beef farm)	> 50% of animals leaving the farm (sold) as stores
3. Calf to finish (C-F)	> 50% of animals entering the farm as calves (sum of the number of	> 50% of animals leaving the farm (sold) as finished cattle

	purchased calves plus the number calves born in the beef farm)	
4. Weanlings/stores to store	> 50% of animals entering the farm as weanlings or stores (sum of the number of purchased weanlings plus the number of purchased stores)	> 50% of animals leaving the farm (sold) as stores
5. Stores to finish	> 50% of animals entering the farm as stores (number of purchased stores)	> 50% of animals leaving the farm (sold) as finished cattle
6. Calf to heifers-in-calf	> 50% of animals entering the farm as calves (sum of purchased calves plus the number calves born in the beef farm)	> 50% of animals leaving the farm (sold) as breeding cattle (breeding cows and replacement heifers)
7. Other	> 50% of animals entering the farm as 'other' cattle (number of purchased 'other cattle').	> 50% of animals leaving the farm (sold) as 'other' cattle
8. Mixed	No dominant animal class	No dominant animal class

Concerning the marketing strategy labelled as 'other', farmers mostly buy and sell cattle which could not be recorded as calves (less than 6 months of age), weanlings (calves 6 months to 1 year old), stores (non-breeding male or female cattle 1 to 2 years old), finished (non-breeding male or female cattle 2 to 3 years old), breeding cows, stock bulls or replacement heifers. These animals could be male or female cattle older than 3 years but also sick animals destined for culling.

Farmers who choose a mixed marketing strategy decide to maintain a diverse herd composed of various cattle classes but none of the classes forms a big proportion (> 50%) in total cattle purchases and sales.

Regulating the size of the herd and its composition is a balancing mechanism for the physiological state and nutritional requirements of animals in relation to forage quality and supply. Consequently adjustments of cattle marketing strategies and herd composition (as illustrated above) can be an important source of flexibility and may increase the adaptive capacity of farms (cf., Havet *et al.*, 2014).

Beef suckler cow-calf farmers predominantly adopt one the first three marketing strategies. The calf to heifers-in-calf marketing strategy refers to specialist beef farms where cattle are mostly sold for breeding. In many of these farms, the beef enterprise is run subsidiary to a dairy farm so these cattle farms are not representative of the beef suckler cow calf industry. Consequently farmer's decision on calf retained ownership is generally revealed if farmers switch their marketing strategy from e.g. calf to weaning to calf to store or calf to finish. Therefore it is important to stress that in this study, calf to weaning farmers refer farmers' whose predominant marketing strategy is to sell calves at weaning most of the years (more than half) of their presence in the sample. Similarly, calves to store farmers are those who predominantly sell more than half of their calves as stores and so forth.

3. Methodology

Data

As we are primarily interested in the measurement of flexibility as an indicator of sustainable competitive advantage, longitudinal data would be the most fitting data for this purpose providing advantages in measuring change and establishing temporal order (Gullstrand and Tezic, 2008). Thus an unbalanced panel of Irish farmers has been constructed for the years from 2000 to 2011 inclusive. Since 1972 Teagasc National Farm Survey (NFS) data are annually collected as part of a requirement to provide farm level data to the EU Farm Accountancy Data Network (FADN) (Buckley et al., 2016).

Each farm is assigned with a weighting factor for more accurate representation of the national farm population (Teagasc, 2014). Farms comprise either specialized or mixed enterprises, such as dairy, beef, sheep, and/or tillage enterprises, with the majority of beef enterprises being combined with a crop and/or dairy enterprise. The gathered data include detailed information on the financial structure of the farm household and enterprise-specific level, such as variable and whole-farm fixed cost, market returns, subsidies and other grants; production data like quantities of purchased and home-produced feed, output yield, sales quantity, livestock numbers, age of animals, technical and physical infrastructure farm characteristics, as well as socio-demographic characteristics of farm holder and household members (age, education, marital status and other information).

Our data refer to 13,885 observations from more than 2,000 farms. Prior to the econometric estimation, data cleaning involved the identification inconsistent and missing records, the exclusion of extreme observations (outliers), and the exclusion of beef cattle farms with less than five grazing livestock units (LU). This process reduced our observations to 12,117. In this sample there are 210 farms classified as predominant or specialized (beef suckler cow) calf to weaning (C-W) farms, 367 specialized calf to store (C-S) farms, and 101 specialized calf to finish (C-F) farms.

Operational and tactical flexibility

Carlsson (1989) distinguishes three types of flexibility; namely the operational (short-term), the tactical (medium-term), and the strategic (long-term) flexibility. Strategic flexibility is related to firm’s planning, resources and organizational structure, and refers to the ability of firms to reposition themselves in the markets and change their strategic long-term production plans. Tactical flexibility is a type of flexibility which is closer to Stigler’s flexibility concept for a single-product firm, and reflects firm’s aptitude to adjust the scale of production to exogenous shocks at relatively low costs (Weiss, 2001). When firms respond to exogenous shocks with changes in the product mix through diversification of production, flexibility is termed as operational or '*product switching*' flexibility. Operational flexibility refers to short time periods when no major changes can take place in firm's infrastructure and fixed capital.

Operational flexibility captures the ability of the farm to change product mix according to consumers' demand and production changes. In order to measure operational flexibility Weiss (2001) used two widely used structural change indices; the Michaely-Stoikov index and the Lilien index (LI) (cf., Lilien, 1982). The main difference between the two indices is that Lilien index measures output dispersion accounting for the weighted standard deviation of each product share change relative to aggregate output changes. The Michaely-Stoikov index, on the other hand, disregards the unequal distribution of products within the aggregate output (Pieniadz et al., 2007). Nevertheless Weiss (2001) concluded that the results of the analysis are very similar when operational flexibility is measured with either index.

In this study, the operational flexibility of farms has been estimated using both a modified Lilien index (MLI), which is a more robust version of the LI, and the LI. MLI is considered superior to the LI as it fulfils the conditions for robust structural change indices which are the following (Ansari et al., 2013)[6]:

1. If no structural change occurs the index for structural change should be zero within one period;
2. Structural change between two periods should be independent of time sequence;
3. Structural change between two periods should be greater or equal to one-period change;
4. The index should be a dispersion measure;
5. The index of structural change should consider the size of the sectors[7].

The LI-based operational flexibility of beef farms was estimated using the formula as estimating follows:

$$O\_FLEX\_LI_{it} = [\sum_{j=1} s_{j,i} \, [\Delta_t \, ln \, (s_{j.i}) - \Delta_t \, ln \, (Q_i)]^2 \,]^{0.5}$$

where $s_{j,i}$ is the share of product j (j = 1, … ,6) in total output of farm i in year t =(2001, … ,2011), and Δ_t refers to first time differences over time[8].

As beef farms sell a wide variety of cattle classes we considered five types of sold cattle (calves, weanlings, stores, finished cattle, breeding and other cattle) and the sum of subsidies coupled with cattle production and allowances related to cattle production in geographically disadvantaged areas as a sixth 'product'. Our decision to include cattle-related subsidies and allowances for the estimation of both types of flexibility (operational and tactical) is based on the

[6] LI satisfies the first and last two conditions but not the second and third condition (Ansari et al., 2013)

[7] In our case, the different types of sold cattle and other revenue generating mechanisms could be considered as distinct industry sectors in a wider economy (farm).

[8] For highly specialized beef farmers who do not produce more than one type of cattle (so the share of the other products equal to zero), a constant of 10^{-5} was added to satisfy the non-zero restriction of logarithms in the formula.

importance of subsidies on farmers' short- and medium-term production decisions and planning adaptations. The values of operational flexibility range from zero to infinity with zero value indicating that there has been no shift in the output mix, and infinite value refers to a situation that a farm has entirely readjusted its total output between products (Weiss, 2001).

The formula to estimate the modified version of the Lilien index (MLI) is almost identical to this of LI with the only difference that $S_{j,i}$ in year t is the average share of product j (j = 1,6) in total cattle output for time periods t and $t-1$.

$$O\_FLEX\_MLI_{it} = [\sum_{j=1} S_{j,i} [\Delta_t \, ln\,(s_{j.i}) - \Delta_t \, ln\,(Q_i)]^2]^{0.5}$$

Unfortunately the use of MLI does not overcome LI's non-negativity restriction on output shares and total output, which combined with the 'disaggregated nature' of output shares as they appear in the last two formulae prohibits the construction of 'net' type of operational flexibility analogous to the net tactical flexibility (*T_FLEX_NET*).

Following the existing empirical literature, we employed a variance-based index, which accounts for farm's output adjustments over years, to measure the tactical flexibility of beef farms:

$$T\_FLEX(\_NET)_{it} = [ln(Q_{it}) - \overline{ln(Qi)}]^2$$

Subscripts i (i = 1,… n) and t (t = 1,…T) indicate the number of farms in the sample and the year of the production respectively. The symbol Q_{it} is the total cattle output and $\overline{ln(Qi)}$ is the average cattle output of a farm throughout the years that remains in the data sample. Cattle output was measured in two ways thus two different estimates of tactical flexibility have been derived.

The first measure of tactical flexibility (*T_FLEX*) considers cattle output as the sum of total cattle sales and subsidies which are coupled with cattle production, plus allowances related to cattle production in geographically disadvantaged areas. In the second measure of tactical flexibility (*T_FLEX_NET*) cattle output is measured as the sum of cattle sales, value of cattle transfers to the dairy herd, value of closing cattle inventory, subsidies coupled with cattle production and allowances related to cattle production in geographically disadvantaged areas, less cattle purchases less cattle transfers from the dairy herd to the beef herd, less the value of opening beef cattle inventory. This net output-based tactical flexibility takes into account the animal flows in and out of the herd which according to Nozieres *et al.* (2011) is one of the major sources of flexibility linked to the herd. The cattle gross output values have been deflated by the cattle price indices for all types of cattle (base year=2000) provided by the Irish Central Statistics Office (CSO). The values of tactical flexibility range from zero to infinity with values equal to zero or close to zero indicate farms where output levels remained unchanged or changed little over years respectively.

Econometric model

Our second objective is to identify the factors that affect (determinants) operational flexibility (*O_FLEX_MLI* and *O_FLEX_LI*) and tactical flexibility (*T_FLEX_NET* and *T_FLEX*). At first stage a pooled Ordinary Least Squares (OLS) regression model was built and estimated with flexibility (either O*_FLEX_MLI*, *O_FLEX_LI*, *T_FLEX_NET* or *T_FLEX*) as regressant. The same model was also estimated as a fixed effects model indicating that it is more appropriate model for our data set compared the pooled OLS model. A major advantage of panel data analysis is the ability to control for unobserved heterogeneity by estimating the farm specific effects but the choice between the standard panel data models (fixed effects model and random effects model) is debatable. In the random effects panel data model all the explanatory variables are assumed to be uncorrelated with the random individual effects, while the opposite assumption holds for the fixed effects models (Baltagi and Liu, 2012). In order to avoid these quite strong assumptions a Hausman-Taylor estimator was used. Hausman-Taylor estimator is based on an instrumental variable estimation method that deals with possible endogeneity issues in longitudinal data sets (Kim *et al.*, 2012). Instruments for time-varying and time-invariant endogenous variables are derived from the model thus Hausman-Taylor estimator economizes on the use of instruments (Dixit and Pal, 2010). Nonetheless, the weak correlation (indicated by calculated Pearson's correlation coefficients) among potentially endogenous variables and candidate instruments, raised doubts regarding the robustness of internal instruments and ultimately discouraged us of following this estimation approach.

Contrary to the standard random effect model, the correlated random effects (CRE) estimator (Mundlak, 1978) allows for unobserved heterogeneity and its correlation with observable farm characteristics, while yielding fixed effects-like interpretation (Xu *et al.*, 2009). By adopting Mundlak's CRE device eliminates the bias due to correlation between the explanatory variables of the model and the omitted time invariant variables (Buckley *et al.*, 2016).

In our panel data model

$$Y_{it} = X_{it}\, \beta + \varepsilon_{it}$$

Y_{it} is the dependent variable which has the value of either *T_FLEX_NET*, *T_FLEX*, *O_FLEX_MLI* or *O_FLEX_LI* of individual farm i at time t (year). The vector of independent variables is denoted by X and β is the vector of parameter coefficients to be estimated while ε_{it} is a random error term.

The error term ε_{it} can be further decomposed into an unobservable farm-specific error component c_i, capturing the time-invariant unobserved heterogeneity and random noise component, ξ_{it} which is assumed to be independently and identically distributed over time and individuals (Buckley *et al.*, 2016).

The CRE estimator is efficient, unbiased, and consistent under the assumption of strict exogeneity of explanatory variables in the panel data model (Xu *et al.*, 2009). According to Mundlak's CRE device allows modelling the distribution of the omitted unobserved variable conditional on the means of strictly exogenous variables (Sheahan *et al.*, 2016):

$$c_i = \lambda + \lambda\, \overline{M} + \theta_{it}$$

where $\overline{M}$ is a vector of farm-mean values for the time-varying continuous variables of our panel data model[9].

Prior to the econometric estimation of the CRE model it was tested if estimated coefficients vary with farmers' predominant choices with respect to calf retention. The dummy variable approach on testing the statistical significance of the differences in the estimated coefficients among specialized C-W, C-S, and C-F farms as proposed by Guajarati (1970), led us to run separate regressions for each of the three farm groups excluding farms with three or less years data. The exclusion of these farms is based on the fact that employment of the CRE device requires sufficient farm-level variation with regards to the time-varying variables.

Explanatory and control variables

The choice of the independent variables (Table 3) of the panel data model is primarily based on published empirical economic studies on the determinants of farms' flexibility, but also on insights from theoretical and qualitative case studies dealing with flexibility within a farm production system framework. All model variables were selected on the basis of having satisfactory variability within our sample of three beef farm groups.

Adjustments with respect to farmers' cattle marketing strategies (Table 2) are expected to be significant determinants of flexibility. As Whitson *et al.* (1976) argued, adding vertical stages to calf production could be considered as a short-run decision, based on expected prices and forage availability, and consequently these vertical choices in cattle production offer flexibility to the farmer because they do not involve large investments in fixed capital. Switching to other than beef suckler cow-calf related marketing strategies, is also considered as low-fixed cost adjustment decision that could benefit both the flexibility and profitability of the beef suckler cow-calf farms.

Nevertheless short- and medium-term flexibility determinants are expected to differ across specialized beef suckler cow calf farms. More specifically retaining calf ownership is expected to increase the flexibility of C-W and/or C-S farms. We do not have clear expectations regarding other marketing strategy deviations from the three predominant marketing strategies (C-W, C-S, and C-F).

[9] In non-linear econometric models, the averages of binary dummy variables should be also included in vector $\overline{M}$ (cf,. Sheahan *et al.*, 2016).

Table 3. Description of variables included in the regression analysis (period: 2000-2011)[*]

Variables	**Definition**	**Calf to weaning (*n*=1994)** Mean (S.D.)	**Calf to store (*n*=3525)** Mean (S.D.)	**Calf to finish (*n*=1062)** Mean (S.D.)	**All systems (*n*=12117)** Mean (S.D.)
Dependent variables					
T_FLEX_NET	Tactical flexibility (as defined in the text)	0.138 (0.314)	0.103 (0.260)	0.072 (0.131)	0.137 (0.395)
T_FLEX	Tactical flexibility (as defined in the text)	0.235 (0.680)	0.198 (0.637)	0.149 (0.594)	0.222 (0.724)
O_FLEX_MLI	Modified Lilien index for operational flexibility for six products (as defined in the text)	5.463 (4.455)	6.084 (4.994)	4.400 (4.438)	5.428 (5.066)
O_FLEX_LI	Lilien index for operational flexibility for six products (as defined in the text)	4.353 (5.146)	4.979 (5.813)	3.374 (4.890)	4.354 (5.705)
Independent variables					
Age	Age of the farm operator	52.716 (12.042)	53.637 (12.361)	51.751 (12.523)	53.811 (17.500)
Family size	Total number of family members (excluding the farm operator)	3.470 (1.768)	3.420 (1.856)	3.400 (1.804)	3.372 (1.768)
Full-time farming	Dummy for full-time farming (1=full-time; 0=part-time)	0.178 (0.382)	0.419 (0.493)	0.596 (0.490)	0.375 (0.484)
Land use potential	Based on a soil classification system as defined in the text (1=good; 2=average; 3=poor)	1.940 (0.676)	1.678 (0.618)	1.354 (0.543)	1.629 (0.656)
LU	Annual average number of beef cattle grazing livestock units	23.405 (14.768)	29.854 (20.022)	62.060 (40.763)	34.543 (29.870)

Opening breeding inventory	Number of beef suckler cows and heifers-in-calf grazing livestock units in January	13.959 (11.787)	14.467 (17.277)	15.377 (13.820)	12.805 (15.848)
Calving percentage	Percentage number of calves born divided by total number of cows and exposed heifers	87.162 (30.221)	74.864 (63.896)	75.769 (40.511)	74.834 (61.975)
Calving death loss	Number of stillbirths and calves less than six months of age which died divided by total number of cows and exposed heifers	0.077 (0.260)	0.218 (0.669)	0.166 (0.383)	0.190 (0.655)
Mature cattle death ratio	Ratio of total number of cows and cattle over six months of age which died divided by the total of cows and cattle over six months of age	0.020 (0.036)	0.016 (0..031)	0.013 (0.017)	0.016 (0.031)
Seasonality of beef cattle production	Control variable for production season as defined in the text (1=summer production; 2=winter production; 3=summer and winter production)	2.160 (0.983)	2.799 (0.587)	2.913 (0.376)	2.682 (0.718)
Calf rearing method	Control variable for calf rearing method (1=single suckling; 2=double or multiple suckling; 3=bucket fed or mixed rearing method)	1.221 (0.618)	1.829 (0.964)	1.765 (0.937)	1.731 (0.947)
Stocking rate	LU ha^{-1}	1.440 (0.883)	1.635 (0.623)	1.828 (0.570)	1.614 (0.709)
Home-produced feed share	Percentage share of home-grown feed cost in total feed cost	36.255 (35.027)	30.358 (29.716)	33.454 (27.910)	30.314 (30.829)
Cattle marketing strategy	Control variable for cattle marketing strategy as defined in the text (8 dummies)	2.027 (2.407)	2.994 (2.247)	3.968 (2.002)	4.250 (2.904)
Diversification	Adjusted Herfindahl index measured at whole-farm level as defined in the text (value range [0,1]; values closer to zero indicate high degree of diversification)	0.436 (0.330)	0.370 (0.291)	0.356 (0.305)	0.378 (0.306)

Trend	Time trend (1=year 2000)	6.310 (3.502)	6.178 (3.478)	6.348 (3.403)	6.282 (3.453)

* Population weighted to 13855 observations. Numbers in parentheses are standard deviations.

The independent socio-demographic variables in the model include farm holder's age, family size, and if the farmer is farming at full- or part-time basis. Since Irish agriculture is family-based business, it is expected that the above socio-demographic variables will account for the role of individual characteristics on farm flexibility.

It is assumed that the older the farmer is, the less flexible would be due to increased risk aversion compared to younger farmers (Pieniadz, 2007). Increased farmer's experience and accumulated wealth with more years of commercial farming though, could increase farm flexibility. Nevertheless, the inclusion of the squared value of age for capturing possible non-linear age effects did not add any explanatory power to our model and it was finally decided not to be included in the model. Moreover, the lack of data on farm holder's education (agricultural or non-agricultural formal education) for most of the years that our sample covers is prohibiting accounting for such characteristic. Off-farm income data were not available as well for the 12-years period under study.

Flexibility is expected to be greater in families with more household members as family-based workforce can be quite flexible to meet the seasonal needs of farms without formal arrangements and transaction costs. We expect that the effect of farmer's full/part-time engagement in farming would vary according to the size of farm enterprise and its commercial orientation. Probably full-time farming would be positively related to farm flexibility in larger and more intensive farms due to the fact that optimal adjustments in farm produce would require the full time commitment of farm holders on their farm enterprises.

In order to capture the natural endowment of the farm a dummy variable capturing farmland use potential was included in the model. Intuitively soil of good quality would increase flexibility as there are not significant use limitations. Total LU serves as measure of beef cattle farm size. As it was mentioned before, research evidence strongly suggests the negative association of size with flexibility mainly due to differences in applied technology. In order to check for linearity between flexibility and farm size, the squared value of LU was also added to the model. A positive (negative) relationship may hint if farms are operating in the area of increasing (decreasing) economies of scale. In similar vein, opening breeding inventory was taken into account as lagged inventories represent biological constraints on adjustments in beef cow numbers (Bobst and Davis, 1987) and sequentially up to a certain degree in overall herd size. Assuming that cattle markets are not imperfect, we would expect that the maintenance of breeding stock from the previous year ensures some level of buffer capacity in periods of high beef demand but also in periods of low beef demand.

Identifying the effect of managerial ability on the ability to adjust scale of production levels and product mix could be a key aspect for the design of relevant agricultural education programs and farm advisory services. Lacking information with regards to education of farm holders which could be used as a proxy for unobserved managerial ability, we employed three herd management-related variables to account for farmers' managerial ability. The first proxy for farmers' management skills is calving percentage which is directly related to breeding, gestation, and calving (Ramsey *et al.*, 2005). The second variable is calving death loss referring to stillbirths and calf mortality, and the third variable is the death ratio of mature cattle over the number of mature cattle. If these variables are adequate proxies for farmer's managerial skills, it would be expected that higher calving percentage increase flexibility, and calving death loss and the death ratio of mature cattle would affect flexibility in adverse mode.

The variables regarding the seasonality of beef production and calf rearing method were selected as explanatory variables in the model as they are parts of the beef system technology applied in the beef farms. As in principle the potential flexibility advantages of smaller firms stem from flexible applied technology, we would be interested in examining the possible effects of the seasonality of production and the calf rearing method on farm flexibility. Farmers with summer production keep more than 75% of all non-breeding stock in the months of April to September inclusive. Farmers producing in the winter keep more than 75% of all non-breeding stock in the months of November to March exclusive. Farmers with both summer and winter beef cattle production keep some non-breeding stock cattle throughout the year. We expect that beef farmers with summer and winter production may take advantage of potential input and output price fluctuations thus adjusting production more easily and increase flexibility. We do not have any particular a priori expectation related to the calf rearing method.

Stocking rate is the fundamental relationship between livestock and the forage resource. We consider that stocking rates reflect decisions that directly affect flexibility (positively or negatively) according to how successful stocking rate adjustments will be, subject to weather conditions, available manpower, and input/output prices. Bearing in mind that the available land for each Irish farm is quite fixed due to limited land mobility (Ciaian *et al.*, 2010) stocking rate changes will be caused by changes in cattle classes and herd size. As it was mentioned before 'juggling' the herd numbers is a source of flexibility inherent to the herd (Nozieres *et al.*, 2011) and is expected to be a quite straight forward process under perfectly functioning markets. The expected effect of stocking rate on flexibility can be obscured though if agricultural policy incentives or regulations limit stocking rate adjustments like in the case of EU-extensification premia holding until 2004.

The share of farm-grown animal feed (home-produced feed share) on animals diets is expected to be positively related to the flexibility of all beef farms because farm-grown feed is produced at relatively low cost and can be good alternative when the prices of purchased feed is high. Its effect might be greater for the vertically integrated farms such as specialized C-S and C-F due to the increased use of high energy feed rations in these farms.

Villano *et al.* (2010) argue that more diversified systems are likely to have greater flexibility to respond to unexpected changes at relatively little cost, thereby generating synergies. On the other hand risk-averse farmers diversify production (Pope *et al.*, 2011). Results from Weiss (2001) and (Pieniadz, 2007) also suggest a positive relationship between operational flexibility and diversification. In order to account for diversification at whole-farm level an adjusted Herfindahl index (H^*) was computed as:

$$H^* = [H-(1/N)] / 1-(1/N)$$

with $H = \Sigma_{i=1...N} s_i^2$, and s_i being equal to the squared share of product value of *i*-th farm subsidiary in total farm output, and *N* is the number of subsidiaries in the farm (six in this study; cattle, dairy, tillage, sheep, and other income plus total grants). Index values closer to zero indicate more diversified farms while a value of one suggests complete specialization in one enterprise (Villano *et al.*, 2010). The possible effect of operational (short-term) flexibility on the medium-term tactical flexibility was also examined. Ultimately a linear time trend was added in the model to capture non-inflatory technological advances in the beef industry.

Conducting multicollinearity diagnostics did not raise concerns about strong linear relationships among the independent variables as the variance inflation factor (VIF) is lower than ten which considered as a critical value.

5. Results

Operational and tactical flexibility

Table 4 presents the estimates for operational (measured as *O_FLEX_MLI*) and tactical flexibility (measured as *T_FLEX_NET*). As expected C-F farms are most inflexible beef farms in the sample. In the short-run C-S farms are the most flexible (based on operational flexibility estimates) whereas in the medium-rum C-W farms are the most flexible (based on tactical flexibility estimates). This could be the reason for the survival of cow-calf segment despite the small farm size in terms of UAA and cattle herd size.

Conducting one-sample t-test indicates that average tactical flexibility differs across all systems at 5% statistical level of significance. Measuring tactical flexibility as *T_FLEX* does not lead us to different conclusions[10]. Similarly, average MLI and LI estimates for the operational flexibility of farms differ at 5% level. However operational flexibility (measures as MLI and LI) is statistically different only between C-W and C-F at 5% level, and between C-S and C-F farms. This implies that in the short-run C-W and C-S are not different at 5% level regarding their estimated short-run flexibility.

Table 4. Flexibility across systems (weighted estimates)[*]

		Operational flexibility (*O_FLEX_MLI*)				**Tactical flexibility (*T_FLEX_NET*)**		
	Observations	**Mean (S.D)**	**Min**	**Max**	**Observations**	**Mean (S.D.)**	**Min**	**Max**
Calf to weaning	*n*=1602	5.463 (4.455)	0	21.713	*n*=1994	0.138 (0.314)	0	5.851
Calf to store	*n*=2901	6.084	0	22.679	*n*=3525	0.103 (0.260)	0	9.697

[10] Estimates of O_FLEX_LI and T_FLEX can be provided by the authors upon request.

Calf to finish	*n*=872	4.400 (4.438)	0	21.817	*n*=1062	0.072 (0.131)	0	1.888
All beef farms	*n*=9657	5.428 (5.066)	0	22.851	*n*=12117	0.137 (0.395)	0	12.020
* Population weighted to 13855 observations.								

Data on beef farm investments, and possible contracts with meat processing companies or cattle traders could provide additional insights regarding C-F farms inflexibility. It is concluded that in average Irish beef farms appear quite flexible in the short-run but in the medium-run they seem unable to adjust aggregate output level. In a European context this conclusion is not surprising due to chronic EU agricultural policy interventions. Figure 1 and figure 2 illustrate how flexibility of the three farm groups of interest has evolved from 2000 to 2011. We suspect that the spike in operational flexibility in 2006 is caused due to the double payment of the new decoupled Single Farm Payment (SFP) and payments coupled with production owing from the previous year.

Figure 1: Operational flexibility across systems (weighted averages, 2000-2011)

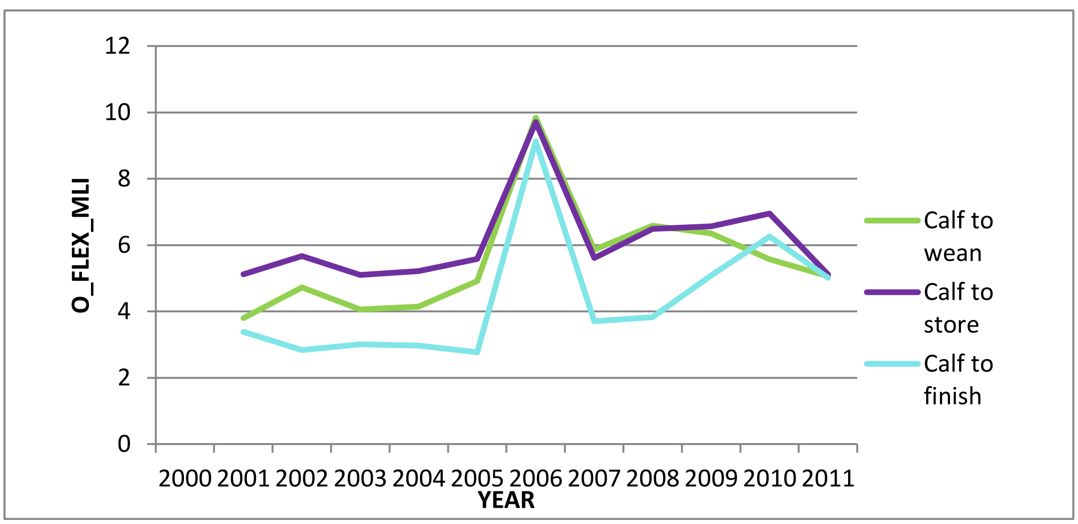
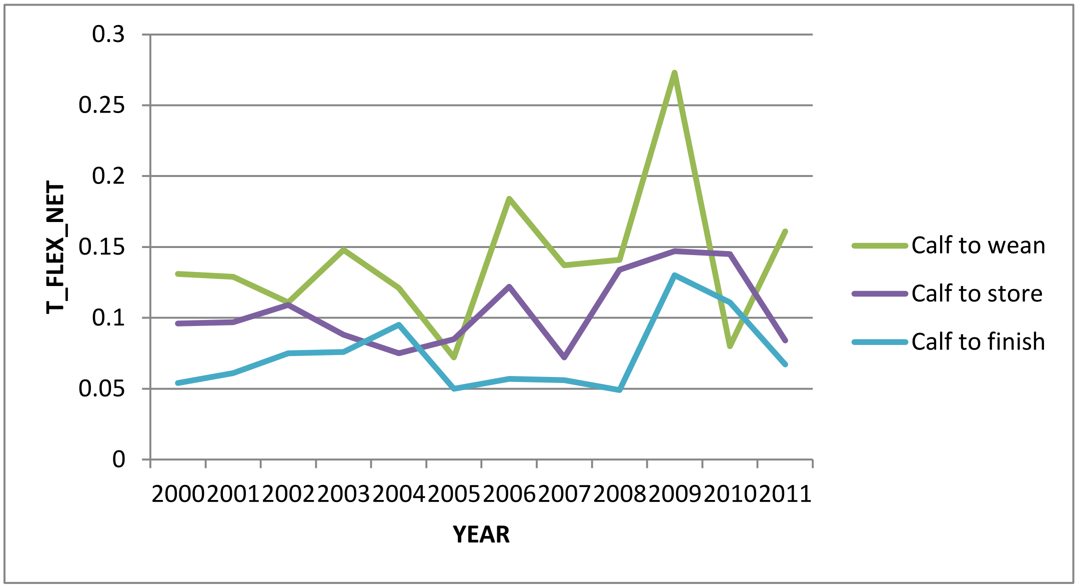


Figure 2: Tactical flexibility across systems (weighted averages, 2000-2011)



Determinants of operational flexibility

In the short-term, flexibility of suckler beef cow calf farms, when operational flexibility is measured with the MLI, is strongly determined by adjustments in marketing strategies (see time varying effects in Table 5). For the specialized C-W farms, retention of calf ownership until the end of backgrounding period or until the finishing stage appear to increase flexibility (coefficients 2.505 and 3.726 are statistically significant at 1% level). Moreover, beef farmers with predominant C-W cattle marketing strategy appear to benefit in flexibility terms when the majority of cattle enter the farm as stores and leave as finished cattle. Switches to cow-calf to heifers-in-calf, other, and mixed strategy are also flexibility-enhancing strategies. For C-S farmers moving to upstream (C-W) and downstream (C-F) beef industry segments increased flexibility (especially moving to C-W segment). Cow-calf to heifers-in-calf, stores to finish, and mixed strategy also increased the operational flexibility of C-S farms. Choosing marketing strategies related to upstream beef industry segments led to increased flexibility for C-F farms but the adaption of 'other' marketing strategy increased more their flexibility. We assume that most of C-F farmers have the infrastructure to operate within the long commercial life-cycle of beef cattle (period lasting more than 2 years), so buying and selling cattle older than 2 years may be beneficial for them in terms of profits and flexibility as they could take advantage of seasonal price fluctuations.

In line with empirical evidence, the more diversified is the farm (smaller value of diversification index) the more flexible is in the short-run. This positive relationship holds for all beef farm groups under study.

Table 5. Determinants of operational flexibility

	Operational flexibility -O_FLEX_MLI			Operational flexibility -O_FLEX_LI		
	Calf to weanling	**Calf to store**	**Calf to finish**	**Calf to weanling**	**Calf to store**	**Calf to finish**
	Mean (Robust std errors)	Mean (Robust std errors)	Mean (Robust std errors)	Mean (Robust std errors)	Mean (Robust std errors)	Mean (Robust std errors)
Time varying effects						
Age	-0.036** (0.016)	-0.033 (0.023)	0.027 (0.049)	-0.020 (0.029)	-0.037 (0.024)	0.029 (0.056)
Family size	0.160 (0.228)	0.119 (0.152)	-0.126 (0.229)	0.192 (0.206)	0.120 (0.171)	-0.197 (0.241)
Full-time farming	0.216 (0.421)	-0.312 (0.321)	1.173** (0.598)	0.409 (0.433)	-0.352 (0.333)	0.773 (0.639)
Land use potential						
Average	0.188 (0.391)	-0.302 (0.249)	0.188 (0.352)	-0.165 (0.409)	-0.486* (0.249)	0.104 (0.399)
Poor	0.113 (0.448)	0.449 (0.480)	-0.840 (0.638)	-0.308 (0.460)	0.372 (0.547)	-0.814 (0.609)
LU	-0.033 (0.061)	-0.024 (0.035)	0.034 (0.042)	0.041 (0.063)	-0.000 (0.038)	0.080** (0.040)
LU^2	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	-0.000** (0.000)
Opening breeding inventory	0.009 (0.033)	0.031 (0.029)	0.041 (0.030)	0.017 (0.031)	0.051* (0.031)	0.049 (0.031)
Calving percentage	-0.003 (0.003)	0.000 (0.001)	0.007** (0.003)	0.003 (0.002)	0.001 (0.002)	0.004 (0.004)
Calving death loss	-1.203 (0.973)	-0.294* (0.165)	0.147 (0.353)	-0.961 (1.210)	-0.642*** (0.214)	-0.260 (0.513)
Mature cattle death ratio	-1.031 (3.403)	3.085 (2.975)	3.984 (10.161)	2.755 (4.839)	0.549 (3.726)	0.742 (10.458)
Seasonality of beef cattle production						

Mainly winter	0.132 (0.841)	-0.022 (0.733)	-2.783*** (0.654)	1.301 (1.287)	-0.097 (0.939)	-2.661*** (0.844)
Winter and summer	0.243 (0.264)	0.001 (0.343)	-0.772 (0.497)	0.339 (0.259)	0.084 (0.409)	-0.222 (0.561)
Calf rearing method						
Multiple suckling	0.976 (1.196)	-0.863* (0.520)	-0.220 (0.440)	1.580 (1.203)	-0.618 (0.462)	0.201 (0.481)
Bucket or mixed	1.008* (0.566)	-0.113 (0.402)	0.138 (0.530)	1.000 (0.757)	0.385 (0.431)	0.215 (0.581)
Stocking rate	-0.199 (0.387)	0.351 (0.525)	0.427 (0.656)	0.064 (0.466)	0.987* (0.524)	0.203 (0.639)
Home-produced feed share	0.005 (0.004)	0.005 (0.004)	0.019** (0.007)	0.000 (0.004)	0.004 (0.004)	0.024*** (0.009)
Cattle marketing strategy						
Calf to weaning	-	2.716*** (0.379)	7.864*** (2.752)	-	3.625*** (0.510)	11.578*** (2.286)
Calf to store	2.505*** (0.420)	-	4.538*** (0.792)	2.254*** (0.606)	-	5.318*** (0.972)
Calf to finish	3.726*** (1.402)	1.970*** (0.471)	-	4.516** (1.977)	1.732*** (0.530)	-
Weanlings to store	-0.871 (0.652)	1.620 (1.778)	2.203 (1.535)	4.314*** (0.769)	2.345 (1.826)	-1.185* (0.710)
Stores to finish	5.642*** (1.430)	2.870*** (0.462)	0.253 (0.342)	6.867*** (1.396)	3.225*** (0.558)	0.514 (0.322)
Calf to heifers-in-calf	3.547*** (0.602)	3.385*** (0.545)	0.515 (0.997)	2.292*** (0.886)	2.647*** (0.685)	1.189 (1.546)
Other	2.868*** (0.364)	5.941 (4.333)	10.233*** (0.797)	4.848*** (1.185)	7.296 (4.449)	16.662*** (0.889)
Mixed	1.575*** (0.448)	1.015*** (0.294)	1.069** (0.485)	3.147*** (0.526)	3.005*** (0.417)	2.900*** (0.588)
Diversification	-2.701*** (0.556)	-2.929*** (0.600)	-4.009*** (1.004)	-0.485 (0.709)	-0.978 (0.685)	-0.281 (1.080)

Trend	0.029 (0.068)	0.093* (0.056)	-0.084 (0.088)	0.161** (0.080)	0.178*** (0.057)	0.089 (0.099)
Time averaged effects (Mundlak-CRE device)						
Age	0.038* (0.022)	0.024 (0.026)	-0.030 (0.053)	0.024 (0.033)	0.031 (0.028)	0.030 (0.059)
Family size	-0.099 (0.252)	-0.047 (0.170)	0.019 (0.257)	-0.183 (0.229)	-0.079 (0.182)	0.082 (0.271)
LU	0.017 (0.065)	-0.006 (0.038)	-0.078* (0.046)	-0.061 (0.064)	-0.025 (0.039)	-0.119*** (0.043)
LU^2	-0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	0.000*** (0.000)
Opening breeding inventory	-0.003 (0.015)	-0.025*** (0.008)	0.001 (0.018)	-0.000 (0.013)	-0.027*** (0.008)	-0.002 (0.016)
Calving percentage	-0.011 (0.013)	0.006 (0.006)	-0.009 (0.007)	-0.000 (0.013)	0.008 (0.006)	-0.004 (0.006)
Calving death loss	1.651 (1.704)	0.304 (0.529)	0.965 (0.618)	-0.011 (2.202)	0.327 (0.584)	1.057 (0.789)
Mature cattle death ratio	3.098 (10.078)	11.538 (8.872)	-5.158 (22.445)	1.031 (11.071)	14.181 (9.872)	8.985 (21.675)
Stocking rate	0.240 (0.430)	-0.120 (0.580)	-0.454 (0.704)	-0.051 (0.536)	-0.938 (0.608)	-0.002 (0.671)
Home-produced feed share	-0.014* (0.008)	-0.006 (0.009)	-0.014 (0.012)	-0.012 (0.008)	-0.008 (0.009)	-0.016 (0.013)
Diversification	1.785 (1.277)	3.985*** (1.103)	7.827*** (1.701)	-0.316 (1.340)	2.062* (1.189)	4.126** (1.675)
Trend	0.319** (0.141)	-0.021 (0.106)	0.258* (0.151)	0.160 (0.149)	-0.174 (0.111)	0.139 (0.175)
Constant	4.462** (2.007)	5.094*** (1.359)	3.460* (2.083)	3.457* (2.076)	4.059*** (1.451)	0.306 (2.005)
Observations (*n*)	1518	2721	804	1518	2721	804
Number of farms	210	367	101	210	367	101

R-squared (overall)	0.170	0.113	0.235	0.119	0.101	0.241
*** p < 0.01, ** p < 0.05, * p < 0.1						

Full-time farming affects positively the flexibility of C-F farms while farmer's age plays a negative role on the operational flexibility of C-W farms. One year increase in farmer's age reduces flexibility by 0.036. Farm size based on total cattle LU is negatively associated with the operational flexibility of C-W and C-S farms as it was expected from literature findings but the effect is not significant at 10% level. In the case of C-F farms, farm size positively affects operational flexibility but the result is not significant at 10% level. The squared value of LU and opening breeding inventory numbers do not strongly affect short-term flexibility and estimates are not significant at 10% level. Calving percentage, as expected, has a positive but weak effect for C-F farms and calving death loss decreases the flexibility of C-W farms. Winter production has strong negative effect on the operational flexibility of C-F farms. Logically such C-F farmers have larger cattle herds than the average Irish beef farmer and adequate housing facilities for the cattle during winter season. Investment cost is probably higher in these farms so large variations in output would induce additional risk without compensating these fixed capital investments. Achieving economies of scale might be the principal goal for these winter operating C-F farms.

In the same vein, multiple suckling affects negatively operational flexibility of C-S farms. The purchase of nurse cows similar to investments in fixed capital could be considered as an investment with sunk costs, so probably C-S farmers avoid output variations and become less flexible in the short-run. Bucket or mixed calf rearing method increases the flexibility of C-W farms. Feeding calves with milk in a bucket or combining bucket feeding with single- and/or multiple suckling (with few nurse cows though), may increase work flexibility and support cattle output variations according to market prices and demand.

Feeding cattle mainly with home-grown (on-farm) forages and crops has positive effect on the operational flexibility of all farm groups but only for C-F farms the effect is stronger and significant (at 5%). Farm intensification based on stocking rates is positively associated with the operational flexibility of C-S and C-F farms but is insignificant at 10% level. Exogenous technological change increases the flexibility of C-S farms.

Estimating operational flexibility with the LI does not change the conclusions regarding the effect of calf retention and marketing strategy adjustments on the operational flexibility of all beef farm groups. However the significance levels for some determinants change. For example the effect of stocking rate on C-S farm flexibility becomes significant at 10% level; the diversification effect on farm flexibility for all farm groups becomes insignificant at 10% level as well as the effect of age on flexibility of C-W farms or the effect of LU for C-F farms. The signs of few statistically insignificant parameters also alter (for example the effect of poor land use potential on flexibility of C-W farms).

Determinants of tactical flexibility

In the medium-run, when tactical flexibility is estimated as *T_FLEX_NET* (index adjusted for cattle purchases and cattle herd outflow), retaining the ownership of calves until weaning increases the C-W farms' flexibility (0.056-significant at 5% level) but extending the calf ownership until finishing stage would reduce flexibility. Switching to cow-calf to heifers-in-calf would also increase flexibility for this farm group. For C-S store farms there should be no medium-term deviation from the dominant the marketing strategy if C-S farmers prefer to remain flexible. Turning to weanling to store producers would decrease flexibility compared to the dominant strategy. For C-F farms moving to the upper stream segment of the industry (C-W) would increase flexibility in certain years but no other alternative strategy would improve their flexibility. Whole-farm specialization and technological advances increase flexibility of all farms in the medium-run, while operational flexibility (measured with the MLI) slightly increases flexibility of C-S farms.

Increased home-grown feed proportion in total feed and stocking rate do not significantly affect tactical flexibility of all farms. Full-time farming and the size of family affects positively the flexibility of C-W farms. Farm size based on total cattle LU is negatively associated with the tactical flexibility of C-W and C-S farms as it was expected from literature findings but the effect is very weak. In the case of C-F farm size does not affect operational flexibility but the result is not significant at 10% level. The squared value of LU does not affect the flexibility of C-W and C-S farms suggesting that farm size was quite optimal for the period under study. Surprisingly, for C-S farms poor land use potential increases flexibility compared to the referent good land use potential. Land plots with limited use potential could be more affected by adverse climatic conditions leading to more volatile forage yields.

Table 6. Determinants of tactical flexibility

	Tactical flexibility - T_FLEX_NET			**Tactical flexibility - T_FLEX**		
	Calf to weaning	**Calf to store**	**Calf to finish**	**Calf to weaning**	**Calf to store**	**Calf to finish**
	Mean (Robust std errors)	Mean (Robust std errors)	Mean (Robust std errors)	Mean (Robust std errors)	Mean (Robust std errors)	Mean (Robust std errors)
Time varying effects						
Age	0.001 (0.001)	-0.000 (0.000)	-0.000 (0.001)	0.001 (0.003)	-0.003 (0.002)	0.003 (0.005)
Family size	0.019* (0.011)	-0.015 (0.012)	-0.002 (0.009)	0.019 (0.031)	0.006 (0.011)	-0.071 (0.069)

Full-time farming	0.045** (0.019)	-0.007 (0.031)	0.014 (0.015)	0.041 (0.038)	0.038 (0.028)	-0.016 (0.122)
Land use potential						
Average	0.002 (0.019)	0.004 (0.013)	0.027 (0.019)	-0.000 (0.035)	0.031 (0.028)	0.197 (0.141)
Poor	-0.004 (0.025)	0.076* (0.043)	0.017 (0.032)	0.017 (0.043)	0.034 (0.047)	0.078 (0.099)
LU	- 0.007*** (0.002)	-0.004*** (0.001)	0.000 (0.001)	-0.017*** (0.006)	-0.001 (0.003)	-0.000 (0.007)
LU^2	0.000*** (0.000)	0.000* (0.000)	0.000 (0.000)	0.000** (0.000)	0.000 (0.000)	0.000 (0.000)
Opening breeding inventory	-0.002 (0.001)	0.001 (0.001)	0.000 (0.001)	0.001 (0.004)	0.007* (0.003)	-0.001 (0.005)
Calving percentage	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000* (0.000)	0.000 (0.000)	-0.001 (0.001)
Calving death loss	-0.031 (0.039)	0.027 (0.025)	0.034 (0.042)	-0.242 (0.176)	-0.025** (0.012)	0.446 (0.395)
Mature cattle death ratio	0.313 (0.294)	0.195 (0.218)	0.781 (0.527)	0.647 (0.585)	0.432 (0.447)	4.165 (2.730)
Seasonality of beef cattle production						
Mainly winter	-0.010 (0.045)	0.029 (0.049)	-0.006 (0.023)	-0.120 (0.095)	-0.061 (0.071)	0.013 (0.070)
Winter and summer	-0.039** (0.018)	-0.013 (0.026)	-0.141 (0.014)	-0.040 (0.027)	-0.015 (0.030)	0.046 (0.053)
Calf rearing method						
Multiple suckling	-0.139*** (0.029)	-0.001 (0.021)	0.018 (0.014)	-0.194** (0.093)	0.044 (0.037)	0.076 (0.071)
Bucket or mixed	-0.053 (0.043)	-0.008 (0.025)	-0.001 (0.016)	-0.134 (0.094)	0.060* (0.030)	-0.069 (0.043)
Stocking rate	-0.022 (0.016)	0.004 (0.026)	-0.028 (0.021)	0.002 (0.039)	0.000 (0.035)	0.086 (0.077)
Home-produced feed	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.001)

Cattle marketing strategy						
Calf to weaning	-	0.043 (0.054)	0.253^{**} (0.115)	-	0.083 (0.055)	1.514 (1.159)
Calf to store	0.056^{**} (0.023)	-	0.024 (0.018)	0.144^{**} (0.069)	-	-0.016 (0.121)
Calf to finish	-0.016 (0.044)	-0.014 (0.013)	-	0.135 (0.148)	-0.019 (0.024)	-
Weanlings to store	0.036 (0.038)	-0.077^{*} (0.046)	0.014 (0.025)	-0.141^{*} (0.074)	-0.054 (0.049)	-0.191 (0.127)
Stores to finish	0.133 (0.121)	-0.000 (0.015)	0.001 (0.012)	0.099 (0.184)	-0.004 (0.040)	0.114 (0.085)
Calf to heifers-in-calf	0.281^{***} (0.101)	0.039 (0.040)	-0.022 (0.016)	0.487^{***} (0.172)	0.277^{***} (0.103)	0.103 (0.132)
Other	-0.125^{***} (0.030)	0.240 (0.201)	-0.102^{***} (0.035)	-0.003 (0.095)	1.888 (1.400)	-0.439^{**} (0.209)
Mixed	0.004 (0.016)	0.005 (0.019)	0.001 (0.017)	-0.011 (0.035)	-0.046^{**} (0.020)	0.053 (0.060)
Diversification	0.127^{**} (0.053)	0.171^{***} (0.062)	0.083^{***} (0.031)	0.128 (0.086)	0.040 (0.052)	0.355^{*} (0.210)
Trend	0.011^{*} (0.006)	0.009^{***} (0.003)	0.004^{***} (0.001)	0.015^{*} (0.008)	0.015^{***} (0.004)	0.021 (0.015)
O_FLEX_MLI	0.001 (0.002)	0.004^{*} (0.002)	-0.001 (0.001)	0.015^{***} (0.003)	0.007^{***} (0.002)	0.016^{*} (0.009)
Time averaged effects (Mundlak-CRE device)						
Age	-0.001 (0.012)	0.001 (0.000)	0.000 (0.001)	-0.000 (0.003)	0.002 (0.002)	-0.004 (0.006)
Family size	-0.025^{*} (0.012)	0.018 (0.015)	-0.002 (0.011)	-0.015 (0.030)	-0.009 (0.015)	0.083 (0.081)
LU	0.003 (0.002)	0.003^{**} (0.001)	-0.001 (0.001)	0.019^{**} (0.007)	0.001 (0.003)	-0.005 (0.010)
LU^2	-0.000 (0.000)	-0.000^{*} (0.000)	0.000 (0.000)	-0.000^{**} (0.000)	-0.000 (0.000)	0.000 (0.000)

Opening breeding inventory	-0.001** (0.000)	0.001 (0.000)	-0.000 (0.000)	0.000 (0.001)	-0.001* (0.000)	-0.002 (0.001)
Calving percentage	0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	-0.002 (0.001)	-0.001*** (0.000)	-0.000 (0.001)
Calving death loss	0.038 (0.088)	-0.009 (0.027)	-0.018 (0.039)	0.818** (0.381)	0.077 (0.050)	-0.243 (0.305)
Mature cattle death ratio	1.427** (0.656)	3.241*** (1.095)	1.140 (0.912)	-1.637 (1.276)	1.647 (1.084)	1.686 (2.694)
Stocking rate	0.009 (0.017)	-0.046 (0.029)	0.021 (0.025)	-0.009 (0.040)	-0.002 (0.041)	0.042 (0.162)
Home-produced feed share	-0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	-0.001 (0.000)	0.002** (0.011)	0.003 (0.003)
Diversification	0.105 (0.071)	-0.109 (0.078)	-0.114* (0.069)	0.197* (0.116)	0.117 (0.097)	-0.384* (0.224)
Trend	-0.007 (0.008)	-0.003 (0.005)	-0.019*** (0.006)	-0.005 (0.013)	-0.016 (0.010)	-0.057** (0.028)
O_FLEX_MLI	0.014** (0.005)	-0.003 (0.002)	0.012*** (0.004)	0.023*** (0.007)	0.024*** (0.005)	0.041 (0.026)
Constant	-0.035 (0.117)	0.039 (0.093)	0.198** (0.101)	-0.037 (0.181)	-0.107 (0.148)	0.035 (0.486)
Observations	1518	2721	804	1518	2721	804
Number of farms	210	367	101	210	367	101
R-squared (overall)	0.132	0.062	0.189	0.194	0.134	0.255
*** p < 0.01, ** p < 0.05, * p < 0.1						

Opening breeding inventory and proxy variables for farmers' managerial ability are all insignificant at 10% level. Whole-year production and multiple suckling reduces flexibility in C-W farms.

Estimation results for the determinants of tactical flexibility when is measured as *T_FLEX* also suggest that retaining the ownership of calves beyond weaning would increase flexibility of C-W farms, as switching to cow-calf to heifers-in-calf marketing strategy would do as well. For C-S farms the only flexibility-enhancing alternative strategy is to switch to cow-calf to heifers-in-calf marketing strategy. It seems that C-F farms should not change their dominant strategy. Opening breeding inventory slightly increases flexibility of C-S farms and increased calving death loss decreases it as it was expected. The effects of family size and full-time farming remain positive but turn insignificant at 10%. In general model's results and conclusions do not change (apart from minor changes) if operational flexibility is measured with the LI (results in appendix).

6. Conclusions

Irish beef farms similar to farms and firms all over the globe, operate under dynamically changing conditions due to shifts in consumers' diets, increased competition with other meat sectors, and changes in economic and natural environment. In order to cope and tackle these challenges farms and firms develop effective adjustment strategies which will ensure their long-term survival and economic prosperity. Given the traditional dual character of farming activity and the existence of many medium-sized family-owned Irish farms, increased flexibility could be a better alternative strategy for economic sustainability than increasing farm size and production scale.

Using a rich nationally representative panel data set of Irish beef farms, short- and medium-term flexibility was estimated for three beef suckler cow calf farms. In the short-term calf to store farms are more capable to adjust product mix, whereas calf to weaning farms are more capable to adjust overall scale of production in the longer-term.

In the case of calf to weaning farms, calf retention beyond weaning increases flexibility in the short- and medium-term. Furthermore, adjustments in cattle marketing strategies also increase the flexibility of all beef suckler cow farms in our sample. Results also suggest that certain technologies embedded to beef production systems such as calf rearing methods and seasonality of production may increase the flexibility in specific beef farm groups. Family size and full time farming increases the medium-term flexibility of C-W farms while whole farm-level diversification increases medium-term flexibility of all beef farms.

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Appendix

Table A1. Determinants of tactical flexibility (with Lilien index as an explanatory variable)

	Tactical flexibility - T_FLEX_NET			**Tactical flexibility - T_FLEX**		
	Calf to weaning	**Calf to store**	**Calf to finish**	**Calf to weaning**	**Calf to store**	**Calf to finish**
	Mean (Robust std errors)	Mean (Robust std errors)	Mean (Robust std errors)	Mean (Robust std errors)	Mean (Robust std errors)	Mean (Robust std errors)
Time varying effects						
Age	0.001 (0.001)	-0.000 (0.000)	-0.000 (0.001)	0.001 (0.003)	-0.003 (0.002)	0.004 (0.005)
Family size	0.020* (0.011)	-0.015 (0.012)	-0.002 (0.009)	0.021 (0.031)	0.007 (0.012)	-0.072 (0.070)
Full-time farming	0.040** (0.019)	-0.008 (0.031)	0.013 (0.015)	0.031 (0.039)	0.036 (0.028)	-0.009 (0.124)
Land use potential						
Average	0.007 (0.019)	0.004 (0.014)	0.027 (0.019)	0.012 (0.035)	0.034 (0.028)	0.199 (0.136)

Poor	0.003 (0.025)	0.076* (0.042)	0.018 (0.033)	0.037 (0.042)	0.041 (0.046)	0.068 (0.093)
LU	- 0.007*** (0.002)	-0.004*** (0.001)	0.000 (0.001)	-0.018*** (0.006)	-0.001 (0.003)	-0.000 (0.006)
LU^2	0.000*** (0.000)	0.000* (0.000)	0.000 (0.000)	0.000** (0.000)	0.000 (0.000)	0.000 (0.000)
Opening breeding inventory	-0.002 (0.001)	0.001 (0.001)	0.000 (0.001)	0.000 (0.004)	0.007** (0.003)	-0.002 (0.006)
Calving percentage	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000* (0.000)	0.000 (0.000)	-0.001 (0.001)
Calving death loss	-0.032 (0.038)	0.027 (0.025)	0.034 (0.042)	-0.257 (0.184)	-0.027** (0.012)	0.451 (0.399)
Mature cattle death ratio	0.306 (0.290)	0.207 (0.218)	0.786 (0.528)	0.620 (0.590)	0.458 (0.449)	4.275 (2.740)
Seasonality of beef cattle production						
Mainly winter	-0.012 (0.045)	0.029 (0.050)	-0.008 (0.023)	-0.116 (0.097)	-0.057 (0.070)	-0.023 (0.068)
Winter and summer	-0.038** (0.018)	-0.014 (0.026)	-0.014 (0.013)	-0.037 (0.028)	-0.014 (0.031)	0.033 (0.048)
Calf rearing method						
Multiple suckling	-0.142*** (0.028)	-0.002 (0.021)	0.017 (0.014)	-0.189** (0.091)	0.032 (0.038)	0.078 (0.068)
Bucket or mixed	-0.054 (0.043)	-0.009 (0.026)	-0.004 (0.016)	-0.141 (0.096)	0.057* (0.030)	-0.083* (0.044)
Stocking rate	-0.022 (0.016)	0.003 (0.026)	-0.027 (0.020)	0.000 (0.041)	0.001 (0.035)	0.100 (0.077)
Home-produced feed share	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	0.000 (0.001)
Cattle marketing strategy						
Calf to weaning	-	0.048 (0.055)	0.250** (0.107)	-	0.094* (0.055)	1.531 (1.175)
Calf to store	0.058** (0.023)	-	0.023 (0.015)	0.173** (0.069)	-	0.013 (0.118)

Calf to finish	-0.01 (0.044)1	-0.009 (0.013)	-	0.180 (0.145)	-0.006 (0.024)	-
Weanlings to store	0.056 (0.034)	-0.073 (0.045)	0.012 (0.024)	-0.144* (0.081)	-0.049 (0.051)	-0.145 (0.126)
Stores to finish	0.135 (0.120)	0.005 (0.015)	0.000 (0.012)	0.158 (0.184)	0.009 (0.040)	0.116 (0.084)
Calf to heifers-in-calf	0.283*** (0.099)	0.050 (0.040)	-0.022 (0.015)	0.526*** (0.176)	0.295*** (0.103)	0.095 (0.134)
Other	-0.136*** (0.031)	0.254 (0.213)	-0.099*** (0.035)	0.016 (0.096)	1.905 (1.417)	-0.369 (0.228)
Mixed	0..000 (0.016)	0.003 (0.020)	0.001 (0.016)	0.001 (0.034)	-0.046** (0.020)	0.049 (0.068)
Diversification	0.123** (0.053)	0.160*** (0.058)	0.086*** (0.030)	0.087 (0.083)	0.020 (0.050)	0.288 (0.189)
Trend	0.011* (0.006)	0.009*** (0.003)	0.004*** (0.001)	0.015* (0.008)	0.015*** (0.004)	0.020 (0.015)
O_FLEX_LI	0.001 (0.001)	0.002 (0.001)	-0.000 (0.001)	0.001 (0.003)	0.002 (0.001)	0.006 (0.007)
Time averaged effects (Mundlak-CRE device)						
Age	-0.001 (0.001)	0.001 (0.000)	0.000 (0.001)	0.000 (0.003)	0.003 (0.002)	-0.004 (0.005)
Family size	-0.024* (0.012)	0.018 (0.015)	-0.001 (0.011)	-0.016 (0.031)	-0.008 (0.015)	0.086 (0.083)
LU	0.003 (0.002)	0.003** (0.001)	-0.001 (0.001)	0.019** (0.008)	0.001 (0.003)	-0.004 (0.010)
LU^2	-0.000* (0.000)	-0.000* (0.000)	0.000 (0.000)	-0.000** (0.000)	-0.000 (0.000)	0.000 (0.000)
Opening breeding inventory	0.001** (0.000)	0.001 (0.000)	-0.000 (0.000)	0.000 (0.001)	-0.001** (0.000)	-0.001 (0.001)
Calving percentage	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.002 (0.001)	-0.001*** (0.000)	-0.000 (0.001)
Calving death loss	0.046 (0.086)	-0.009 (0.028)	-0.012 (0.038)	0.849** (0.385)	0.079 (0.050)	-0.218 (0.303)

Mature cattle death ratio	1.549** (0.659)	3.259*** (1.099)	1.184 (0.899)	-1.272 (1.280)	1.691 (1.078)	1.873 (2.651)
Stocking rate	0.009 (0.017)	-0.045 (0.028)	0.019 (0.025)	-0.006 (0.042)	-0.000 (0.041)	0.018 (0.148)
Home-produced feed share	-0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	-0.001 (0.000)	0.002** (0.001)	0.002 (0.003)
Diversification	0.106 (0.074)	-0.096 (0.079)	-0.123* (0.070)	0.226* (0.116)	0.146 (0.097)	-0.351 (0.222)
Trend	-0.006 (0.008)	-0.003 (0.005)	-0.020*** (0.006)	-0.003 (0.013)	-0.014 (0.010)	-0.063** (0.031)
O_FLEX_LI	0.012*** (0.004)	-0.003 (0.002)	0.012** (0.005)	0.033*** (0.007)	0.026*** (0.006)	0.057* (0.033)
Constant	-0.016 (0.117)	0.050 (0.091)	0.221** (0.100)	0.007 (0.182)	-0.080 (0.151)	0.159 (0.431)
Observations	1518	2721	804	1518	2721	804
Number of farms	210	367	101	210	367	101
R-squared (overall)	0.130	0.060	0.192	0.183	0.129	0.258

*** p < 0.01, ** p < 0.05, * p < 0.1