The impact of the BSE crisis on the European beef industry structure

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Abstract

The Bovine Spongiform Encephalopathy (BSE) crisis is one of the most significant food scares in recent years. The first BSE case was diagnosed in the UK in 1996, and its origin is still unknown. Possible links between the BSE and the fatal human disease Variant Creutzfeldt-Jakob disease (vCJD) were first suggested by British Secretary of State for Health in 1996, following by an up-surge in the BSE cases throughout the EU. The BSE crisis has influenced many aspects of the economic structure of societies, from consumer demand, international trade, to prices along the supply chain, etc. Due to the increased public awareness, food safety is regarded as a prominent political issue. In order to protect the health of animals and consumers and to eliminate the BSE, the European Union laid down regulations for its control, prevention and eradication. Even though both the BSE crisis and relative regulations may affect the beef industry structure in the EU, little research has focused on this aspect. Therefore, the objective of this study is to measure the impact of the BSE crisis on the structure of European Beef industry. The data for our analysis mainly come from the FADN database which is carried out annually by the EU. We focus on the nine countries with more than 100 BSE cases in total from the year 1989 to 2008. We also differentiate the effects of the BSE crisis on farms of different size (Small, Medium and Large). Five metrics including Farm Number, Land, Net Asset, Beef production and Herfindahl index are chosen to measure the beef industry structure. For each group as well as the entire sample (pooled data), we perform model specification tests based on the BIC method. Finally, the regressions are performed with the most appropriate models which have the minimum BIC values. The results indicate that the BSE crisis has statistically significant impact on the structure of the European beef industry. Specifically, with the impact of BSE crisis, the beef industry may have become slightly less industrialized. Additionally, there seems to be more farms participating in the beef production, especially smaller ones. The BSE crisis also appears to lead to divestments as the average investment and the land for larger farms have decreased in the wake of the BSE crisis.

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1 Introduction

1.1 Background of the BSE crisis

Food scares are generally associated with a rapidly heightened level of public anxiety and media attention over the safety of a particular product (Schlenker and Villas-Boas, 2009b). Based on the agent which has caused it, the food scare can be categorized as microbiological, contaminant and animal disease-related incident (Knowles et al., 2007).

The majority of Western European countries have been hit by food safety related incidents at least once over the past three decades. Among the recent food scares, one of the most significant cases is the Bovine Spongiform Encephalopathy (BSE) crisis.

BSE is a Transmissible Spongiform Encephalopathy disease of cattle with the symptom of behavior changes, difficulty in standing up, lack of coordination, weight loss and milk production decrease (Europa, 2013b). The average incubation of BSE in cattle is around 4-6 years. The first confirmed BSE case was diagnosed in UK in 1986, and its origin is still unknown. However, the BSE epidemic may due to cattle being fed with the recycling of bovine tissues (Peter and Bradley, 2003).

In March 1996, a possible link between the BSE and a fatal human disease (Variant Creutzfeldt-Jacob Disease) was announced by the UK Secretary of state for Health (Phillips, 2000) for the first time. After that, there was an upsurge in the number of countries found the BSE cases for the first time.

Table 1. Sequence of the first report of the BSE cases in native-born cattle in EU

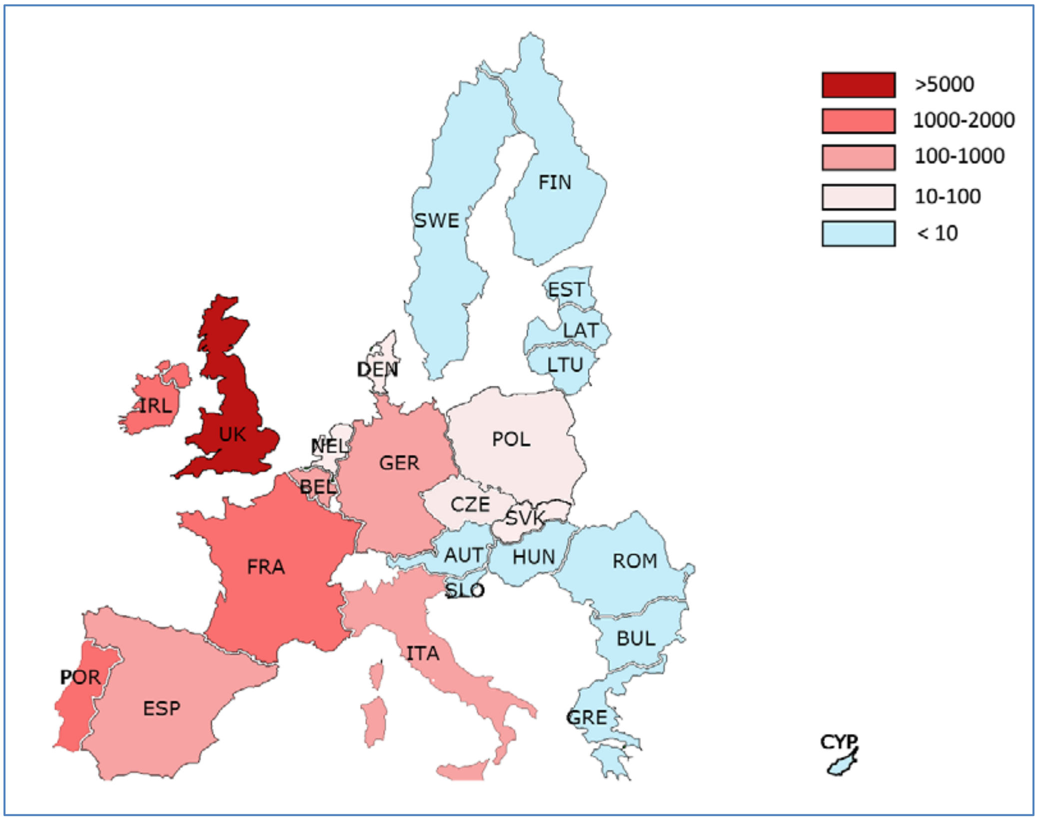
1986	UK
1989	Ireland
1990	Portugal
1991	France
1992	Denmark, Germany
1994	Italy
1997	Belgium, Luxembourg, the Netherlands
2000	Spain
2001	Czech Republic, Greece, Austria, Finland, Slovenia
2003	Poland, Slovakia
2006	Sweden
2007	Hungary

Source: Bovine spongiform encephalopathy (BSE) and its epidemiology (Peter and Bradley, 2003) and FADN database

Table 1 shows the sequence of the first reported BSE case of the EU member states. It is strongly plausible that the BSE cases in others counties rather than UK were seeded either by infected cattle imported from the UK or by the import of Meat and Bone Meal contaminated with the BSE agent (Peter and Bradley, 2003).

Figure 1 shows the map of the total number of the BSE cases reported from the year 1989 to 2011 in the EU27. It can be seen that the UK was the most severely impacted country with about 181,674 BSE cases during this period (FADN, 2013). While some counties had around thousand BSE cases like France, Ireland, Spain, and Portugal, some had no more than ten BSE cases during this period, such as Austria, Finland, Sweden, Greece, and Luxemburg (see Appendix 1.).

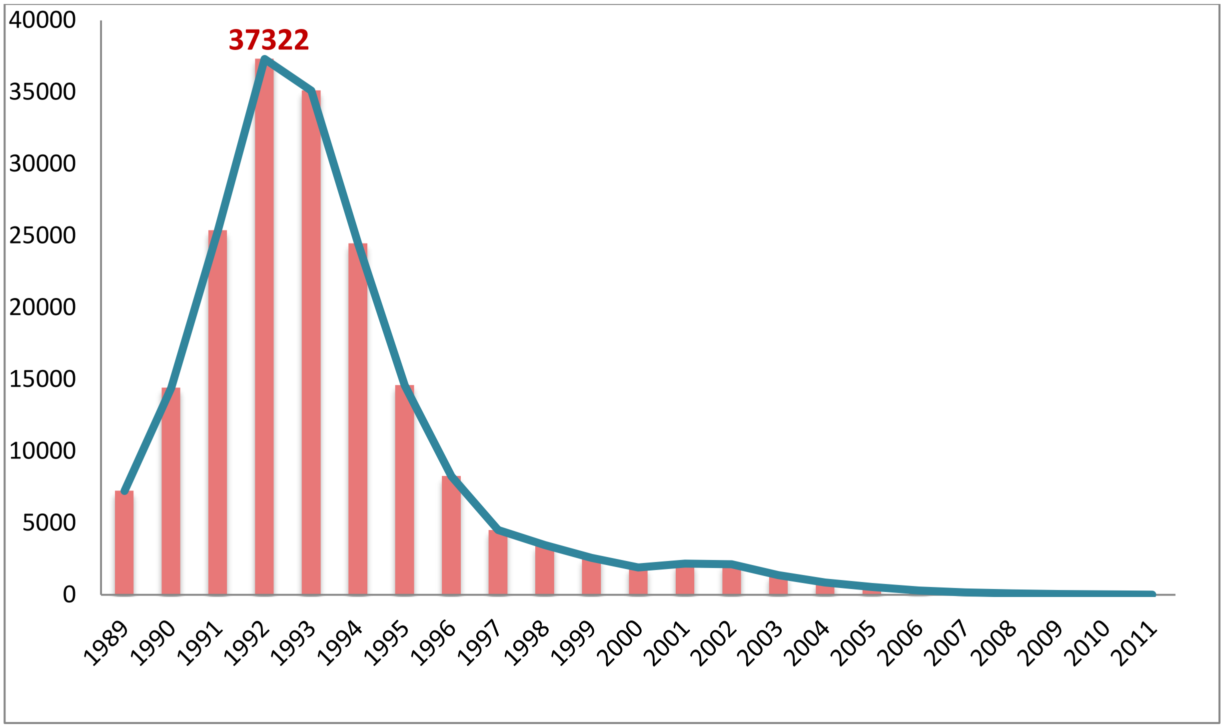
Figure 1. Map of the BSE cases in the EU27



Source: Report on the monitoring of ruminants for the presence of transmissible spongiform encephalopathies (TSEs) in the EU in 2011 (Europa, 2012b).

Figure 2 shows the total number of the reported BSE cases in the EU27 from the year 1989 to 2011. The cases between the year 1989-1996 accounted for about 90% of the total cases during this period. From the year 1989, the BSE cases increased dramatically, reaching the summit of 37,322 cases at 1992, and then dropped sharply. By 2003, the total BSE cases dropped under 1,000 cases. Additionally, from 2007 onward, there had been less than 100 annual BSE cases in the EU27 following a decreasing trend.

Figure 2. Total BSE cases in the EU27 during 1989-2011



Source: Report on the monitoring of ruminants for the presence of transmissible spongiform encephalopathies (TSEs) in the EU in 2011 (Europa, 2012b).

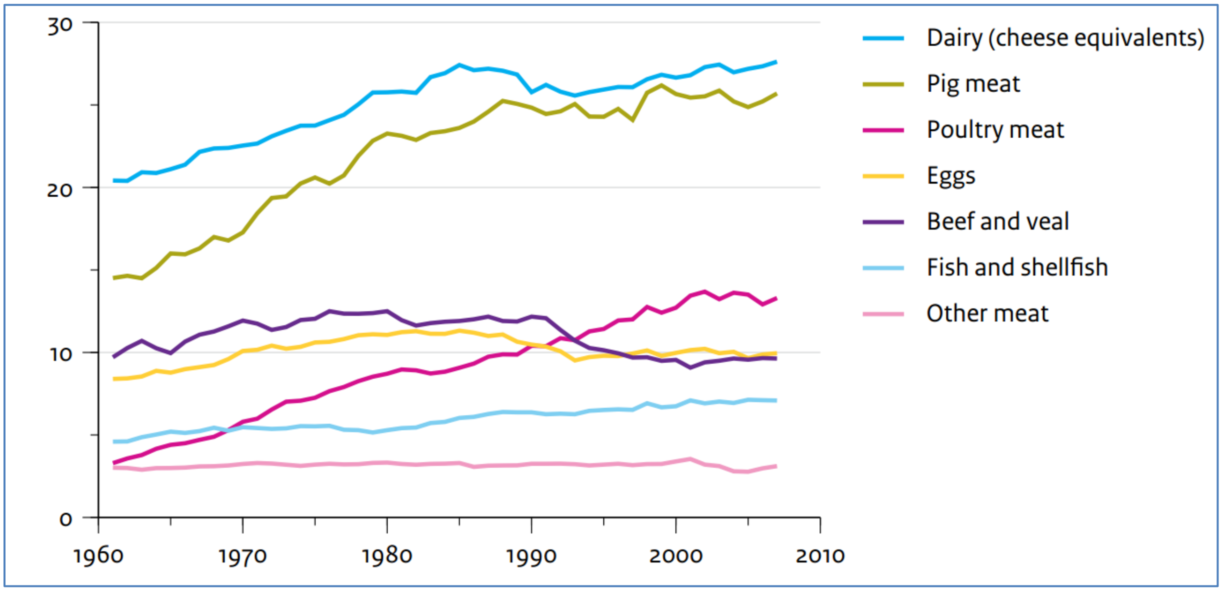
1.2 The European beef industry

The European Union is the second-largest producer of beef in the world with a production of about 7.8 Million metric tons (mmt) in the year 2010 behind the U.S. (12 mmt), and followed by Brazil (6.9 mmt) (Eurostat, 2010). France, Germany, Italy and UK are the main beef producer which account for 56% of the EU total beef production. The EU as a whole is self-sufficient in terms of beef consumption and production, and it has been one of the largest exporters in the world since the 1990s (Europa, 2013a).

The development of beef sector has been very slow over the past decades. Two thirds of the cows in the EU is dairy cows and farmers receive 80% of their income from the milk production. Beef production is a byproduct of milk production for most of the farms in the EU (Nielsen and Jeppesen, 2001).

In the EU, beef represents 20% of total meat intake and is the third-most consumed meat over the past fifty years with per-capita consumption around 10Kg per year (Figure 3) (Westhoek et al., 2011). While the average intake of most kind of meat had been increasing during this period, beef and veal consumption had been decreasing since the early 1990s. This may be partly due to the BSE crisis at that time (Fox, 2003).

Figure 3. Intake of animal products in EU27 over fifty years (Kg per capita per year)



Source: The consumption and production of meat, dairy and fish in the European Union (Westhoek et al., 2011).

1.3 Problem statement and objectives

The BSE crisis has influenced many aspects of the economic structures of societies, from consumer demand, international trade, to prices along the supply chain (Lloyd et al., 2001, Miran and Akgüngör, 2005). For example, the outbreak of the BSE crisis in the UK in 1996 led to an immediate fall of beef consumption by 40%, a fall of beef retail price by 18% (Lloyd et al., 2001, Miran and Akgüngör, 2005), and the complete loss of all export markets (Islam et al., 2009).

Due to the increased public awareness, food safety is regarded as a prominent political issue rather than just a scientific subject (DTZ, 1998). Therefore, many laws have been enacted defining safety standards of the final product, production practices, as well as the liabilities along the supply chain (Martin, 1991). In Europe, a white paper on food safety was published in 2000 by the European Commission and two years later the general food law came into force, introducing traceability requirements and generalized assessments of risks, based on the principles of HACCP (Hammoudi et al., 2009). In particular, in order to protect the health of both animal and consumers and to eliminate the BSE, the European parliament and Council regulation No 999/2001 laid down rules for control, prevention and eradication of the transmissible spongiform encephalopathy (Christophe et al., 2012).

The BSE crisis and the related regulations may have potential effects on the structure of the beef industry. On one hand, the BSE crisis can lead to the fall of consumer demand

and the reduction of the beef market size (European-Commission, 2001). On the other hand, the related regulations introduced additional costs along the supply chain (Schlenker and Villas-Boas, 2009b).

However, little research has been done to analyze the influence of the BSE crisis on the structure of European beef industry. Therefore, the objective of this study is to measure the impact of the BSE crisis on the structure of the beef industry in the European Union.

1.4 Organization of the thesis

With the aim of measuring the impact of BSE crisis on the European beef industry structure, this study is structured as follows. Firstly, a literature review will be conducted introducing recent studies relevant to the BSE crisis and the beef industry. Secondly, materials and methods will be discussed, in which the FADN database, data manipulation, and the regression model will be presented. Thirds, the results of the econometric analysis will be illustrated. Finally, we will proceed with a discussion of the results, followed by concluding remarks.

2 Literature Review

2.1 The impacts of the BSE crisis

The BSE crisis was one of the most significant food scares worldwide. And most of the existing literatures focused on the impact of the BSE crisis on the beef price transmission and consumers demand.

2.1.1 The impacts of the BSE crisis on beef price

Many papers have been written on the effect of the BSE crisis on the beef price, margins, and price transmission, especially using the British BSE crisis in 1996 as a case study. According to Meat and Livestock Commission (MLC) statistics, the retail beef price in UK fell by 11% and the beef consumption fell by 24% in the first two quarters of 1996. In addition, Christophe et al. (2012) examined the impact of the BSE crisis on beef price transmission between producers, wholesalers and retailers. Another paper showed that a long run relationship exist between producer-retail price, and a structural break occurred with the BSE crisis, which increased the price margin by more than ₤1/kg (Lloyd et al., 2001). Additionally, a quantitative analysis from Sanjuán and Dawson (2003) revealed that the 1996 British BSE crisis had different impacts on retailers and producers. The prices at the production level fell by more than double compared to those at the retail level. Besides the studies in UK, Islam et al. (2009) examined the impact of the BSE crisis in 2003 in United States, who found the crisis impacted producer’s price and retailer’s price differently. Similarly, Sayed (2007) also found that in Spain the BSE crisis affected the beef price of retailers and producers differently. As for the cost of recall due to the BSE crisis, Islam et al. (2009) analyzed the impact of beef recalls on the beef marketing channel and found that the price responses at the wholesale level did not transmit back to the farm level. A more recent study evaluated the effect of different food safety incidents on the beef marketing channel (Andrew and Michael, 2001), concluding that recall variable did not impact the price margins. Furthermore, Dhoubhadel (2009) did their research based on the US beef market, indicating that the information shocks were fairly transient in retail prices, but persist at the wholesale and farm levels.

There are also studies investigating the cross-country effects of the food scares on the market and price margins. For instance, Livanis (2005) had shown that the BSE outbreak in Canada and the United States had significant effects on the trade, and prices of US cattle. Japan, a major export market for the US beef products, banned all imports which resulted in considerable economic losses for beef producers (Coffey et al., 2005, Marsh et al., 2004). Similarly, Sayed (2007) also found evidences that the BSE crisis in UK had a great impact on the Korean meat market. Specifically, the retail price margin increased relatively to the farm and wholesale levels.

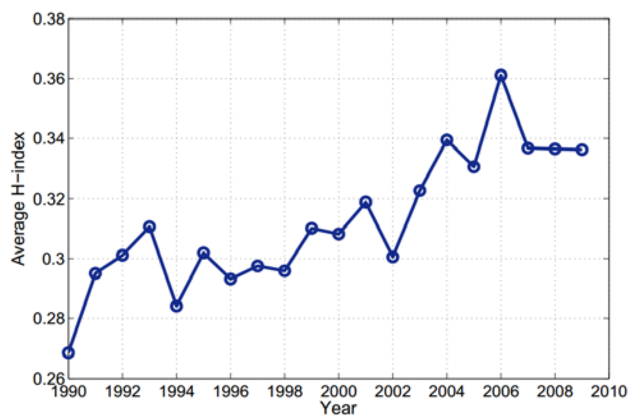
2.1.2 The impacts of the BSE crisis on the demand for beef

After the announcement that the BSE could result in human fatalities, beef demand changed greatly. Moonsoo et al. (2008) analyzed the impact of the BSE crisis on the demand for beef and other meat in UK. In the study, a short-run impact was identified accounting for large part of the discernible drop in the beef market size in the early 1990s. Meanwhile, a long-run impact of the BSE crisis was also found, which by the end of the year 1993 the beef market share decreased by 4.5%. Micheal and Trevor (1996) developed a theoretical model to capture the consumer response to the publicized food safety information. Piggot and Marsh (2004) analyzed the buying habits of consumer following the first discovery of the BSE cases in the United States in 2003. They found a statistically significant drop in beef consumption. Similarly in France, a paper showed that the beef consumption fell sharply by 22.1% after the French consumers being informed of the link between the BSE and the fetal human disease Creutzfeldt-Jacob disease (Schlenker and Villas-Boas, 2009a).

2.2 The structure of the European beef industry

The EU beef industry has undergone a significant change since the past twenty years. The concentration in the EU beef industry is increasing, especially at the slaughtering stage. The average size of farms also grows larger as well as the beef retailer (Nielsen and Jeppesen, 2001).

Figure 4. The average H-index of beef market for nine countries in EU from 1989-2009



Source: calculated based on the Standard result database (FADN, 2013)

In addition, based on the FADN database, we can calculate the average H-index (which measures the concentration level of an industry) for nine European countries per year from the year 1989 to 2009. It appeared that the average H-index for these countries was increasing during this period (Figure 4), indicating that the beef market had becoming more industrialized over the twenty years.

3 Material and Method

3.1 Description of the database

3.1.1 The FADN database

The data for our analysis mainly come from the Farm Accountancy Data Network (FADN) which is an annual survey collecting accountancy data from about 80,000 agricultural holdings in the EU 27. The FADN, carried out by the European Union, is the only source of micro-economic data that is harmonized and representative of the commercial agricultural holdings in the EU (Hajderllari and Karantininis, 2012).

3.1.2 Economic Size group

In the FADN database, the economic size of a farm, expressed in European size unit (ESU), is calculated using the SGM/ESU coefficient, where SGM is the standard gross margin (SGM) expressed in EURO. Initially, one ESU corresponded to 1,000 EURO, and it is adjusted regularly in order to account for inflation, whose effect would lead to the artificial growth of ESU. There are six different Economic size groups in the FADN database: 0 - <4 ESU group, 4 - <8 ESU group, 8 - <16 ESU group, 16 - <40 ESU group, 40 - <100 ESU group, >= 100 ESU group (Europa, 2012a).

For this research, the six ES groups are re-categorized as small, medium and large groups. The small group includes farms belonging to the 0 - <4 ESU and 4 - <8 ESU group. The medium group includes farms belonging to the 8 - <16 ESU and 16 - <40 ESU groups. And, the 40 - <100 ESU and >= 100 ESU groups are re-categorized as "large" group.

The reason for the re-categorization of farms is twofold. First, the categorization makes it possible to analyze the influences of the BSE crisis on the small, medium and large groups respectively instead of on the beef industry as a whole. Second, for each regression equation, there are about 15 independent variables except the Dummy variables. And the total observations are 660. Consequently, after the re-categorization, there are circa 200 observations for each group.

3.1.3 Variable definition

The farms analyzed are "Specialist cattle" farms, including "Specialist cattle-rearing and fattening" as well as "Cattle-dairying, rearing and fattening combined" ones. In order to measure the industry structure of the beef industry, several relevant variables have been chosen directly from the FADN database. The definition and calculation of these variables are listed as follows (FADN, 2013):

- Farm number: total number of agricultural holdings in the area. The FADN database uses a special weighting system based on the principle of free expansion in order to extrapolate the data in the sample to all holdings in the EU covered by the survey. Each holding in the sample has a weighting coefficient related to the population it represents. The weight of each individual farm is calculated as the population/sample. And the sum of the weighting coefficients is the total farm number in the population.
- Land: area used for agriculture reasons and expressed in hectares. This variable also includes the land temporarily out of cultivation for agricultural reasons or for policies. It does not include the land rented for less than one year, the area used for mushrooms, woodland or other areas such as roads, ponds and non-farmed area, etc.
- Livestock unit: number of animals kept in the farms including the number of cattle, sheep, pigs, goats, equines and poultry. And those numbers are converted into livestock units (LU) by multiplying a coefficient corresponding to the animal category. The coefficient table is in the Appendix 2.
- Beef production: value of beef and veal products expressed in Euros and calculated as production plus the change in valuation which is calculated as the closing valuation less the opening valuation.
- Net fixed asset: calculated as “total fixed assets” minus “land, permanent crops and quotas”. The “total fixed assets” includes land, forest capital, building, machinery, equipment and breeding livestock.
- Labor: total labor input of the agriculture holding. Labor is expressed in annual work units which is the full-time person equivalent.
- Cost: total amount of inputs related to the agricultural activity and linked to the output of the year. The cost is calculated as the sum of specific cost, overheads, depreciation and the external factors.
- Income: income obtained by the farm operators, calculated as the output minus the intermediate consumption plus the subsidies and taxes.
- Subsidy: total farm subsidies given by the government on the livestock and livestock products.

There are three variables obtained from sources other than the FADN database. And H-index is calculated from the FADN data. In the following section of this study, those four variables are denoted as ‘non-FADN data’.

- BSE: since May 1998, every Member State has to carry out a monitoring program for Transmissible spongiform encephalopathies (TSEs) in accordance with the

Regulation (EC) No 999/2001 of the European council (FADN, 2013). The numbers of positive BSE cases per year for each Member States are published online (EuropeanCommission, 2012).

- GDP: gross domestic product (GDP), calculated as the sum of the gross added value of all resident industries engaged in production, plus taxes, and minus subsidies. The GDP per capita is used as an indicator of living standard. The information is published every year by Eurostat (Europa, 2013b).
- Population: average population, calculated as the mean of the population on the January 1th of two consecutive years. The Eurostat published the census results every year (Eurostat, 2012).
- Herfindahl index (H-index): defined as the sum of the squared market shares for all firms within the industry, it measures its concentration level. A higher H-index indicates a higher industrial concentration. The H-index can range from 0 to 1.0. Generally, the industry can be considered highly competitive when the H-index is below 0.01, with moderate concentration when the H-index is between 0.15 and 0.25, and high concentration when it is above 0.25 (US-Justice, 2010).

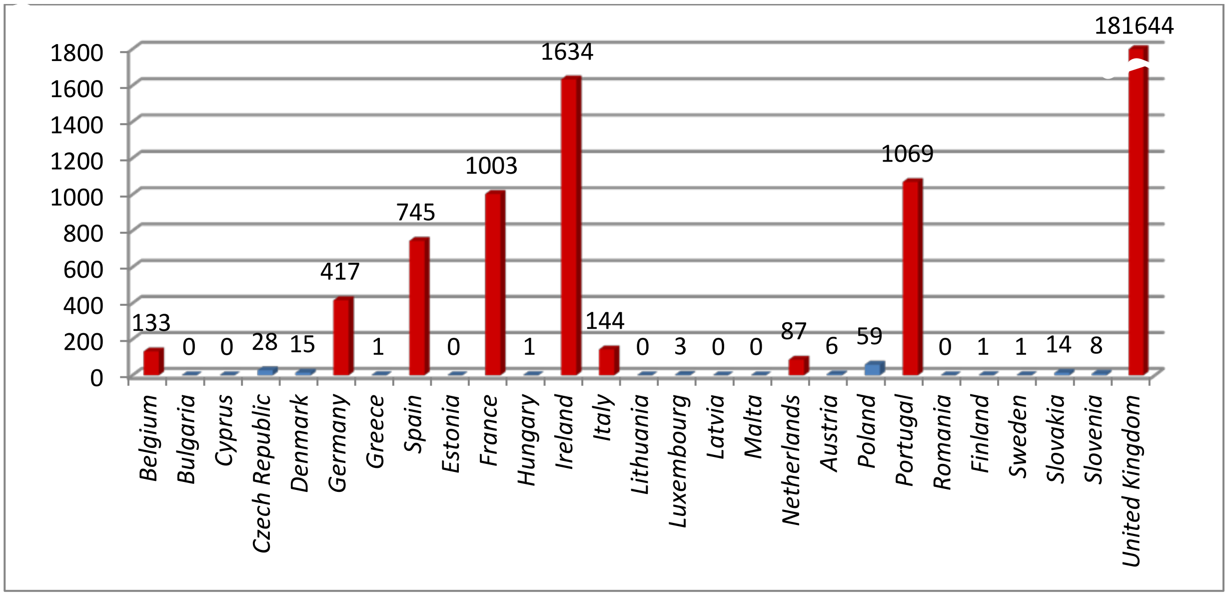
3.1.4 Data description

The data of the BSE cases in EU27 is retrieved for the period 1989-2011 (EuropeanCommission, 2012). The data in the FADN database is available from the year 1989 to 2009. Because the influence of BSE crisis on the industry structure is lagged, in our model, the BSE variable is lagged by one year. Therefore, the BSE cases are chosen from 1989 to 2008 and the data in the FADN database is chosen from 1990 to 2009.

Figure 5 shows the distribution of the total number of the BSE cases in the EU27 from 1989-2008. The red columns are the nine countries with more than 100 cases, selected for this analysis: Belgium, Germany, Spain, France, Ireland, Italy, Netherlands, Portugal and United Kingdom. It can be seen that the BSE cases in UK overweighed the other countries with 181,644 cases. In contrast, there are very few BSE cases in countries such as Greece, Finland and Sweden with only one case respectively.

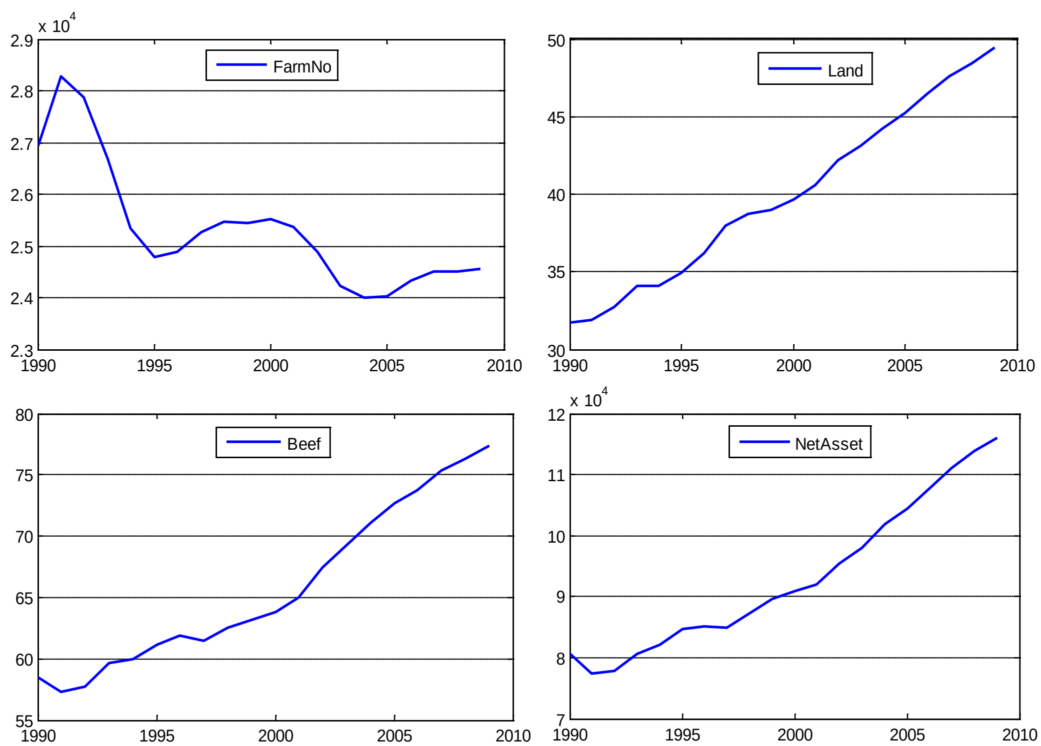
Figure 6 shows the trend of average Farm Number, Land, Beef and Net Asset from the year 1990 to 2009 for the nine counties selected for this analysis. The average Farm Number in all nine counties decreased throughout the years although had some bumps during the period. But for Land, Beef and Net Asset, the average value was increasing, indicating that the beef market had become more industrialized over the twenty years.

Figure 5. Distribution of total BSE cases by Country: 1989-2009



Source: Report on the monitoring of ruminants for the presence of transmissible spongiform encephalopathies (TSEs) in the EU in 2011 (Europa, 2012b)

Figure 6. Trend of average Farm Number, Land, Beef and Net Asset (1990-2009)



Source: Standard result database (FADN, 2013)

3.2 Data manipulation

This section illustrates the measures taken to manipulate and to prepare the data for the estimation, mainly the 'non-FADN data': BSE, H-index, population and GDP.

3.2.1 Calculation of the BSE cases for different groups

Since the officially reported BSE cases are only available at the country level, it needs to be re-calculated properly for different ES groups. It is assumed that each cattle in the country has the same chance to be infected by the BSE. As a result, each ES group receives a portion of the BSE cases based on its total cattle number. It can be formulated as:

$$BSE_i = BSE_{Tot} \frac{LU_i FarmNumber_i}{LU_{Tot} FarmNumber_{Tot}} \quad (1)$$

$$\sum_{i=1}^{6} LU_i FarmNo_i = LU_{Tot} FarmNumber_{Tot} \quad (2)$$

where BSE_{Tot}, $Farm\ Number_{Tot}$ and LU_{Tot} are the number of BSE cases, farm number and the average livestock units per farm in the country respectively, while LU_i and $Farm\ Number_i$ are the farm number and the averaged live units per farm for a specific ES group. And the index *i* denotes the ES group which is from 1 to 6. Using equation(1), the calculated BSE cases for each ES group (BSE_i) can be obtained.

3.2.2 Calculation of the H-index

The H-index is calculated as:

$$H = \sum_{i=1}^{N} s_i^2 \quad (3)$$

where s_i is the market share of firm *i* and N is the number of firms (US-Justice, 2010). In this thesis, s_i is defined as the market share of each ES group in the beef production:

$$S_i = \frac{FarmNumber_i Beef_i}{FarmNumber_{Tot} Beef_{Tot}} \quad (4)$$

In which $Beef_i$ and $Beef_{Tot}$ is the beef production expressed in Euros for each ES group and for the whole country, respectively.

Ideally, for nine countries over twenty years, there are in total 180 observations. However, due to the missing data in the FADN database, i.e. missing $Beef_i$ values, only 61 observations have the complete data for all ES groups, where the H-index can be directly calculated using (3) and (4).

Fortunately, in many observations, the missing $Beef_i$ value only occurs in one ES group. For these observations, the missing $Beef_i$ can be recovered by the following equation:

$$\sum_{i=1}^{6} Beef_i FarmNumber_i = Beef_{Tot} FarmNumber_{Tot} \qquad (5)$$

where all the other variables are known except for the missing $Beef_i$.

After data recovery(5), there are in total 139 observations available for the H-index calculations. But there are still 41 observations which cannot be recovered because they have missing data in more than one ES groups.

3.3 Regression model

3.3.1 General model

A regression model for measuring the impact of the BSE crises on the beef industry structure can be written as:

$$Y_{it} = \beta_0 + f(\mathrm{BSE}_{\mathrm{it}}) + \sum_k \beta_k X_{it} + D_i\beta_i + D_t\beta_t + \varepsilon_{it} \qquad (6)$$

where Y_{it} is the dependent variables. In this analysis five different dependent variables are chosen as the measures of the beef industry structure: NetAsset, FarmNumber, Beef, Land and H-index. The indexes *i* and *t* identify the i_{th} country in year *t*. $f(BSE_{it})$ is a BSE function, of which we consider several alternative specifications. The details regarding all the specifications of $f(BSE_{it})$ will be discussed in section *3.3.2*. X_{it} represents the independent variables other than the BSE. β_0 is the intercept, while D_i are the country fixed effects and D_t are the time dummies. ε is the error item.

3.3.2 Specification of the BSE function

For different dependent variables, the relationship between the BSE cases and the dependent variable may be different. Therefore, the form for $f(BSE_{it})$ can be selected from one of the three different forms listed in Table 2.

Table 2. Different forms of the BSE function *f*(BSE)

***f*(BSE)**	**Type of Regression**
β_1Lag(BSE)	Linear
β_1Log(BSE)	Logarithm
β_1Lag(BSE)+β_2Lag^2(BSE)	Quadratic

It is worth to mention that to obtain the Log(BSE), it is not possible to directly take a natural logarithm of the number of BSE cases. Because in may observations the value of the BSE cases is 0, yielding -∞ for Log(BSE). To avoid this issue, the logarithm is taken as follows:

$$Log(\text{BSE}) = \begin{cases} 0 & if \quad \text{Lag(BSE)} \leq 1 \\ Log(\text{Lag(BSE)}) & if \quad \text{Lag(BSE)} > 1 \end{cases} \tag{7}$$

This approximation assumes that when the number of BSE cases is smaller or equal than 1, the impact of BSE crises can be ignored.

3.3.3 Data scaling and Multicollinearity minimization

In addition to the BSE function, there are ten other independent variables in the X_{it} vector. The reason for data scaling is that the value of these independent variables range from 10^0 to 10^7. Although such data scaling issue does not influence the accuracy of the results, it is not convenient to compare and analyze their coefficients in the regression. There are some general methods to rescale the data, e.g. taking a logarithm of the data, normalizing the data with a constant, or dividing a variable by its variance, etc (Europa, 2013b)

Another potential issue in our data is multicollinearity. This issue can also be mitigated by data transformation, e.g. take difference, logarithm or exponential (Sheskin, 2007).

Therefore, in this study, all the independent variables are used in logarithm form (except for the form of the BSE which is selected using BIC method). Correspondingly, five dependent variables except the H-index[1] are transformed into logarithm form to simplify the analysis.

[1] The H-index is not transformed in logarithmic form because its value is from 0 to 1.

3.3.4 Model selection

In the model selection, the dummy variables are maintained as fixed while the specification of $f(BSE_{it})$ and the variables entering the X_{it} are to be determined. And these two unfixed parts are denoted as $g\left(\beta_k, BSE_{it}, X_{it}\right)$:

$$g\left(\beta_k, BSE_{it}, X_{it}\right) = f(\mathrm{BSE}_{\mathrm{it}}) + \sum_k \beta_k X_{it} \tag{8}$$

Thus, (6) can be rewritten as:

$$Y_{it} = \beta_0 + g\left(\beta_k, BSE_{it}, X_{it}\right) + \beta_i D_i + \beta_t D_t + \varepsilon_{it} \tag{9}$$

The model selection is performed in two steps:

Step1. Coarse selection: for each dependent variable, choose the expression of $\sum_k \beta_k X_{it}$.

Step2. Fine selection: using Bayesian Information Criterion (BIC) to optimize the term $g\left(\beta_k, BSE_{it}, X_{it}\right)$ and to determine the final empirical model.

To illustrate how the coarse model selection works, we take the Beef Production as an example. The averaged beef production is mainly determined by the beef demand and supply. From the supply point of view, variables such as labor, land, LU, total cost are included. To control the demand side factors, population and GDP are used. Table 3 shows the result of the coarse model selection.

Table 3. Result of the coarse model selection and the number of model alternatives in BIC

Dependent Variable	Chosen independent variable for X_{it}	Number of model specifications
Farm Number	Net Asset, Land, LU, Sub, Labor, GDP*, POP*	$3\times2^5=96$
Land	Labor, LU, Income, Beef	$3\times2^4=48$
Net Asset	Labor, Land, LU, Sub, TotalCost, Beef	$3\times2^6=192$
Beef	Labor, Land, LU, TotalCost, Net Asset, GDP*, POP*	$3\times2^5=96$
H-index	Net Asset, Land, LU, Sub, Labor, GDP*, POP*	$3\times2^5=96$

* In order to see the impact of GDP and POP, they are both fixed in the BIC selection

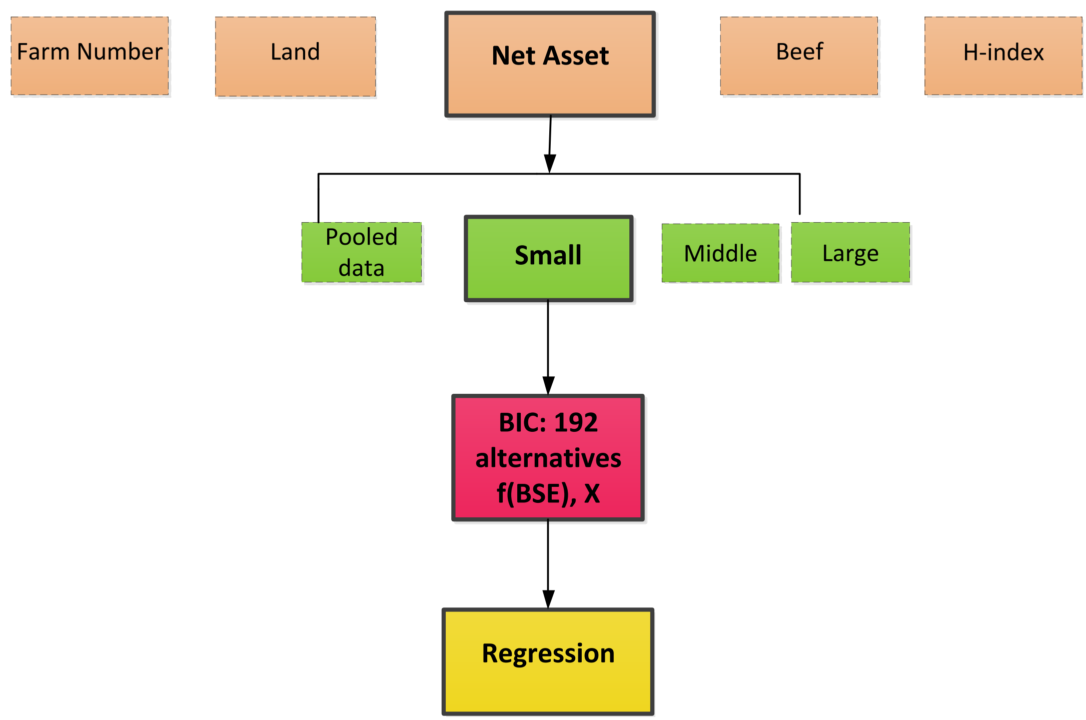
In the second step, Bayesian Information Criterion is applied to optimize the chosen model. The advantage of using BIC rather than the stepwise method is to avoid over-fitting issue, which is caused by introducing too many variables. Using BIC as we can see in the equation (10), it takes into account this issue by introducing penalties to the number of variables (Hadi, 2000).

$$BIC = n \cdot \ln(\sigma_e^2) + k \cdot \ln(n) \quad (10)$$

Where n is the number of observations, k is the number of repressors (including the intercept), and σ_e^2 is the variance of the error.

During the BIC selection, the expression $g\left(\beta_k, BSE_{it}, X_{it}\right)$ will be determined. For each dependent variable, the BIC values are calculated and compared. And the most appropriate specification is the one with the minimum BIC value. Taking Farm Number as an example, *f*(BSE) has 3 alternative forms and the other five unfixed independent variables have 2^5 different combinations. As a result, there are $3\times2^5=96$ alternative specifications in total for the Farm Number.

Figure 7. Analysis procedure



In sum, there are four major steps in our analysis as shown in Figure 7. First of all, five variables including Farm Number, Land, Net asset, Beef and H-index are chosen to measure the industry structure. Secondly, for each dependent variable, there are four different groups: Pooled sample group, Small group, Medium group and Large group. And then, for each group, the specification for $f(BSE_{it})$ and X_{it} variables will be selected using the BIC method. For example, in the Small group of the Net Asset, there are 192 alternative specifications for the $f(BSE_{it})$ and X_{it}. Finally, the regressions will be performed using the model specifications with the lowest BIC value.

4 Results

In this chapter, the results of the BIC model selection and the regressions will be presented for all five dependent variables respectively.

4.1 BIC model selection results

Table 4 shows the selection results for each dependent variable in four different groups. The more detail BIC results can be found in Appendix4. As we can see in the table, logarithm form of the BSE is selected by most of the groups.

Table 4 BIC model selection results for five dependent variables in each ES groups

Dependent variable	Groups	Expression for $g(\beta_k, BSE_{it}, X_{it})$	BIC Value
Farm Number	Pooled	β_1Log(BSE)+β_2Area+β_3Sub+β_4Labor+β_5GDP+β_6POP	-1577.4000
	Small	β_1Log(BSE)+β_2Net Asset+β_3Area+β_4LU+β_5GDP+β_6 POP	-411.4000
	Middle	β_1Log(BSE)+β_2LU +β_3Sub +β_4GDP +β_5POP	-726.7000
	Large	β_1Log(BSE)+β_2LU+β_3Labor+β_4GDP+β_5POP	-546.1000
Land	Pooled	β_1Lag(BSE)+β_2Labor+β_3LU+β_4Beef	-1065.0400
	Small	β_1Log(BSE)+β_2LU+β_3Income	-79.8776
	Middle	β_1Lag(BSE)+β_2Labor+β_3LU	-675.7670
	Large	β_1Log(BSE)+β_2Labor+β_3Beef	-650.8140
Net Asset	Pooled	β_1Log(BSE)+β_2Labor+β_3LU+β_4TotalCost+β_5Beef	-3285.9300
	Small	β_1Log(BSE)+β_2Area+β_3LU+β_4TotalCost+β_5Beef	-652.6620
	Middle	β_1Log(BSE)+β_2Area+β_3LU+β_4Sub+β_5TotalCost	-1437.6300
	Large	β_1Log(BSE)+β_2LU+β_3TotalCost+β_4Beef	-1308.2200
Beef	Pooled	β_1Log(BSE)+β_2Labor+β_3Area+β_4LU+β_5TotalCost+β_6GDP+β_7PO P	-3247.3400
	Small	β_1Log(BSE)+β_2Area+β_3LU+β_4TotalCost+β_5Net Asset+β_6GDP+β_7POP	-633.7090
	Middle	β_1Lag(BSE)+β_2Labor+β_3LU+β_4TotalCost+β_5GDP+β_6POP	-1537.9600
	Large	β_1Lag(BSE)+β_2Labor+β_3Area+β_4LU+β_5TotalCost+β_6GDP+β_7POP	-989.3140
H-index		β_1Log(BSE)+β_2Area+β_3GDP+β_4POP	-395.1970

Except for BSE, all variables in $g(\beta_k, BSE_{it}, X_{it})$ are used in logarithm form (see section 3.3.3).

4.2 Regression results

In this section, the regression results for five dependent variables will be shown respectively. Time dummies and estimated coefficients for country fixed effects are not shown for brevity. And the p-values are much lower than 1% in all the performed regressions, indicating that the models providing good descriptions of the data.

4.2.1 Farm Number

As shown in Table 5, for all different groups, the estimated parameters for the BSE cases are positive and statistically significant at the 1% level. This means that one can expect an increase in Farm number with the increase in the number of the BSE cases. For example, in the Pooled data group, with a 1% increase in BSE cases, there will be a 0.0263% increase in Farm Number. Additionally, by comparing the estimated BSE coefficients for different groups, it emerges that it is only 0.0167 for larger farms while twice as much (0.0345) for smaller farms. Therefore, the influence of the BSE crisis on farm number is larger on smaller farms.

Table 5(a) Estimated parameters and model fit: impact of BSE on Farm Number for Pooled data group (N=660)

Variable	Estimate coefficient	Standard Error	t-Statistic	p-value
constant	5.5430	1.6619	3.3353	0.0009
LOG(BSE)	0.0263	0.0024	11.0449	0.0000
Area	-0.0472	0.0051	-9.2358	0.0000
Sub	-0.0051	0.0012	-4.1887	0.0000
Labor	-0.1527	0.0114	-13.3213	0.0000
GDP	0.0808	0.0381	2.1161	0.0347
Population	-0.2284	0.0957	-2.3865	0.0173

R Square: 0.7704
$F_{33,626}$= 63.6790; *p*-value = 0.0000

(b) Estimated parameters and model fit: impact of BSE on Farm Number for Small ES group (N=148)

Variable	Estimate coefficient	Standard Error	t-Statistic	p-value
Constant	8.2626	2.9135	2.8360	0.0054
LOG(BSE)	0.0345	0.0049	6.9847	0.0000
Net_asset	0.0823	0.0171	4.7996	0.0000
Area	0.0291	0.0121	2.4106	0.0175
LU	-0.0969	0.0190	-5.1067	0.0000
GDP	-0.0359	0.0538	-0.6668	0.5062
Population	-0.3650	0.1738	-2.0997	0.0379

R Square: 0.8630
$F_{28,119}$: 26.7700; *p*-value = 0.0000

(c) Estimated parameters and model fit: impact of BSE on Farm Number for Medium ES group (N=287)

Variable	Estimate coefficient	Standard Error	t-Statistic	p-value
Constant	1.1184	1.9142	0.5843	0.5596
LOG(BSE)	0.0240	0.0028	8.6892	0.0000
LU	-0.0380	0.0091	-4.1806	0.0000
Sub	-0.0058	0.0016	-3.5904	0.0004
GDP	0.0638	0.0462	1.3815	0.1683
Population	0.0250	0.1094	0.2290	0.8191
R Square: 0.8140				
$F_{31,225}$: 36.2000; *p*-value = 0.0000				

(d) Estimated parameters and model fit: impact of BSE on Farm Number for Large ES group (N=225)

Variable	Estimate coefficient	Standard Error	t-Statistic	p-value
Constant	4.7192	2.8037	1.6832	0.0940
LOG(BSE)	0.0167	0.0034	4.9494	0.0000
LU	-0.0729	0.0185	-3.9443	0.0001
Labor	-0.2024	0.0277	-7.2967	0.0000
GDP	-0.0372	0.0689	-0.5395	0.5902
Population	-0.1019	0.1667	-0.6109	0.5420
R Square: 0.8427				
$F_{32,192}$: 32.1500; *p*-value = 0.0000				

4.2.2 Land

The regression results for Land are shown in Table 6. It can be seen that the impact of BSE crisis is only significant in the Large group where the BSE coefficient shows a p-value of 0.0310. For large farms, there is a decrease of 0.00562% in the Land with an increase of 1% in the number of BSE cases. This may implies that larger farm groups are more capable of adjusting their land management strategies to different market situation.

Table 6(a) Estimated parameters and model fit: impact of BSE on Land for Pooled data group (N=660)

Variable	Estimate coefficient	Standard Error	t-Statistic	p-value
Constant	0.9223	0.1214	7.5951	0.0000
LAG(BSE)	0.0000	0.0000	0.5633	0.5734
Labor	-0.1994	0.0222	-8.9758	0.0000
LU	0.3535	0.0210	16.8668	0.0000
Beef	-0.0925	0.0194	-4.7691	0.0000
R Square: 0.8443				
$F_{31,628}$: 109.9305; *p*-value = 0.0000				

(b) Estimated parameters and model fit: impact of BSE on Land for Small ES group (N=148)

Variable	**Estimate coefficient**	**Standard Error**	**t-Statistic**	**p-value**
Constant	1.4838	0.3817	3.8871	0.0002
LOG(BSE)	-0.0188	0.0154	-1.2223	0.2239
LU	0.4552	0.0508	8.9681	0.0000
Income	-0.1599	0.0475	-3.3670	0.0010

R Square: 0.6094
$F_{25,122}$: 7.6155; *p*-value = 0.0000

(c) Estimated parameters and model fit: impact of BSE on Land for Medium ES group (N=287)

Variable	**Estimate coefficient**	**Standard Error**	**t-Statistic**	**p-value**
Constant	0.3142	0.0547	5.7491	0.0000
LAG(BSE)	0.0000	0.0000	0.9971	0.3196
Labor	-0.1703	0.0382	-4.4567	0.0000
LU	0.2658	0.0130	20.4932	0.0000

R Square: 0.8156
$F_{25,257}$: 39.2100; *p*-value = 0.0000

(d) Estimated parameters and model fit: impact of BSE on Land for Large ES group (N=225)

Variable	**Estimate coefficient**	**Standard Error**	**t-Statistic**	**p-value**
Constant	1.2140	0.0923	13.1561	0.0000
LOG(BSE)	-0.0056	0.0026	-2.1728	0.0310
Labor	0.1717	0.0145	11.8363	0.0000
Beef	0.0325	0.0084	3.8532	0.0002

R Square: 0.9537
$F_{30,194}$: 133.2300; *p*-value = 0.0000

4.2.3 Net Asset

Table 7(a) Estimated parameters and model fit: impact of BSE on Net Asset for Pooled data group (N=660)

Variable	**Estimate coefficient**	**Standard Error**	**t-Statistic**	**p-value**
Constant	1.7823	0.0369	48.3092	0.0000
LOG(BSE)	-0.0022	0.0006	-3.5111	0.0005
Labor	-0.0239	0.0052	-4.5995	0.0000
LU	0.0250	0.0048	5.1930	0.0000
Total_cost	0.0706	0.0049	14.4382	0.0000
Beef	-0.0211	0.0038	-5.5923	0.0000

R Square: 0.9578
$F_{32,627}$: 445.0373; *p*-value = 0.0000

(b) Estimated parameters and model fit: impact of BSE on Net Asset for Small ES group (N=148)

Variable	Estimate coefficient	Standard Error	t-Statistic	p-value
Constant	1.8328	0.0915	20.0397	0.0000
LOG(BSE)	-0.0013	0.0022	-0.6019	0.5484
Area	-0.0155	0.0054	-2.8371	0.0053
LU	0.0402	0.0126	3.1933	0.0018
Total_cost	0.0878	0.0090	9.7655	0.0000
Beef	-0.0381	0.0097	-3.9199	0.0001

R Square: 0.9040
$F_{27,120}$: 41.8966; *p*-value = 0.0000

(c) Estimated parameters and model fit: impact of BSE on Net Asset for Medium ES group (N=287)

Variable	Estimate coefficient	Standard Error	t-Statistic	p-value
Constant	1.8090	0.0454	39.8342	0.0000
LOG(BSE)	-0.0029	0.0008	-3.7881	0.0002
Area	-0.0140	0.0042	-3.3365	0.0010
LU	0.0343	0.0082	4.2111	0.0000
Sub	-0.0011	0.0005	-2.4496	0.0150
Total_cost	0.0503	0.0061	8.2200	0.0000

R Square: 0.8692
$F_{31,255}$: 54.6775; *p*-value = 0.0000

(d) Estimated parameters and model fit: impact of BSE on Net Asset for Large ES group (N=225)

Variable	Estimate coefficient	Standard Error	t-Statistic	p-value
Constant	2.0630	0.0371	55.6757	0.0000
LOG(BSE)	-0.0018	0.0006	-3.0334	0.0028
LU	0.0446	0.0065	6.8768	0.0000
Total_cost	0.0292	0.0055	5.2889	0.0000
Beef	-0.0121	0.0028	-4.3139	0.0000

R Square: 0.9299
$F_{31,193}$: 82.6951; *p*-value = 0.0000

Table 7 shows the results of regression of the Net Asset for each group. It can be seen that for all the groups except for Small ones, the BSE has a negative and statistically significant impact on the Net Assets at the 1% level. For example, in the Pooled data group, with an increase of 1% of the number of the BSE cases, there will be a 0.0022% decrease in the Net Asset. It indicates that in the wake of the BSE crisis, the average investment in the beef industry seems to have decreased.

4.2.4 Beef Production

Based on the regression results in Table 8, the impact of the BSE crisis on the Beef production is only significant in the Small group with a p-value of 0.0715. With a 1% increase of the BSE cases, there is a 0.0042% decrease in the Beef production for the Small group. It implies that the average beef production declined with the increase in the number of the BSE cases.

Table 8(a) Estimated parameters and model fit: impact of BSE on Beef production for Pooled data group (N=660)

Variable	Estimate coefficient	Standard Error	t-Statistic	p-value
Constant	2.3429	0.4779	4.9021	0.0000
LOG(BSE)	-0.0007	0.0007	-1.0772	0.2818
Labor	-0.0602	0.0052	-11.6799	0.0000
Area	-0.0064	0.0023	-2.8022	0.0052
LU	0.0791	0.0050	15.8345	0.0000
Total_cost	0.0509	0.0055	9.3158	0.0000
Net_asset	-0.0139	0.0039	-3.5916	0.0004
GDP	-0.0013	0.0106	-0.1268	0.8992
Population	-0.0392	0.0283	-1.3848	0.1666

R Square: 0.9732
$F_{35,624}$: 648.9660; *p*-value = 0.0000

(b) Estimated parameters and model fit: impact of BSE on Beef production for Small ES group (N=148)

Variable	Estimate coefficient	Standard Error	t-Statistic	p-value
Constant	3.2228	1.4055	2.2930	0.0236
LOG(BSE)	-0.0042	0.0023	-1.8182	0.0716
Area	-0.0142	0.0058	-2.4461	0.0159
LU	0.1070	0.0106	10.0619	0.0000
Total_cost	0.0435	0.0125	3.4892	0.0007
Net_asset	-0.0332	0.0092	-3.5981	0.0005
GDP	-0.0055	0.0251	-0.2205	0.8259
Population	-0.0703	0.0841	-0.8357	0.4050

R Square: 0.9229
$F_{29,118}$: 48.7725; *p*-value = 0.0000

(c) Estimated parameters and model fit: impact of BSE on Beef production for Medium ES group (N=287)

Variable	Estimate coefficient	Standard Error	t-Statistic	p-value
Constant	1.6341	0.4634	3.5259	0.0005
LAG(BSE)	0.0000	0.0000	0.9173	0.3598

Labor	-0.0543	0.0105	-5.1909	0.0000
LU	0.0721	0.0052	13.7673	0.0000
Total_cost	0.0406	0.0064	6.3801	0.0000
GDP	0.0123	0.0109	1.1229	0.2625
Population	-0.0105	0.0269	-0.3906	0.6964

R Square: 0.9296
$F_{32,254}$: 104.9695; *p*-value = 0.0000

(d) Estimated parameters and model fit: impact of BSE on Beef production for Large ES group (N=225)

Variable	Estimate coefficient	Standard Error	t-Statistic	p-value
Constant	2.0832	1.0343	2.0140	0.0454
LAG(BSE)	0.0000	0.0000	0.8195	0.4135
Labor	-0.1056	0.0133	-7.9261	0.0000
Area	0.0179	0.0072	2.5021	0.0132
LU	0.0414	0.0132	3.1302	0.0020
Total_cost	0.0844	0.0134	6.2845	0.0000
GDP	-0.0341	0.0247	-1.3784	0.1697
Population	-0.0318	0.0605	-0.5256	0.5998

R Square: 0.8564
$F_{34,190}$: 33.3409; *p*-value = 0.0000

4.2.5 Industry concentration (H- Index)

The regression results for the H-index are shown in Table 9. The parameters of the model are jointly significant ($F_{32, 105}$=13.093, p < 0.01). The BSE incidence has a negative effect on the H-index, although statistically significant only at the 10% level. In other words, with an increase of 1% BSE cases, the H-index of beef market will reduces by 0.0052*1%= $5.2*10^{-5}$. It implies that, with the impact of the BSE crisis, the beef market is shared by more farms rather than dominating by just a few big farms.

Table 9 Estimated parameters and model fit: impact of BSE on H-index (N=180)

Variable	Estimate coefficient	Standard Error	t-Statistic	p-value
Constant	2.3589	2.1208	1.1123	0.2685
LOG(BSE)	-0.0052	0.0027	-1.8970	0.0605
Area	-0.0339	0.0158	-2.1429	0.0344
GDP	-0.1385	0.0606	-2.2840	0.0244
POP	-0.0230	0.1306	-0.1762	0.8605

R Square: 0.7996
$F_{32,105}$: 13.0930; *p*-value = 0.0000

5 Discussion

The results presented in Chapter 4 lead to several points for discussion. Overall, the regression results indicate that, with the impact of BSE crisis, the beef industry may have become slightly less industrialized.

First of all, the H-index reduces as the BSE cases increase. This indicates that the differences between the market shares of different groups become smaller. In other words, the beef market is less concentrated which shared by more and more farms rather than dominating by only a few big farms. Therefore, the BSE crisis slowed down the consolidation process of the European beef industry.

Second, the average number of cattle farms in all groups is positively related to the BSE cases, and this effect is more significant in small farms. The reason may be that larger farms are more likely to use animal remains as feed which links to the spread of the BSE. Therefore, consumers prefer to buy beef products from local smaller farms which they perceived to be more safe and trustworthy than big manufacturers. Thus, we can see there are more small farms participating in the beef industry.

Third, the BSE crisis negatively impacts the Net Asset. The reason is twofold. On the one hand, the outbreak of BSE crisis reduced the demand of beef products. Supply also decreased, resulting in a reduced investment for the cattle farms. On the other hand, under the pressure of the BSE crisis, it is more risky to invest on cattle industry, which may have, on average caused a decrease in the Net Assets. Regarding to the exception of smaller farms, it may be because that it is more difficult for smaller farms to adapt their strategies due to the resources that have already been invested.

In addition, the average land of cattle farm seems to be negatively related to the number of BSE. However, this effect is only found in large farms. One explanation is that the smaller farms are less capable of changing their land management strategies. Comparably, the larger farms have more resources to adapt their land management strategies to the changes of the market.

Finally, the average beef production is negatively related to the BSE cases for the small group. On one hand, the decreases in beef production may be due to the reduced beef demand. On the other hand, the UK government introduced a slaughter program in 1996 which accounted for the removal of millions of risk cattle (Knowles et al., 2007). For large farms, however, the impact of the BSE crisis on beef production is found to be non-statistically significant. The reason may be that there are more observations for those larger groups than for smaller group, in which the positive and negative relationship may counteract with each other.

Based on the discussion above, we can see that, in the wake of the BSE crisis, the European industry structure may have been impacted to some extent. In order to help the recovery of the beef market, several methods would be considered. For Larger farms, they need to abandon the usage of the animal remains as feed to lessen consumers' worries and regain some consumption. What' more, the consumers perceive the smaller farms to be more trustworthy than bigger manufacturer, thus, the smaller farms could market their products to be more safe in order to suit better the consumer demand to obtain more market share. In addition, the government should step in to help the recovery of the industry. For example, the government can build the monitor program, supply more information to the public in order to help rebuild consumer confidence in the product.

6 Conclusion

In this thesis, I analyze the impact of the BSE crisis on the European beef industry structure. Linear regressions are performed using the FADN data of nine countries over twenty years. Five dependent variables are chosen to measure the different aspects of the beef industry structure. In order to differentiate the impacts of the BSE crisis on different size of cattle farms, we estimate the model for the full sample of farms (pooled data), Small, Medium, and Large groups respectively.

Based on the results of this study, it can be concluded that the BSE crisis has had an impact on the structure of the European beef industry. Specifically, with the increases of the number of BSE cases, the EU beef industry moved slightly towards less industrialization. This conclusion is supported by the results of the H-index and Farm Number regression which imply that, with the impact of the BSE crisis, there tend to be more farms participating in the beef production. In other words, the beef market is less concentrated which shared by more farms rather than dominating by just a few large farms. Meanwhile, the average Net asset and Land seems to have decreased due to the fall of consumer demand as well as the investment risks under the BSE crisis.

The method and analysis presented in this thesis can be further improved in several ways. First of all, a unit root test can be performed to verify if the collected data is stationary. Based on the trend of each dependent variable shown in Figure 6, it can be seen that most of the variables have either a positive or negative trend over the time period. This can influence the effectiveness of the final results (Knowles et al., 2007).

Secondly, there will be differences between the aggregate and individual data analysis. The FADN database used in this thesis is on the country level. However, individual farms may be impacted differently by the BSE crisis due to their different conditions (Bierens, 2001). With more available individual farm data, one could analyze the BSE impact at the farm level.

Additionally, due to the loop of causality or the interrelationship between independent and dependent variables, there may be a problem of endogeneity, which will lead to biased and inconsistent estimates. Two-stage least-squares regression can be considered to solve this problem (King, 1997).

Appendix 1.

The BSE cases in EU27 over 20 years

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Belgium	0	0	0	0	0	0	0	0	1	6	3	9	46	38	15	11	2	2	0	0	0	0	0	133
Bulgaria														0	0	0	0	0	0	0	0	0	0	0
Cyprus															0	0	0	0	0	0	0	0	0	0
Czech Republic	0	0	0	0	0	0	0	0	0	0	0	0	2	2	4	7	8	3	2	0	2	0	0	30
Denmark	0	0	0	1	0	0	0	0	0	0	0	1	6	3	2	1	1	0	0	0	1	0	0	16
Germany	0	0	0	1	0	3	0	0	2	0	0	7	125	106	54	65	32	16	4	2	2	0	0	419
Greece	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Spain	0	0	0	0	0	0	0	0	0	0	0	2	83	134	173	138	103	68	40	4	18	13	7	783
Estonia															0	0	0	0	0	0	0	0	0	0
France	0	0	5	0	1	4	3	12	6	18	31	162	277	240	138	54	31	8	8	5	10	5	3	1021
Hungary															0	0	0	0	1	0	0	0	0	1
Ireland	15	14	17	18	16	19	16	74	80	83	95	149	246	331	185	121	69	38	25	23	9	2	3	1648
Italy	0	0	0	0	0	2	0	0	0	0	0	0	50	36	31	8	8	7	2	0	2	0	1	147
Lithuania															0	0	0	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	3
Latvia															0	0	0	0	0	0	0	0	0	0
Malta															0	0	0	0	0	0	0	0	0	0
Netherlands	0	0	0	0	0	0	0	0	2	2	2	2	20	24	19	6	3	2	2	3	0	3	0	90
Austria	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	2	1	0	0	2	0	8
Poland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	11	20	10	9	4	4	2	1	66
Portugal	0	1	1	1	3	12	15	31	30	127	159	150	113	86	133	91	51	33	14	18	8	6	5	1088
Romania																		0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Sweden	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Slovakia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	7	3	0	1	1	0	1	0	15
Slovenia	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	1	1	1	0	0	0	0	8
United Kingdom	7228	14407	25359	37301	35090	24436	14562	8149	4393	3235	2301	1441	1198	1125	614	343	226	129	65	42	11	11	8	181674
Total	7243	14422	25382	37322	35110	24476	14596	8266	4515	3471	2591	1923	2170	2127	1376	865	561	320	175	102	67	45	28	187153

* blank cell means no report

Sourse: Europa annual report (Europa, 2012b)

Appendix 2.

Coefficient table for Livestock unit calculation (Europa, 2012a)

D22	Equines	0.8
D23	Calves for fattening	0.4
D24	Other cattle < 1 year	0.4
D25	Male cattle 1-2< years	0.7
D26	Female cattle 1-2< years	0.7
D27	Male cattle >= 2 years	1.0
D28	Breeding heifers	0.8
D29	Heifers for fattening	0.8
D30	Dairy cows	1.0
D31	Cull dairy cows	1.0
D32	Other cows	0.8
D34	Rabbits (breeding females)	0.02
D38	Goats, breeding females	0.1
D39	Other goats	0.1
D40	Ewes	0.1
D41	Other sheep	0.1
D43	Piglets	0.027
D44	Breeding sows	0.5
D45	Pigs for fattening	0.3
D46	Other pigs	0.3
D47	Table chickens	0.007
D48	Laying hens	0.014
D49	Other poultry	0.03

As the number of animals is recorded in the FADN farm return multiplied by ten (except for poultry), the LU coefficients are divided by ten (except for poultry) in the following formulas: SE080, SE085, SE090, SE095, SE100, SE105.

Source: EUROSTAT

Appendix 3.

Statistic of missing data in non-FADN data for different ES groups

	Variable	**For Different ES groups**	
		Observations Avaliable /In Theory	Number of Missing Data
FADN Data*	Farm Number	824/824	0
	LU	660/822	162
	Land	660/822	162
	Net Asset	660/822	162
	Sub	660/822	162
	TotalCost	660/822	162
	Beef	660/822	162
	Labor	660/822	162
	Income	660/822	162
Non-FADN Data	BSE	Not Available for Different ES groups	Need to re-generate these data for all 864 Observations
	Population		
	GDP		

*except for Farm Number, all the FADN data express the averaged value in one farm, e.g. the value of land refers to the average land area of one farm.

Appendix 4

BIC Model selection results: best three specifications in each ES groups for five dependent variables

Dependent variable	ES groups	Expression for $g\left(\beta_k, BSE_{it}, X_{it}\right)$	BIC Value
Farm Number	Pooled data Group	**β_1Log(BSE)+β_2Area+β_3Sub+β_4Labor+β_5GDP+β_6POP**	**-1577.4**
		β_1Log(BSE)+β_2 Area+β_3LU+β_4Sub+β_5Labor+β_6GDP + β_7POP	-1574.1
		β_1Log(BSE)+β_2Net Asset+β_3 Area+β_4Sub+β_5Labor+ β_6GDP + β_7POP	-1571.6
	Small ES Group	β_1Log(BSE)+β_2Net Asset+β_3LU+β_4GDP+β_5POP	-409.6
		β_1Log(BSE)+β_2Net Asset+β_3Area+β_4LU+β_5GDP+β_6 POP	**-411.4**
		β_1Log(BSE)+β_2Net Asset+β_3Area+β_4 LU+β_5Labor+β_6 GDP+β_7 POP	-410.1
	Middle ES Group	**β_1Log(BSE)+β_2LU +β_3Sub +β_4GDP +β_5POP**	**-726.7**
		β_1Log(BSE)+β_2Area+β_3Sub+β_4GDP+β_5POP	-725.7
		β_1Log(BSE)+β_2Net Asset +β_3 LU+β_4Sub+β_5GDP +β_6POP	-723.9
	Large ES Group	**β_1Log(BSE)+β_2LU+β_3Labor+β_4GDP+β_5POP**	**-546.1**
		β_1Log(BSE)+β_2LU+β_3Sub+β_4Labor +β_5GDP +β_6POP	-545.6
		β_1Log(BSE)+β_2Area+β_3LU+β_4Labor+ β_5GDP+β_6POP	-542.2
Land	Pooled data Group	**β_1Lag(BSE)+β_2Labor+β_3LU+β_4Beef**	-1065.04
		β_1Log(BSE)+β_2Labor+β_3LU+β_4Beef	**-1064.89**
		β_1Lag(BSE)+β_2Labor+β_3LU+β_4Income+β_5Beef	**-1059.29**
	Small ES Group	β_1Lag(BSE)+β_2LU+β_3Income	**-78.9826**
		β_1Log(BSE)+β_2LU+β_3Income	**-79.8776**
		β_1Log(BSE)+β_2Labor+β_3LU+β_4Income	**-74.8122**
	Middle ES Group	**β_1Lag(BSE)+β_2Labor+β_3LU**	**-675.767**
		β_1Log(BSE)+β_2Labor+β_3LU	**-674.941**
		β_1Lag(BSE)+β_2Labor+β_3LU +β_4 Beef	**-670.436**
	Large ES Group	β_1Lag(BSE)+β_2Labor+β_3Beef	**-649.052**
		β_1Log(BSE)+β_2Labor+β_3Beef	**-650.814**
		β_1Log(BSE)+β_2Labor+β_3LU	**-649.466**
Net Asset	Pooled data Group	**β_1Log(BSE)+β_2Labor+β_3LU+β_4TotalCost+β_5Beef**	-3285.93
		β_1Log(BSE)+β_2 Labor+β_3LU+β_4Sub+β_5TotalCost+β_6Beef	-3280.27
		β_1Log(BSE)+β_2Labor+β_3Area+β_4LU+β_5TotalCost+β_6Beef	-3285.29
	Small ES Group	β_1Lag(BSE)+β_2Area+β_3LU+β_4TotalCost+β_5Beef	-652.576
		β_1Log(BSE)+β_2Area+β_3LU+β_4TotalCost+β_5Beef	-652.662
		β_1Lag(BSE)+β_2Area+β_3LU+β_4Sub+β_5TotalCost +β_6Beef	-652.439
	Middle ES Group	β_1Lag(BSE)+β_2TotalCost	-1432.64
		β_1Log(BSE)+β_2Area+β_3LU+β_4TotalCost	-1436.73
		β_1Log(BSE)+β_2Area+β_3LU+β_4Sub+β_5TotalCost	-1437.63
	Large ES Group	**β_1Log(BSE)+β_2LU+β_3TotalCost+β_4Beef**	-1308.22
		β_1Log(BSE)+β_2Labor+β_3LU	-1305.04
		β_1Log(BSE)+β_2Labor+β_3LU+β_4TotalCost+β_5Beef	-1307.62
Beef	Pooled data Group	β_1Log(BSE)+β_2Labor+β_3LU+β_4TotalCost+β_5GDP+β_6POP	-3245.64
		β_1Lag(BSE)+β_2Labor+β_3Area+β_4LU+β_5TotalCost+β_6GDP+ β_7POP	-3246.34
		β_1Log(BSE)+β_2Labor+β_3Area+β_4LU+β_5TotalCost+β_6GDP+β_7POP	-3247.34
	Small ES Group	β_1Log(BSE)+β_2LU+β_3TotalCost+β_4Net Asset+β_5GDP+β_6POP	-631.635
		β_1Lag(BSE)+β_2Area+β_3LU+β_4TotalCost+β_5Net Asset+β_6GDP+β_7POP	-632.412
		β_1Log(BSE)+β_2Area+β_3LU+β_4TotalCost+β_5Net Asset+β_6GDP+β_7POP	-633.709
	Middle ES Group	β_1Lag(BSE)+β_2Labor+β_3LU+β_4TotalCost+β_5GDP+β_6POP	-1537.96
		β_1Log(BSE)+β_2Labor+β_3LU+β_4TotalCost+β_5GDP+β_6POP	-1537.08
		β_1Lag(BSE)+β_2Lag^2(BSE)+β_3Labor+β_4LU+β_5TotalCost+β_6GDP+β_7POP	-1532.88
	Large ES Group	**β_1Lag(BSE)+β_2Labor+β_3Area+β_4LU+β_5TotalCost+β_6GDP+β_7POP**	-989.314
		β_1Log(BSE)+β_2Labor+β_3Area+β_4LU+β_5TotalCost+β_6GDP+β_7POP	-989.246
		β_1Lag(BSE)+β_2Labor+β_3Area+β_4LU+β_5TotalCost+β_6Net Asset+β_7GDP+β_8POP	-988.408
H-index		β_1Log(BSE)+β_2GDP+β_3POP	-394.568
		β_1Log(BSE)+β_2Area+β_3GDP+β_4POP	-395.197
		β_1Lag(BSE)+β_2Area+β_3LU+β_4GDP+β_5POP	-394.694

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