# From meat to plant-based products?

## The impact of Mad Cow Disease on consumer preferences in the European Union

Jader Velásquez Castaño

Degree project/Independent project • 30 credits
Swedish University of Agricultural Sciences, SLU
Faculty of Natural Resources and Agricultural Sciences/Department of Economics
Envrionmental Economics and Management – Master's Programme
Degree project/SLU, Department of Economics, 1609 • ISSN 1401-4084
Uppsala 2024

# From meat to plant-based products? The impact of Mad Cow Disease on consumer preferences in the European Union

Jader Velásquez Castaño

| | |
|---|---|
| **Supervisor:** | **Shon Ferguson, Swedish University of Agricultural Sciences, Department of Economics** |
| **Examiner:** | Rob Hart, Swedish University of Agricultural Sciences, Department of Economics |


| | |
|---|---|
| **Credits:** | 30 credits |
| **Level:** | Second cycle, A2E |
| **Course title:** | Master thesis in Economics |
| **Course code:** | EX0905 |
| **Programme/education:** | Environmental Economics and Management - Master's Programme |
| **Course coordinating dept:** | Department of Economics |
| **Place of publication:** | Uppsala |
| **Year of publication:** | 2024 |
| **Copyright:** | All featured images are used with permission from the copyright owner. |
| **Title of series:** | Degree project/SLU, Department of Economics |
| **Part number:** | 1609 |
| **ISSN:** | 1401-4084 |

**Keywords:** Food Safety, Food Demand, Meat reduction, Event Study



**Swedish University of Agricultural Sciences**
Faculty of Natural Resources and Agricultural Sciences
Department of Economics

## Abstract

Shifting towards plant-based diets with reduced red meat consumption is a global priority in both food and environmental policies. While studies on this transition have primarily been confined to experimental economics, analyses of observational data in response to red meat demand shocks have focused on substitution effects with other animal proteins. This study examines the long-term effects of the Bovine Spongiform Encephalopathy (BSE) outbreak on beef consumption in the EU compared to plant-based products. We specifically investigate whether the decline in beef consumption persisted after the outbreak. Using an event study methodology that incorporates dynamic effects, we analyze data from 1980 to 2020. Our findings reveal that the BSE outbreak triggered a substantial and persistent decrease in beef consumption. Compared to pre-outbreak levels, beef consumption declined by 79% relative to pulses (legumes), 29% relative to cereals (grains), and 27% relative to vegetable oils. Notably, the impact on beef consumption compared to other meats (pork, chicken, or fish) was less pronounced. Moreover, beef consumption never fully recovered its pre-outbreak relationship with plant-based food groups, unlike its recovery relative to other meats. Given the link between BSE and a fatal human brain disease, a key implication of these findings is that they enable the estimation of the current willingness-to-pay (WTP) for a 1% reduction in red meat consumption relative to plant-based products. This has further implications for designing mechanisms to mitigate the prevalence of red meat-associated diseases (e.g., diabetes, cardiovascular disease, obesity, and certain cancers) and aligns with environmental policy goals of greenhouse gas (GHG) reduction.



*Keywords:* Food Safety, Food Demand, Meat reduction, Event Study

*JEL Classification:* Q11, Q18, C14

# Table of contents

# List of tables

# List of figures

# Abbreviations

| | |
|---|---|
| ATT | Average Treatment Effect for the Treated |
| BSE | Bovine Spongiform Encephalopathy |
| CPI | Consumer Price Index |
| DID | Difference in Differences |
| DR | Doubly Robust (estimator) |
| EEA | European Environment Agency |
| EFSA | European Food Safety Authority |
| EPRS | European Parliamentary Research Service |
| FAO | Food and Agriculture Organization of the United Nations |
| GDP | Gross Domestic Product |
| GDPpc | Per capita Gross Domestic Product |
| GHG | Greenhouse gas |
| IPW | Inverse Probability Weighting |
| OLS | Ordinary Least Square |
| OR | Outcome Regression |
| STOA | Scientific Foresight Unit |
| TSE | Transmissible Spongiform Encephalopathies |
| TWFE | Two-Way Fixed Effects |
| vCJD | variant Creutzfeldt-Jakob Disease |
| VSL | Value of a Statistical Life |
| WEF | World Economic Forum |
| WHO | World Health Organization |
| WTP | Willingness to pay |

# 1. Introduction

Shifting towards plant-based diets lower in red meats is a priority on the global policy agenda to tackle both environmental and healthy goals (Semba, 2020; Chad, 2020). Livestock production in the European Union (EU) is a major contributor to greenhouse gas (GHG) emissions from the agricultural sector, accounting for roughly 70% of total agricultural emissions (EEA, 2019). Furthermore, studies link red meat consumption to several adverse health outcomes (González, 2020) including diabetes (Ibsen et al., 2019, Du et al., 2020) and cardiovascular disease (De Oliveira et al., 2019) and certain cancers such as colorectal (Tantamango-Bartley et al., 2013). The transition to a more plant-based diet with less red and processed meat is also at the heart of the European Union's food systems strategy (European Commission, 2020).

Economists have provided robust evidence to elucidate the mechanisms that can facilitate this transition in consumption patterns. Their contributions encompass a wide range of approaches, spanning from experimental economics to estimate the willingness to pay (WTP) or accept a switch from meat consumption to plant-based products, to the analysis of observed data to explore the price elasticity of red meat and substitution effects between meat options. Our research aligns with this latter approach, observed data, extending the existing body of work on the impacts of Bovine spongiform encephalopathy (BSE – a.k.a. "Mad Cow Disease") on observed consumption patterns.

BSE is a neurodegenerative disease in cattle first identified in the UK during the 1980s. The country was disproportionately affected by BSE compared to other European countries. At its peak in 1992, the UK reported over 37,000 cases followed by Ireland with 18 cases that same year. By 2001, BSE had spread to most EU member states (see Appendix 1). Since BSE is highly transmissible through contaminated feed, more than 4.4 million cattle were slaughtered in Europe. Stringent import bans on UK beef were implemented by the EU between 1994 and 1996, the latter of which took 10 years to be lifted, impacting both production and consumption. The disease’s impact on human health became apparent with the emergence of variant Creutzfeldt-Jakob Disease (vCJD). Humans likely contracted vCJD by consuming BSE-infected beef products. As of 2018, a total of 231 cases of vCJD had been reported globally.

As the BSE outbreak provides a natural experiment to examine consumption patterns from various perspectives, e.g. substitution effects, consumer expectations, persistence and habit formation, and media influence, the impact of BSE on beef consumption has been extensively studied. Regarding the measurement of substitution effects, studies suggest a temporary preference for pork and chicken, before beef consumption returns (fully or partially) to pre-outbreak levels. Depending on the timing of the outbreak in the analyzed country: before or after the mid-1990s, the persistence of the substitution effect could last for several years or only a couple of weeks, respectively. In any case, research suggests potential structural changes in consumption.

These structural changes overlook two aspects. First, it is pertinent to consider a broader time window beyond the EU's import bans on beef and high media exposure. Second, chicken and pork are considered close substitutes for beef. Consequently, the BSE outbreak likely also impacted their consumption patterns, making them less suitable comparison groups to isolate the effect on red meat in general. Plant-based products, on the other hand, represent a distinct category without this confounding factor. Therefore, focusing on plant-based product consumption as a comparison group appears to be a more appropriate strategy. Furthermore, analysis of the available raw data suggests that plant-based products warrant further investigation as a suitable comparison group.

Figure 1-1 presents the long-term growth in per capita production of animal-based and plant-based foods. The global trend indicates a higher growth rate in meat consumption, which becomes more pronounced from the 1990s onwards. In contrast, in the United Kingdom, the growth rate of plant-based products is not only higher, but the growth of animal-based products is negative. This gap widens in the mid-1980s. In Germany, the growth trends switch in the mid-1990s[1], with plant-based products experiencing higher growth. This pattern in Germany is also observed in other countries like Belgium or  Ireland (at the end of the 1980s). The timing of these shifts coincides more or less with the BSE outbreak years in each country.

[1] The data for Germany includes both East and West Germany prior to reunification in 1990.

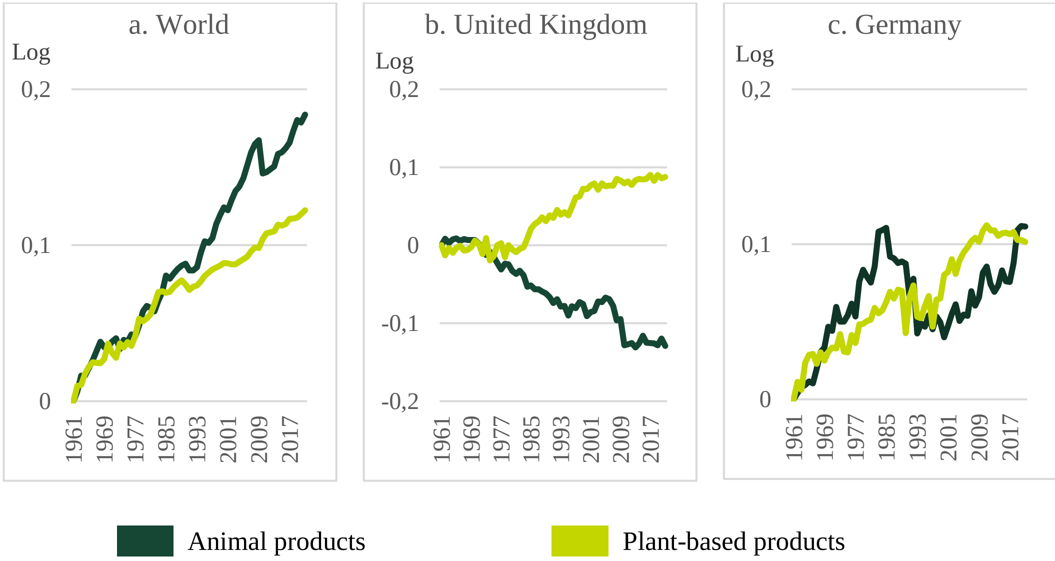


*Figure 1-1. Long-run (60 years) growth rate of Food supply (kcal/capita/day) by aggregated food sources. Data from FAOstat.*

There are only two sources from which humans can obtain the 'fuel' (calories, fat, protein) for our daily function: animal-based and plant-based food. The intuition behind Figure 1-1 and the gaps in previous literature lead us to the following questions,

- *What was the effect of the BSE outbreak on the consumption of beef compared to plant-based products? And if any,*
- *How long did it last?*

This research aims to measure the impact and persistence of the BSE outbreak on consumption patterns towards plant-based products in the EU.

To achieve this, we use aggregated categories of domestic consumption 19 EU states (including the UK) spanning the period from 1980 to 2020. Our methodology employs a two-step approach. First, we conducted a panel data regression with country and time fixed effects. Our treatment variable corresponded to the years that experienced BSE outbreaks in each country within the sample. Second, we performed an event study using the doubly robust DID estimator developed by Sant'Anna and Zhao (2020) to estimate the causal group-time average treatment effect $(ATT(g, t))$. Following the recommendation of Callaway and Sant'Anna (2021), we employed a 'not-yet-treated' group as the comparison group. Additionally, we included covariates in both regressions, such as income, prices, production, EU membership, and population.

Our results suggest that the BSE outbreak in the EU produced a structural decrease in beef consumption compared to plant-based products, with a less pronounced effect compared to consumption of other meats. This is supported by two key observations. First, we note that following the BSE outbreak, the decline in beef consumption appears to have been more pronounced when compared to plant-based products than to other meats (chicken, pork and fish). Second, beef consumption never fully recovered its pre-outbreak relationship with plant-based products, in contrast to its recovery relative to other meats.

Aggregate estimators revealed an average decline in beef consumption of 15% and 7% compared to pigmeat and poultry, respectively. When compared to pulses, cereals, and vegetable oils, the average reductions in beef consumption were 79%, 29%, and 27% respectively. The estimators perform adequately during the pre-treatment period exhibiting no significant differences between the treatment group and the control group. They also demonstrated post-treatment results that align with previous research, suggesting a partial substitution effect for chicken and pork.

This study provides new evidence to improve our understanding of the mechanisms driving food system transitions, which are essential policy goals. The results offer insights to refine the estimation of willingness to pay (WTP) for dietary changes towards reduced meat consumption in experimental economic settings. For instance, Since BSE is linked to human deaths through the vCJD disease, it is possible to estimate a revealed (rather than stated) WTP for a 1% reduction in beef consumption in household diets using the statistical value of life.

Following this introduction, the research is organized into the following sections. Section 2 presents the literature review. Section 3 outlines the empirical strategy, including the assignment of the treatment variable, the specification of the panel data model and the specification for the average treatment effect estimator in the event study. Next, Section 4 describes the data. Section 5 presents the results of both panel regressions and the event study. Finally, the discussion and conclusion are presented in Section 6.

# 2. Literature review

Consumers generally exhibit weakly separable preferences for meat (Schösler, et al., 2012; Graça and Calheiros, 2015; Apostolidis, 2016), implying that beef, pork, and chicken serve as strong substitutes for one another (Andersen et al., 2007; Zhou, 2015; Lusk et al., 2016). Consequently, research on the impact of BSE on consumption patterns has primarily focused on three key aspects: examining the extent to which consumers substitute between different meat alternatives; assessing the persistence of the observed changes in consumption patterns; and determining whether BSE outbreaks led to permanent or temporary shifts in the new equilibrium consumption levels.

Early studies in the UK, such as those by Burton and Young (1996, 1999) indicated that BSE led to a long-run decline in beef consumption, although with a relatively moderate impact. Notably, these studies observed compensatory increases in the consumption of pork and chicken.

The UK's consumption reaction to BSE stands in contrast to that of other countries. In France, as consumers panicked, the demand for beef dropped by 26% within a few weeks. Recovery exhibits a U-shape with a small habit formation (a small permanent reduction in beef consumption) during the study period (76 weeks, between 1995 and 1996) (Adda, 2007). Estimations in Danish pork and chicken markets suggest that the 1996 BSE incident did not, in itself, appreciably influence these markets. Furthermore, the BSE outbreak in Britain did not appear to have cross-market effects in Denmark (Andersen, et al., 2007). While Mazzocchi and Lobb (2005) observed a short-lived initial impact in Italy in 1996, the second outbreak in late 2000 had a longer-lasting effect, with increased chicken demand for 14 months. Similarly, Mengen and Burrell (2001) found a brief shift in the Netherlands towards poultry and pork following the BSE crisis, but demand for beef and prepared meats recovered within a month.

Outside Europe, Kuchler and Tegene (2006) concluded that the impact of BSE in 2003 on U.S. consumers lasted no more than two weeks. This aligns with the findings of Pritchett et al. (2007), who found no long-term impact from the U.S. BSE event and observed that the pork substitution effect was strongest in the month of BSE discovery, diminishing in subsequent months. Similar findings were observed in Canada where the outbreak started in 2003 (Peng et al., 2004; Ding et al., 2011). In contrast, Japan, which experienced a BSE outbreak in 2001, is reported to have undergone a structural shift in the consumption of specific beef cuts (Jin & Koo, 2003; Saghaian & Reed, 2007).

The findings of these studies are primarily influenced by the timing of the BSE outbreak in the analyzed country: early 1990s, late 1990s, or after 2000. Figure 2-1 illustrates this categorization. Countries experiencing outbreaks in the early 1990s exhibit slower habit recovery, with analysis periods ranging from 1.5 to 5 years and suggesting a structural shift in beef consumption and a small permanent loss. For countries with outbreaks in the late 1990s, the persistence of the consumption impact lasted between two months and slightly over a year, with a full recovery in beef consumption. Countries experiencing outbreaks after 2000 saw a decline in beef consumption that lasted only a few weeks (between 2 and 5 weeks) before its full recovery.

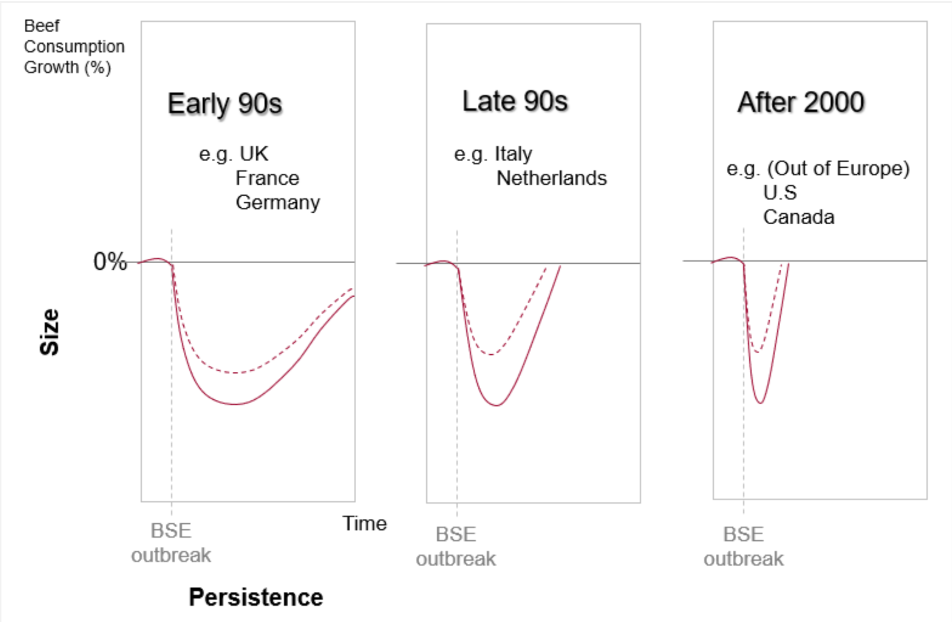


*Figure 2-1. Representation of overall findings in previous literature of the BSE outbreak effect on beef consumption.*

*Source: Own elaboration*

A common pattern across the studies is a U-shaped effect, indicating a full (or almost full) recovery from the decline in beef consumption. In terms of the impact's magnitude, there is no consistent pattern regarding the timing of the outbreak. Even countries experiencing outbreaks after 2000 witnessed substantial declines in consumption. The primary distinction lies in the effect's persistence.

Overall, consumption levels linked to food safety concerns depend more on whether consumers' expectations are permanent or transitory rather than on habit persistence per se (Zhen and Wohlgenant, 2006). Studies suggest media coverage of the BSE outbreak plays a role in shaping those expectations (Verbeke et al., 1999; Rieger et al., 2016; Lee et al., 2023), aligning with our classification in Figure 2-1. The impact on beef consumption is more persistent if the outbreak occurred in the early 1990s, when BSE uncertainty was high, compared to after 2000, when effective control measures quickly restored consumer confidence. Similarly, a second outbreak in a country leads to a drop in confidence and slower recovery towards the pre-outbreak beef consumption levels (Mengen and Burrell, 2001; Pritchell, 2007), as seen in Italy, the US and Canada (Ding, et al., 2011).

Two gaps in the BSE literature are worth noting. First, as with other outbreaks (e.g., COVID-19), there is a surge of literature in the early years following or even during the outbreak, making it difficult to assess the persistence of estimated structural changes. Second, with a strong focus on consumer meat preferences, most studies analyze the BSE effect on beef consumption within meat demand system models to account for substitution effects with other meats (mainly pork and chicken). While this analysis is relevant, raw data observations (Figure 1-1 above), suggest that the analysis of consumption patterns is incomplete. Therefore, This study deviates from much of the existing literature on BSE's impact on consumption patterns by shifting the focus to plant-based food consumption.

# 3. Empirical Methodology

Our main strategy is to estimate a multiple-period Difference-in-Differences (DID) model based on the extension proposed by Callaway and Sant'Anna (2021). The authors provide a procedure to handle a setup with variation in treatment timing and heterogeneous treatment effects, which is the setting we face. Before delving into the details of the event study regression methodology, we first need to define the treatment variable and the baseline panel regression.

## 3.1 Measurement of the BSE

The conventional way of assigning the treatment variable (or event) in a DID model is through the interaction between a time indicator variable, which takes the value of 1 in the periods when the event occurs, and a treatment indicator variable, equal to 1 for treated countries and 0 for untreated ones. In our analysis, we have termed the result of this interaction the 'BSEdummy' variable.

However, before doing what the manual says, we recognize that the timing and severity of BSE outbreaks may influence having a more suitable treatment variable. For instance, the impact of a first case reported after 2000 (e.g. Greece, Sweden and Finland), when more information and control measures were available, may not be as significant as a first case reported in the early 1990s (e.g. Portugal, France, Denmark or Germany). Similarly, the 37,301 cases reported in the United Kingdom during the peak of the outbreak in 1992 likely had a more substantial impact than a single case reported in another country the same year. On the other hand, stricter prohibition policies affecting the entire EU took place in 1994, 1996, and 2001. Notably, 1994 also marked the first fatal human CJD case reported.

To investigate the effectiveness of different treatment measures, we conducted a series of regressions analyzing the relationship between bovine meat consumption and six different treatment options. First, at a country-level i) the original dummy ($BSEdummy$): 1 for the years that have reported BSE cases, 0 otherwise; ii) An alternative dummy ($BSEdummy\_yr1onw$): 1 from first case year onwards and 0 for the years before. Second, from a EU-wide perspective iii) a dummy that takes a value of 1 from 1992 onwards for all countries ($BSEdummy\_EU92$); and iv) an alternative dummy from 1994 onwards ($BSEdummy\_EU94$). Additionally, we explored the natural logarithm of reported BSE cases as a treatment measure, potentially enabling a discrete scale based on case severity. This approach was applied at both v) country and vi) EU levels. Results are in Appendix 2.

The choice of treatment variable was guided by theoretical expectations and empirical evidence from raw data, which suggest that BSE should have reduced beef consumption. Appendix 2 shows that this expected effect is only observed for the EU dummy variables in 1992 and 1994, and partially for the country-level dummy variable from the first reported case onwards ($BSEdummy\_yr1onw$). In other cases, the opposite effect is observed: BSE appears to increase beef consumption, which cannot be supported.

Based on these findings, we select the $BSEdummy\_yr1onw$ variable as it preserves the heterogeneity of countries in the sample and reflects the essence of the EU dummies in 1992 and 1994. Henceforth, we will present results using *BSEdummy_yr1onw* treatments. The main results using *BSEdummy* as treatment are shown in Appendix 4. Notably, the difference in approach will not affect the regression analysis for the event study, as the procedure considers the year of the outbreak and calculates the length of the post-treatment effect.

## 3.2 Panel regression methodology

To investigate the potential impact of BSE on the consumption of plant-based products, we employ a panel data approach. We begin by estimating an Ordinary Least Squares (OLS) regression model using the natural logarithm of the dependent variable. Subsequently, we incorporate individual and time fixed effects to estimate the percentage change coefficients. Our baseline regression for assessing the impact is represented by the following equation:

$$ln(beef/product_i)_{ct} = \beta_0 + \beta_1 BSE_{ct} + \beta_2 W_{ct} + v_c + w_t + \varepsilon_{ct} \tag{3.1}$$

where *c* denotes countries and *t* denotes years. The dependent variable is the natural logarithm of the ratio between per capita beef consumption and per capita consumption of other products (or groups of products), which can be animal-based or plant-based. BSE is the dummy variable which can be specified as either$BSEdummy$ or $BSEdummy\_yr1onw$. The vector of controls, $W_{ct}$, includes GDP, GDP per capita, CPI and a dummy variable that takes a value of 1 if country c was a member of the EU in year t and 0 otherwise. The terms $v_c$ and $w_t$ represent country and year fixed effects, respectively. Note that instead of including the interaction between the treatment and the other product consumption (different than beef) as the main regressor, we incorporated the other product into the ratio of the dependent variable for easier interpretation.

We focus on coefficient $\beta_1$. Given the decline in beef consumption, previous studies predict a significant substitution effect towards other meat alternatives, particularly pork and chicken ($\beta_1$ <0 with high significance). This is due to the rigidity of preferences and thus the low elasticity in the budget allocated to meat in households in developed countries. Therefore, there is not the same evidence to expect that the coefficient $\beta_1$ for plant-based products will be significant, much less high.

Another issue is what is expected regarding the duration of the effect. Once the outbreak is controlled, it is expected that beef consumption will return (partially or completely) to its initial trend, as suggested by previous studies (see section 2). This potential recovery can be further investigated using the event study methodology. Figure 3-1 illustrates the expected effect when comparing beef consumption relative to other meat options. Moving beyond an examination of BSE's impact on beef consumption relative to other meats, our underlying hypothesis is that the BSE outbreak caused a significant, long-term decline in beef consumption specifically relative to plant-based alternatives, rather than other meat sources.

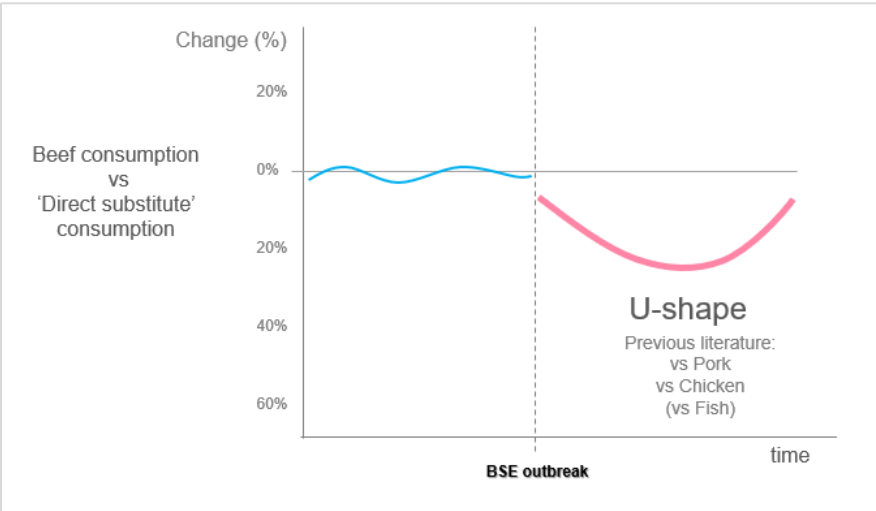


*Figure 3-1. Expected beef consumption response against other meat options*
*Source: Own elaboration*

## 3.3 Event study

In the analysis of event studies with dynamic effects (multiple treatment groups and time periods), recent research (e.g., Rambachan and Roth (2020); Sun and Abraham (2021); de Chaisemartin and D'Haultfoeuille (2020); Sant'Anna and Zhao (2020)) cautions against the pitfalls of using coefficients generated by the traditional two-way fixed effects (TWFE) event-study regressions. Among various solutions, Rambachan and Roth (2020) highlight the advantages of the treatment effect summary measures developed by Callaway and Sant'Anna (2021), which is the framework we will adopt henceforth.

We consider $T$ periods, $t = 1,2, \dots, T$. Define $G_g$ to be a binary variable that is takes a value of 1 if country had the first BSE case in period $g$ and 0 otherwise, i.e., $G_{i,g} = \mathbf{1}\{G_i = g\}$ with $G_i \subset \{2, \dots, T, \infty\}$. It's worth noting that some countries may never have experienced the outbreak, represented as $G_i = \infty$ (as is the case for Cyprus, Bulgaria, Hungary, Malta and Romania). Let $Y_{i,t}(g)$ be the potential variation in beef consumption relative to other products that country $i$ would experience at time $t$ if they first started the BSE outbreak at time $g$. And let $Y_{i,t}(0)$ represent the potential outcome for country $i$ at time $t$ if it were to remain untreated (zero BSE cases) throughout all time periods.

As a result, Callaway and Sant'Anna (2021) introduced a causal parameter *group-time average treatment effect* denoted by:

$$ATT(g,t) = \mathbb{E}[Y_t(g) - Y_t(0)|G_g = 1] \qquad \text{for } \ t \geq g \tag{3.2}$$

The parameter captures the average treatment effect for the countries in the cohort $g$ at a particular time period $t$. Equation (3.2) has the same content as the 2x2 DID estimand, but does not limit the heterogeneity among different cohorts or over time.

The identification stage leads us to inquire about how the comparison group behaves, namely, whether the sample provides a 'never-treated' comparison group or if it has a 'not-yet-treated' comparison group at time $t$, which is likely to receive treatment in a later period. In our case, the countries that never reported a BSE outbreak are reduced to the five aforementioned (a small subset and barely representative of the sample), while the remaining countries experience outbreaks in a progressive manner. Therefore, we adhere to the 'not-yet-treated' approach: countries that have not experienced the outbreak yet in year $t$ also act as control group.

The next step in identification is to decide between recovering the 'not-yet-treated' estimator, $ATT^{ny}(g,t)$, under the parallel trends assumption, which does not include covariates, or to recover the estimator using one of the nonparametric identification alternatives that incorporates covariates ($X$) and allows for relaxing the parallel trends assumption. Given the significant influence of our covariates (particularly per capita income and prices) in aggregate consumption behaviour, we opt for nonparametric identification to accommodate covariate-specific trends.

Among the family of nonparametric estimators[2], we selected the doubly robust (DR) DID estimator developed and suggested by Sant'Anna and Zhao (2020). Let

[2] In the nonparametric identification, Callaway and Sant'Anna (2021) show that one can use outcome regression (OR), inverse probability weighting (IPW), or doubly robust (DR) estimands to recover the ATT(g, t)'s.

$\mathbb{E}[Y_t - Y_{g-1}|X, D_t = 0, G_g = 0]$ be the expected outcome of the comparison group: those countries that do not observe BSE cases at time $t$ ($D_t = 0$) and did not start outbreak at time $g$ ($G_g = 0$), conditioned on covariates $X$. We denote the previous expression as $m_{g,t}^{ny}(X)$. Now, define $p_{g,t}(X)$ as the probability of being in the cohort $g$, conditional on covariates $X$, and either being a member of group g or a member of the "not-yet-treated" group by time t. Then, the expression $p_{g,t}(X)(1-D_t)$ adjust the probability for the absence or presence of treatment at time $t$. Accordingly, Sant'Anna and Zhao (2020) define the DR estimator as follows:

$$ATT_{dr}^{ny}(g,t) = \mathbb{E}\left[\left(\frac{G_g}{\mathbb{E}[G_g]} - \frac{\frac{p_{g,t}(X)(1-D_t)}{1-p_{g,t}(X)}}{\mathbb{E}\left[\frac{p_{g,t}(X)(1-D_t)}{1-p_{g,t}(X)}\right]}\right)(Y_t - Y_{g-1} - m_{g,t}^{ny}(X))\right] \tag{3.3}$$

In essence, Equation (3.3) calculates the $ATT(g,t)$ starting from the assumption of parallel trends with a 'not-yet-treated' group (expression $Y_t - Y_{g-1} - m_{g,t}^{ny}(X)$), and applies a normalization factor, denoted by the 'big parenthesis'. The factor ensures that the event effect is comparable across different time periods and treated groups, accounting for differences in the frequency of event initiation and country characteristics.

Lastly, we gather all *group-time average treatment effects* to be estimated into one aggregated causal parameter using the following aggregation scheme

$$\theta(e) = \sum_{g \in G} \mathbf{1}\{g + e \le T\} P(G = g | G + e \le T)\, ATT_{dr}^{ny}(g,t) \tag{3.4}$$

$e$ denotes the event-time relative to treatment, i.e., $e = t - g$, capturing the number of years since the country initially obtained the outbreak. $P(G = g | G + e \le T)$ calculates an average of $ATT(g,t)$ weighted by the cohort size. Then, $\theta(e)$ is the treatment effect heterogeneity in $e$ and is our target parameter in the event study results in section 5.2. The parameter place in the standard framework of event-studies, and can be interpretated as the dynamic treatment effects in TWFE regressions, though it completely avoids the pitfalls associated with the dynamic TWFE specification.

# 4. Data and descriptive statistics

*Sample and years*

Our research focuses on 19 EU states (including the UK) during the period from 1980 to 2020. We excluded seven of the current 27 EU states due to the lack of separate economic data before their respective dissolution processes in the early 1990s[3]. Additionally, Belgium and Luxembourg were excluded as their economic aggregated data is only available individually from 1999 onwards. With the exception of Belgium, the excluded countries do not exhibit a substantial number of BSE cases (see Appendix 1) and do not compromise the control and treatment groups for the analysis.

This leaves us the 19 countries: 18 EU states (Austria, Bulgaria, Cyprus, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Malta, Netherlands, Poland, Portugal, Romania, Spain and Sweden) plus the United Kingdom. Similarly, the study period starts from 1980 to ensure several pre-treatment years before the first BSE cases were recorded, extending up to the year 2020.

*The dependent variable: Food consumption*

We employed FAOstat to gather domestic food demand data categorized by item and country. This involved merging two FAOstat databases: the "old methodology" Food Balance database spanning 1961-2013 and the post-2010 database. To ensure consistency, food categories were unified based on the codes and names from the "old methodology," and new categories introduced after 2010, primarily representing marginal quantities, were incorporated.

From the merged dataset, we obtained 98 items (subproducts) classified into 21 groups, Table 4-1. The groups and subgroups are coded using the FoodEx2 system, which is the food classification and description system developed by the EFSA. To facilitate interpretation, we used the group classification (Column 3) as part of the dependent variable.

---

[3] The following countries were excluded (in parentheses the former state and the year of dissolution): Czechia and Slovakia (Czechoslovakia, 1993 ); Croatia and Slovenia (Yugoslav SFR, 1990-1992) and Lithuania, Estonia, and Latvia (Soviet Union, 1990 and 1991).

The dependent variable is the ratio between the per capita consumption of bovine meat and the per capita consumption of each food group (except meat) in column (3) of Table 4-1. From the "meat" group, we have extracted its subgroups individually. Subsequently, the group of dependent variables also includes the ratio of bovine meat consumption to the per capita consumption of pigmeat, poultry, and mutton & goat individually. This will allow us to compare our results with the findings of previous studies regarding the substitution effect between meats.

Four items were excluded. The 'Animal Fats' and 'Offals' groups represent minor consumption of mixed animal sources (beef, pork, chicken, mutton, and lamb). Including these groups would introduce more noise than signal into the analysis., We excluded the 'Peas' subgroup from the 'Pulses' group due to the significant impact of the US soybean meal export embargo on the European pea market[4]. Finally, the 'Alcoholic Beverages' group was excluded due to its irrelevance to nutritional considerations.

This resulted in 20 comparison pairs in our dependent variable (bovine meat vs. 20 specific groups/subgroups), with seven pairs representing animal sources and thirteen pairs representing plant sources. The panel data is strongly balanced for the selected comparison groups.

*Table 4-1. FAO/WHO classification of foods into groups and subgroups*

| (1) Classification | (2) Group Code | (3) Group | (4) Subgroup |
|---|---|---|---|
| Animal-based | 2943 | Meat | Bovine Meat<br>Mutton & Goat Meat<br>Pigmeat<br>Poultry Meat<br>Meat, Other |
| | 2945 | Offals | Offals, Edible |
| | 2946 | Animal fats | Butter, Ghee<br>Cream<br>Fats, Animals, Raw<br>Fish, Body Oil<br>Fish, Liver Oil |
| | 2949 | Eggs | Eggs |
| | 2948 | Milk - Excluding Butter | Milk - Excluding Butter |
| | 2960 | Fish, Seafood | Freshwater Fish<br>Demersal Fish<br>Pelagic Fish<br>Marine Fish, Other<br>Crustaceans<br>Cephalopods<br>Molluscs, Other<br>Aquatic Animals, Others |
| | | | Meat, Aquatic Mammals |

[4] The US imposed a soybean export embargo in 1973 due to exceptional drought conditions. Around 1985, France, the leading pea producer, increased pea cultivation by 1,000-fold to address the protein deficit. Domestic Pea consumption soared 20-fold (1980-1994) in France, then fell dramatically, stabilizing at a fraction by 2020. This significantly increases the bovine meat/pea ratio in the EU in the post-BSE outbreak period, which biases the analysis. Pulses still include beans, chickpeas, and lentils among others.

| (1) Classification | (2) Group Code | (3) Group | (4) Subgroup |
| --- | --- | --- | --- |
| | 2961 | Aquatic Products, Other | Aquatic Plants |
| Plant-based | 2905 | Cereals - Excluding Beer | Wheat and products |
| | | | Rice and products |
| | | | Barley and products |
| | | | Maize and products |
| | | | Rye and products |
| | | | Oats |
| | | | Millet and products |
| | | | Sorghum and products |
| | | | Cereals, Other |
| | 2907 | Starchy Roots | Cassava and products |
| | | | Potatoes and products |
| | | | Sweet potatoes |
| | | | Yams |
| | | | Roots, Other |
| | 2908 | Sugar Crops | Sugar cane |
| | | | Sugar beet |
| | 2909 | Sugar & Sweeteners | Sugar non-centrifugal |
| | | | Sugar (Raw Equivalent) |
| | | | Sweeteners, Other |
| | | | Honey |
| | 2911 | Pulses | Beans |
| | | | Peas |
| | | | Pulses, Other and products |
| | 2912 | Treenuts | Nuts and products |
| | 2913 | Oilcrops | Soyabeans |
| | | | Groundnuts |
| | | | Sunflower seed |
| | | | Rape and Mustardseed |
| | | | Cottonseed |
| | | | Coconuts - Incl Copra |
| | | | Sesame seed |
| | | | Palm kernels |
| | | | Olives (including preserved) |
| | | | Oilcrops, Other |
| | 2914 | Vegetable Oils | Soyabean Oil |
| | | | Groundnut Oil |
| | | | Sunflowerseed Oil |
| | | | Rape and Mustard Oil |
| | | | Cottonseed Oil |
| | | | Palmkernel Oil |
| | | | Palm Oil |
| | | | Coconut Oil |
| | | | Sesameseed Oil |
| | | | Olive Oil |
| | | | Ricebran Oil |
| | | | Maize Germ Oil |
| | | | Oilcrops Oil, Other |
| | 2918 | Vegetables | Tomatoes and products |
| | | | Onions |
| | | | Vegetables, other |
| | 2919 | Fruits - Excluding Wine | Oranges, Mandarines |
| | | | Lemons, Limes and products |
| | | | Grapefruit and products |
| | | | Citrus, Other |
| | | | Bananas |
| | | | Plantains |
| | | | Apples and products |

| (1) Classification | (2) Group Code | (3) Group | (4) Subgroup |
|---|---|---|---|
| | | | Pineapples and products<br>Dates<br>Grapes and products (excl wine)<br>Fruits, other |
| | 2922 | Stimulants | Coffee and products<br>Cocoa Beans and products<br>Tea (including mate) |
| | 2923 | Spices | Pepper<br>Pimento<br>Cloves<br>Spices, Other |
| | 2924 | Alcoholic Beverages | Wine<br>Beer<br>Beverages, Fermented<br>Beverages, Alcoholic<br>Alcohol, Non-Food |
| | 2928 | Miscellaneous | Infant food<br>Miscellaneous |

*Source: FAOstat*

*BSE cases*

Before 2013, data on the number of BSE cases per country and year was obtained from the Health and Food Safety department of the European Commission (European Commission, 2015). To complete the data for subsequent years, the Scientific Reports of the European Food Safety Authority (EFSA) were utilized (EFSA, 2020 and EFSA, 2023). The EFSA reports provide a continuation of the data published by the Health and Food Safety department. The existence of BSE cases was used to decisively assign the treatment dummy variable.

*Control variables*

Six control variables were incorporated into the analysis. Data for total real Gross Domestic Product (GDP) and real GDP per capita were also obtained from FAOstat. The Consumer Price Index (CPI) was sourced from the World Bank. All these variables were transformed using the natural logarithm. To account for EU membership, a dummy variable was included with a value of 1 in the years the country was an EU member and 0 otherwise. This variable was assigned a value of 0 for Spain and Portugal prior to 1986, Cyprus, Hungary, Malta, and Poland before 2004, Romania and Bulgaria before 2007, and the UK in 2020, reflecting their respective EU accession/exit dates.

Additionally, fixed effects are employed for both countries and years. Country fixed effects control for time-invariant country-level factors that might influence the changes in the beef and wheat consumption ratio. Year fixed effects control for common shocks that may have affected all countries simultaneously. Note that population growth is implicitly controlled for by using the dependent variable in per capita units.

*Descriptive statistics*

Table 4-2 highlights the significant heterogeneity within the sample data. Countries witht the highest per capita beef consumption (>20 kg/pc/yr) in the last year are Denmark, Sweden, France, Malta, Portugal, and the UK. The observed beef consumption levels indicate a substantial variation in dietary patterns across the sample countries. However, pigmeat boasts the highest per capita consumption among the meat options, while beef and chicken exhibit a similar distribution of consumption. Among the entire category of animal-based products, dairy products (excluding butter) have the highest per capita consumption, albeit with extreme heterogeneity across the sample.

Among plant-based products, cereals hold the highest average consumption, with wheat products standing out. Denmark, the Netherlands, Ireland, and Hungary are the countries with the highest per capita wheat consumption (>300 kg/pc/yr). Following cereals are unprocessed sugars (sugar crops) and starchy roots, the latter reflecting the high consumption of potatoes. Closely following these two groups is the consumption of fruits and vegetables, which exhibit a similar distribution across the sample.

The control variables also reflect considerable heterogeneity. However, it is important to note that the minimum and maximum values encompass the entire analysis period (1980-2020), rendering their interpretation less straightforward due to economic cycles.

Data reveals the expected correlation patterns among the control variables and the aggregates food categories, Table 4-3. Price levels exhibit a stronger association with per capita income compared to overall economic growth. Furthermore, per capita income demonstrates a high positive correlation with meat consumption. In general, average meat consumption rises with increasing income levels. Conversely, vegetable consumption remains largely constant in response to changes in per capita income.

It is noteworthy that GDP and GDP per capita exhibit a weak correlation. This dual inclusion helps to isolate the impact of economic growth (reflected by GDP) from the influence of population growth. While GDP captures the overall economic capacity, GDP per capita provides insights into the distribution of this capacity across the population. This latter is particularly relevant for understanding the effect of individual wealth on consumption behaviour. Consequently, both variables allow for more precise and nuanced analyses, being common controls in literature.

Examining the correlations between different product groups (see Appendix 3), bovine meat consumption exhibits a negative correlation with the consumption of pigmeat (-0.22) and poultry (-0.25). This suggests that consumers tend to substitute beef with other meat sources when beef prices increase or availability decreases. Similarly, comparing bovine meat consumption with plant-based products reveals a negative correlation with cereals (-0.16) and spices (-0.36). In general, plant-based products display moderate to weak correlations among themselves(<0.40).

*Table 4-2. Panel Data descriptive statistics*

| Description | Variable name | Mean | SD | Min | Max |
|---|---|---:|---:|---:|---:|
| Bovine meat kg/capita | bovin dome kgpc | 17.15 | 7.26 | .13 | 39.47 |
| Pigmeat kg/capita | pigme dome kgpc | 39.18 | 12.48 | 12.99 | 80.01 |
| Poultry kg/capita | poult dome kgpc | 19.95 | 7.37 | 3.14 | 39.34 |
| Mutton & Goat kg/capita | mutto dome kgpc | 3.32 | 3.61 | 0 | 15.55 |
| Offal kg/capita | offal dome kgpc | 4.38 | 3.15 | -5.3 | 18.86 |
| Milk Ex. Butter kg/capita | milk dome kgpc | 337.41 | 169.97 | 93.29 | 1643.91 |
| Eggs kg/capita | eggs dome kgpc | 13.8 | 3.38 | 5.54 | 24.94 |
| Fish, Seafood kg/capita | fish seaf dome kgpc | 39.39 | 28.99 | 1.56 | 200.55 |
| Other Aquatic kg/capita | aquat prod dome kgpc | .54 | 1.64 | 0 | 11.23 |
| Cereals kg/capita | cerea dome kgpc | 620.09 | 258.18 | 271.32 | 1616.25 |
| Starchy roots kg/capita | starc dome kgpc | 169.35 | 169.46 | 29.09 | 1188.11 |
| Sugar crops kg/capita | sugar crop dome kgpc | 221.93 | 180.29 | -2.44 | 723.75 |
| Sugar and Sweeteners | sugar sweet dome kgpc | 51.95 | 22.12 | 22.67 | 169.9 |
| Pulses Ex. Peas kg/capita | pulse dome kgpc | 10.8 | 10.1 | 1.21 | 77.99 |
| Treenuts kg/capita | treen dome kgpc | 4.68 | 4.17 | -2.43 | 26.71 |
| Oilcrops kg/capita | oilcr dome kgpc | 97.08 | 80.58 | 2.49 | 396.92 |
| Vegetable oils kg/capita | veget oil dome kgpc | 36.14 | 25.54 | 7.93 | 238.95 |
| Vegetables kg/capita | veget dome kgpc | 142.85 | 62.45 | 35.62 | 383.42 |
| Fruit Ex. wine kg/capita | fruit dome kgpc | 155.02 | 71.78 | 29.29 | 349.74 |
| Stimulants kg/capita | stimu dome kgpc | 8.01 | 4.14 | -12.68 | 27.11 |
| Spices kg/capita | spice dome kgpc | .72 | 1.16 | -.1 | 8.83 |
| Miscellaneous kg/capita | misce dome kgpc | -1.35 | 6.94 | -43.8 | 21.97 |
| Gross Domestic Product | GDP | 654497 | 854260 | 2726 | 3595200 |
| GDP per capita | GDPpc | 25647 | 14541 | 3382 | 79670 |
| Consumer Price Index 2010=100 | CPI | 73.81 | 32.1 | 0 | 127.04 |
| BSE outbreak indicator | BSEdummy yr1onw | .45 | .5 | 0 | 1 |
| EU member indicator | EUdummy | .73 | .44 | 0 | 1 |
| Reported cases of BSE | bsecases | 979.44 | 4699.61 | 1 | 37301 |

*The variables in 'kg/capita' represent the domestic supply (as a proxy of consumption) of the corresponding product*

*Table 4-3. Pairwise correlation between controls and aggregates food categories*

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| (1) GDP | 1.000 | | | | | | | |
| (2) GDPpc | 0.396 | 1.000 | | | | | | |
| (3) CPI | 0.266 | 0.547 | 1.000 | | | | | |
| (4) BSEdummy_yr1onw | 0.447 | 0.616 | 0.577 | 1.000 | | | | |
| (5) EUdummy | 0.368 | 0.526 | 0.631 | 0.531 | 1.000 | | | |
| (6) bsecases | 0.131 | -0.013 | -0.279 | | 0.021 | 1.000 | | |
| (7) animal products | 0.234 | 0.611 | 0.212 | 0.315 | 0.273 | -0.036 | 1.000 | |
| (8) plant-based products | 0.149 | -0.098 | 0.064 | 0.258 | 0.233 | -0.218 | -0.288 | 1.000 |

# 5. Results

The results are presented in two parts. Firstly, we present the results of our panel regression analysis. We estimated the impact of BSE on beef consumption relative to the aggregate of plant-based products. To achieve this, we employed various model specifications, with our preferred specification being the one that incorporates all controls, including fixed effects. Subsequently, we utilize this preferred specification to delve deeper into the impact of BSE on beef consumption, this time comparing it to specific products or product groups (20 comparison pairs).

Secondly, we conduct event studies for each of the 20 comparison pairs. Graphical results are analyzed, and aggregate ATT estimates are derived in accordance with the framework outlined in Section 3.3.

## 5.1 Panel regression results

Table 5-1 presents the findings of panel regression analyses investigating changes in domestic bovine meat consumption using the entire set of plant-based products as a comparison group. The table showcases results from various model specifications. Columns (1) and (2) are OLS regressions. Columns (3) and (4) add country fixed effects, while columns (5) and (6) display the full specification in Equation (3.1), incorporating both country and year fixed effects, which is our preferred specification. The odd-numbered columns do not include controls for EU membership and GDP, while the even-numbered columns do.

The results from Table 5-1 allow us to explore our early intuition: the BSE outbreak led to a decrease in beef consumption compared to plant-based product consumption. However, this assertion is not consistent across the specifications. In the full model, columns (5) and (6), the statistical significance and the impact size are moderate. The point estimate in Column (6) suggests that the BSE outbreak is associated with an 8.9% decrease in beef consumption compared to plant-based products consumption ($(e^{-0.093} - 1) * 100 \cong -8.9$). This result is not surprising as consumers' preferences are weakly separable regarding meat (Schösler, et al., 2012; Apostolidis, 2016). However, the result provides us with insights to compare with specific plant-based products.

Among the control variables, in the fixed effects specifications, columns (3) to (6), per capita income plays a major role in consumption preferences with a negative, substantial, and statistically significant effect. The overall price level of the economy and EU membership also exhibit a negative and statistically significant effect but with a moderate impact. Overall economic growth has a positive and highly significant impact on per capita beef consumption.

The divergent effects observed for GDP and GDP per capita on beef consumption align with the weak association between these variables noted in the *Descriptive statistics* section. Economic growth (GDP) typically translates to increased disposable income and greater access to a wider variety of foods, making meat more affordable for a larger population. Conversely, higher GDP per capita often coincides with a shift towards healthier, more sustainable, and ethically-conscious food choices, potentially leading to reduced meat consumption among wealthier populations.

*Table 5-1. Panel regression results. Bovine meat vs plant-based products.*

| | OLS | | Country FE | | Country & Year FE | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| BSEdummy_yr1onw | -.231*** | -.119** | .047 | .016 | -.099** | -.093** |
| | (.056) | (.055) | (.033) | (.032) | (.039) | (.040) |
| ln_GDPpc | .741*** | .840*** | -.412*** | -1.624*** | -.805*** | -1.513*** |
| | (.048) | (.051) | (.058) | (.233) | (.087) | (.239) |
| ln_CPI | -.201*** | -.193*** | -.154*** | -.119*** | -.183*** | -.148*** |
| | (.016) | (.016) | (.010) | (.011) | (.011) | (.013) |
| ln_GDP | | -.053*** | | 1.11*** | | .77*** |
| | | (.012) | | (.182) | | (.204) |
| EUdummy | | -.234*** | | -.165*** | | -.170*** |
| | | (.050) | | (.038) | | (.039) |
| _cons | -10.15*** | -10.39*** | 1.02* | -.715 | 5.13*** | 2.51*** |
| | (.423) | (.424) | (.551) | (.613) | (.870) | (.956) |
| Observations | 764 | 764 | 764 | 764 | 764 | 764 |
| R-squared | .380 | .413 | .802 | .817 | .822 | .831 |
| Country FE | | | YES | YES | YES | YES |
| Year FE | | | | | YES | YES |

*The dependent variable is the natural logarithm of the ratio between the consumption of bovine meat and the consumption of plant-based products (in kcal/capita/day).*
*Standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*

Table 5-2 toTable 5-4 delve deeper into the impact of BSE on the consumption per capita of specific products both other animal products (Table 5-2) and plant-based products (Table 5-3 and Table 5-4). We employ our preferred specification, incorporating both country and year fixed effects and the full set of controls.

Table 5-2 shows a negative effect on beef consumption compared to all alternative animal products, but with high statistical significance only for pigmeat, poultry, eggs, and mutton and goat meat. The overall decline in beef consumption following the BSE outbreak ranged from 19% to 23% relative to these other animal proteins[5]. These results align with the established notion that beef, pork, and chicken are close substitutes for each other (Zhou, 2015; Lusk et al., 2016).

When using eggs or fish and seafood as comparison groups, the decline in beef consumption is smaller and statistically less significant, with a decrease of 14% relative to eggs and 10% relative to fish and seafood, respectively[6]. Although dairy products are a byproduct of cows, early evidence during the outbreak suggested that BSE cannot be transmitted through cow's milk, even from cows with BSE (WHO, 1996; EC, 2001). This provides a plausible explanation for the negative relationship between beef consumption and milk consumption following the outbreak.

Finally, the impact on beef consumption compared to other aquatic products, such as aquatic mammals or plants, is estimated to be the highest, but this estimate is not statistically robust.

The plant-based product groups in Table 5-3 and Table 5-4 represent completely separate products that are arguably suitable as a control group of beef consumption.

Table 5-3 shows point estimates suggesting a large, negative, and statistically significant effect of BSE. Beef consumption declined by 36% compared to both pulses[7], column (3), and vegetable oils column (5) ($(e^{-0.44} - 1) * 100 \cong -36\%$). Similarly, column (1) shows a 24% decline in beef consumption when compared to cereals ($(e^{-0.27} - 1) * 100 \cong -24\%$). These three groups - pulses, vegetable oils, and cereals - exhibit a larger effect than that observed for animal products. Notably, these three groups represent alternative plant-based sources of protein and fat compared to animal sources. Both their production and consumption are part of the European Union's long-term strategy for promoting sustainable food systems (STOA&EPRS, 2024; Frezal et al., 2022; WEF, 2019).

Other comparison groups in Table 5-3 present mixed effects. The vegetable comparison group, column (6), also exhibited a significant and statistically relevant effect. Beef consumption declined by 18% compared to this group ($(e^{-0.2} - 1) * 100 \cong -18\%$). The oilcrops comparison group had a similar effect, albeit statistically less stable (column 4). Finally, when compared to starchy roots products, mainly potatoes, the effect is not substantial or statistically significant.

Regarding Table 5-4, all comparison groups exhibit negative and statistically significant effects on beef consumption. The impact is particularly noteworthy when compared to sugar crops, treenuts, and miscellaneous products, columns (2), (4), and (7). These groups show the highest relative declines in beef consumption, with 39%, 45%, and 49%, respectively ($(e^{-0.5} - 1) * 100 \cong -39\%$; $(e^{-0.6} - 1) * 100 \cong -45\%$ and $(e^{-0.67} - 1) * 100 \cong -49\%$). They are followed by fruits and spices, columns (1) and (5), with relative declines of around 25% each. Finally, the estimated effects when using processed sugars and stimulants (coffee, tea, and

[5] $(e^{-0.21} - 1) * 100 \cong -19\%$ w.r.t. pigmeat. $(e^{-0.26} - 1) * 100 \cong -23\%$ w.r.t. poultry.
[6] $(e^{-0.15} - 1) * 100 \cong -14\%$ w.r.t. fish and seafood. $(e^{-0.1} - 1) * 100 \cong -10\%$ w.r.t. milk.
[7] Excluiding peas

cocoa products) show a relative decline in beef consumption of approximately 13% for each group.

*Table 5-2. Panel regression results. Bovine meat vs specific products in Country&Year FE specification*

| | (1) bovine vs pigmeat | (2) bovine vs poultry | (3) bovine vs fish&seafood | (4) bovine vs eggs | (5) bovine vs milk | (6) bovine vs mutton&goat | (7) bovine vs aquatic others |
|---|---|---|---|---|---|---|---|
| BSEdummy_yr1onw | -.21*** | -.26*** | -.15** | -.22*** | -.10** | -.22*** | -.31 |
| | (.05) | (.06) | (.07) | (.05) | (.05) | (.06) | (.2) |
| ln_GDPpc | -.87*** | -1.9*** | -1.28*** | -.56** | -1.4*** | -1.71*** | -4.*** |
| | (.32) | (.34) | (.41) | (.28) | (.28) | (.34) | (1.32) |
| ln_CPI | -.16*** | -.14*** | -.15*** | -.15*** | -.15*** | .12*** | .05 |
| | (.02) | (.02) | (.02) | (.02) | (.02) | (.02) | (.2) |
| ln_GDP | -.39 | .57** | -.77** | -.39 | -.07 | 1.22*** | 2.53** |
| | (.27) | (.29) | (.35) | (.24) | (.24) | (.29) | (1.18) |
| EUdummy | -.17*** | -.24*** | .15** | -.01 | .02 | -.22*** | -.42** |
| | (.05) | (.05) | (.07) | (.05) | (.05) | (.05) | (.19) |
| _cons | 13.41*** | 12.4*** | 22.21*** | 11.3*** | 12.2*** | 3.72*** | 12.8** |
| | (1.26) | (1.36) | (1.66) | (1.12) | (1.14) | (1.38) | (5.19) |
| Observations | 764 | 764 | 764 | 764 | 764 | 756 | 625 |
| R-squared | .8 | .81 | .64 | .77 | .76 | .92 | .76 |

*The dependent variable is the natural logarithm of the ratio between the consumption of bovine meat and the consumption of specific animal products (kg/capita/day)*
*Standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*

*Table 5-3. Panel regression results. Bovine meat vs specific plant-based products in Country&Year FE specification.*

| | (1) bovine vs cereals | (2) bovine vs starchy roots | (3) bovine vs pulses[a] | (4) bovine vs oil crops | (5) bovine vs vegetable oils | (6) bovine vs vegetables |
|---|---|---|---|---|---|---|
| BSEdummy_yr1onw | -.27*** | .06 | -.44*** | -.17** | -.44*** | -.2*** |
| | (.05) | (.05) | (.09) | (.07) | (.06) | (.05) |
| ln_GDPpc | -1.4*** | -.67** | -2.5*** | -4.4*** | -2.3*** | -1.0*** |
| | (.3) | (.3) | (.56) | (.44) | (.35) | (.3) |
| ln_CPI | -.11*** | -.13*** | -.23*** | -.11*** | -.13*** | -.13*** |
| | (.02) | (.02) | (.03) | (.02) | (.02) | (.02) |
| ln_GDP | .3 | -.01 | .28 | 2.06*** | 1.19*** | -.08 |
| | (.25) | (.26) | (.48) | (.37) | (.3) | (.26) |
| EUdummy | .19*** | -.09* | .57*** | .03 | 0 | -.08 |
| | (.05) | (.05) | (.09) | (.07) | (.06) | (.05) |
| _cons | 7.5*** | 5.3*** | 23.5*** | 17.7*** | 8.3*** | 9.6*** |
| | (1.19) | (1.21) | (2.24) | (1.76) | (1.4) | (1.22) |
| Observations | 764 | 764 | 736 | 764 | 764 | 764 |
| R-squared | .84 | .86 | .69 | .85 | .78 | .81 |

*[a]Excluding pea.*
*The dependent variable is the natural logarithm of the ratio between the consumption of bovine meat and the consumption of of specific plant-based products (kg/capita/day)*
*Standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*

*Table 5-4. (continuation Table 5-3) Panel regression results. Bovine meat vs specific plant-based products in Country&Year FE specification.*

| | (1) bovine vs fruits | (2) bovine vs sugar crops | (3) bovine vs sugar& sweeteners | (4) bovine vs treenuts | (5) bovine vs spices | (6) bovine vs stimulants | (7) bovine vs miscellaneous |
|---|---|---|---|---|---|---|---|
| BSEdummy_yr1onw | -.28*** | -.5*** | -.15*** | -.6*** | -.3*** | -.14** | -.67*** |
| | (.05) | (.13) | (.05) | (.09) | (.08) | (.06) | (.23) |
| ln_GDPpc | -3.2*** | -5.*** | -.63** | -2.*** | -.94 | .12 | -1.53 |
| | (.33) | (1.02) | (.3) | (.56) | (.62) | (.39) | (.94) |
| ln_CPI | -.13*** | .1** | -.12*** | -.13*** | -.24*** | -.29*** | -.13 |
| | (.02) | (.04) | (.02) | (.03) | (.03) | (.02) | (.11) |
| ln_GDP | 1.3*** | 4.3*** | -.37 | -.48 | -.82 | -1.5*** | -2.25** |
| | (.28) | (.92) | (.26) | (.48) | (.56) | (.33) | (1.03) |
| EUdummy | .24*** | -.3*** | -.08 | .09 | .15* | -.1 | .59** |
| | (.05) | (.13) | (.05) | (.09) | (.08) | (.06) | (.23) |
| _cons | 13.9*** | -4.8 | 10.4*** | 28.6*** | 24.4*** | 19.6*** | 46.3*** |
| | (1.32) | (3.63) | (1.2) | (2.24) | (2.33) | (1.57) | (8.1) |
| Observations | 764 | 661 | 764 | 741 | 675 | 762 | 323 |
| R-squared | .75 | .74 | .76 | .68 | .86 | .61 | .82 |

*The dependent variable is the natural logarithm of the ratio between the consumption of bovine meat and the consumption of specific plant-based products (kg/capita/day)*
*Standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*

In line with the more general regression presented Table 5-1, the control variables exhibit consistent behaviour across  Table 5-2 to Table 5-4 . Income per capita displays a large, negative, and statistically significant effect on beef consumption in most of the comparison groups. CPI also shows a negative and statistically significant effect, with two exceptions. GDP and EU membership exhibit mixed impacts in terms of significance and sign.

The findings presented in Table 5-2 to Table 5-4 align with both prior research and empirical evidence. The BSE outbreak had a significant impact on the consumption of other meats, particularly pork and poultry (Table 5-2). Conversely, there is growing empirical evidence supporting the expansion of the plant-based product market as meat substitutes in Europe (EC, 2020; STOA&EPRS, 2024), primarily for the groups listed in Table 5-3 (cereals, pulses and vegetable oils). This study now enables us to infer the impact of the outbreak on this latter food group.

The upcoming event study aims to enhance the robustness of the findings from the panel regression analysis. Firstly, it will help in understanding the persistence of the observed effects. Secondly, it will serve as a robustness check for both the effect size and the presence of potential biases due to country-specific linear time trends in the pre-outbreak periods.

## 5.2 Event study regression results

Based on the panel data regression results, this section will primarily focus on eight comparison groups: pigmeat, poultry, fish, and eggs (from Tables Table 5-2), and cereals, pulses, vegetable oils, and vegetables (from Table 5-3). Results for the remaining food groups will be available in Appendix 5.

Figure 5-1 visualizes the main results of the event study regression analysis for each comparison group, eight graphs. The figure present both the estimated effects of the event (point estimates) and their associated uncertainty (95% C.I.).

We made two adjustments to reduce noise and gain precision in estimating the $ATT(g,t)$. Firstly, consistent with the results from the panel data section, we only selected income per capita and the consumer price index as covariates in the non-parametric estimation. Secondly, due to the 'Not-yet-treated' approach, there were very few 'treated' units/countries at the beginning of the treatment period, as well as a lack of control units at the end, leading to dramatic deviations at both extremes. Therefore, we trimmed five years from each end.

Graphs (1) to (4) depict the effect of BSE on beef consumption compared to other animal-based proteins. While there is an immediate reaction, it is short-lived and does not deepen. Pigmeat and poultry exhibit an immediate response to the outbreak, Graph (1) y (2). Bovine meat consumption declines relative to pigmeat and poultry in a sustained manner until the fifth year, reaching a decrease of 24% and 17%, respectively. Thereafter, a recovery in relative beef consumption is observed, exhibiting the most significant rebound when compared with poultry.

Fish and seafood as a comparison group exhibit a delayed response, Graph (3). The relative decline in beef consumption occurs from the fourth year onwards. However, the decline is deeper than for pigmeat and poultry as comparison groups and reaches 36% before reversing in the final years.

These three groups - pigmeat, poultry, and fish and seafood - all share the characteristic that the relative decline in beef consumption exhibits a U-shape in the post-outbreak period. This U-shape is most evident in poultry and fish and seafood.

In contrast, when compared to egg consumption, beef consumption shows a continuous decline throughout the entire post-outbreak period. This decline reaches a maximum of 38%.

On the other hand, Graphs (5) to (8) highlight a consistent downward trend in beef consumption relative to each comparative plant-based groups following the BSE outbreak. All groups exhibit an immediate response. However, the most profound impact is seen on pulses, Graph (2). Beef consumption decreased by up to 93% when using pulses as comparison groups[8]. Cereals and vegetable oils, as comparison groups in Graph (5) and Graph (7), also exhibit sharp declines in relative beef consumption, falling below 40% in each case, although the decline is more sustained for cereals. Regarding vegetables as a comparison group, Graph (8), the relative decline in beef consumption is less pronounced but stabilizes around 13%.

[8] PNote that these percentages are the result of the exponential conversion of the ATT, as done in the results of the panel regression.

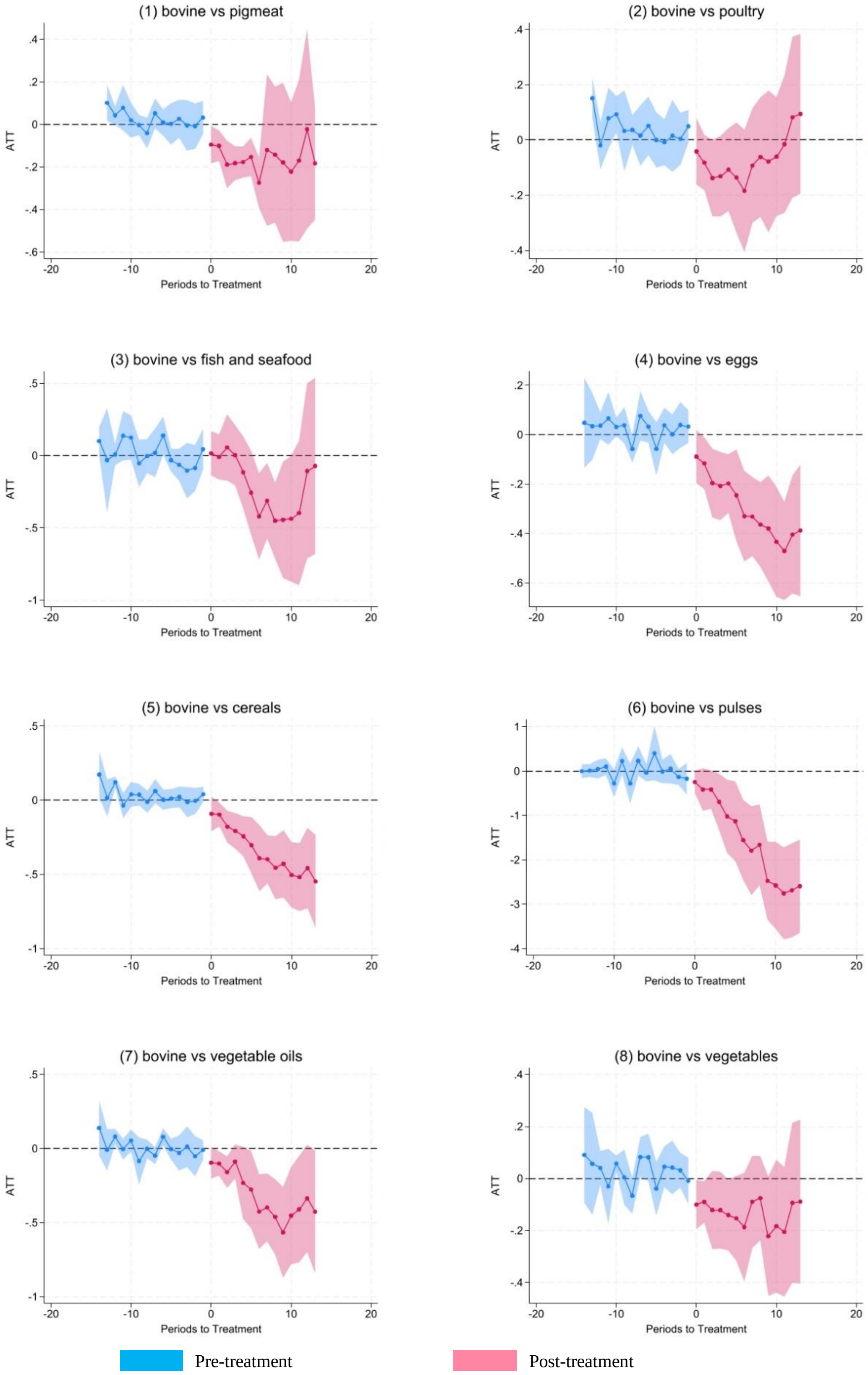


*Figure 5-1. Event study (dynamic effects) results by specific comparison products*

Across all eight graphs analyzed, no clear evidence of an anticipation effect is observed. This suggests that consumers did not significantly alter their consumption patterns in anticipation of the BSE outbreak. The above, despite the gradual spread of BSE from western to eastern EU countries and the first EU import ban policies in 1994 and 1996.

Similarly, in pre-treatment consumption patterns, the consumption ratio between bovine meat and all comparison products exhibits a relatively consistent pattern during the pre-treatment period. This is relevant as it supports that the assumption of parallel trends is met, implying that in the absence of BSE, the consumption trends exhibited by the control and treatment group countries were not systematically different.

We can summarize the dynamics shown in Figure 5-1 by calculating the aggregate estimates of the ATT. Table 5-5 presents the aggregated estimator for all pre-treatment and post-treatment effects along with their corresponding joint significance, Column (1). Note that the coefficients in column (1) are the aggregated estimators, $\theta(e)$, from equation (3.4). Columns (2) to (4) display the standard deviation and the confidence intervals, while column (5) is the transformation of the coefficient into percentage change, calculated as $e^{coefficient} - 1) * 100$.

Our primary interest focuses on the average ATT estimates in the post-treatment period (Column (1) "Post_avg" rows). These estimates reveal two key aspects: the magnitude and significance of the effect. When examining the comparison groups utilizing plant-based products, the estimators exhibit high statistical significance for the cereals, pulses and vegetable oils groups, indicating average reductions in relative beef consumption of 29%, 79% and 27%, respectively (Column (5).

In the comparison groups employing animal-based products, the magnitude of the estimators is generally smaller, with relative beef consumption declines of 15%%, 7%, and 19% for pigmeat, poultry and fish and seafood groups, respectively. However, none of these latter reductions are precisely estimated. Only when eggs are used as the comparison group does the average decline in beef consumption become significant and stable, reaching 29%.

Findings from the event study largely align with the results of our baseline regressions. While our initial panel regression did not detect a clear increase in overall plant-based product consumption following the BSE outbreak, the event study analysis reveals a specific impact on certain plant-based groups considered nutritional alternatives to red meat. Notably, this observed increase in the consumption of these specific plant-based groups appears to be both greater in magnitude and more persistent compared to the effect of BSE on direct meat substitutes, such as pork and poultry.

*Table 5-5. The aggregate ATT by Periods Before and After treatment*

| | | Statistics | | | | |
|---|---|---|---|---|---|---|
| | | (1) | (2) | (3) | (4) | (5) |
| | | Coef. | SD | [95% CI] | | % |
| bovine vs pigmeat | Pre_avg | 0.023*** | 0.01 | 0.01 | 0.05 | 2.8% |
| | Post_avg | -0.158* | 0.09 | -0.33 | 0.02 | -15% |
| bovine vs poultry | Pre_avg | 0.041*** | 0.01 | 0.02 | 0.07 | 4.2% |
| | *Post_avg* | -0.068 | 0.08 | -0.22 | 0.08 | -7% |
| bovine vs fish&seafood | Pre_avg | 0.014 | 0.01 | -0.01 | 0.04 | 1.4% |
| | Post_avg | -0.211 | 0.14 | -0.48 | 0.06 | -19.0% |
| bovine vs eggs | Pre_avg | 0.025*** | 0.00 | 0.02 | 0.03 | 2.6% |
| | Post_avg | -0.297*** | 0.06 | -0.41 | -0.18 | -25.7% |
| bovine vs cereals | Pre_avg | 0.033*** | 0.01 | 0.02 | 0.05 | 3.3% |
| | Post_avg | -0.345*** | 0.07 | -0.47 | -0.22 | -29.1% |
| bovine vs pulses[a] | Pre_avg | 0.012 | 0.02 | -0.03 | 0.06 | 1.2% |
| | *Post_avg* | -1.573*** | 0.34 | -2.23 | -0.91 | -79.3% |
| bovine vs vegetable oils | *Pre_avg* | 0.009 | 0.01 | -0.01 | 0.03 | 0.9% |
| | *Post_avg* | -0.316*** | 0.10 | -0.51 | -0.13 | -27.1% |
| bovine vs vegetables | *Pre_avg* | 0.03** | 0.01 | 0.01 | 0.05 | 2.9% |
| | *Post_avg* | -0.14** | 0.07 | -0.29 | 0.002 | -13.3% |

*[a]The group excludes peas*
*The dependent variable is the natural logarithm of the ratio between the consumption of bovine meat and the consumption of specific products (in kg/capita/day). Column (5) equals* $(e^{Coefficient} - 1) * 100$
**** $p<.01$, ** $p<.05$, * $p<.1$*

# 6. Conclusion and Discussion

Current research overlooks the potential substitution of red meat with plant products when examining beef consumption shocks. The study of this effect has primarily been conducted within experimental economics (stated preferences). Unlike much of the existing research that examines BSE through the lens of meat consumption, This study shifts its focus to analyzing the impact of the BSE outbreak on beef consumption relative to plant-based product consumption. Utilizing aggregated domestic consumption data spanning 1980 to 2020 across 18 EU member states and the UK, we employed a panel regression and an event study approach to investigate the causal relationship between the BSE outbreak and the consumption of plant-based food groups.

The results suggest that the BSE outbreak produced a structural decrease in beef consumption compared to plant-based products, and this conclusion has two components. First, following the BSE outbreak, the decline in beef consumption appears to have been more pronounced when compared to plant-based food than to other meats. Second, beef consumption never fully recovered its pre-outbreak relationship with plant-based food groups, in contrast to its recovery relative to other meats.

These findings align with established research demonstrating that the BSE outbreak significantly impacted consumption of alternative meats, particularly pork and poultry. These studies suggest the substitution effect was temporary, with only marginal long-term changes observed in pork and poultry consumption patterns in some countries. This effect is also evident in our own results.

Conversely, our findings also resonate with current European food market trends. Empirical evidence shows a growing market for plant-based substitutes, particularly cereals, pulses, oilseed, vegetable oils. These groups represent the main plant-based alternatives to animal proteins, fat and calories.

It is noteworthy that pork and poultry, being strong substitutes for beef, are not suitable comparison groups when evaluating the impact of food safety concerns on beef consumption. A more objective analysis can be achieved by comparing with plant-based food groups, which represent entirely separate products that are arguably suitable as a control group for beef (and red meat) consumption. This highlights the need for more holistic analyses of substitution effects in future research.

One implication of this study lies in estimating households' willingness to pay (WTP) for transitioning to plant-based diets with a reduced intake of red meat.

The BSE outbreak, which led to the human disease vCJD (variant Creutzfeldt-Jakob disease), exemplifies how consumers tend to focus on the deadly consequences of animal diseases. Utilizing country-specific vCJD prevalence rates and the Value of a Statistical Life (VSL), we can estimate the actual WTP for a 1% reduction in red meat consumption in favour of plant-based products.

This has two additional implications. On the one hand, it helps refine research in the field of experimental economics to obtain stated preferences based on the observed willingness to pay (WTP). On the other hand, it helps to better understand the mechanisms that food and health policies can develop to influence the reduction in prevalence and mortality rates of diseases associated with red meat consumption, such as diabetes, cardiovascular diseases, certain types of cancer, and obesity.

A key limitation of this study lies in the scarcity of observations and control variables. While the model specification accounts for fixed effects, and the event study approach enhances the robustness of the results, further control is necessary to strengthen the stability and generalizability of the findings. This could include incorporating factors such as environmental policy stringency, agricultural and food policies and taxes, and household food purchase distribution. Given the EU-wide nature of the limitation, one approach to address it would be to analyze the case of a specific country and incorporate the behaviour of those variables.

Another limitation of the study lies in the omission of the media coverage effect on the consumption impacts of BSE. Research suggests that consumer reactions to food safety concerns hinge more on whether their expectations are perceived as permanent or transitory. Media plays a crucial role in shaping these expectations for certain consumer groups (info adapters).

Despite the limitations acknowledged, this study offers a valuable contribution to the understanding of consumer food preferences. The empirical evidence presented provides a foundation for further research in this area, encouraging the development of instruments and strategies to facilitate a necessary and strategic transition towards sustainable food systems.

# Acknowledgement

*(In English below)*

A Natalia y María, "En ocasiones pienso que no son mi esposa e hija, sino mis alas" (F.G.). Les agradezco su apoyo incondicional y amor, por haber soportado la distancia. A mi padre, aunque ya no estará presente a mi regreso de este programa de maestría, su fuerza siempre estará viva en todo lo que haga. A mis hermanos y a mi madre, quienes siempre se sintieron orgullosos y me animaron a seguir adelante. A mis compañeros del programa de maestría que llenaron los días de estudio de color y gratos recuerdos. A mi supervisor Shon Ferguson, era quien llevaba la vela encendida para guiarme a través de los pasillos de esta tesis, siempre amable, diligente y perspicaz. Al Departamento de Economía de SLU, por diseñar un program excepcional que nos llevó a la frontera de la Economía Ambiental, donde encontramos una fuente ilimitada de inspiración.

A todos ustedes, gracias

To Natalia and María, "Sometimes I think you are not my wife and daughter, but my wings" (F.G.). Thank you for your unconditional support and love, for enduring the distance. To my father, who will no longer be there when I return from this master's program, but his strength will always be present in everything I do. To my brothers and my mother, who always felt proud and encouraged me. To my classmates, who filled the study days with colours and pleasant memories. To my supervisor Shon Ferguson. He was the one who carried the lit candle to guide me through the corridors of this thesis, always kind, diligent and insightful. To the SLU Department of Economics, for crafting an outstanding program that propelled us to the frontiers of Environmental Economics, and once there, we found boundless inspiration.

Thank you all.

# Appendix 1: Total number of reported BSE cases

*Table A-1. Total number of reported BSE cases (classical-BSE+atypical H-BSE+atypical L-BSE) in reporting countries by year (up to 2020) and country*

| Country | Year | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
| Austria | | | | | | | | | | | | | | | 1 | | | |
| Belgium | | | | | | | | | | | 1 | 6 | 3 | 9 | 46 | 38 | 15 | 11 |
| Czechia | | | | | | | | | | | | | | | 2 | 2 | 4 | 7 |
| Denmark | | | | | | 1 | | | | | | | | 1 | 6 | 3 | 2 | 1 |
| Finland | | | | | | | | | | | | | | | 1 | | | |
| France | | | | | 5 | | 1 | 4 | 3 | 12 | 6 | 18 | 31 | 162 | 277 | 240 | 138 | 54 |
| Germany | | | | | | 1 | | 3 | | | 2 | | | 7 | 125 | 106 | 54 | 65 |
| Greece | | | | | | | | | | | | | | | 1 | | | |
| Ireland | | | 15 | 14 | 17 | 18 | 16 | 19 | 16 | 74 | 80 | 83 | 95 | 149 | 246 | 331 | 185 | 121 |
| Italy | | | | | | | | 2 | | | | | | | 50 | 36 | 31 | 7 |
| Luxembourg | | | | | | | | | | | 1 | | | | | 1 | | |
| Netherlands | | | | | | | | | | | 2 | 2 | 2 | 2 | 20 | 24 | 19 | 6 |
| Poland | | | | | | | | | | | | | | | | 4 | 5 | 11 |
| Portugal | | | | 1 | 1 | 1 | 3 | 12 | 15 | 31 | 30 | 127 | 159 | 150 | 113 | 86 | 133 | 91 |
| Slovakia | | | | | | | | | | | | | | | 5 | 6 | 2 | 7 |
| Slovenia | | | | | | | | | | | | | | | 1 | 1 | 1 | 2 |
| Spain | | | | | | | | | | | | | | 2 | 83 | 134 | 173 | 138 |
| Sweden | | | | | | | | | | | | | | | | | | |
| UK | 442 | 2514 | 7228 | 14407 | 25359 | 37301 | 35090 | 24436 | 14562 | 8149 | 4393 | 3235 | 2301 | 1441 | 1198 | 1125 | 614 | 343 |
| Total | 442 | 2514 | 7243 | 14422 | 25382 | 37322 | 35110 | 24476 | 14596 | 8266 | 4515 | 3471 | 2591 | 1923 | 2175 | 2137 | 1376 | 864 |

*Table A-1. (Continuation)Total number of reported BSE cases (classical-BSE+atypical H-BSE+atypical L-BSE) in reporting countries by year (up to 2020) and country*

| Country | Year | | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | |
| Austria | 2 | 2 | 1 | | | 2 | | | | | | | | | | | 8 |
| Belgium | 2 | 2 | | | | | | | | | | | | | | | 133 |
| Czechia | 8 | 3 | 2 | | 2 | | | | | | | | | | | | 30 |
| Denmark | 1 | | | | 1 | | | | | | | | | | | | 16 |
| Finland | | | | | | | | | | | | | | | | | 1 |
| France | 31 | 8 | 8 | 8 | 10 | 5 | 3 | 1 | 2 | | | 4 | 2 | 3 | 4 | 2 | 1042 |
| Germany | 32 | 16 | 4 | 2 | 2 | | | | | 2 | | | | | | | 421 |
| Greece | | | | | | | | | | | | | | | | | 1 |
| Ireland | 69 | 38 | 25 | 22 | 9 | 2 | 3 | 3 | 1 | 8 | 1 | | 1 | | | 1 | 1662 |
| Italy | 8 | 7 | 2 | 1 | 2 | | 1 | | | | | | | | | | 147 |
| Luxembourg | 1 | | | | | | | | | | | | | | | | 3 |
| Netherlands | 3 | 2 | 2 | 1 | | 3 | | | | | | | | | | | 88 |
| Poland | 20 | 10 | 9 | 5 | 4 | 2 | 1 | 3 | 1 | | | | | | 1 | | 76 |
| Portugal | 51 | 33 | 14 | 18 | 8 | 6 | 5 | 2 | | | | | | | | | 1090 |
| Slovakia | 3 | | 2 | 1 | | 1 | | | | | | | | | | | 27 |
| Slovenia | 1 | 1 | 1 | | | | | | | | 1 | | | | | | 9 |
| Spain | 103 | 68 | 40 | 25 | 18 | 13 | 7 | 6 | | 2 | 1 | 1 | 3 | | 2 | 1 | 820 |
| Sweden | | 1 | | | | | | | | | | | | | | | 1 |
| UK | 226 | 129 | 65 | 42 | 11 | 11 | 8 | 3 | 3 | | 2 | | | 1 | | | 184639 |
| Total | 561 | 320 | 175 | 125 | 67 | 45 | 28 | 18 | 7 | 12 | 5 | 5 | 6 | 4 | 7 | 4 | 190214 |

From: European Commission (2013); EFSA (2020, 2023)

# Appendix 2: Results of regressions to choose the treatment

*Table A-2. Regressions results for six different treatment options.*

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| BSEdummy | .038 | | | | | |
| | (.0433) | | | | | |
| BSEdummy_yr1onw | | -.1601*** | | | | |
| | | (.0521) | | | | |
| BSEdummy_EU92 | | | -.2778*** | | | |
| | | | (.0354) | | | |
| BSEdummy_EU94 | | | | -.3233*** | | |
| | | | | (.0342) | | |
| ln_BSEcases | | | | | -.0081 | |
| | | | | | (.0092) | |
| ln_BSEcasesEU | | | | | | .062*** |
| | | | | | | (.0076) |
| ln_GDPpc | .7355*** | .7693*** | .7056*** | .7008*** | .7843*** | .7442*** |
| | (.0526) | (.0575) | (.053) | (.0526) | (.1099) | (.0511) |
| ln_CPI | -.1752*** | -.1712*** | -.1344*** | -.1259*** | -1.173*** | -.1432*** |
| | (.0171) | (.0159) | (.016) | (.0151) | (.2142) | (.0168) |
| ln_GDP | -.05*** | -.034** | -.0468*** | -.048*** | .0131 | -.0506*** |
| | (.0162) | (.0145) | (.0148) | (.0146) | (.0259) | (.016) |
| EUdummy | -.1775*** | -.1369*** | -.104** | -.0749 | -.0272 | -.0696 |
| | (.0522) | (.0508) | (.0514) | (.051) | (.1537) | (.0605) |
| _cons | -3.17*** | -3.67*** | -2.921*** | -2.896*** | -.155 | -3.86*** |
| | (.3725) | (.4543) | (.3808) | (.3773) | (.7691) | (.3787) |
| Observations | 764 | 764 | 764 | 764 | 194 | 643 |
| R-squared | .3478 | .3563 | .3768 | .3895 | .4886 | .4392 |

*Dependent variable: ln of domestic bovine meat consumption (kg/per capita)*
*Robust standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*

# Appendix 3: Pairwise correlations between different food groups

*Table A-3. Pairwise correlations between different food groups*

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) | (22) | (23) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) bovin_dome_kgpc | 1.00 | | | | | | | | | | | | | | | | | | | | | | |
| (2) pigme_dome_kgpc | -0.23 | 1.00 | | | | | | | | | | | | | | | | | | | | | |
| (3) poult_dome_kgpc | -0.25 | 0.09 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| (4) mutto_dome_kgpc | 0.05 | -0.30 | 0.18 | 1.00 | | | | | | | | | | | | | | | | | | | |
| (5) offal_dome_kgpc | 0.27 | -0.04 | -0.01 | 0.27 | 1.00 | | | | | | | | | | | | | | | | | | |
| (6) anima_fat_dome~c | 0.24 | 0.35 | -0.10 | -0.35 | 0.25 | 1.00 | | | | | | | | | | | | | | | | | |
| (7) milk_dome_kgpc | 0.28 | -0.04 | -0.10 | -0.18 | -0.02 | 0.41 | 1.00 | | | | | | | | | | | | | | | | |
| (8) eggs_dome_kgpc | 0.15 | 0.27 | -0.01 | -0.33 | 0.06 | 0.38 | 0.15 | 1.00 | | | | | | | | | | | | | | | |
| (9) fish_seaf_dome~c | 0.22 | 0.08 | -0.02 | 0.08 | 0.09 | 0.20 | 0.10 | -0.04 | 1.00 | | | | | | | | | | | | | | |
| (10) aquat_prod_do~c | 0.22 | -0.08 | 0.19 | 0.17 | 0.50 | 0.28 | 0.43 | -0.09 | 0.03 | 1.00 | | | | | | | | | | | | | |
| (11) cerea_dome_kgpc | -0.17 | 0.23 | 0.04 | -0.15 | 0.27 | 0.58 | 0.24 | 0.37 | 0.14 | 0.20 | 1.00 | | | | | | | | | | | | |
| (12) starc_dome_kgpc | 0.05 | 0.12 | -0.30 | -0.21 | 0.08 | 0.37 | 0.29 | 0.08 | -0.04 | 0.06 | 0.06 | 1.00 | | | | | | | | | | | |
| (13) sugar_crop_do~c | 0.31 | 0.34 | -0.23 | -0.23 | 0.30 | 0.63 | 0.35 | 0.37 | 0.04 | 0.23 | 0.34 | 0.42 | 1.00 | | | | | | | | | | |
| (14) sugar_sweet_d~c | 0.21 | 0.09 | 0.15 | -0.27 | -0.09 | 0.51 | 0.52 | 0.35 | 0.05 | 0.23 | 0.33 | 0.08 | 0.28 | 1.00 | | | | | | | | | |
| (15) pulse_dome_kgpc | 0.18 | 0.29 | -0.02 | -0.07 | 0.20 | 0.45 | 0.21 | 0.25 | 0.25 | 0.12 | 0.12 | 0.32 | 0.49 | 0.11 | 1.00 | | | | | | | | |
| (16) treen_dome_kgpc | 0.17 | -0.04 | 0.16 | 0.18 | -0.25 | 0.03 | 0.20 | 0.09 | 0.05 | -0.11 | -0.02 | -0.22 | -0.04 | 0.27 | 0.00 | 1.00 | | | | | | | |
| (17) oilcr_dome_kgpc | -0.05 | 0.03 | 0.07 | 0.17 | -0.10 | 0.06 | 0.01 | 0.12 | 0.04 | -0.17 | -0.03 | 0.14 | 0.08 | -0.08 | 0.25 | 0.43 | 1.00 | | | | | | |
| (18) veget_oil_dom~c | 0.10 | 0.00 | 0.19 | -0.08 | -0.16 | 0.25 | 0.41 | 0.25 | 0.00 | 0.08 | 0.21 | 0.01 | 0.17 | 0.36 | 0.12 | 0.60 | 0.52 | 1.00 | | | | | |
| (19) veget_dome_kgpc | 0.03 | -0.25 | 0.13 | 0.54 | -0.03 | -0.38 | -0.26 | -0.05 | -0.06 | -0.18 | -0.15 | -0.17 | -0.30 | -0.19 | -0.13 | 0.43 | 0.37 | 0.09 | 1.00 | | | | |
| (20) fruit_dome_kgpc | 0.19 | 0.01 | 0.19 | 0.38 | 0.06 | -0.24 | -0.15 | 0.01 | -0.02 | -0.12 | -0.13 | -0.31 | -0.08 | -0.22 | 0.08 | 0.41 | 0.38 | 0.18 | 0.53 | 1.00 | | | |
| (21) stimu_dome_kgpc | 0.35 | 0.08 | -0.08 | -0.26 | -0.10 | 0.41 | 0.40 | 0.02 | 0.45 | 0.06 | 0.04 | -0.04 | 0.19 | 0.45 | 0.20 | 0.23 | -0.05 | 0.17 | -0.32 | -0.22 | 1.00 | | |
| (22) spice_dome_kgpc | -0.36 | 0.31 | 0.17 | -0.22 | -0.07 | 0.17 | -0.06 | 0.44 | -0.21 | -0.06 | 0.38 | -0.05 | 0.14 | 0.09 | -0.04 | -0.12 | 0.01 | -0.03 | -0.12 | -0.10 | -0.11 | 1.00 | |
| (23) misce_dome_kgpc | -0.10 | 0.07 | -0.11 | 0.06 | -0.10 | -0.18 | -0.54 | -0.14 | -0.02 | -0.43 | -0.24 | -0.10 | -0.14 | -0.35 | -0.05 | -0.20 | -0.08 | -0.40 | 0.04 | -0.02 | 0.03 | 0.01 | 1.00 |

# Appendix 4: Panel regression results using *BSEdummy*

*Table A 4-1. Panel regression results using BSEdummy as the treatment variable. Bovine meat vs Plant-based products*

| | OLS | | Country FE | | Country & Year FE | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (1) | (2) | (3) |
| BSEdummy | -.0517 | .052 | .0323 | .0291 | -.0579* | -.0533 |
| | (.042) | (.0448) | (.0309) | (.0298) | (.0348) | (.034) |
| ln_GDPpc | .6612*** | .8146*** | -.3778*** | -1.6351*** | -.776*** | -1.5823*** |
| | (.036) | (.0448) | (.049) | (.2328) | (.0876) | (.2364) |
| ln_CPI | -.2056*** | -.1968*** | -.154*** | -.1192*** | -.1767*** | -.1406*** |
| | (.0178) | (.0168) | (.0104) | (.011) | (.011) | (.0125) |
| ln_GDP | | -.0665*** | | 1.124*** | | .8581*** |
| | | (.0138) | | (.1813) | | (.1999) |
| EUdummy | | -.2672*** | | -.1652*** | | -.1586*** |
| | | (.051) | | (.0376) | | (.0382) |
| _cons | -9.4273*** | -9.9926*** | .7009 | -.7556 | 4.7846*** | 2.1256** |
| | (.3141) | (.3315) | (.4675) | (.5273) | (.873) | (.953) |
| Observations | 764 | 764 | 764 | 764 | 764 | 764 |
| R-squared | .3595 | .409 | .8022 | .8175 | .8209 | .8304 |
| Country FE | | | YES | YES | YES | YES |
| Year FE | | | | | YES | YES |

*The dependent variable is the natural logarithm of the ratio between the consumption of bovine meat and the consumption of plant-based products (in kcal/capita/day).*

*Standard errors are in parentheses *** p<.01, ** p<.05, * p<.1*

*Table A 4-2. Panel regression results using BSEdummy as the treatment variable. Bovine meat vs specific products in Country&Year FE specification*

| | (1) bovine vs pigmeat | (2) bovine vs poultry | (3) bovine vs fish&seafood | (4) bovine vs eggs | (5) bovine vs milk | (6) bovine vs mutton&goat | (7) bovine vs aquatic others |
|---|---|---|---|---|---|---|---|
| BSEdummy | -.046 | .0517 | -.0495 | -.035 | .0366 | .1269*** | .3935** |
| | (.0452) | (.0489) | (.059) | (.0405) | (.0404) | (.0486) | (.1535) |
| ln_GDPpc | -1.0793*** | -2.2405*** | -1.419*** | -.8037*** | -1.5227*** | -2.0744*** | -4.189*** |
| | (.3142) | (.34) | (.4101) | (.2812) | (.281) | (.3362) | (1.3084) |
| ln_CPI | -.1378*** | -.1159*** | -.1419*** | -.1325*** | -.1394*** | .1509*** | .1462 |
| | (.0166) | (.018) | (.0217) | (.0149) | (.0149) | (.0177) | (.1954) |
| ln_GDP | -.1742 | .8827*** | -.6255* | -.1531 | .0584 | 1.5006*** | 2.7079** |
| | (.2657) | (.2876) | (.3468) | (.2378) | (.2376) | (.2857) | (1.1654) |
| EUdummy | -.1407*** | -.1947*** | .1668** | .0184 | .0415 | -.1812*** | -.4878** |
| | (.0508) | (.055) | (.0663) | (.0455) | (.0454) | (.0542) | (.1942) |
| _cons | 12.6881*** | 11.7568*** | 21.6662*** | 10.5649*** | 11.9459*** | 3.6584*** | 12.9427** |
| | (1.2666) | (1.3707) | (1.6532) | (1.1335) | (1.1328) | (1.3945) | (5.1611) |
| Observations | 764 | 764 | 764 | 764 | 764 | 756 | 625 |
| R-squared | .7941 | .8079 | .6382 | .764 | .756 | .9149 | .758 |

*The dependent variable is the natural logarithm of the ratio between the consumption of bovine meat and the consumption of specific animal products (kg/capita/day)*
*Standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*

*Table A 4-3. Panel regression results using BSEdummy as the treatment variable. Bovine meat vs specific plant-based products in Country&Year FE specification*

| | (1)<br>bovine<br>vs<br>cereals | (2)<br>bovine<br>vs<br>starchy roots | (3)<br>bovine<br>vs<br>pulses[a] | (4)<br>bovine<br>vs<br>oil crops | (5)<br>bovine<br>vs<br>vegetable oils | (6)<br>bovine<br>vs<br>vegetables |
|---|---|---|---|---|---|---|
| BSEdummy | -.0406 | .1374*** | -.2038** | -.0864 | -.1182** | .0781* |
| | (.043) | (.0428) | (.0811) | (.0626) | (.0516) | (.0436) |
| ln_GDPpc | -1.7283*** | -.7039** | -2.8501*** | -4.5766*** | -2.7455*** | -1.3171*** |
| | (.2987) | (.2971) | (.5569) | (.4348) | (.3585) | (.303) |
| ln_CPI | -.0903*** | -.1351*** | -.1991*** | -.0974*** | -.0959*** | -.1043*** |
| | (.0158) | (.0157) | (.0298) | (.023) | (.019) | (.016) |
| ln_GDP | .5801** | -.0223 | .6576 | 2.2153*** | 1.6345*** | .1804 |
| | (.2526) | (.2513) | (.4712) | (.3678) | (.3032) | (.2562) |
| EUdummy | .228*** | -.0884* | .6404*** | .0512 | .0603 | -.0419 |
| | (.0483) | (.0481) | (.0931) | (.0703) | (.058) | (.049) |
| _cons | 6.581*** | 5.7275*** | 21.8903*** | 16.9832*** | 6.7216*** | 9.1596*** |
| | (1.204) | (1.198) | (2.2554) | (1.753) | (1.4455) | (1.2214) |
| Observations | 764 | 764 | 736 | 764 | 764 | 764 |
| R-squared | .8287 | .8596 | .684 | .8478 | .7682 | .8064 |

*The dependent variable is the natural logarithm of the ratio between the consumption of bovine meat and the consumption of specific plant-based groups (kg/capita/day)*
*Standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*

*Table A 4-4. (continuation Table 5-3) Panel regression results using BSEdummy as the treatment variable. Bovine meat vs specific plant-based products in Country&Year FE specification.*

| | (1)<br>bovine<br>vs<br>fruits | (2)<br>bovine<br>vs<br>sugar crops | (3)<br>bovine<br>vs<br>sugar& sweeteners | (4)<br>bovine<br>vs<br>treenuts | (5)<br>bovine<br>vs<br>spices | (6)<br>bovine<br>vs<br>stimulants | (7)<br>bovine<br>vs<br>miscellaneous |
|---|---|---|---|---|---|---|---|
| BSEdummy | .0078 | -.1152 | -.0226 | -.0841 | -.0211 | -.0597 | -.5961*** |
| | (.0478) | (.1033) | (.0429) | (.0803) | (.0676) | (.0559) | (.1896) |
| ln_GDPpc | -3.5474*** | -5.1507*** | -.7894*** | -2.7628*** | -.8637 | -.005 | -1.8* |
| | (.3325) | (1.034) | (.298) | (.5634) | (.6307) | (.3881) | (.9211) |
| ln_CPI | -.1011*** | .1306*** | -.1071*** | -.0623* | -.2147*** | -.2814*** | -.0998 |
| | (.0176) | (.0386) | (.0158) | (.0335) | (.0249) | (.0205) | (.1071) |
| ln_GDP | 1.622*** | 4.101*** | -.2206 | .2241 | -.9609* | -1.3722*** | -1.8963* |
| | (.2812) | (.933) | (.2521) | (.4795) | (.5637) | (.3283) | (.9991) |
| EUdummy | .2796*** | -.3185** | -.0585 | .1732* | .1641* | -.0792 | .8015*** |
| | (.0538) | (.1293) | (.0482) | (.0905) | (.0849) | (.0628) | (.2344) |
| _cons | 13.1771*** | -3.7 | 9.9218*** | 26.4753*** | 25.1086*** | 19.0584*** | 44.1056*** |
| | (1.3404) | (3.6808) | (1.2015) | (2.2937) | (2.37) | (1.5644) | (7.9736) |
| Observations | 764 | 661 | 764 | 741 | 675 | 762 | 323 |
| R-squared | .7458 | .7291 | .7622 | .6633 | .8572 | .6056 | .8234 |

*The dependent variable is the natural logarithm of the ratio between the consumption of bovine meat and the consumption of specific plant-based groups (kg/capita/day)*

*Standard errors are in parentheses*

**** p<.01, ** p<.05, * p<.1*

# Appendix 5: Event Study results for the remaining food groups

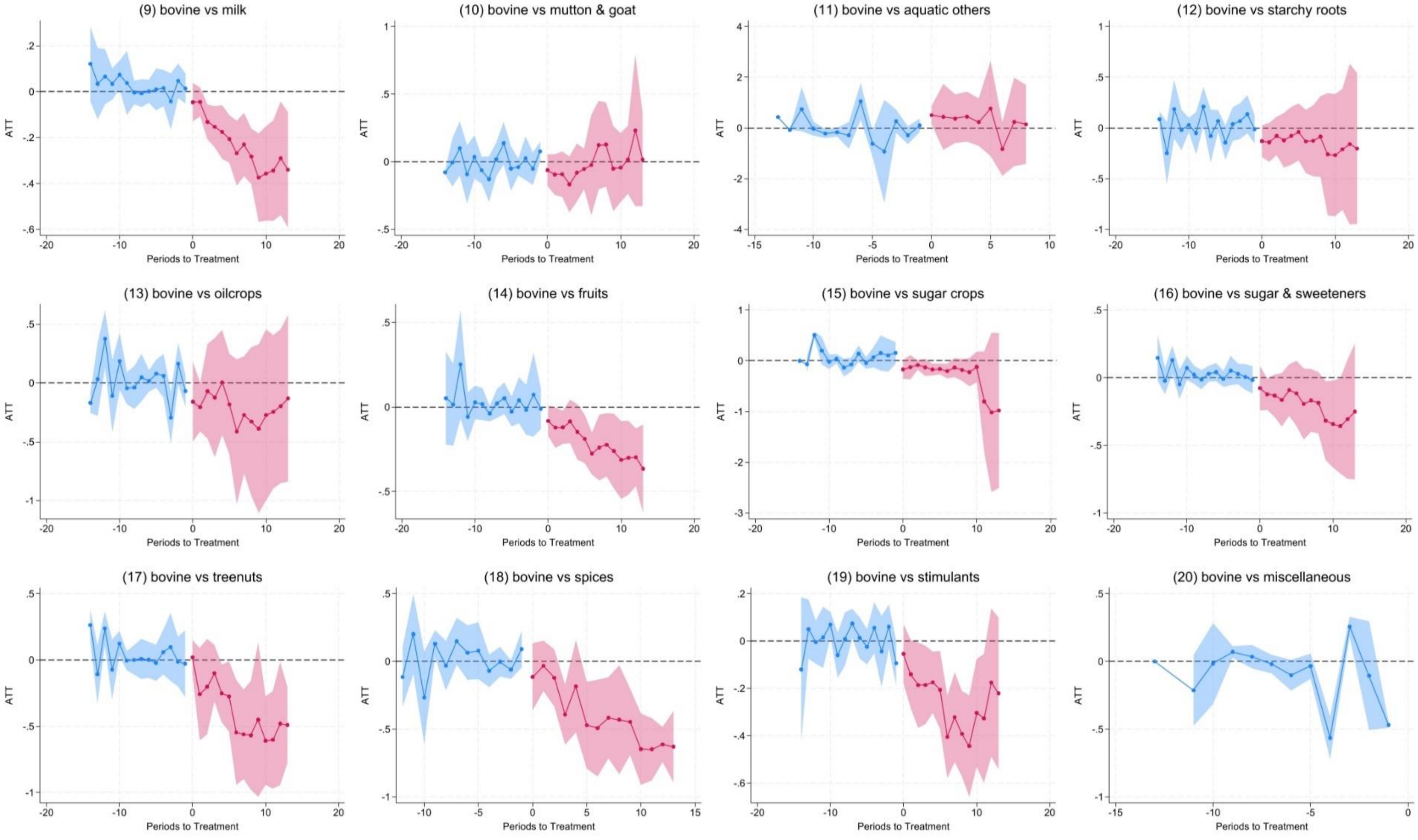


*Figure A 5-1. Event study (dynamic effects) results by specific comparison products. In blue is the pre-treatment period and in red is the post-treatment period.*

*Table A 5-1. The aggregate ATT by Periods Before and After treatment for the remaining food groups*

| | | Statistics | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| | | Coefficient | Std. err. | z | P>\|z\| | [95% conf. interval] | | % |
| bovine vs mutton & goat | Pre_avg | 0.03 | 0.02 | 1.68 | 0.09 | -0.01 | 0.07 | 3% |
| | Post_avg | -0.21 | 0.26 | -0.79 | 0.43 | -0.72 | 0.31 | -19% |
| bovine vs milk | Pre_avg | 0.03 | 0.01 | 2.36 | 0.02 | 0.00 | 0.05 | 3% |
| | Post_avg | -0.23 | 0.06 | -4.00 | 0.00 | -0.35 | -0.12 | -21% |
| bovine vs aquatic others | Pre_avg | 0.03 | 0.02 | 1.68 | 0.09 | -0.01 | 0.07 | 3% |
| | Post_avg | -0.21 | 0.26 | -0.79 | 0.43 | -0.72 | 0.31 | -19% |
| bovine vs starchy roots | Pre_avg | 0.02 | 0.01 | 1.24 | 0.22 | -0.01 | 0.05 | 2% |
| | Post_avg | -0.16 | 0.20 | -0.81 | 0.42 | -0.55 | 0.23 | -15% |
| bovine vs oilcrops | Pre_avg | 0.03 | 0.02 | 1.68 | 0.09 | -0.01 | 0.07 | 3% |
| | Post_avg | -0.21 | 0.26 | -0.79 | 0.43 | -0.72 | 0.31 | -19% |
| bovine vs fruits | Pre_avg | 0.03 | 0.01 | 3.20 | 0.00 | 0.01 | 0.04 | 3% |
| | Post_avg | -0.22 | 0.06 | -3.50 | 0.00 | -0.35 | -0.10 | -20% |
| bovine vs sugar_crops | Pre_avg | 0.08 | 0.03 | 2.57 | 0.01 | 0.02 | 0.13 | 8% |
| | Post_avg | -0.33 | 0.17 | -1.95 | 0.05 | -0.66 | 0.00 | -28% |
| bovine vs sugar and sweeteners | Pre_avg | 0.03 | 0.01 | 4.73 | 0.00 | 0.02 | 0.04 | 3% |
| | Post_avg | -0.21 | 0.11 | -1.86 | 0.06 | -0.43 | 0.01 | -19% |
| bovine vs treenuts | Pre_avg | 0.03 | 0.02 | 1.93 | 0.05 | 0.00 | 0.06 | 3% |
| | Post_avg | -0.39 | 0.13 | -2.96 | 0.00 | -0.66 | -0.13 | -33% |
| bovine vs spices | Pre_avg | 0.01 | 0.01 | 0.48 | 0.63 | -0.02 | 0.03 | 1% |
| | Post_avg | -0.42 | 0.08 | -5.11 | 0.00 | -0.58 | -0.26 | -34% |
| bovine vs stimulants | Pre_avg | 0.01 | 0.01 | 0.74 | 0.46 | -0.02 | 0.03 | 1% |
| | Post_avg | -0.26 | 0.08 | -3.27 | 0.00 | -0.42 | -0.11 | -23% |
| bovine vs miscellaneous | Pre_avg | -0.10 | . | . | . | . | . | -9% |
| | Post_avg | n.d. | | | | | | n.d. |

*The dependent variable is the natural logarithm of the ratio between the consumption of bovine meat and the consumption of specific products (in kg/capita/day). Column (5) equals* $(e^{Coefficient} - 1) * 100$

*Note: The "miscellaneous" group only reported aggregate data since 2014. Therefore, there is not enough data to estimate the post-treatment effect.*

# 7. References

Alieva, M. (n.d.). The role of information and behavioral biases in consumer choice for climate friendly proteins.

Andersen, L., Babula, R. A., Hartmann, H., & Rasmussen, M. M. (2007). A time series analysis of Danish markets for pork, chicken, and beef. Food Economics - Acta Agriculturae Scandinavica, Section C, 4(2), 103–118. https://doi.org/10.1080/16507540701439787

Annual European Union greenhouse gas inventory 1990–2017 and inventory report 2019 — European Environment Agency. (n.d.). Retrieved May 22, 2024, from https://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2019.

Apostolidis, C., & McLeay, F. (2016). Should we stop meating like this? Reducing meat consumption through substitution. Food Policy, 65, 74–89. https://doi.org/10.1016/J.FOODPOL.2016.11.002

Brugués, F., Brugués, J., & Giambra, S. (2024). Political connections and misallocation of procurement contracts: Evidence from Ecuador. Journal of Development Economics, 170, 103296. https://doi.org/10.1016/J.JDEVECO.2024.103296

Burton, M., & Young, T. (1996). The impact of BSE on the demand for beef and other meats in Great Britain. Applied Economics, 28(6), 687–693. https://doi.org/10.1080/000368496328434

Burton, M. P., Young, T., & Cromb, R. (1999). Meat consumers' long-term response to perceived risks associated with BSE in Great Britain. Cahiers d'Economie et Sociologie Rurales, 50(1), 7–19. https://doi.org/10.3406/REAE.1999.1605

Callaway, B., & Sant'Anna, P. H. C. (2021). Difference-in-Differences with multiple time periods. Journal of Econometrics, 225(2), 200–230. https://doi.org/10.1016/j.jeconom.2020.12.001

Carlsson, F., Kataria, M., & Lampi, E. (2022). How much does it take? Willingness to switch to meat substitutes. Ecological Economics, 193, 107329. https://doi.org/10.1016/J.ECOLECON.2021.107329

Chand, A. (2020). Paris Agreement needs food system change. Nature Food 2020 1:12, 1(12), 772–772. https://doi.org/10.1038/s43016-020-00205-5

Chen, B., Zhou, G., & Hu, Y. (2023). Estimating consumers' willingness to pay for plant-based meat and cultured meat in China. Food Quality and Preference, 111, 104962. https://doi.org/10.1016/J.FOODQUAL.2023.104962

de Chaisemartin, C., & D'Haultfœuille, X. (2020). Two-Way Fixed Effects Estimators with Heterogeneous Treatment Effects. American Economic Review, 110(9), 2964–2996. https://doi.org/10.1257/AER.20181169

De Chaisemartin, C., & D'Haultfœuille, X. (2024). Difference-in-Differences Estimators of Intertemporal Treatment Effects. Review of Economics and Statistics, 1–45. https://doi.org/10.1162/REST_A_01414/119488

De Oliveira Mota, J., Boué, G., Guillou, S., Pierre, F., & Membré, J. M. (2019). Estimation of the burden of disease attributable to red meat consumption in France: Influence on colorectal cancer and cardiovascular diseases. Food and Chemical Toxicology, 130, 174–186. https://doi.org/10.1016/J.FCT.2019.05.023

Ding, Y., Veeman, M. M., & Adamowicz, W. L. (2011a). Habit, BSE, and the Dynamics of Beef Consumption. Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie, 59(3), 337–359. https://doi.org/10.1111/J.1744-7976.2010.01205.X

Du, H., Guo, Y., Bennett, D. A., Bragg, F., Bian, Z., Chadni, M., Yu, C., Chen, Y., Tan, Y., Millwood, I. Y., Gan, W., Yang, L., Yao, P., Luo, G., Li, J., Qin, Y., Lv, J., Lin, X., Key, T., … Chen, Z. (2020). Red meat, poultry and fish consumption and risk of diabetes: a 9 year prospective cohort study of the China Kadoorie Biobank. Diabetologia, 63(4), 767–779. https://doi.org/10.1007/S00125-020-05091-X

Edenbrandt, A. K., & Lagerkvist, C. J. (2021). Is food labelling effective in reducing climate impact by encouraging the substitution of protein sources? Food Policy, 101, 102097. https://doi.org/10.1016/j.foodpol.2021.102097

Elzerman, J. E., Hoek, A. C., van Boekel, M. A. J. S., & Luning, P. A. (2010). Consumer acceptance and appropriateness of meat substitutes in a meal context. https://doi.org/10.1016/j.foodqual.2010.10.006

European Commission (2001). Safety of milk with regard to TSE: State of affairs. Food Safety. From https://food.ec.europa.eu/document/download/704f412a-b212-48a5-96f5-cf34199190d9_en?filename=sci-com_ssc_out175_en.pdf. Retrieved June 2, 2024.

Frezal C, Nenert C, Gay H. Meat Protein Alternatives: Opportunities and Challenges for Food Systems' Transformation, OECD Food, Agriculture and Fisheries Papers, No. 182, OECD Publishing, Paris, 2022. https://doi.org/10.1787/387d30cfen

González, N., Marquès, M., Nadal, M., & Domingo, J. L. (2020). Meat consumption: Which are the current global risks? A review of recent (2010–2020) evidences. Food Research International (Ottawa, Ont.), 137, 109341. https://doi.org/10.1016/J.FOODRES.2020.109341

Graça, J., Oliveira, A., & Calheiros, M. M. (2015). Meat, beyond the plate. Data-driven hypotheses for understanding consumer willingness to adopt a more plant-based diet. Appetite, 90, 80–90. https://doi.org/10.1016/J.APPET.2015.02.037

Jin, H. J., & Koo, W. W. (2003) . The effect of the BSE outbreak in Japan on consumers' preferences. European Review of Agricultural Economics, 30(2), 173–192. https://doi.org/10.1093/ERAE/30.2.173

Katare, B., Yim, H., Byrne, A., Wang, H. H., & Wetzstein, M. (2023). Consumer willingness to pay for environmentally sustainable meat and a plant-based meat substitute. Applied Economic Perspectives and Policy, 45(1), 145–163. https://doi.org/10.1002/AEPP.13285

Lee, J., Schulz, L. L., Hoffman, E., & Tonsor, G. T. (2023). How can reporting on foreign animal diseases affect meat purchases? The case of African swine fever. Agricultural and Resource Economics Review, 52(1), 89–111. https://doi.org/10.1017/AGE.2022.23

Lusk, J. L., & Tonsor, G. T. (2016). How Meat Demand Elasticities Vary with Price, Income, and Product Category. Applied Economic Perspectives and Policy, 38(4), 673–711. https://doi.org/10.1093/AEPP/PPV050

Mangen, M. J. J., & Burrell, A. M. (2001). Decomposing Preference Shifts for Meat and Fish in the Netherlands. Journal of Agricultural Economics, 52(2), 16–28. https://doi.org/10.1111/J.1477-9552.2001.TB00922.X

Marcus, M., & Sant'anna, P. H. C. (2021). The Role of Parallel Trends in Event Study Settings: An Application to Environmental Economics. Journal of the

Association of Environmental and Resource Economists, 8(2), 235–275. https://doi.org/10.1086/711509

Mazzocchi, M., Lobb, A., Traill, W. B., & Cavicchi, A. (2008). Food scares and trust: A European study. Journal of Agricultural Economics, 59(1), 2–24. https://doi.org/10.1111/J.1477-9552.2007.00142.X

McKenzie, A. M., & Thomsen, M. R. (2001). The Effect Of E. Coli O157:H7 On Beef Prices. Journal of Agricultural and Resource Economics, 26(2), 1–14. https://doi.org/10.22004/AG.ECON.31038

Ortez, M. A., Tolhurst, T. N., Thompson, N. M., & Widmar, N. O. (2024). Not all beef-cut price shocks are alike: Disentangling supply and demand shocks in the US beef market. Journal of the Agricultural and Applied Economics Association, 3(1), 25–40. https://doi.org/10.1002/JAA2.94

Peng, Y., McCann-Hiltz, D., & Goddard, E. W. (2004). CONSUMER DEMAND FOR MEAT IN ALBERTA, CANADA: IMPACT OF BSE. https://doi.org/10.22004/AG.ECON.20331

Polansky, A. (2005). Prepared for The Kansas Department of Agriculture.

Pritchett, J. G., Johnson, K. K., Thilmany, D. D., & Hahn, W. F. (2007). Consumer Responses to Recent BSE Events. Journal of Food Distribution Research, 38(2), 1–12. https://doi.org/10.22004/AG.ECON.43498.

Rambachan, Ashesh, Roth, Jonathan, 2020. An honest approach to parallel trends.

Rieger, J., Kuhlgatz, C., & Anders, S. (2016). Food scandals, media attention and habit persistence among desensitised meat consumers. Food Policy, 64, 82–92. https://doi.org/10.1016/J.FOODPOL.2016.09.005

Saghaian, S. H., & Reed, M. R. (2007). Consumer Reaction to Beef Safety Scares. International Food and Agribusiness Management Review, 10(1), 1–19. https://doi.org/10.22004/AG.ECON.8173

Sant'Anna, P. H. C., & Zhao, J. (2020). Doubly robust difference-in-differences estimators. Journal of Econometrics, 219(1), 101–122. https://doi.org/10.1016/j.jeconom.2020.06.003

Schlenker, W., & Villas-Boas, S. B. (2009). Consumer and market responses to mad cow disease. American Journal of Agricultural Economics, 91(4), 1140–1152. https://doi.org/10.1111/J.1467-8276.2009.01315.X

Schösler, H., Boer, J. de, & Boersema, J. J. (2012). Can we cut out the meat of the dish? Constructing consumer-oriented pathways towards meat substitution. Appetite, 58(1), 39–47. https://doi.org/10.1016/J.APPET.2011.09.009

Semba, R. D., de Pee, S., Kim, B., McKenzie, S., Nachman, K., & Bloem, M. W. (2020). Adoption of the "planetary health diet" has different impacts on countries' greenhouse gas emissions. Nature Food, 1(8), 481–484. https://doi.org/10.1038/S43016-020-0128-4

Scientific Foresight Unit (STOA) & European Parliamentary Research Service (EPRS) (2024). Alternative protein sources for food and feed. Eurpean Parliament. From: https://www.europarl.europa.eu/RegData/etudes/STUD/2024/757806/EPRS_STU(2024)757806_EN.pdf. Retrieved June 2, 2024.

Sun, L., & Abraham, S. (2021). Estimating dynamic treatment effects in event studies with heterogeneous treatment effects. Journal of Econometrics, 225(2), 175–199. https://doi.org/10.1016/j.jeconom.2020.09.006

Tantamango-Bartley, Y., Jaceldo-Siegl, K., Fan, J., & Fraser, G. (2013). Vegetarian diets and the incidence of cancer in a low-risk population. Cancer Epidemiology Biomarkers and Prevention, 22(2), 286–294. https://doi.org/10.1158/1055-9965.EPI-12-1060

van Loo, E. J., Caputo, V., & Lusk, J. L. (2020). Consumer preferences for farm-raised meat, lab-grown meat, and plant-based meat alternatives: Does information or brand matter? https://doi.org/10.1016/j.foodpol.2020.101931

Verbeke, W., Viaene, J., & Guiot, O. (1999). Health communication and consumer behavior on meat in Belgium: from BSE until dioxin. Journal of Health Communication, 4(4), 345–357. https://doi.org/10.1080/108107399126869

Weinrich, R., & Elshiewy, O. (2019). Preference and willingness to pay for meat substitutes based on micro-algae. Appetite, 142. https://doi.org/10.1016/J.APPET.2019.104353.

World Economic Forum (WEF). Meat: the Future series – Alternative Proteins, 2019.https://www3.weforum.org/docs/WEF_White_Paper_Alternative_Proteins.pdf.

World Health Organization -WHO- (1996). Consultation on Public Health Issues Related to Bovine Spongiform Encephalopathy and the Emergence of a New Variant of Creutzfeldt-Jakob Disease. From https://www.cdc.gov/mmwr/preview/mmwrhtml/00040791.htm. Retrieved June 2, 2024.

Zhen, C., & Wohlgenant, M. K. (2006). Meat Demand under Rational Habit Persistence. Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie, 54(4), 477–495. https://doi.org/10.1111/J.1744-7976.2006.00062.X

## Publishing and archiving

Approved students' theses at SLU are published electronically. As a student, you have the copyright to your own work and need to approve the electronic publishing. If you check the box for **YES**, the full text (pdf file) and metadata will be visible and searchable online. If you check the box for **NO**, only the metadata and the abstract will be visible and searchable online. Nevertheless, when the document is uploaded it will still be archived as a digital file. If you are more than one author, the checked box will be applied to all authors. You will find a link to SLU's publishing agreement here:

- https://libanswers.slu.se/en/faq/228318.

☒ YES, I/we hereby give permission to publish the present thesis in accordance with the SLU agreement regarding the transfer of the right to publish a work.

☐ NO, I/we do not give permission to publish the present work. The work will still be archived and its metadata and abstract will be visible and searchable.