Measuring and comparing economic resilience within the UK agri-food and drink industry

Final report

London Economics

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Table of Contents

Page

List of defined terms and acronyms

Defined term/acronym	Meaning
ABS	Annual Business Survey
Actual output	Observed economic activity/output.
AI	Artificial Intelligence
BCM	Business Continuity Management
CAP	Common Agricultural Policy
CEPR	Centre for Economic Policy Research
CGE	Computable General Equilibrium
Common shock	Shock affecting all sectors in the UK agri-food and drink industry.
CPI	Consumer Price Index
DEFRA	Department for Environment, Food and Rural Affairs
DSGE	Dynamic stochastic general equilibrium modelling.
Econometrics	Application of statistical methods to economic data.
FSA	Food Standards Agency
GDP	Gross Domestic Product
GVA	Gross value added. GVA reflects an industry's own-value added as it deducts all the inputs that are not produced by the industry itself but obtained or purchased from other units from the industry's gross output.
HP filter	Hodrick-Prescott filter
Idiosyncratic shock	Opposite of common shock. In the context of this study, an idiosyncratic shock is understood to be a shock only affecting a particular sector.
IoP	Index of Production
NBER	National Bureau of Economic Research (United States)
ONS	Office for National Statistics
Output	Production, proxied by production sold (turnover/value of sales) in this study.
Output gap	Difference between actual and potential output, commonly expressed in percent.
Potential output	Estimated long-run potential level of economic activity/output. Potential output is most commonly estimated by means of statistical procedures that split an output measure time series into cyclical and trend components (see 'time series filters').
RAS	Robotics and Autonomous Systems
Resilience	Ability of an entity or system to return to its original state, or an improved state, following an adverse shock. Attributes of resilience include shock absorption and shock counteraction.
Shock	Risk and challenge affecting the output of a sector.
Shock absorption	Ability to withstand a shock, i.e., the ability to absorb or neuter the adverse effect of a shock so that the end effect is small.
Shock amplification	Extent to which a shock gets amplified, inverse of a sector's ability to absorb or neuter a shock (shock absorption).
Shock counteraction	Ability to recover quickly from a shock after having been adversely affected by a shock.
Shock persistence	Amount of time the effect of a shock lingers, inverse of a sector's ability to recover from a shock (shock counteraction).
SIC	(UK) Standard Industrial Classification of economic activities. Five-digit classification providing the framework for collecting and presenting a large range of statistical data according to economic activity.
Time series filters	Statistical procedures that split the series into cyclical and trend components.
Turnover	Production sold on the market during the reference period (value of sales).
VAR	Vector Auto Regression

Source: London Economics

Executive Summary

Key findings

- This study provides evidence on how the agri-food and drink industry responds across the supply chain to a broad set of **economic risks and challenges**.
- How well each sub-sector in the industry is able to respond to these challenges – which we call '**shocks**' – reflects how '**resilient**' the sub-sector is.
- The study produces two complimentary **measures of resilience** for each sub-sector of the agri-food and drinks industry, based on data from 2000 to 2017.
- These measures show how well each sub-sector is able to **limit the size of any impact** that a shock has; and how quickly each sub-sector is able to **recover from** any shock.
- The most resilient sub-sectors include **animal production**; growing of **crops**; the food **wholesale** sector; processing and preserving of **meat** and production of **meat products**; and manufacture of **other food products**.
- The least resilient sub-sectors include the **oils and fats** sector in particular, which performs poorly mainly because it is less able to limit the impact of any shocks.
- This is an **initial piece of research** that shows how resilience varies across sub-sectors of the industry, but does not explain why it might vary.
- The **results are very sensitive** to the **choice of output measure**, though not to the statistical methods that we have tested.
- **Further research is required** to corroborate these findings and to gain a fuller understanding of resilience in this industry, including why it varies across sub-sectors.

Introduction

The Food Standards Agency's (FSA) has a mandate to **protect consumers' interests in relation to food.** In order to develop a regulatory system that is modern, risk-based and proportionate, the FSA seeks to better understand the sectors it regulates.

The present study supports this overarching goal by providing **evidence on how the agri-food and drink industry responds across the food chain to a broad set of economic risks and challenges.** These risks and challenges – which we call **'shocks'** – could be of many kinds, including changes in regulation and, changes in consumer tastes, animal and crop diseases and problems in the wider economy**.** How well the industry is able to respond to these shocks reflects how resilient it is.

This study produces **two complementary measures of economic resilience** for the purpose of conducting comparisons across sub-sectors of the UK agri-food and drink industry. One measure of resilience examines how well each sub-sector is able to **limit the size of any impact** that a shock has; and the other measures how quickly each sub-sector is able to **recover from** any shock that it does experience**.**

This research was **innovative** in the sense that it applies methods more usually used for analysing resilience at the level of the whole economy, to the analysis of resilience at the sector level. We also interpreted a statistical method commonly employed to control for common shocks in a novel way in that we used the method to quantify the reaction to those common shocks. However, the research was undertaken over a short time period and there are a number of caveats which relate principally to the **limitations of the data and methods** that we used.

It is also important to understand that this is an initial piece of research on resilience in the agri-food and drink sector and **further research is required** to corroborate these findings and to gain a fuller understanding of resilience in this sector. Further research could make greater use of sector expertise and knowledge and, for example, could seek to understand why resilience might vary across the industry, to which types of shock is the sector most vulnerable, and whether and how resilience should be improved.

Approach

This study proceeds as follows.

First, the **relevant literature** on the risks affecting **the UK agri-food and drink sector** and on the **methodologies used to develop measures of economic resilience** at the sector level is reviewed. Based on this review of the literature, we **define the concepts of 'shocks' and 'economic resilience'.**

Next, we measure economic resilience. We use **publicly available data** and a **statistical approach** more commonly applied in the analysis of national economies to identify the impact of an undefined set of common 'shocks' on the output of each sub-sector within the agri-food industry. By 'output', we mean the value of sales ('turnover') in each sector, or where that is not available, estimates of quantities produced.

Finally, we test the **sensitivity of our results** to different input assumptions.

Risks and challenges in the UK agri-food and drink sector

The literature suggests that food and drink supply chains in the UK are exposed to multiple internal and external drivers of change. These risks and challenges include sudden shocks such as weather events, changes to food regulations, and animal disease. They also include long-term challenges such as climate change, which in turn increase the food and drink sector's vulnerability to shocks and threaten the resources, infrastructure and markets that the food and drink industry relies upon.

Table 1 Shocks affecting the UK agri-food and drink sector

Type of shocks	Shock
Environmental	• Bio-security • Bio-diversity • Soil degradation • Weather events • Climate change
Political	• Brexit
Technological	• Bio-fuels

Type of shocks	Shock
Business continuity	• Critical infrastructure • Idiosyncratic supply chain shocks
Macroeconomic	• Household Income • Consumer preferences • Exchange rate volatility • Agricultural commodity price volatility • International markets • Interest rates • Energy and oil • Labour supply
Legal/Regulatory	• Food standards & animal welfare • Labour market

Source: London Economics

Defining economic resilience

For our research, we consider economic resilience to be about the way in which sectors of the economy respond to adverse shocks. Economic resilience has three main attributes:

- **Shock counteraction —** the ability to recover quickly from a shock after having been adversely affected by a shock;
- **Shock absorption —** the ability to withstand a shock, i.e., the ability to absorb or neuter the adverse effect of a shock so that the end effect is small; and
- **Shock avoidance —** the ability to avoid a shock altogether.

Many existing empirical studies focus on the first two attributes of resilience only. In line with those studies, we produce **separate resilience indices for each sub-sectors' shock counteraction and shock absorption capacity.**

Measuring economic resilience

In this study, we employ an **empirical approach** to quantify and rank UK agri-food and drink sectors' resilience to shocks.

Using quarterly, sector-level output data and a **statistical approach** more commonly applied in macro-economic analysis, we identify the impact of an undefined set of common 'shocks' on the output of each sub-sector within the agri-food industry. Our approach involves using **business cycle analysis** to model how we would expect output for each food and drink sector to change over time in the absence of shocks. We then compare this with what actually happened in order to estimate the impact of shocks on sector output.

Results

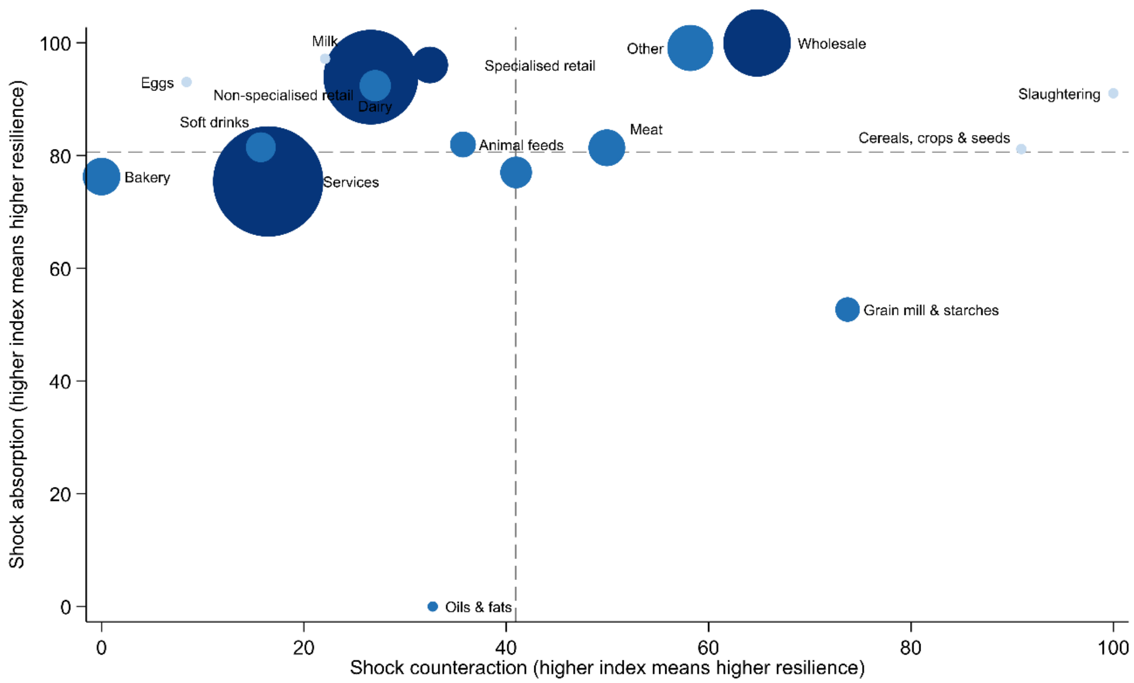
The figure overleaf summarises our main results. The **ability of a sector to react swiftly after a shock** is depicted on the vertical axis (shock counteraction) , while the **ability of a sector to absorb or neuter a shock** is reported on the horizontal axis (shock absorption). For both resilience attributes, the sectors' resilience has been set to range between zero and one hundred**, with higher values implying higher levels of resilience.** Sectors with higher levels of output (in 2017) are represented by larger circles.

Sectors in the **top-right quadrant are the most resilient** because they have relatively high scores for both shock absorption and shock counteraction, meaning that those sectors both manage to dampen the initial impact of a common negative shock and to recover more quickly to pre-shock levels in the aftermath of the shock**.** These include animal production (01.4), growing of crops (01.11), the food wholesale sector (46.3), processing and preserving of meat and production of meat products (10.1) and manufacture of other food products (10.8).

Sectors in the **bottom-left quadrant are the least resilient** because they have relatively low scores for both shock absorption and shock counteraction**.** The oils and fats sector (10.4), in particular, performs poorly mainly because it has a very low level of shock absorption resilience, meaning that the negative impact of a common shock gets amplified considerably more for this sector compared to the rest of the agri-food and drink industry.

Sectors in the **top-left quadrant** perform well on shock absorption resilience and poorly on shock counteraction resilience, whereas sectors in the **bottom-right quadrant** perform poorly on shock absorption resilience and well on shock counteraction resilience.

Figure 1 Main results (higher values mean higher resilience)



Note: The horizontal axis depicts economic resilience in terms of shock counteraction, i.e. the ability of a sector to recover quickly from a shock after having been adversely affected by a shock. The vertical axis depicts economic resilience in terms of shock absorption, i.e. ability of a sector to absorb or neuter the adverse effect of a shock so that the end effect is small. The size of the circles representing each sector are scaled by GVA for each sector in 2017 – larger circles represent sectors which higher GVA[1]. Estimations are based on data for 2000-2017. Please refer to Annex 2 for the official SIC codes and full names of the agri-food and drink sectors depicted in the graph above.

Source: London Economics' analysis based on data obtained from Eurostat, ONS and Defra.

The table below provides the resilience index in terms of both sectors' ability to recover from and absorb a shock and adds an (unweighted) average of both indices to arrive at an overall index of resilience. **Rankings of the sectors are provided in brackets.** Again, **higher values are to be read as higher levels of resilience.**

While our results are not very sensitive to the statistical methods that we use, we find that results vary considerably if we use alternative sector output measures. In the report, we further explore whether sectors' resilience varies depending on the **type or origin of the shock** and whether resilience has changed **over time.**

In order to understand the policy implications of these results, further research is required. This could make greater use of sector expertise and knowledge and, for example, could seek to understand why resilience might vary across the industry, to which types of shock is the sector most vulnerable, and whether and how resilience should be improved.

[1] Since no GVA (or turnover) data was available for the primary sector (Cereals, crops & seeds, Eggs, Milk, and Slaughtering) at such a disaggregate level, the smallest weight was used for those sectors (equal to the GVA of manufacture of oils and fats).

Table 2 Main results (higher values mean higher resilience)

100 = most resilient 0 = least resilient *(n)* = rank	Ability to recover from shock	Ability to absorb shock	Average resilience index
01.4 - Animal production (slaughtering)	100 *(1)*	92 *(8)*	96 *(1)*
01.11 - Growing of cereals (except rice), leguminous crops and oil seeds	91 *(2)*	81 *(12)*	86 *(2)*
46.3 - Wholesale of food, beverages and tobacco	65 *(4)*	100 *(1)*	82 *(3)*
10.8 - Manufacture of other food products	58 *(5)*	100 *(2)*	79 *(4)*
10. 1 - Processing and preserving of meat and production of meat products	50 *(6)*	82 *(11)*	66 *(5)*
47.2 - Retail sale of food, beverages and tobacco in specialised stores	32 *(10)*	97 *(4)*	64 *(6)*
10.6 - Manufacture of grain mill products, starches and starch products	74 *(3)*	53 *(16)*	63 *(7)*
47.11 - Retail sale in non-specialised stores with food; beverages or tobacco predominating	27 *(12)*	94 *(5)*	61 *(8)*
10.5 - Manufacture of dairy products	27 *(11)*	93 *(7)*	60 *(9)*
01.41 - Raising of dairy cattle (milk production)	22 *(13)*	98 *(3)*	60 *(10)*
10.9 - Manufacture of prepared animal feeds	36 *(8)*	82 *(9)*	59 *(11)*
10. 2 and 10.3 - Processing and preserving of fish, crustaceans, molluscs, fruit and vegetables	41 *(7)*	77 *(13)*	59 *(12)*
01.47 - Raising of poultry (egg production)	8 *(16)*	94 *(6)*	51 *(13)*
11.07 - Manufacture of soft drinks; production of mineral waters and other bottled waters	16 *(15)*	82 *(10)*	49 *(14)*
56 -Food and beverage service activities	16 *(14)*	76 *(15)*	46 *(15)*
10.7 - Manufacture of bakery and farinaceous products	0 *(17)*	77 *(14)*	38 *(16)*
10.4 - Manufacture of vegetable and animal oils and fats	33 *(9)*	0 *(17)*	16 *(17)*

Note: Estimations are based on data for 2000-2017. The average resilience index is an unweighted average of the other two indices.

Source: London Economics analysis

1 Introduction

The Food Standard Agency has asked London Economics to produce a **'rough and ready'** but **robust**[2] index of economic resilience for the purpose of conducting cross-sector comparisons and rankings within the UK agri-food and drink industry. The main requirements are as follows.

- The research should be supported by a **review of relevant literature** on the evidence and methodologies used to develop and construct measures of economic resilience at an industrial sector level.
- The index should be **fit for purpose** and **user-friendly** to aid policy design and decisions**.** The analysis further needs to be replicable as the FSA may seek to periodically update and revise the index.
- The index should be constructed at the **most granular sector breakdown possible** given the available data.
- The Food Standard Agency wishes to understand the food and drink sectors' resilience to a **broad set of risk factors** rather than one particular type of shock, with a focus on macroeconomic risks. Moreover, the approach to developing an economic resilience index should include some sensitivity analysis and investigate whether the ranking of sectors' resilience varies across different types of shocks (e.g. supply as compared to demand shocks).
- Finally, the FSA wishes to **understand, if possible, what factors make certain sub-sectors more resilient** than others.

This report sets out:

- A **review of the literature** concerned with defining and measuring economic resilience **(Chapter 2).**
- A description of our **statistical approach and results, including two complementary indices of resilience (Chapter 3).**
- Tests of the **sensitivity** of our results to changes in methods and assumptions **(Chapter 4)**.
- A description of the **limitations and recommendations for future research (Chapter 5).**

The Technical Annexes to this report, provided in a separate document, give additional background and technical information:

- **Annex 1** provides a review of the relevant **literature on shocks affecting the UK agri-food and drink sector,** including information on the nature of shocks; inter-sectoral transmission of shocks; and the determinants of resilience.
- **Annex 2** outlines important conceptual considerations regarding appropriate measures of sector-level economic activity, an overview of how we define the UK agri-food and drink industry and a review of available **data sources** of sectoral output.
- **Annex 3** provides an introduction into **business cycle analysis** and describes how we derived sector-level output gaps for the purposes of the analysis presented in the main report.

[2] As far as possible within the timescales.

- **Annex 4** provides a descriptive analysis of output levels, output volatility and output gaps in the UK agri-food and drink industry.
- **Annex 5** provides additional information and results for the statistical analysis employed in this paper. In particular, it provides **additional technical information about the statistical method** used to develop the two indices of economic resilience, including a description and **justification of the estimators** used in this study and the **test statistics that informed our main model specification.** Annex 5 also provides **additional regression results** not reported in the main report.
- **Annex 6** contains the results from a preliminary attempt at **structurally identifying common shocks in the data.**

2 Approach to measuring economic resilience

Chapter 2 Summary: Approach to measuring economic resilience

This Chapter provides context for our analysis by:

- Outlining the risks and challenges faced by the UK agri-food sector;
- Discussing what 'economic resilience' means and how it can be measured;
- Describing different potential methods for estimating how resilient a sector is and explaining which method we have chosen for our analysis.

2.1 Risks and challenges in the UK agri-food and drink sector

Food and drink supply chains in the UK are exposed to multiple internal and external drivers of change. These range from **sudden shocks** such as weather events, changes to food regulations, and animal disease; to **long-term stressors** that in turn increase the systems' vulnerability to shocks and threaten the resources, infrastructure and markets that the food and drink industry relies upon. Climate change is an exemplar of these stressors, increasing the likelihood of weather-related shocks, and threatening to impact the success of certain crops and growing methods in the UK.

The table below gives an overview of the shocks and stressors identified in the relevant literature. A **full review of the literature,** including additional information on both the incidence and likely impact of the factors listed below, is provided in **Annex 1.**

Table 1 Shocks affecting the UK agri-food and drink sector

Type of shocks	Shock
Environmental	• Bio-security • Bio-diversity • Soil degradation • Weather events • Climate change
Political	• Brexit
Technological	• Bio-fuels
Business continuity	• Critical infrastructure • Idiosyncratic supply chain shocks
Macroeconomic	• Household Income • Consumer preferences • Exchange rate volatility • Agricultural commodity price volatility • International markets • Interest rates • Energy and oil • Labour supply
Legal/Regulatory	• Food standards & animal welfare • Labour market

Source: London Economics

2.2 Defining economic resilience

Resilience is the **ability for a system or organisation to return to its original state, or an improved state,** following an adverse shock. Resilience is a term used to indicate what is necessary to 'keep the show on the road' in times of crises (Barling et al. 2015). Others define resilience around a notion of managing adversity and achieving success in the face of such adversity. Resilient organisations have the capacity to absorb shocks and changes in the market environment by adapting their business strategy and organisational structure (McNaughton and Gray 2017). Business continuity management is based on planning for shocks, disasters crises, extreme threats and other discontinuities, with a focus on enabling capacities to be easily rebuilt following a shock.

Briguglio et al. (2006) define economic resilience along the following three main attributes:

- **Shock counteraction —** the ability to recover quickly from a shock after having been adversely affected by a shock;
- **Shock absorption —** the ability to withstand a shock, i.e., the ability of to absorb or neuter the adverse effect of s a shock so that the end effect is small; and
- **Shock avoidance —** the ability to avoid a shock altogether.

The OECD (2016) refers to the former two of the above attributes as **ex-post resilience,** and the latter as **ex-ante resilience.**

A related concept to that of economic resilience is **economic vulnerability,** which is commonly defined as a system's proneness or exposure to exogenous shocks (Briguglio, 2003; Briguglio et al., 2006; Graveline and Gremont, 2017). Economic resilience encompasses **economic vulnerability** in the sense that a system's ability to avoid shocks can be considered the inverse of economic vulnerability (Briguglio et al., 2006; Graveline and Gremont, 2017).

Many of the empirical studies focus on ex-post resilience. For example, Duval and Vogel (2008) define economic resilience as 'the ability to maintain output close to potential in the aftermath of shocks'. Hence, they focus on the first two dimensions of economic resilience while abstracting from the latter.

The literature assesses economic resilience at various levels (Rose and Krausman, 2013). A large share of the economic resilience literature focuses on ***macro-economic*** resilience, comparing the resilience of different countries or regions (see for example Briguglio et al., 2006; Duval et al., 2007). Studies concerned with the measurement of resilience at the ***meso-economic*** level, i.e. with reference to individual industries or markets, are sparser and include Canova et al. (2012) and Pelkmans et al. (2008). Finally, a number of studies in business administration aim to understand why different enterprises react differently to the same exogenous shock, thus seeking to measure ***micro-economic resilience*** (see for example Rose and Krausman, 2013). While the aim of the present study is to assess resilience at the meso-economic level, as it pertains to the UK agri-food and -drink sector, **lessons can be drawn from economic resilience measurement studies across all levels.**

2.3 Measuring economic resilience

The following section reviews the existing literature concerned with measuring economic resilience of countries, regions, sectors and firms. While there is **no single agreed approach to the**

measurement of resilience (Sensier et al., 2016), the existing literature can be broadly categorised into a priori (theoretical) and a posteriori (empirical) approaches:

- **Theoretical (a priori) approaches:** A priori approaches rely on economic theory to quantify economic resilience at the macro-, meso- or micro-level. Based on a theoretical conception of what makes certain countries, sectors or firms more resilient compared to others, those studies focus on quantifying the determinants of resilience, or proxies thereof, in order to assess and compare entities' resilience.
- **Empirical (a posteriori) approaches:** A posteriori approaches calculate economic resilience indicators based on the observed economic impact of adverse shocks on countries, industries or firms.

2.3.1 Theoretical approaches to measuring economic resilience

Theoretical approaches to measure economic resilience rely on theoretical notions of what determines a sector's economic resilience. This literature is best developed at the macro-economic level. That is, determinants of resilience are applied to the economy as a whole. Some potential determinants of resilience at the macro level are[3]:

- price and wage flexibility[4];
- ability to substitute inputs;
- ability to substitute demand;
- level of excess capacity and inventory;
- product market and labour market rigidity; and
- income elasticity of demand.

The following sections illustrate various ways of operationalising the theoretical approach to measuring economic resilience.

Individual resilience indicators

One approach to measure economic resilience is to use a single indicator as proxy for resilience. Following Briguglio et al. (2006), such indicators can be classified as follows:

- **Macro-economic stability:** Examples include the fiscal deficit relative to GDP, employment rates and inflations rates. The fiscal deficit can proxy for the governmental fiscal policy. Inflation and unemployment may indicate how well a country can absorb shocks without significant costs to welfare.
- **Micro-economic market efficiency:** Indicators may include wage rigidity, freedom to trade internationally and the size of the government in the economy. Economies that function more efficiently are better able to adapt to the new economic situation generated by a shock.

[3] Also see Rose and Krausmann (2013).

[4] See Mundell (1961), McKinnon (1963) and Mongelli (2008). At a sector level, price and wage flexibility are considered to be crucial in allowing sectors to absorb external shocks (Canova et al, 2012).

- **Governance indicators:** This may include independence and impartially of the judiciary, protection of property rights and the integrity of the political system. The lack of good governance can amplify an adverse shock, and potentially create social unrest.
- **Social development indicators:** Examples include the level of education, health and social cohesion in an economy. Better developed social structures may foster an economy's ability to collaboratively respond to shocks. This would mean that actions against shocks may be taken more swiftly.

At the sectoral level, indicators that proxy **dynamics of demand, vertical linkages across sectors, levels of state-aid and sectorial product and labour markets** may be useful resilience indicators (Canova et al., 2012). Vertical linkage, for instance, could leave a sector less resilient if its downstream market is less resilient. An example may be the steel sector, which may be less resilient to shocks if downstream sectors such as the car sector are less resilient.

At the individual level, resilience characteristics may include;

- the existence of **excess economic capacity,** such as inventories (Bruneau et al., 2003; Rose and Krausmann, 2013);
- home **ownership and property** values (Jordan et al, 2011; Mayunga, 2007);
- levels of **employment** (Cutter et al., 2010; Jordan et al, 2011; Burton, 2012)
- **equality and equity** of income and resources (Cutter et al., 2010; Jordan et al, 2011); and,
- single-sector **dependence** (Jordan et al, 2011).

Composite indices

Given the wide array of economic indicators available to proxy economic resilience, several studies attempt to combine individual indicators in a **composite index** (e.g. Briguglio et al., 2006, CLES, 2010; Burton, 2012; Rose and Krausmann, 2013).

To appropriately construct a composite index from multiple theoretically motivated indicators of resilience, variables need to be transformed. For instance, unemployment levels cannot be combined with inventory levels without transforming the data. Briguglio et al. (2006) highlights that the **choice of the variables included in the composite index, as well as the weight attached to each individual component, is somewhat subjective.** However, the choice of individual indicators can be made dependent on several suitability criteria, including theoretical suitability, availability of data and ease of comprehension.

One approach to make individual components comparable is to normalise them between 0 and 1. As illustration, suppose that data is available per sector on the unemployment level. The unemployment level in each sector is normalised by subtracting the lowest level across all sectors and dividing the outcome by the range of values across all sectors (i.e. the difference between the largest and smallest unemployment level)[5]. This normalisation ensures that the largest value for each individual component equals 1 and the smallest equals 0. This approach has for instance been taken by the regional development agency for the West Midlands (Advantage West Midlands, 2010).

[5] Mathematically, this is defined as follows: $\bar{x}_i = [x_i - \min(x)]/[\max(x) - \min(x)]$, where x_i is the value for observation i, $\min(x)$ is the smallest value across the sample and $\max(x)$ is the value across the sample.

The weights of individual components can be defined theoretically. That is, if the underlying theory predicts differences in importance to resilience, these predictions can be used. Alternatively, statistical techniques, such as Principal Component Analysis, can be used to let the data determine the weights.

Production function approach

As an alternative to composite indices, some studies examine economic resilience at the micro-level within a production function framework.

Rose and Krausman (2013) argue that individual resilience indicators can be used as independent variables in a formal **production function.** This allows an analysis of how several indicators of resilience are interlinked or linked to production parameters. Rose and Liao (2005), for instance, introduce resilience measures into a Constant Elasticity of Substitution (CES) production function to examine resilience towards water supply shocks in Portland, Oregon.

2.3.2 Empirical approaches to measuring resilience

Several studies have examined economic resilience **empirically, measuring resilience in terms of post-shock developments of outcome measures** at the macro-, meso- or micro level. The simplest form of empirical resilience measurement consists of a **descriptive analysis of output data** of different countries, sectors or firms across time, with economic units that experience higher volatility in economic output being considered less resilient. Another common approach in the literature is the examination of the impact of a particular shock on firms, sectors or countries through a **case-study approach** or **examination of the evolution of output data** in the aftermath of a shock. More advanced approaches examine the **conditional correlation between country- or sector-level business cycles and common shocks through regression analysis** (Canova et al., 2012; Duval et al., 2007). Finally, the response of countries or sectors to shocks are also examined in a Vector Auto Regression framework (Pelkmans et al., 2008).

Descriptive analysis of output measures

The vulnerability of macro- or meso-economies to shocks, and thus **ex-ante resilience** of economic systems, is often assessed by examining measures of output volatility. Wells (1997), for example, examine income volatility as a proxy for economic vulnerability, and output volatility is also used to assess the macro-economic vulnerability index developed by Atkins et al. (2000).

Briguglio and Vella (2015) expand on the set of output measures commonly used to gauge economic resilience, and propose to examine **(i) volatility in output and consumption** (GDP and consumption at current and constant prices per capita); **(ii) volatility in value and volume of international transactions** (exports and imports of goods and services at current and constant prices); **(iii) volatility in exchange rates and prices** (highest and lowest monthly averages of the nominal and real effective exchange rate); **(iv) short-term shock absorbers** (external current account balance and government expenditure as percent of GDP).

The **time horizon** over which the above indicators are calculated vary between different studies and is subjective. Briguglio and Vella (2015) propose to use 10 years of most recent data.

Static analysis of output changes in the aftermath of a shock

A wide range of studies examine how a country, sector or firm has reacted to a particular shock in the past. The first step that is common to those studies is the identification of an adverse shock of interest. In comparative studies, a focus on shocks that are common across the cross-sectional observations of interest as opposed to idiosyncratic shocks is more prevalent. Moreover, most studies focus on macro-economic shocks (Cellini and Cuccia, 2014; Martin, 2012; Tan et al., 2017).

Cellini and Cuccia (2014) investigate the resilience of various segments of the Italian tourism industry by examining **changes in both supply and demand indicators during the Great Recession (2008-2012)** for different sub-sectors and regions.

Martin (2012), who examines the resilience of UK regions, go one step further by explicitly examining **the degree of co-movement in regional employment with country-wide employment** changes during national recessions. They calculate the ratio of decline in regional employment to the respective decline in the country as a whole over the duration of the national recession and interpret a ratio of less than unity as being indicative of the region being resilient to the national shock. Similarly, they examine (positive) growth during the recovery phase and consider a region experiencing faster growth compared to the national average during this phase as being resilient.

Similarly, **Tan et al. (2017) examine regional economic resilience of resource-based cities in Northeast China** by comparing city-level annual GDP growth rates between different cities and the national average during the Asian financial crisis and the global financial crisis. Following Martin (2012), they define cities with slow GDP declines relative to the national average during the recession period, and high GDP growth relative to the national average during the expansion period, as resilient.

Rose and Krausman (2013) and Rose et al. (2009) examine firm-level resilience in the context of the September 11, 2001 terrorist attack on the World Trade Center. Focussing on the shock absorption attribute of resilience, they calculate the **percentage avoidance of the maximum economic disruption.**

The advantage of examining resilience in the aftermath of a particular shock is that it generally does **not rely on complex methods to identify shocks in the data.** However, given that the relative resilience of different sectors is likely to vary both across time and across different types of shocks, building a resilience measure based on a single shock or a single recessionary period might lead to spurious results. Moreover, the observed movement in output variables of different sectors or regions in the aftermath of a macro-economic shock might in part be driven by longer-term trends or idiosyncratic cyclical fluctuations as business cycles across different sectors and regions are likely to vary.

Business cycle analysis

Another approach to measuring meso-economic (or macro-economic) resilience is the examination of amplification and persistence of external shocks at the country- or sector level. Those business cycle studies relate output changes during **industry- (or country-)specific business cycles** to the occurrence of adverse external shocks. Resilience in those studies is defined as a low impact of common shocks on sectoral (country-wide) output changes.

By explicitly examining business cycles at the sector, region or country level, a **meaningful path against which the extent of recovery from an adverse common shock can be judged is established** (Martin and Sunley, 2014). Moreover, looking at sector-specific cycles allows to not only look at the amplitude and duration of economic downturns induced by adverse shocks as well as speed of recovery, thereby allowing to distinguish between shock absorption and shock counteraction (Sensier et al., 2016).

The business cycle method usually involves the following three steps:

1) Identification of **sectoral business cycle phases** and construction of measures of sectoral output changes over the identified business cycle phases;
2) Identification of **adverse shocks** and quantification of prevalence and intensity of those shocks over the modelling period; and
3) Econometric analysis to examine the **correlation between common shocks and sectoral output** over the business cycles.

Canova et al. (2012) identify sectoral business cycles for 21 industry subsectors[6] across 19 European countries[7] between 1980 and 2008 based on the **identification of sectoral peaks and troughs[8].** They then construct variables to measure the change of output from peak to trough (and from trough to peak) and normalise by the duration of the business cycle phase in order to combine information on both the size and the duration of a cycle in one variable. As is common in the business cycle literature, the second step in Canova et al.'s (2012) approach then consists of identifying common adverse shocks. The authors employ a fully-fledged **structural Vector Auto Regression (VAR) model** to identify pure euro area aggregate GDP shocks[9], i.e. changes in GDP that cannot be predicted using information contained in current and past values of GDP itself (at constant prices), inflation (GDP deflator and CPI), short-term interest rate, and money supply (M3). The GDP shock in a given time period is obtained through a Choleski factorisation, which imposes short-term restrictions[10].

In order to obtain an estimate of cumulative GDP shocks accruing over each business cycle, Canova et al. (2012) then cumulate the estimated structural residuals in differences to obtain a cumulative shock for each sector and country and business cycle. Finally, the variable measuring sectoral output change is regressed against the variable used to measure the sign and intensity of common shocks.

Duval et al. (2007) and **Duval and Vogel (2008)** adapt the methodology of Blanchard and Wolfers (2000) to investigate the impact of a range of structural policies on the resilience of 20 OECD countries over the period 1982-2003. Rather than looking at economic fluctuations in terms of output levels, they focus on **fluctuations in the deviation of observed economic activity from the estimated long-run potential level, i.e. fluctuations in the *output gap*.** They define resilience as the ability of countries to maintain output close to potential in the aftermath of shocks. Based on a non-linear least square in panel regressions, whereby output gaps are regressed on their lags, on the shocks, and on country specific effects. Their specification further allows them to **distinguish**

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[6] Classified according to the 2-digit NACE classification.

[7] Norway, Denmark, Hungary, UK, Poland. Czech Republic, Sweden, Portugal, Italy, Netherlands, Austria, Ireland, Greece, Belgium, Germany, Spain, France, Finland, Switzerland.

[8] Canova et al. (2012) use the Bry and Boschan (1971) method to date business cycles, which consists of a computerised procedure to emulate the analytical process of the National Bureau of Economic Research, the private nonprofit research organisation that dates business cycles for the United States. In cases where the Bry and Boschan method cannot identify sectoral turning points, Canova et al. (2012) rely on a simple application of the two-consecutive-quarter rule, essentially defining an economic downturn as two more consecutive quarters with negative growth.

[9] Canova et al. (2012) further consider US GDP shocks as a robustness test, as euro area GDP might be correlated with the sectoral business cycles in some countries.

[10] An alternative approach to identify aggregate shocks is the Blanchard and Quah (1989) identification method, which imposes long-term restrictions that distinguish between permanent supply and transitory demand shocks. [explain]. Canova et al. (2012) employ this method as a robustness test.

between resilience in terms of shock counteraction and shock absorption, with the coefficients on the lagged output gap measuring the ability of a country to recover from a shock and the parameter associated with the common shock variables measuring the ability to absorb a shock. Rather than identifying the common macroeconomic shock explicitly, the **inclusion of unobserved common shock variables in their regression allows them to examine countries' resilience against an undefined set of shocks that are common to all countries.**

Vector auto regressions

The economic resilience of sectors can further be assessed within a **Vector Auto Regression (VAR) framework.** Pelkmans et al. (2008) analyse the economic resilience of twelve industries across eleven euro area countries[11] by examining the cumulative response of their variables of interest to unpredictable shock impulses.

Using annual data for the period 1970-2005 from the EU KLEMS dataset, they run **country- and sector-specific bivariate VARs,** whereby the two endogenous variables (inflation and real output growth) are explained based on their own lagged values, the lagged values of the other model variable, and an error term. After **identifying sector-level supply and demand shocks** by imposing the long-run restriction that demand shocks have no long-run real effects (Blanchard and Quah, 1989), they measure resilience via the **cumulative inflation change following a supply and demand shock** and via the **cumulative output growth loss in the case of supply shocks**[12]. Cumulative changes are measured over a period of eight years. Sectors with a lower cumulative output loss are regarded as those that are more able to absorb and recover from the shock.

2.3.3 Simulation studies

Another approach commonly employed in the literature on economic resilience, in particular as it relates to the resilience of macro-economies, is the simulation of the impact of shocks on the economy through dynamic stochastic general equilibrium (DSGE) models or computable general equilibrium (CGE). Those models rely on structural models of the economy to simulate the impact of shocks, with input parameters either being calibrated or estimated.

Grenouilleau et al. (2007) compare the **persistence of output effects induced by demand and supply shocks** in the European Union to those observed for the United States. They employ an open economy DSGE model for both geographic areas, using a set of 21 macroeconomic series from 1978Q1 to 2006Q1 and applying a Bayesian information approach, to explore the relative impact of real and nominal rigidities, monetary and fiscal policy shocks, and volatility and persistence of demand and supply shocks.

2.3.4 Preferred approach

In what follows, we employ an empirical approach to quantify and rank UK agri-food and drink sectors' resilience to shocks. While theoretically motivated resilience measures are potentially useful for assessing what factors make an entity resilient and monitoring progress in resilience enhancement over time (Briguglio et al., 2006; Rose & Krausman, 2013), the **reliance on a priori**

[11] The countries included in the analysis provided by Pelkman et al. (2007) are Austria, Belgium, Germany, Finland, France, Greece, Ireland, Italy, Netherlands, Portugal and Spain.

[12] As highlighted in the previous section on business cycle analysis, demand shocks do not have a long-run effect on output by construction in the Blanchard and Quah framework.

assumptions about the determinants of resilience in the absence of an objective means of identifying which sectors have proven to be resilient to economic shocks in the past might risk conflating cause and effect (Sensier et al., 2016). As highlighted by Sensier et al. (2016), ‘in order to understand what might make a region resilient to economic shocks we need to be able to measure its resilience in a way that does not lead to later problems of autocorrelation’ (Sensier et al., 2016).

3 Assessment of economic resilience in the UK agri-food and drink industry

Chapter 3 Summary: Analysis of economic resilience in the UK agri-food and drink industry

This chapter includes our main results. It provides:

- An explanation of the methods we used to produce the results;
- A description of the results, showing two complimentary measures of resilience for each sub-sector of the agri-food and drinks industry, as well as an overall measure of resilience;
- A discussion of how sensitive our results are to different assumptions and approaches and what the main limitations of our analysis are;
- Suggestions for further research that could be undertaken to develop the understanding of economic resilience in the sector.

3.1 Econometric model

In order to produce an index of economic resilience for the agri-food and drinks sector in the UK, we identify the impact of an undefined set of common 'shocks' on the output of each sub-sector within the industry. Our approach involves using **business cycle analysis** to model how we would expect output for each food and drink sector to change over time in the absence of shocks. We then compare this with what actually happened in order to isolate output movements that are due to shocks ('cyclical component') from output movements due to longer-term trends ('trend component'). The difference between the expected output and the actual output is known as the 'output gap'.

We then loosely follow Duval and Vogel (2008) and Duval et al. (2007) and regress sector-level output gaps on the lagged output gap[13] as well as an error term, which captures both common and idiosyncratic shocks:

$GAP_{it} = \phi_i(GAP_{i,t-1}) + u_{i,t}$ ....(1),

where $u_{it} = \gamma_i \lambda_t + \varepsilon_{it}$ ....(2).

GAP_{it} represents the sector-level output gap of sector i at time t. We do not include any **sector-specific fixed effects** in equation (1) because the output gap has a zero mean over the modelling period by construction[14].

[13] The AR(1) structure proposed in equation (2) follows from the visual inspection of the Partial Autocorrelation Functions (PACF). We moreover estimated autoregressive models of order one to six, with both the Akaike information criterion (AIC) and Bayesian information criterion (BIC) confirming that sectoral output gaps are best characterised by an AR(1) process (see A3.1.2 for further details).

[14] This zero mean is achieved by applying the Hodrick-Prescott filter on a fully balanced output panel, and by running all estimations on the same modelling period that was used to determine potential and cyclical output. All estimations were repeated including a sector-level fixed effect, with outcomes in terms of sector resilience rankings being exactly the same for the two models.

The error term $u_{i,t}$ contains information on both common and sector-specific shocks. **λ_t is a variable capturing common shocks** to all agri-food and drink sectors, with the impact of common shocks being allowed to vary across sectors through the **heterogeneous slope coefficient ('factor loading') γ_i** . ε_{it} captures idiosyncratic shocks and is assumed to be white noise.

In this study on the economic resilience of the UK agri-food and drink industry, we thus **approximate sectors' ability to absorb common shocks by modelling an unobserved set of common shocks through heterogeneous slope coefficients γ_i and common factors λ_t** within the error term $u_{i,t}$ **.** This empirical strategy is preferred to an explicit, structural identification of common shocks given i) the difficulties in identifying' common' shocks in view of different transmission timings of shocks (see Annex 1.2), ii) the apparent lack of clearly discernible common output shocks over the modelling period (see Annex 4), and iii) the wide variety of shocks that the industry is exposed to (see Annex 1.1).

Thus, the small system of equations outlined above allows us to capture both attributes of ex-post resilience. **ϕ_i captures sector-specific output gap persistence** and thus the inverse of a sector's ability to recover from a shock (shock counteraction). The heterogeneous slope coefficient **γ_i captures sector-specific amplification of common shocks** and hence the inverse of a sector's ability to absorb or neuter a shock (shock absorption).

3.2 Estimation method

Equation (1) above cannot be estimated using conventional micro-panel approaches[15] because

i) those estimators rely on micro-panels with **large N and small T** to achieve desirable properties such as consistency;
ii) the presence of **common shocks and spillover impacts (captured through λ_t) induces cross-sectional dependence** in the error term $u_{i,t}$ [16]; and
iii) obtaining sector-specific slope coefficients ϕ_i and γ_i using traditional panel techniques would rely on the introduction of T*N interaction terms, which would reduce the residual degrees of freedom to zero.

For these reasons, we employ **linear[17] panel time series methods** designed for moderate to large T and N, which allow for both cross-sectional dependence and **heterogeneous slope coefficients** across panel units.

Our estimator of choice is Chudik and Pesaran's (2015) **dynamic common correlated effects (CCE) estimator,** which is further described in Annex 5.1. In essence, CCE estimation accounts for the common shock variable λ_t by approximating the projection space of the unobserved common factors with the inclusion of cross-section averages of the contemporaneous and lagged

[15] By conventional panel estimators we mean pooled OLS, fixed effects, random effects and system GMM.

[16] The presence of cross-sectional dependence is confirmed formally by Pesaran's (2004) test for cross-section dependence (CD). We implement Pesaran's (2004) CD test using Stata's *xtcd* command, which can be applied to a variable series pre-estimation analysis. Results confirm that we can reject the null hypothesis of cross-section independence/weak cross-section dependence (CD test-statistic: 5.80; p-value: 0.000).

[17] As highlighted in A3.2.2, the Autocorrelation Functions and Partial Autocorrelation Functions for the output gaps of all sectors under consideration indicate that the output gap series can be modelled as pure autoregressive models which include only autoregressive (AR) and no moving average (MA) terms. This simplifies the estimation approach considerably, pure autoregressive models (in contrast to models that include MA terms) are just special cases of linear regression models, which can be estimated using OLS.

dependent variables[18] in the regression equation. Heterogeneous slope coefficients are then obtained by running panel-specific Ordinary Least Squares (OLS) regressions for each sector on the augmented equation. Alternative panel time series estimators are used as a robustness test (see Annex 5.3.1).

3.3 Main results

The figure below summarises the results from estimating the main regression equation described in equation (1).

The **ability of a sector to react swiftly after a shock** is depicted on the x-axis (shock counteraction, inverse of persistence effects ϕ_i) , while the **ability of a sector to absorb or neuter a shock** is reported on the y-axis (shock absorption, inverse of amplification effects $\gamma_i \lambda_t$). For both resilience attributes, the sectors' resilience has been set to range between zero and one hundred**, with higher index levels implying higher levels of resilience.**

Sectors in the **top-right quadrant are the most resilient** because they have relatively high scores for both shock absorption and shock counteraction, meaning that those sectors both manage to dampen the initial impact of a common negative shock and to recover more quickly to pre-shock levels in the aftermath of the shock. These include animal production (01.4), growing of crops (01.11), the food wholesale sector (46.3), processing and preserving of meat and production of meat products (10.1) and manufacture of other food products (10.8).

Sectors in the **bottom-left quadrant are the least resilient** because they have relatively low scores for both shock absorption and shock counteraction. The oils and fats sector (10.4), in particular, performs poorly mainly because it has a very low level of shock absorption resilience, meaning that the negative impact of a common shock gets amplified considerably more for this sector compared to the rest of the agri-food and drink industry.

Sectors in the **top-left quadrant** perform well on shock absorption resilience and poorly on shock counteraction resilience, whereas sectors in the **bottom-right quadrant** perform poorly on shock absorption resilience and well on shock counteraction resilience.

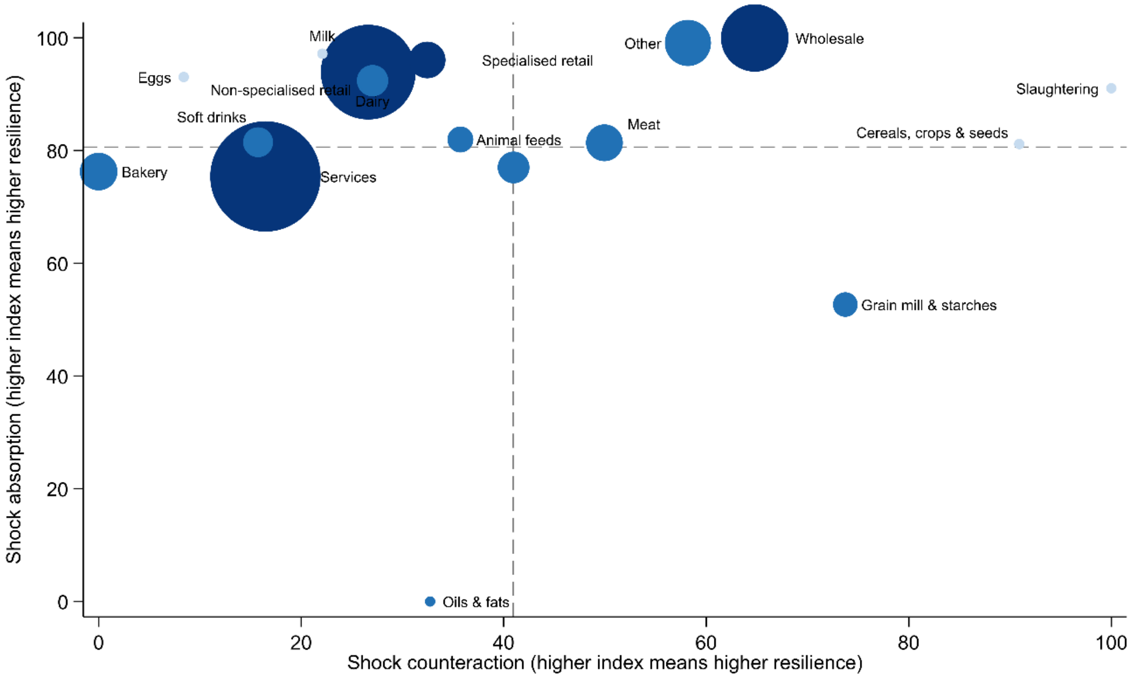
This analysis, whilst it enables the production of an index of resilience – see below – does not enable the provision of an explanation in response to some important policy questions such as:

- why resilience varies across sub-sectors of the industry;
- the types of shock to which the industry is most vulnerable; and
- whether and how resilience could be improved.

Further research is needed to understand the answers to these questions.

[18] If equation (1) is expanded to include additional regressors x_{it} in addition to the lagged dependent variable and the error term, then cross-sectional averages of the independent variables are added as well. See also Section 5.4.3.

Figure 2 Main results (higher index means higher resilience)



Note: The x-axis depicts economic resilience in terms of shock counteraction, i.e. the ability of a sector to recover quickly from a shock after having been adversely affected by a shock. The y-axis depicts economic resilience in terms of shock absorption, i.e. ability of a sector to absorb or neuter the adverse effect of a shock so that the end effect is small. The size of the circles representing each sector are scaled by GVA for each sector in 2017 – larger circles represent sectors which higher GVA. Since no GVA data was available for the primary sectors (Cereals, crops & seeds; Eggs; Milk; and Slaughtering), the smallest weight was used for those sectors (equal to the GVA of manufacture of oils and fats). GVA data was obtained from the ABS (weights are based on 2017 data).

Estimations are based on data for 2000q1-2017q4. We use Chudik and Pesaran's (2015) Dynamic Common Correlated Effects estimator, implemented by Jan Dicken's *xtdcce2* command in Stata. Please refer to Annex 2 for the official SIC codes and full names of the agri-food and drink sectors depicted in the graph above.

Source: London Economics' analysis based on data obtained from Eurostat, ONS and Defra.

The table below provides the resilience index in terms of both shock counteraction and shock absorption and adds an (unweighted) average of both indices to arrive at an overall index of resilience. **Rankings of the sectors are provided in brackets.** Again, **higher index levels are to be read as higher levels of resilience.** Coefficient estimates and significance levels are reported in Annex 5.3.2.

Table 3 Main results (higher index means higher resilience)

100 = most resilient 0 = least resilient *(n)* = rank	Ability to recover from shock(1)	Ability to absorb shock(2)	Average resilience index
01.4 - Animal production (slaughtering)	100 *(1)*	92 *(8)*	96 *(1)*
01.11 - Growing of cereals (except rice), leguminous crops and oil seeds	91 *(2)*	81 *(12)*	86 *(2)*
46.3 - Wholesale of food, beverages and tobacco	65 *(4)*	100 *(1)*	82 *(3)*
10.8 - Manufacture of other food products[19]	58 *(5)*	100 *(2)*	79 *(4)*
10. 1 - Processing and preserving of meat and production of meat products	50 *(6)*	82 *(11)*	66 *(5)*
47.2 - Retail sale of food, beverages and tobacco in specialised stores	32 *(10)*	97 *(4)*	64 *(6)*
10.6 - Manufacture of grain mill products, starches and starch products	74 *(3)*	53 *(16)*	63 *(7)*
47.11 - Retail sale in non-specialised stores with food; beverages or tobacco predominating	27 *(12)*	94 *(5)*	61 *(8)*
10.5 - Manufacture of dairy products	27 *(11)*	93 *(7)*	60 *(9)*
01.41 - Raising of dairy cattle (milk production)	22 *(13)*	98 *(3)*	60 *(10)*
10.9 - Manufacture of prepared animal feeds	36 *(8)*	82 *(9)*	59 *(11)*
10. 2 and 10.3 - Processing and preserving of fish, crustaceans, molluscs, fruit and vegetables	41 *(7)*	77 *(13)*	59 *(12)*
01.47 - Raising of poultry (egg production)	8 *(16)*	94 *(6)*	51 *(13)*
11.07 - Manufacture of soft drinks; production of mineral waters and other bottled waters	16 *(15)*	82 *(10)*	49 *(14)*
56 -Food and beverage service activities	16 *(14)*	76 *(15)*	46 *(15)*
10.7 - Manufacture of bakery and farinaceous products	0 *(17)*	77 *(14)*	38 *(16)*
10.4 - Manufacture of vegetable and animal oils and fats	33 *(9)*	0 *(17)*	16 *(17)*
R-squared	0.44	0.44	0.44
Observations	1,139	1,139	1,139

Note: (1) Shock counteraction refers to the ability of a sector to recover quickly from a shock after having been adversely affected by a shock. (2) Shock absorption refers to the ability of a sector to withstand a shock, i.e., the ability of to absorb or neuter the adverse effect of a shock so that the end effect is small. Estimations are based on data for 2000q1-2017q4. We use Chudik and Pesaran's (2015) Dynamic Common Correlated Effects estimator, implemented by Jan Dicken's *xtdcce2* command in Stata.

Source: London Economics analysis

[19] Manufacture of other food products includes manufacture of sugar (10.81), manufacture of cocoa; chocolate and sugar confectionery (10.82), processing of tea and coffee (10.83), manufacture of condiments and seasonings (10.84), manufacture of prepared meals and dishes (10.85), manufacture of homogenised food preparations and dietetic food (10.86), and manufacture of other food products not elsewhere classified (10.89).

4 Sensitivity analysis

Chapter 4 Summary: Sensitivity analysis

This Chapter provides our tests of the **sensitivity** of our results to changes in methods and assumptions.

We find that the economic resilience index is very sensitive to the output measure used. It is not very sensitive to the statistical methods that we use.

In order to **test whether the economic resilience index derived in the previous section is sensitive to certain methodological assumptions and data inputs,** we conduct a series of robustness tests, investigating changes in the resilience index for either the shock counteraction or shock absorption capacity of a sector.

In the remainder of this section, we report the main insights from running robustness tests for an alternative output measure (GVA), sub-samples and different types of shocks. The results from additional sensitivity tests used to investigate the impact of alternative estimators and time series de-trending methods are deferred to Annex 3. Those additional checks confirm that our estimates of economic resilience are **consistent across various estimators and de-trending techniques.** Annex 5.3.1 also provides further details such as full economic resilience indices, rankings and regression outputs for the various sensitivity tests covered in this Section.

4.1.1 Alternative output measures

In order to test whether our results are sensitive to the indicator of economic activity chosen, we replicate our analysis using a GVA rather than turnover-based measure of the output gap.

As highlighted in Annex 2.1 and 2.3, businesses are not surveyed on a quarterly basis and information on intermediate inputs and stocks are only collected at an annual level. The ONS uses this annual information to re-base the monthly production data used for our regressions in order to obtain estimates of quarterly, nominal GVA. We then use the food sector CPI to deflate the ONS' nominal series.

The ONS' GVA series only covers the primary sector, wholesale and retail sectors at an aggregate level. As no other quarterly information on GVA is available for those sectors from other data sources either, the sensitivity analysis was run on a more limited sector sample. In order to account for the fact that changes in the cross-section sample might lead to changes in the common factors, we replicate the main estimations for the reduced sample. This allows us to single out the impact of changes in the output measure from the impact of changes in the sample.

The figures below show the results from re-estimating our model for the GVA-based output measure. They show that our economic resilience index is very sensitive to the output measure chosen.

This can potentially be interpreted as evidence of the importance of stocks in mitigating economic shocks. For example, manufacture of vegetable and animal oils and fats (10.5) has a very high ranking in terms of shock absorption for the GVA measure, but a very low ranking in terms of shock absorption for the turnover measure. This might imply that while the sector is reacting strongly to common shocks in terms of achieved sales in the market (turnover-based measure), the sector might in fact be rather resilient in that it does not have to alter production processes in response to shocks, with decreased demand being compensated with an increase in stocks. Inversely, manufacture of less storable goods such as bakery and farinaceous products (10.7) exhibits a much lower shock absorption index if the GVA-based output gap is used.

However, results are not consistent across sectors, and given that both the use of annual supply and use tables and the use of aggregate deflators might distort the short-term business dynamics underlying the main (turnover-based) regression, caution is in order when interpreting these results.

Figure 3 Use of turnover-based output measure (higher index means higher resilience)

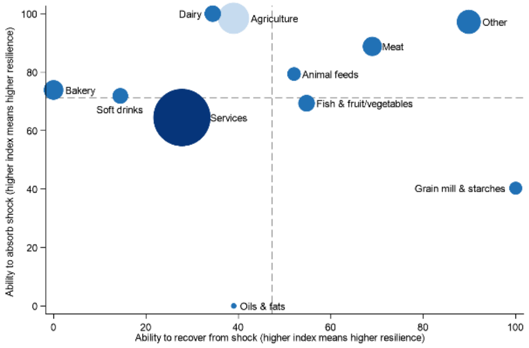
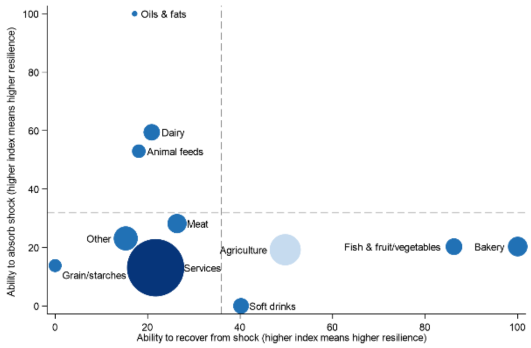


Figure 4 Use of GVA-based output measure (higher index means higher resilience)



Note: The x-axis depicts economic resilience in terms of shock counteraction, i.e. the ability of a sector to recover quickly from a shock after having been adversely affected by a shock. The y-axis depicts economic resilience in terms of shock absorption, i.e. ability of a sector to absorb or neuter the adverse effect of a shock so that the end effect is small. The size of the circles representing each sector are scaled by GVA for each sector in 2017 – larger circles represent sectors which higher GVA. Since no GVA data was available for the primary sectors (Cereals, crops & seeds; Eggs; Milk; and Slaughtering), the smallest weight was used for those sectors (equal to the GVA of manufacture of oils and fats). GVA data was obtained from the ABS (weights are based on 2017 data).

Estimations are based on data for 2000q1-2017q4. We use Chudik and Pesaran's (2015) Dynamic Common Correlated Effects estimator, implemented by Jan Dicken's xtdcce2 command in Stata.

Please refer to Annex 2 for the official SIC codes and full names of the agri-food and drink sectors depicted in the graph above. Note that the agriculture sector is approximated in the figure on the left through the mean output gap observed for the primary sectors used in the main regression (Cereals, crops & seeds; Eggs; Milk; and Slaughtering). In the figure on the right, agriculture refers to the full SIC sector 1: Crop and animal production.

London Economics' analysis

4.1.2 Alternative subsamples

Alternative time period

Our main regression covers the period from 2000q1 to 2017q4. The time period was selected so as to obtain a fully balanced panel of sectors and also to determine sectors' *current* resilience while maintaining a large enough time series to run the estimations.

Here, we re-run our estimations for a longer panel covering 1990q1-2018q4. As is the case for the estimations relying on the ONS' GVA series (see Section 4.1.1), this is only possible for a sub-sample of the sector, with no granular information being available for the primary and trade sectors. We therefore again report the original estimations (for 2000q1 to 2017q4) as estimated for the reduced sample as a comparator.

In terms of shock counteraction, the services sector (56), manufacture of other food products (10.8) and manufacture of prepared animal feeds (10.9) seem to have become more resilient over time, while manufacture of bakery and farinaceous products (10.7) and manufacture of soft drinks (including production of mineral waters and other bottled waters) (11.07) achieved the biggest improvements in terms of shock absorption. It is important to note, however, that any changes in especially the shock absorption index might also be due to changes in the exposure to (common) shocks rather than the sectors' ability to respond to those shocks.

Figure 5 Results for time period 2000q1 to 2017q4 (higher index means higher resilience)

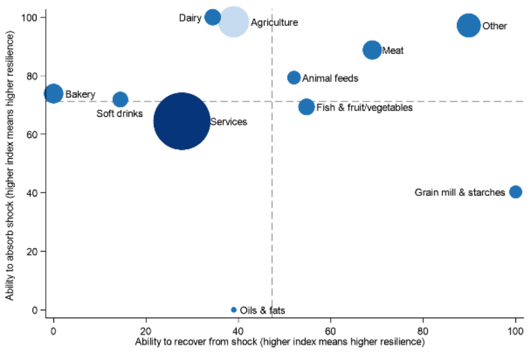
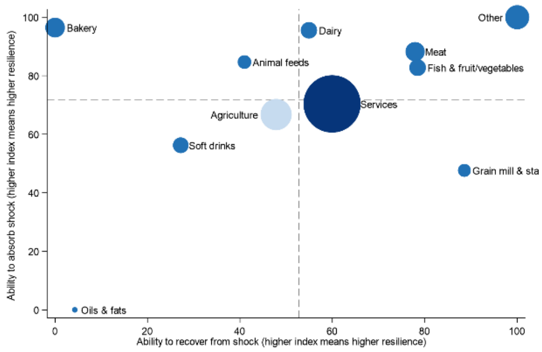


Figure 6 Extending time period to 1990-2018 (higher index means higher resilience)



Note: The x-axis depicts economic resilience in terms of shock counteraction, i.e. the ability of a sector to recover quickly from a shock after having been adversely affected by a shock. The y-axis depicts economic resilience in terms of shock absorption, i.e. ability of a sector to absorb or neuter the adverse effect of a shock so that the end effect is small. The size of the circles representing each sector are scaled by GVA for each sector in 2017 – larger circles represent sectors which higher GVA. Since no GVA data was available for the primary sectors (Cereals, crops & seeds; Eggs; Milk; and Slaughtering), the smallest weight was used for those sectors (equal to the GVA of manufacture of oils and fats). GVA data was obtained from the ABS (weights are based on 2017 data).

Estimations are based on data for 2000q1-2017q4. We use Chudik and Pesaran's (2015) Dynamic Common Correlated Effects estimator, implemented by Jan Dicken's xtdcce2 command in Stata.

Please refer to Annex 2 for the official SIC codes and full names of the agri-food and drink sectors depicted in the graph above. Note that the agriculture sector is approximated in the figure on the left through the mean output gap observed for the primary sectors used in the main regression (Cereals, crops & seeds; Eggs; Milk; and Slaughtering). In the figure on the right, agriculture refers to the full SIC sector 1: Crop and animal production.

London Economics' analysis

Alternative cross-section samples

Our main results do not shed any light on intra-industry transmission of shocks between various sub-sectors, with λ_t capturing both external common shocks and spillover effects between sectors.

Estimating the regression equation for separate subsamples allows to shed further light on inter-sectoral transmission of shocks. As λ_t only captures shocks that are experienced by all sectors in the sample, changes in the economic resilience ranking of sectors across sub-samples can be attributed to the fact that common shocks that were captured in the full sample are no longer captured in the sub-sample.

The table below show the economic resilience ranking for different cross-section samples. The high correlation with the original results for both cases where the primary and services sectors are excluded suggests that shocks originating in those sectors do not affect individual other sectors in the sample disproportionally.

Table 4 Sensitivity of resilience index to alternative cross-section samples

	Ability to recover from shock(1)	Ability to absorb shock(2)
Excluding primary sectors	98%	95%
Excluding manufacturing sectors	100%	23%
Excluding services sectors	100%	96%

Note: (1) Based on estimates of ϕ_i. Shock counteraction refers to the ability of a sector to recover quickly from a shock after having been adversely affected by a shock. (2) Based on Based on estimates of $\gamma_i\lambda_t$. Shock absorption refers to the ability of a sector to withstand a shock, i.e., the ability of to absorb or neuter the adverse effect of a shock so that the end effect is small. (2) Estimations are based on a balanced panel for 2000q1-2017q4. We use Chudik and Pesaran's (2015) Dynamic Common Correlated Effects estimator and implement using Jan Dicken's *xtdcce2* command in Stata.

Source: London Economics

The table below provides more detailed information on the discrepancy in the estimated ability of sectors to absorb a shock between the main analysis and the case where manufacturing sectors are excluded from the sample (to explain the low correlation between the two cases of 23%). The table shows that the **retail sector (47.2) and food and beverage services sectors (56) as well as the animal production (01.4) sector achieve a better relative ranking in terms of shock absorption once manufacturing sectors are excluded,** suggesting that those sectors are more sensitive to shocks originating in the manufacturing industries compared to other sectors. The wholesale sector (46.3) also achieves a worse relative ranking if manufacturing sectors are excluded, **suggesting that transmission channels between the manufacturing and wholesale sectors might not be strong.**

It is important to note, however, that removing nine out of 17 sectors from the sample also leads to a rather small N compared to T, with our estimator relying on moderate to large N and T for consistency. The change in shock absorption index might also indicate that the 'common factors' are largely dominated by the manufacturing sectors, which are the most represented in our sample. This further highlights the merit of investigating alternative shock variables (see Section 4.1.3).

Table 5 Main results (higher index means higher resilience)

100 = most resilient 0 = least resilient *(n)* = rank	**Ability to absorb shock(1) (all sectors)**	**Ability to absorb shock(1) (excluding manufacturing sectors)**
01.11 - Growing of cereals (except rice), leguminous crops and oil seeds	81 *(7)*	0 *(8)*
01.4 - Animal production (slaughtering)	92 *(6)*	63 *(3)*
01.41 - Raising of dairy cattle (milk production)	98 *(2)*	51 *(4)*
01.47 - Raising of poultry (egg production)	94 *(5)*	16 *(6)*
46.3 - Wholesale of food, beverages and tobacco	100 (1)	10 (7)
47.11 - Retail sale in non-specialised stores with food; beverages or tobacco predominating	94 (4)	68 (2)
47.2 - Retail sale of food, beverages and tobacco in specialised stores	97 (3)	100 (1)
56 -Food and beverage service activities	76 (8)	48 (5)
R-squared	0.44	0.44
Observations	1,139	1,139

Note: (1) Based on Based on estimates of $\gamma_i\lambda_t$. Shock absorption refers to the ability of a sector to withstand a shock, i.e., the ability of to absorb or neuter the adverse effect of a shock so that the end effect is small. Estimations are based on a balanced panel for 2000q1-2017q4. We use Chudik and Pesaran's (2015) Dynamic Common Correlated Effects estimator and implement using Jan Dicken's *xtdcce2* command in Stata. Note that the ranking for the original resilience index was changed so as to not rank the manufacturing sectors that were removed for the sensitivity analysis, however, the re-basing required to arrive at the index was undertaken for the full sample.

Source: London Economics analysis

4.1.3 Alternative types of shocks

Our main specification does not allow us to explicitly distinguish between **different types of shocks,** such as supply and demand shocks. As shown by Pelkmans et al. (2008), however, the ranking of different sectors' economic resilience differs depending on the nature of the aggregate shock that is examined.

We therefore augment our original system of equations by a **set of (potentially endogenous) regressors that are thought to capture different types of shocks.** In particular, we consider the following framework:

$$GAP_{it} = \phi_i(GAP_{i,t-1}) + \beta_i x_t + u_{i,t} \quad (3),$$

$$u_{it} = \gamma_i \lambda_t + \varepsilon_{it} \quad (4),$$

$$x_t = \alpha_i + \gamma_i \lambda_t + \epsilon_t \quad (5).$$

This framework is commonly used in the literature to consistently estimate the impact of either exogenous or endogenous *panel-unit level* variables x_{it} on the dependent variable in the presence of cross-section correlation due to the presence of common shocks or spillover effects captured by λ_t. We adapt the framework so as to include *cross-section level shock variables* x_t. Importantly, the explicit shock variables are allowed to depend on the unobserved common factors as well, taking note that none of the alternative shock variables used in the following sensitivity tests is likely to fully capture all shocks captured by the common factors λ_t.

The figures below provide an indication of the importance of **demand and supply shocks, proxied by consumer expenditure on non-durables and services and the primary sector's output gap** (in terms of deflated GVA as per the sensitivity in the previous Section), respectively.

Different manufacturing industries seem to be affected by different types of shocks. **Processing and preserving of fish, crustaceans, molluscs, fruit and vegetables (10.2-3), manufacture of bakery and farinaceous products (10.7), and manufacture of soft drinks (including production of mineral waters and other bottled waters) (11.07) seem to be more affected by demand shocks,** while manufacture of grain mill products, starches and starch products (10.6) and manufacture of vegetable and animal oils and fats (10.4) are noticeably less affected by demand shocks. The **food and beverage service activities (56) are clearly more sensitive to demand shocks,** as expected.

Not surprisingly, **primary sectors exhibit lower shock absorption indices for supply shocks** compared to the undefined set of shocks used in the main regressions. Among the food manufacturing industries, results are also intuitive, with **sectors more directly relying on primary sector inputs such as manufacture of grain mill products, starches and starch products (10.6), animal feed production (10.9) or processing and preserving of fish, crustaceans, molluscs, fruit and vegetables (10.2-3) registering the biggest decrease in terms of shock absorption compared to the original regressions.**

Figure 7 Demand shocks (higher index means higher resilience)

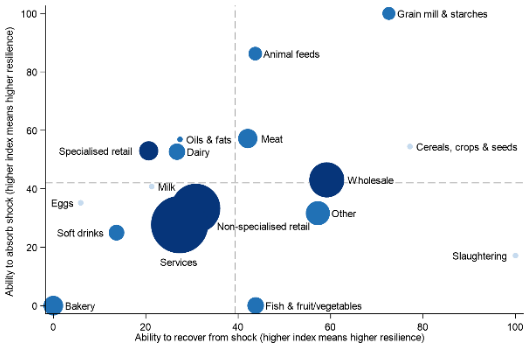
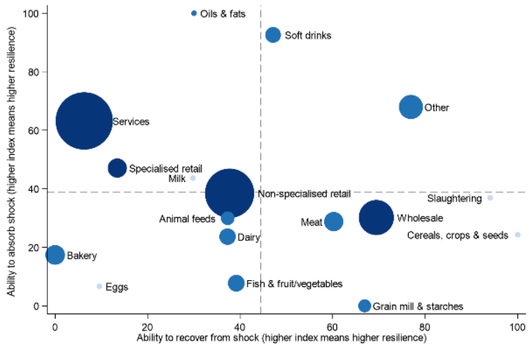


Figure 8 Supply shocks (higher index means higher resilience)



Note: Shock counteraction refers to the ability of a sector to recover quickly from a shock after having been adversely affected by a shock. Shock absorption refers to the ability of a sector to withstand a shock, i.e., the ability of to absorb or neuter the adverse effect of a shock so that the end effect is small. The size of the circles representing each sector are scaled by GVA for each sector in 2017 – larger circles represent sectors which higher GVA. Since no GVA (or turnover) data was available for the primary sector (Cereals, crops & seeds, Eggs, Milk, and Slaughtering) at such a disaggregate level, the smallest weight was used for those sectors (equal to the GVA of manufacture of oils and fats). GVA data was obtained from the ABS (weights are based on 2017 data).

Estimations are based on data for 2000q1-2017q4. We use Chudik and Pesaran's (2015) Dynamic Common Correlated Effects estimator, implemented by Jan Dicken's *xtdcce2* command in Stata.

Please refer to Annex 2 for the official SIC codes and full names of the agri-food and drink sectors depicted in the graph above.

London Economics' analysis

5 Limitations and recommendations for further research

Chapter 5 Summary: Limitations and recommendations for further research

This chapter describes the data and conceptual limitations of the research and also recommends further research, to corroborate our findings and to gain a fuller understanding of resilience in this industry, including why it varies across sub-sectors and where the shocks originate and how they are transmitted among the various sub-sectors.

5.1.1 Data limitations

Use of turnover- and volume-based output measures

The use of turnover-based production indices as a proxy for output is an important limitation of this paper as **GVA would be conceptually preferable.**

First, turnover measures production **sold on the market** during the reference period as opposed to goods or services produced during the reference period. As a result, turnover-based measures might lead to an under-estimation of the economic resilience of a sector if that sector can mitigate the impact of shocks through accumulation (demand shocks) or decrease (supply shocks) of stocks.

Moreover, GVA reflects an industry's **own-value added** by deducting the inputs that are not produced by the industry itself but obtained or purchased from other units from the industry's gross output, and thus appropriately reflects any changes in production processes and vertical integration that might occur over the modelling period.

Use of time series filters

The use of time series filters to distinguish between cyclical and trend components is heavily discussed in the literature.

While we took account of the fact that different de-trending methods may yield different growth cycle chronologies (Canova et al., 2012) through sensitivity analysis, it is important to remain aware of the more general limitations of de-trending sector-level output data.

Moreover, Grech (2013) shows that the HP filter is less reliable when estimating potential output for small economies or more granular sector breakdowns that exhibit larger fluctuations, more pronounced trends, and recurrent structural breaks – causing excess volatility in estimated potential output. Finally, the HP filter gives an undue weight to the last and first data points of the series, resulting in the movements of the end-points of data being disproportionately attributed to movements in trend as opposed to the cyclical component (St-Amant and van Norden, 1997).

A more detailed discussion of the technical limitations of the HP filter used to derive the sector-level output gap series in the present study is provided in Annex 3.2.2.

5.1.2 Conceptual limitations

This study employs an empirical approach to quantify and rank UK agri-food and drink sectors' resilience to shocks so as to avoid relying on a priori assumptions about the determinants of resilience. However, using regression analysis to determine economic resilience necessarily implies that **variation in the economic resilience indices over time is limited,** to the extent that a relatively long time-series is required to apply the estimators used in this study.

While the estimation of the **shock counteraction index by means of a first-order autocorrelation** coefficient ϕ_i is conceptually straightforward and proves robust across various specifications, it is important to note that our shock counteraction index is **not able to distinguish between common and idiosyncratic shocks,** meaning that a sector might be exhibiting lower resilience levels in terms of shock counteraction either because it recovers slowly from common and/or because it recovers slowly from idiosyncratic shocks. Moreover, our **shock counteraction index does not distinguish between positive and negative shocks,** and a sector that maintains output above potential for a longer time after a positive shock would hence be considered to be less resilient by our estimations.

Conversely, our **shock absorption index does take account of the direction of a shock and only focuses on shocks that are common to all sectors.** However, measuring a sectors' ability to absorb common shocks proves to **present more methodological challenges.**

In this study, we **approximated sectors' ability to absorb common shocks by modelling an unobserved set of common shocks through heterogeneous slope coefficients γ_i and common factors λ_t.** This empirical strategy is preferred to an explicit, structural identification of common shocks given i) the difficulties in identifying' common' shocks in view of different transmission timings of shocks (see Annex 1.2), ii) the apparent lack of clearly discernible common output shocks over the modelling period (see Annex 6), and iii) the wide variety of shocks that the industry is exposed to (see Annex 1.1).

The use of DCCE estimation, and in particular the interpretation of the (heterogeneously) loaded common factors λ_t as being indicative of a sector's amplification of common shocks, however, is a **novel approach** and not without its limitations.

First, DCCE relies on **moderate to large T and N panels.** While T can be considered sufficiently large in our sample (2000q1-2017q4, equivalent to 72 time periods), our cross-section sample of 17 sectors is rather low especially when compared to T. Future research is required to test the robustness of this approach, for example by re-estimating our model for shorter time-series panels with more comparable T and N dimensions. Moreover, alternative econometric approaches, such as Principal Component Analysis (PCA) or stochastic frontiers, should be used to test whether the common factor approach is robust.

Our main econometric approach does not explicitly address the fact that different sectors might be affected by the same shock in different time periods (due to **varying transmission timings** of shocks). However, implicitly, our approach allows for differences in the transmission timing due to the fact that cross-sectional averages are included for each time period, and by us looking at the combined factor load and common factor coefficients ($\gamma_i\lambda_t$) to determine our shock absorption index.

Finally, our meso-economic approach to examining the UK agri-food and drink industry's resilience means that we are not able to say anything about whether all companies within an industry experience the shocks equally. For example, we cannot make any inferences about the impact of shocks on small as compared to large firms, or say anything about whether vertically integrated firms are more or less sensitive to shocks compared to other firms. Similarly, the inter-sectoral transmission of shocks can only be observed on a very aggregate level, and it is not possible to take explicit account of any familial networks that may have an impact on how shocks are transmitted between companies.

5.2 Recommendations for future research

The analysis presented in this report enables the production of an index of resilience, but it does not enable the provision of an explanation in response to some important policy questions such as:

- why resilience varies across sub-sectors of the industry;
- the types of shock to which the industry is most vulnerable; and
- whether and how resilience could be improved.

Further research is needed to both understand the answers to these questions and to corroborate our findings. This could include both further quantitative research and research that makes greater use of sector expertise and knowledge.

This paper provides a preliminary analysis of the **intra-industry transmission of shocks** through re-estimation of different cross-sectional sub-samples and the explicit inclusion of a primary sector shock variables. A further understanding of where the shocks originate and how shocks are transmitted among the various sub-sectors could be achieved by estimating a **system of seemingly unrelated regression equations (SURE)**. Using this approach, sectoral output gaps would be regressed on sectoral output gaps of all other sectors and lags thereof, and errors would be allowed to be correlated across the various equations.

This study provides an index of economic resilience based on sectors' observed reaction to common shocks. While we provide an overview of the literature on the **drivers of the UK agri-food and drink industry,** we do not further examine the determinants of resilience empirically. In addition to the use of more qualitative approaches that access sector expertise, this research gap could be addressed by future empirical research either through an **extension of the existing mean group framework** or by means of a new econometric specification where the (average) economic resilience index derived here enters as the dependent variable.

For the former approach, determinants of output gaps could be estimated by including sector-specific regressors x_{it} (instead of x_t) in equation (3) above. An advantage of using the current framework is that it allows for the determinants of resilience, $x_{it,}$ to be allowed to be affected by the same shocks that have an impact on sectors' output gap.

The latter approach was employed by Duval and Vogel (2008), who use the coefficient estimates derived in a very similar framework to the one employed here as a proxy for the dependent resilience variable in subsequent analysis.

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Index of Tables and Figures

Tables

Figures

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