An resilience analysis of the contraction of the accommodation and food service on the Scottish food industry

Abstract

The Scottish economy, such as the United Kingdom (UK) economy, has been exposed to several adverse shocks over the past 5 years. Examples of these are the effect of the UK exiting the European Union (Brexit), the effects of the COVID-19 pandemic and more recently the Russia-Ukraine war, which can result in adverse direct and indirect economic losses across various sectors of the economy. The purpose of this paper is threefold: (1) to explore the degree of resilience of the Scottish food and drinks sector, (2) to estimate the effects on interconnected sectors of the economy; and (3) to estimate the economic losses which is the financial value associated with the reduction in output. For this analysis, the study relied on the Dynamic Inoperability Input-Output Model (DIIM). The results indicate that the accommodation and food service sector was the most affect by the covid-19 pandemic lockdown contracting by about 60 per cent having a cascading effect on the remaining 17 sectors of the economy. The Processed and preserved fish, fruits and vegetable sector is the least resilient whilst Preserved meat and meat products sector is the most resilient to final demand disruption in the accommodation and food service sector. The least economically affected sector was the other food products sector whilst the other services sector had the highest economic loss. Despite the fact that the soft drinks sector had a slow recovery rate, economic losses were lower compared to the agricultural, fishery and forestry sector. From the policy perspective, stakeholders in the accommodation and food service sector should re-examine the sector and develop capacity against future pandemics. In addition, it is important for economic sectors to collaborate either vertically or horizontally by sharing information and risk to reduce the burden of future disruptions. Finally, the most vulnerable sector of the economy i.e. other services sector should form a major part of government policy decision-making when planning against future pandemics.

Keywords: COVID-19; Scotland food and drink industry; dynamic interoperative input-output model; dynamic recovery.

I. Introduction

The food and drink industry are a major contributor to Scotland’s economy, with a turnover of approximately £14 billion and accounting for one in five manufacturing jobs. Scotland has approximately 18,850 food and drink businesses, which employ about 115,400 people. Whilst all the supply chains that comprise the F&D industry have been subject to shocks such as the UK’s departure from the EU (Brexit) and the global COVID-19 pandemic, particular supply chains have suffered individual chain shocks or are subject to stresses (i.e., long term trends).

The Scottish economy suffered greatly in 2020 due to the global COVID-19 pandemic. This was reflected on high absenteeism from work due to fear of infections, lockdown preventing people from assessing their place of work, or sickness due to infections. Estimates of the monthly gross domestic product (GDP) indicated that it fell by about 22 per cent using 2016 as the baseline. In addition, there was also a contraction of several final demand components. For instance, a recent estimate shows that exports between April – June 2020 were 31.1 per cent lower than that recorded in the same period in 2019 (Scottish Government, 2022a).

It is important to note that the impact of the pandemic has been disproportionate, with some sectors being heavily affected whilst others were mildly or not affected. For instance, the food retail sector performed well over the course of 2020 but the accommodation and food services showed the worse performance with the greatest drop in 2020 (Scottish Government, 2022b).

The economic impact of disruptions such as COVID-19 and Brexit on the economy manifested on two fronts: the labour market and the final demand (i.e., consumption of households, exports, and government expenditure). Labour shortage in a productive sector can render it inoperable and since different sectors are mutually dependent, they become indirectly affected because of their linkages. Similarly, the contraction of the final demand of a sector or several of them generates a contraction on the output not only directly affected but also on the related sectors.

The present paper is similar to the work by Haimar and Santos, (2014) in the sense that it uses the dynamic inoperability input-output model (DIIM) to analyse the impacts from a pandemic (influenza, in their case). However, in contrast with them, the purpose of this paper is to explore the effect that the contraction of the final demand of the 'accommodation and food service activities' sector had on the Scottish food and drink sector. The choice of sector was due to its close relation with the agricultural and food processing sectors.

As in Haimar and Santos, (2014), this paper uses two indicators to measure the extent of the disruption on the different productive sectors: inoperability and economic loss. In addition, this paper estimates the coefficient of resilience, which indicate how fast a sector recover from a shock.

The structure of the research paper is as follows. It starts with a brief literature review. Next, it summarises the empirical approach use in the research, namely the methodology and the data used for the estimation. It is followed by the presentation and discussion of the results. The final section presents the research conclusions.

II. Literature review

The purpose of this section is twofold: first to provide an overview of the Scottish economy during the COVID-19 pandemic period, and second, to briefly to review the literature about the aggregated measurement of resilience.

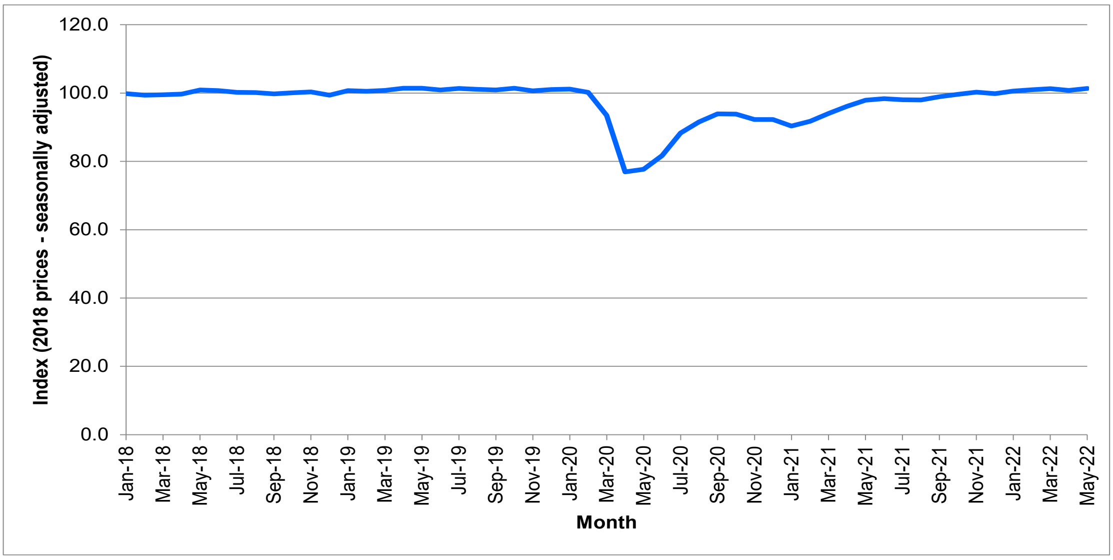
II.1 The Scottish economy during the COVID-19 pandemic period

The Scottish economy has been exposed to several adverse shocks over the past 5 years. Examples of these are the effect of the UK exiting the European Union (Brexit), the effects of the COVID-19 pandemic and more recently the Russia-Ukraine war.

The exit of the UK from the EU had implications for Scottish businesses. Free movement of people including citizens and workers is one of the four freedoms underpinning the EU Single Market (de la Connaissance sur l'Europe, 1957). Brexit impacted on the movement of seasonal workers, permanent workers, and ease of visiting. Labour flows from Eastern Europe were somewhat disrupted as some sectors now need to obtain authorisation from new regulatory bodies – institutional changes (Scottish Government, 2022b).

Despite the difficulties brought by Brexit, Figure 1 below, which presents the evolution of the monthly onshore Gross Domestic Product (GDP) for Scotland from 2018 to 2022, shows that COVID-19 was a massive shock for the economy. In April 2020 the monthly GDP decrease by about 21 per cent with respect to the average January to March 2020 levels.

Figure 1. Scotland – Monthly evolution of the gross domestic product



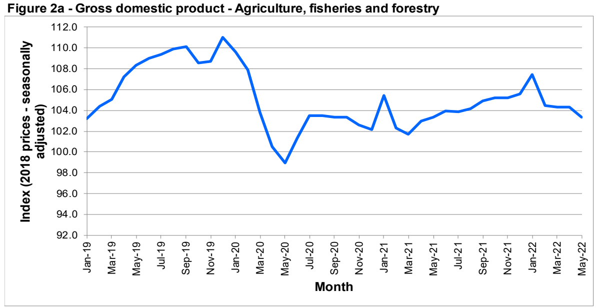
Source: Scottish Government.

The pattern showed in the aggregated GDP can also be seen in the panels presented in Figure 2, which shows the evolution of eighteen production sectors, all of them, in different measure tough, show the impact of the COVID-19 shock. From all the sectors, the most important impact of COVID-19 was on the Accommodation and food service sector. In April 2020, this sector contracted by about 78 per cent with respect to the average of January and February 2020.

It should be noted that the patterns showed in the Figure 2 panels, which are based on production, are not necessarily reflected on the sectoral employment. This is because of the furlough scheme ran by the UK Government.

Figure 2 – Evolution of the gross domestic product by production sector

Figure 2a - Gross domestic product - Agriculture, fisheries and forestry

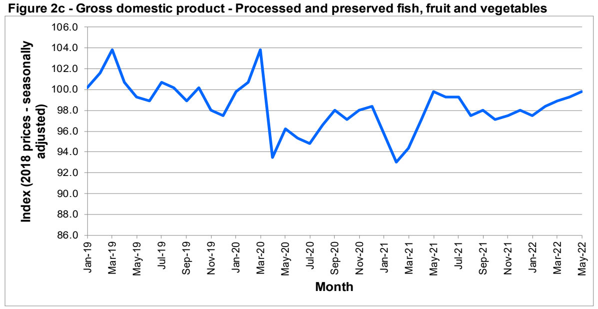


Source: Scottish Government

Figure 2b - Gross domestic product - Preserved meat and meat products

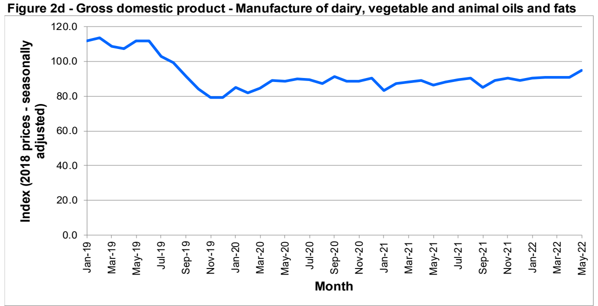
Source: Office for National Statistics

Figure 2c - Gross domestic product - Processed and preserved fish, fruit and vegetables



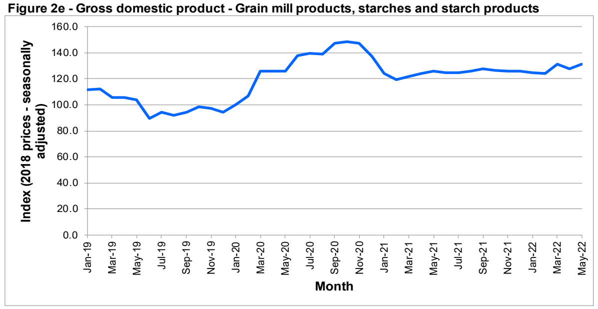
Source: Office for National Statistics

Figure 2d - Gross domestic product - Manufacture of dairy, vegetable and animal oils and fats



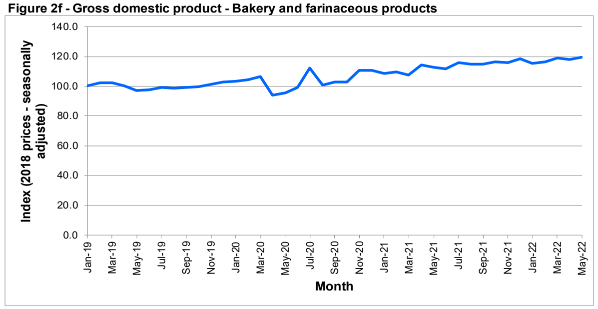
Source: Office for National Statistics

Figure 2e - Gross domestic product - Grain mill products, starches and starch products



Source: Office for National Statistics

Figure 2f - Gross domestic product - Bakery and farinaceous products

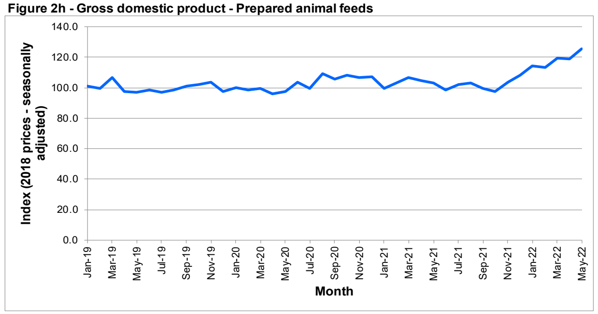


Source: Office for National Statistics

Figure 2g - Gross domestic product - Other food products

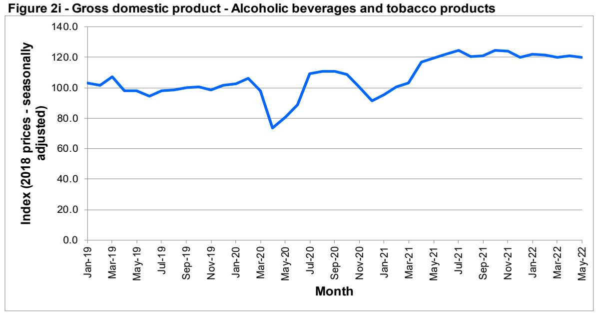
Source: Office for National Statistics

Figure 2h - Gross domestic product - Prepared animal feeds



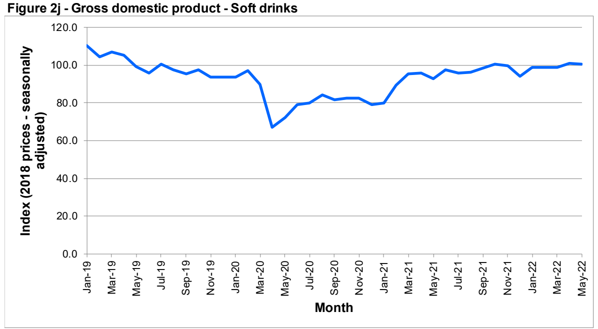
Source: Office for National Statistics

Figure 2i - Gross domestic product - Alcoholic beverages and tobacco products



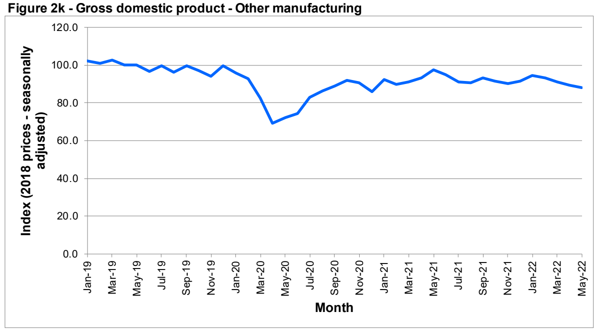
Source: Office for National Statistics

Figure 2j - Gross domestic product - Soft drinks



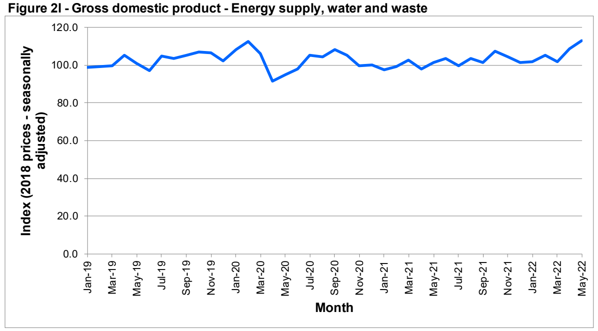
Source: Office for National Statistics

Figure 2k - Gross domestic product - Other manufacturing



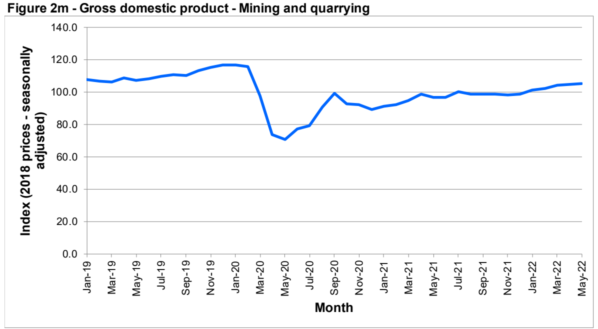
Source: Scottish Government

Figure 2l - Gross domestic product - Energy supply, water and waste



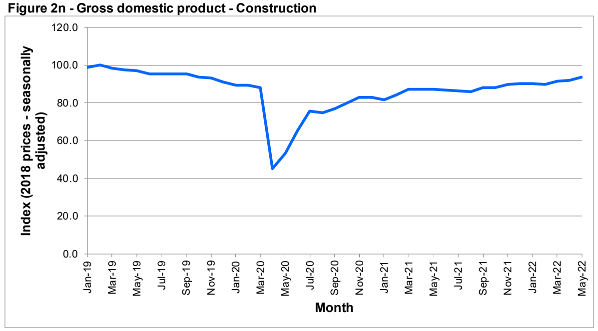
Source: Scottish Government

Figure 2m - Gross domestic product - Mining and quarrying



Source: Scottish Government

Figure 2n - Gross domestic product - Construction

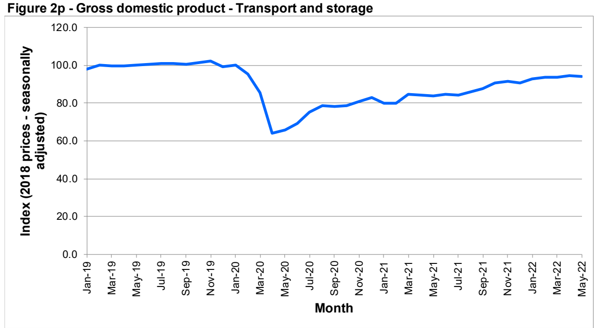


Source: Scottish Government

Figure 2o - Gross domestic product - Wholesale and retail trade and repairs

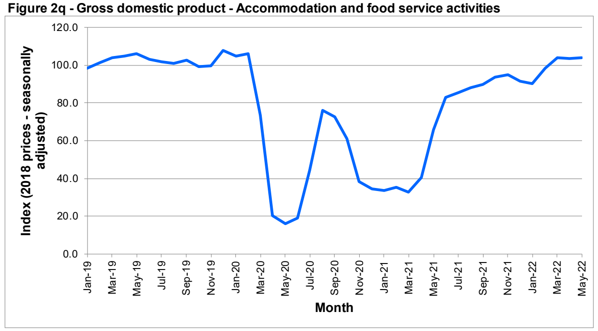
Source: Scottish Government

Figure 2p - Gross domestic product - Transport and storage



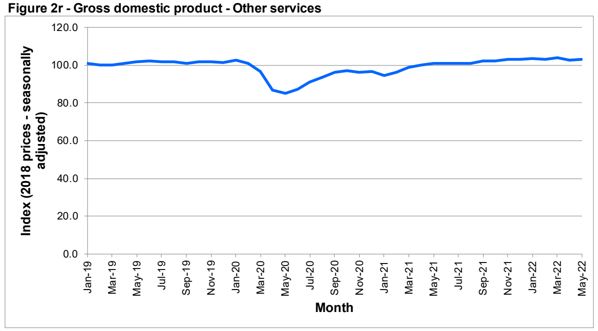
Source: Scottish Government

Figure 2q - Gross domestic product - Accommodation and food service activities



Source: Scottish Government

Figure 2r - Gross domestic product - Other services



Source: Scottish Government

Under the Coronavirus Job Retention scheme, commonly known as the 'furlough scheme' companies were allowed to place staff on leave during a determined period set by the Government, while ensuring that those affected still have a source of income. As part of the scheme employers had to notify staff members in writing before their period of furlough begins. Once on leave, the company had to pay affected employees no less than 80 per cent of their regular monthly income, up to a cap of £2,500. These funds could later be claimed back through the Job Retention Scheme. While furloughed, individuals remained formally employed by the company, meaning that they were entitled to their usual protection from unfair dismissal, and entitlement to any redundancy pay should the company cease trading. The Office for National Statistics (2020) provides an overview how COVID-19 affected the different ways to measure GDP.

II.2 Measuring sector resilience and interdependence

This section focuses on aggregated models that measure the resilience of sectors. Specifically, it refers to models that use the input-output tables to track the effects of a shock (on supply or demand). According to Zhang et al. (2022), the use of input-output models has many advantages including the ability to identify system vulnerabilities and provide a scientific insight for the development of industry management strategies.

As pointed out by Leontief (1987) the "Input-Output analysis is a practical extension of the classical theory of general interdependence which views the whole economy of a region, a country or even the entire world as a single system and sets out to describe and to interpret its operation in terms of directly observable basic structural relations". The model presents a framework capable of describing the extent of interconnectedness among different sectors of the economy (Haimes et al., 2005). This feature is key to understand the network type of relationships that are observed amongst supply chains.

Haimes and Jiang (2001) extended the Leontief model by focusing on the spread of operability into a networked system – input-output inoperability model (IIM). Whilst the Leontief model was used to explain the level of interdependencies among sectors in the economy, the inoperability model is able to assess how catastrophic disasters in one sector affect other sectors of the economy (Lian and Haimes, 2006). In addition, the model offers insights on the sensitivity of economic systems to various classes of disruptions providing guidance towards policymaking activities (Santos, 2006). Finally, results from the inoperability input-output model allows for the ranking of the disrupted and interconnected sectors according to their degree of vulnerability to perturbations whichcan serve as important input to risk management (Lian and Haimes, 2006).

Setola and Porcellinis, (2007) cited examples of how a disruption in one sector of the economy cascade to other sectors. First, in 1998 in the US, failure of the telecommunication satellite Galaxy IV caused more than 40 million pagers to be out of service. In addition, 20 United Airlines flights were without the required data about high-altitude weather conditions, resulting in take-off delays.

Second, in 2004 in Italy, a failure of Telecom Italia node in Rome disrupted the operations of both fixed and mobile TLC system, about 5000 bank branches and 3000 post offices, and air transport check-in operations were disrupted.

Setola and Porcellinis (2007) defined inoperability as the inability of a given system to perform its intended functions. Mathematically, it is estimated as the percentage loss of a system's function relative to its ideal output. It has a value between 0 and 1, where 0 corresponds to a flawless operation while 1 is complete failure (Santos, 2006; Santos and Haimes, 2004).

The IIM is capable of "1) estimating the impact of initial disruptions to a sector (or group of sectors) to other "external" sectors; 2) assessing the cascading impacts of disruptive events for various regions; and 3) presenting various perspectives of impact, including inoperability and economic loss, which can provide insights for risk management" (Santos, 2006).

The IIM has been used in economic literature to study the impact of disruptions such as terrorism, power outages, pandemics. For instance, Santos and Haimes (2004) used the IIM to study the impact of 10 per cent reduction in demand for air transport as a result of terrorism on interconnected economic systems. Jung et al. (2009) used international trade (IT)-IIM to investigate the international trade inoperability for all industry sectors resulting from disruptions to a major port of entry.

Santos et al. (2009) assessed the economic losses due to the 2009 H1N1 pandemic for the Commonwealth of Virginia. Results show that even a moderate 15 per cent attack rate scenario could lead to a $5.5 billion loss. Yaseen et al., (2020) assessed sector inoperability and the economic impact of workforce absenteeism due to flooding. They concluded that the impact of flooding through workforce absenteeism can render the whole economy inoperable.

On terrorism, Santos and Haimes (2004) used the IIM to model demand reduction in interconnected sectors of the economy due to terrorism. Similarly, Lian and Haimes, (2006) assessed the risk of terrorism to interdependent infrastructure systems in the US using the dynamic input-output inoperability model. In the IT sector, Hyatt and Santos, (2022) used the inoperability input-output model to determine the inoperability and economic impact of IT on interdependent industries in the US. The authors found that the IT sector is susceptible to various form of malicious attacks.

For the energy sector, Guo and Hou, (2019) used the IIM to analyse the vulnerability and recoverability of the energy sector in China in the presence of demand and supply perturbation.

It is important to note that the interdependence among various sectors of the economy may take the form of flows of information, shared security, physical flows of commodities, etc (Haimes et al., 2005). The growing dependence of one sector of the economy on other sectors makes the whole economy vulnerable to unexpected side-effects, making it complex and prone to disruptions (Setola and Porcellinis, 2007). In fact, the socio-economic effects of disruptions can be considerably larger when the cascading effects and interdependencies among sectors are taken into account (Kjølle, Utne, and Gjerde, 2012).

Despite the potential benefits of using the IIM, it does not allow researchers to perform intertemporal analysis due to the fact that IIM is a static model. The dynamic inoperability input-output mode (DIIM) was therefore proposed to account for the limitations of the IIM.

According to Lian and Haimes (2006) the DIIM addresses the following pertinent questions that are overlooked in the static model: 1) how the disrupted sector(s) recovers over time; 2) what are the associated economic losses during the recovery period; and 3) What can be done to minimize the losses during the recovery period after the disruption.

The DIIM uses industry interdependence index to measure the degree to which sectors are dependent on each other in an interconnected economy. This is a function of hardening, prevention and redundancy – resilience factors. In addition, the DIIM uses an estimated industry resilience coefficient to determine the speed with which industries recover after a disruption. The model also allows researchers to represent the dynamic behaviour of disrupted and interdependent sectors in the recovery duration.

Santos et al. (2009) used the DIIM to analyse the impacts from a pandemic (influenza). They develop a modelling framework to account for workforce inoperability and recovery factors. The proposed workforce-explicit enhancements to the DIIM is then used in a case study to simulate a pandemic scenario in the Commonwealth of Virginia (USA).

For the energy sector, Guo and Hou, (2019) used the DIIM (in addition of the IIM) to analyse the recovery dynamics of the energy sector in China due to demand and supply perturbations. Zhang et al. (2022) also used the DIIM to assess industrial water network vulnerability in China.

In what follows this study uses the DIIM to study how disruption due on the demand faced by the accommodation and food service due to the COVID-19 could affect the economic performance food and drinks sector and interdependent sectors.

III. Empirical approach

This section starts presenting brief version of the dynamic inoperability input-output model (DIIM), which will be used for the empirical work and it is followed by introducing the data used.

III.1 Method

The starting point of the DIIM is the dynamic version of the Leontief input-output, which is written as in (1):

$$x(t) = Ax(t) + c(t) + B\dot{x}(t) \quad (1)$$

where $x(t)$ is the output vector, A is the matrix of technical coefficients, $c(t)$ is the final demand vector (i.e., households, government, exports and investment) and $\dot{x}(t)$ is the change in the vector of output. The dimension of the vectors is (nx1) where n is the number of sectors in the economy and A is a nxn matrix. Matrix B can be described as the willingness of the economy to invest in capital resources. Haimes et al. (2005), citing Ramos Carvajal et al. (2002), argued that the economic system would only be stable when the elements of the B matrix are either zero or negative. $B = -I$, where I is the identity matrix and in that case, the economy quickly adjusts its production levels following information about mismatches in supply and demand yielding:

$$\dot{x}(t) = Ax(t) + c(t) + x(t) \quad (2)$$

To model the industry sectors' dynamic recovery behaviours and dynamic interactions caused by demand reduction or labour disruptions on industry sectors, we start with a diagonal matrix of the capital coefficient matrix B:

$$B = diag(b_i) \qquad \forall\, i = 1,2,\dots,n \quad (3)$$

Let a matrix K be equal to:

$$K = diag(k_i) \qquad \forall\, i = 1,2,\dots,n \quad (4)$$

Relating diagonal matrices K and B yields:

$$K = -B^{-1} \leftrightarrow k_i = \frac{1}{b_i}; \qquad \forall\, i = 1,2,\dots,n \quad (5)$$

Merging equations (5) and (1) gives:

$$\dot{x}(t) = K[Ax(t) + c(t) - x(t)] \quad (6)$$

Or in discrete form:

$$x(t+1) - x(t) = K[Ax(t) + c(t) - x(t)] \quad (7)$$

Transforming equation (7) into the normalized inoperability form results in the following equation (8) (Haimes et al., 2005):

$$q(t+1) - q(t) = K[A^{*}q(t) + c^{*}(t) - q(t)] \quad (8)$$

Matrix A^{*} is the normalised interdependency matrix, $c^{*}(t)$ is the normalised final demand vector at time t; and $q(t)$ is the inoperability vector at time t, and K is the industry resilience coefficient which measures the resilience of sector i in the presence of disruption in demand and supply. As can be seen from (8) the greater the value of the resilience coefficients (i.e., diagonal values of the matrix

K) the higher is the recovery of the sector. An intuitive view of this can be obtained by the fact that the term $A^{*}q(t) + c^{*}(t) - q(t)$ represents the different of supply and demand (in inoperability terms), thus, the greater the resilience coefficients the smaller will be the difference between $q(t+1) - q(t)$, indicating that the system is reaching the steady state.

The inoperability vector at time t after a disruption is defined as the vector of normalised economic losses and be derived as

$$q = [\mathrm{diag}(x)]^{-1}[x - \tilde{x}] \tag{9}$$

where x is the as-planned level of output and $\tilde{x}$ is the degraded level of output and its elements have values between 0 and 1. The interdependency matrix, A^{*}, it is defined as the additional inoperability that sectors contribute to each other due to their interaction. It is defined as in (10):

$$A^{*} = [\mathrm{diag}(x)]^{-1}A[\mathrm{diag}(x)] \tag{10}$$

The initial demand perturbation vector c^{*}, which is the normalised demand vector is derived as:

$$c^{*} = [\mathrm{diag}(x)]^{-1}[c - \tilde{c}] \tag{11}$$

where c is the as-planned level of final demand and $\tilde{c}$ is the degraded level of final demand resulting from the exogenous system disruption.

The sectoral resilience coefficient k_i can be derived as (12) (Lian and Haimes, 2006)

$$k_i = \frac{\ln\left(\frac{q_i(0)}{q_i(T)}\right)}{T(1 - a_{ii}^{*})} \tag{12}$$

Where $q_i(0)$ is the initial operability, $q_i(T)$ is the inoperability after T period from the shock and a_{ii}^{*} is the sector own coefficient in the interdependency matrix.

The recovery pathway can be used to derive the economic loss during recovery from each individual sector. The cumulative economic loss for each individual industry i is given by $Q_i(t)$

$$Q_i(t) = x_i \int_{t=0}^{T} q_i(t)\,dt \tag{13}$$

Where x is the as-planned output rate of industry i; $q_i(t)$ is inoperability of industry i by time t. In discrete terms (13) can be expressed as (14)

$$Q_i(t) = x_i \sum_{t=0}^{T} q_i(t) \tag{14}$$

III.2 Data

The present study is based on input-output data obtained from the Scottish supply, use and input-output tables from 1998 to 2019 (Scottish Government, 2022). The table provides a complete picture of the flows of goods and services in Scotland's onshore economy each year.

The original 98 economic sectors of the Scottish input output tables were aggregated (to simplify the calculations) into 18 industries. The 2019 Input Output table for Scotland is presented in Table 1.

The aggregated sectors were: Agriculture, fisheries and forestry; Preserved meat and meat products; Processed and preserved fish, fruit and vegetable; Manufacture of dairy vegetable and animal oils and fats; Grain mill products, starches and starch products; Bakery and farinaceous products; Other food products; Prepared animal feeds; Alcoholic beverages and tobacco products; Soft drinks; Other manufacturing; Energy supply, water and waste; Mining and quarrying Construction; Wholesale and retail trade and repairs; Transport and storage; Accommodation and food service activities; and Other services.

It should be mentioned that due to data confidentiality the Scottish Government aggregate some of the food sectors and it is not possible to break them down into more meaningful sectors. Examples of this are the groups of 'Preserved meat and meat products'; 'Processed and preserved fish, fruit and vegetable'; 'Manufacture of dairy, vegetable and animal oils and fats'.

In order to analyse the evolution of the food and drink sector, in this study the estimated monthly GDP by sector was used (the series were presented in Figure 2 before). The GDP is not the total sectoral output (this is only estimated annually and the latest figures are for 2019), it is only the value added part; however, it has close relationship with the total output see Arrow (1974) and also it is possible to compute changes in the value added using a multiplier (see the Ghosh model in Miller and Blair, 2009).

Table 1 – Aggregated version of the Scottish Input-Output table – 2019

Products	Section	Industry	Agriculture fisheries and forestry	Preserved meat and meat products	Processed and preserved fish, crustaceans molluscs fruit and vegetables	Manufacture of dairy vegetable and animal oils and fats	Grain mill products, starches and starch products	Bakery and farinaceous products	Other food products	Prepared animal feeds	Alcoholic beverages & Tobacco products	Soft drinks	Other manufacture	Energy supply water and waste	Mining and quarrying (Section B)	Construction (Section F)	Wholesale and retail trade and repairs	Transport and storage	Accommodation and food service activities	Other services	Total Intermediate Demand
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1		Agriculture, fisheries and forestry	602.4	393.7	355.8	85.9	22.0	2.7	7.4	59.1	59.8	2.1	192.1	28.0	3.5	29.2	48.4	8.5	35.0	81.5	2,016.9
2		Preserved meat and meat products	5.3	53.1	0.4	0.5	0.0	4.4	7.3	1.6	0.2	0.1	1.7	0.1	0.1	0.3	16.1	4.0	74.3	21.9	191.2
3		Processed and preserved fish, fruit and veg.	1.6	1.0	81.6	0.4	0.8	8.2	11.8	1.3	1.4	2.5	1.0	0.1	0.1	0.3	2.4	1.1	54.3	15.1	185.1
4		Manufacture of dairy, vegetable and animal oils and fats	0.1	0.4	0.6	3.3	0.1	8.7	3.7	0.3	0.1	0.1	0.7	0.0	0.0	0.2	0.9	0.8	7.9	3.4	31.4
5		Grain mill products, starches and starch products	0.0	0.2	0.2	0.0	0.6	5.0	0.5	2.5	11.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.9	0.5	22.1
6		Bakery and farinaceous products	0.6	0.7	2.8	0.1	0.1	5.7	7.3	0.3	1.1	0.4	1.6	0.2	0.2	0.6	4.7	0.6	41.3	15.4	84.0
7		Other food products	0.6	3.2	4.8	0.3	0.3	8.4	9.6	0.9	2.5	2.9	2.7	0.2	0.1	0.7	1.6	0.7	23.7	10.4	73.6
8		Prepared animal feeds	199.3	0.2	0.0	0.2	0.0	0.1	0.1	31.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.1	234.2
9		Alcoholic beverages and tobacco products	6.8	2.2	4.4	0.5	0.2	1.4	0.9	0.8	38.4	0.5	29.8	2.2	1.8	11.4	6.8	3.5	28.9	34.0	174.3
10		Soft drinks	0.2	0.1	0.4	0.0	0.0	0.2	0.1	0.0	1.2	8.1	0.8	0.1	0.1	0.3	0.4	0.2	33.4	10.3	55.7
11		Other manufacturing	247.2	18.8	29.5	5.4	1.9	30.3	18.2	11.9	171.6	16.8	2,420.7	295.4	141.2	878.0	331.6	281.9	64.9	1,517.3	6,482.6
12		Energy supply, w ater and w aste	74.4	17.1	25.2	9.1	2.7	34.2	13.5	7.3	110.7	11.1	456.7	4,438.5	38.2	174.8	476.5	106.4	242.7	1,478.1	7,717.2
13		Mining and quarrying	10.4	1.9	3.6	0.6	0.2	1.6	1.0	0.7	9.0	1.2	90.9	7.0	218.5	188.8	28.3	16.1	3.4	62.7	645.8
14		Construction	85.9	1.7	1.2	0.1	0.0	0.4	0.2	0.1	2.3	0.2	130.7	271.1	48.6	4,435.3	257.7	36.0	20.7	1,814.8	7,107.1
15		Wholesale and retail trade and repairs	349.4	95.9	184.7	20.4	7.2	71.8	47.7	40.9	214.8	22.9	1,602.6	125.0	93.2	511.0	663.7	256.3	276.6	1,506.8	6,090.9
16		Transport and storage	147.4	17.2	31.7	10.5	2.2	19.5	11.1	7.4	91.1	16.0	394.7	98.6	72.5	47.8	1,162.7	1,159.4	25.4	1,404.8	4,720.0
17		Accommodation and food service activities	4.6	0.4	0.6	0.2	0.0	1.9	0.4	0.2	2.7	0.4	25.2	5.7	8.4	21.0	35.2	46.2	38.3	632.2	823.5
18		Other services	398.7	25.2	51.7	11.3	2.5	44.6	43.2	9.6	200.7	15.9	1,128.8	793.3	506.8	1,214.9	1,940.7	1,093.8	651.4	18,971.8	27,105.0
	TDC	Total domestic consumption	2,134.9	633.0	779.3	148.8	40.6	249.2	184.1	176.8	919.0	101.1	6,480.9	6,065.5	1,133.3	7,514.7	4,977.7	3,015.7	1,623.2	27,583.0	63,760.7
	RUKImp	Imports from rest of UK	1,028.6	227.2	309.5	59.1	24.3	318.7	187.9	136.1	930.6	95.2	3,975.7	2,558.1	601.0	2,881.2	2,811.7	1,758.2	1,062.8	14,408.2	33,373.9
	RoWImp	Imports from rest of w orld	434.8	150.3	160.7	35.6	10.0	105.3	70.4	34.2	381.5	49.5	4,209.8	619.8	413.0	1,341.9	1,203.1	883.9	391.1	6,081.0	16,575.9
	TIC	Total intermediate consumption at basic prices	3,598.3	1,010.5	1,249.5	243.5	74.9	673.2	442.4	347.1	2,231.1	245.8	14,666.4	9,243.3	2,147.3	11,737.7	8,992.4	5,657.8	3,077.1	48,072.2	113,710.5
	TISPrds	Taxes less subsidies on products	95.1	0.5	4.4	1.1	0.2	8.3	1.8	1.5	192.8	7.5	413.7	583.8	21.1	121.4	248.9	497.5	199.5	3,343.4	5,742.5
	TISPrdn	Taxes less subsidies on production	-479.8	2.8	2.7	0.3	0.1	5.9	2.4	0.6	11.0	2.2	183.0	339.4	21.0	138.0	1,007.0	196.0	297.0	581.0	2,310.5
	CoE	Compensation of employees	798.0	227.0	308.1	94.3	14.0	322.0	153.7	57.5	872.2	72.3	7,493.0	2,024.3	1,102.0	4,785.0	8,592.0	4,285.0	3,545.0	49,295.0	84,040.3
	GOS	Gross operating surplus	1,963.8	49.3	119.9	43.7	4.8	139.2	69.0	46.6	1,608.3	55.3	3,488.0	4,215.1	337.0	4,062.0	4,557.0	1,381.0	1,208.0	39,188.0	62,535.9
	GVA	Gross value added	2,282.0	279.0	430.7	138.3	18.9	467.1	225.1	104.7	2,491.5	129.8	11,164.0	6,578.7	1,460.0	8,985.0	14,156.0	5,862.0	5,050.0	89,064.0	148,886.7
	TOut	Total output at basic prices	5,975.3	1,290.0	1,684.6	383.0	94.1	1,148.5	669.3	453.3	4,915.4	383.0	26,244.1	16,405.8	3,628.4	20,844.0	23,397.3	12,017.3	8,326.6	140,479.6	268,339.6

Continues

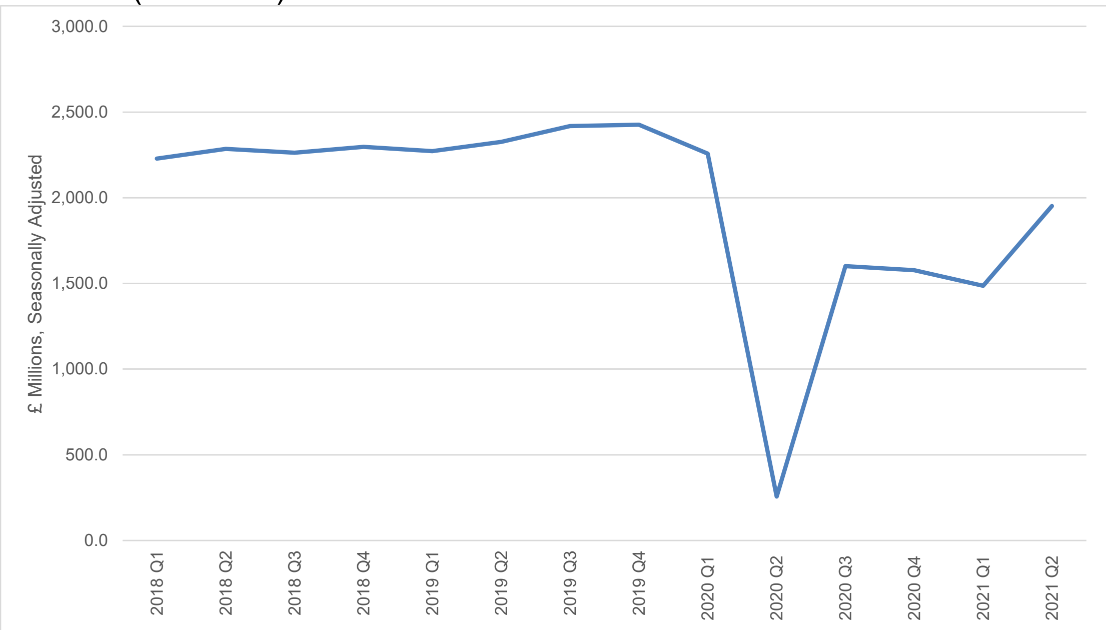
Households	Non-Profit Institutions Serving Households	Central Government	Local Authorities	Gross Fixed Capital Formation	Valuables	Changes in Inventories	Exports			Total Demand for Products at Basic Prices
							Non-resident households	Rest of UK	Rest of w orld	
20	21	22	23	24	25	26	27	28	29	30
1,381.1	4.9	0.3	8.5	188.2	-0.5	220.4	107.3	1,163.5	884.7	5,975.3
331.1	0.0	0.0	0.0	0.6	0.0	0.6	8.6	673.2	84.7	1,290.0
259.5	0.1	0.0	0.0	1.2	0.0	0.5	4.7	809.2	424.3	1,684.6
108.8	0.0	0.0	0.0	0.3	0.0	1.5	3.4	187.9	49.6	383.0
9.8	0.0	0.0	0.0	0.0	0.0	0.6	0.2	53.3	8.0	94.1
418.5	0.0	0.0	0.0	1.4	0.0	0.4	21.8	494.7	127.7	1,148.5
140.5	0.0	0.0	0.0	1.5	0.0	-1.0	4.2	309.3	141.1	669.3
104.3	0.0	0.0	0.0	0.4	0.0	5.8	0.4	42.8	65.4	453.3
241.2	0.2	0.0	0.0	22.6	0.0	-1.6	43.9	606.9	3,827.9	4,915.4
156.5	0.0	0.0	0.0	0.4	0.0	0.9	10.6	146.0	13.0	383.0
2,456.5	6.2	215.9	0.0	1,538.5	-43.6	15.1	131.7	7,023.7	8,417.5	26,244.1
3,031.4	1.1	0.0	818.8	88.7	0.0	10.6	38.3	4,313.4	386.2	16,405.8
99.8	0.2	0.0	0.0	32.4	0.3	-1.2	13.7	2,319.8	517.5	3,628.4
327.2	1.4	0.0	0.0	11,002.8	0.0	-76.8	62.8	1,995.4	424.0	20,844.0
10,135.3	16.1	0.0	18.2	1,161.7	0.7	-0.1	601.5	2,753.5	2,619.4	23,397.3
2,336.7	1.0	704.9	0.0	23.2	0.0	-0.1	248.6	2,498.8	1,484.1	12,017.3
4,899.3	1.2	0.0	0.0	19.8	0.0	-0.1	2,549.3	23.0	10.6	8,326.6
31,538.0	4,379.7	26,723.4	13,517.8	2,796.1	7.0	-51.3	738.0	21,978.8	11,747.2	140,479.6
57,975.5	4,412.3	27,644.5	14,363.2	16,880.1	-36.1	124.3	4,589.0	47,393.2	31,232.8	268,339.6
23,880.9	0.0	556.3	0.0	8,606.3	8.1	240.9	553.8	1,594.5	314.8	69,129.4
11,779.9	0.0	285.8	0.0	4,607.8	12.7	230.1	397.8	1,435.0	0.0	35,324.9
93,636.3	4,412.3	28,486.6	14,363.2	30,094.1	-15.4	595.3	5,540.5	50,422.7	31,547.6	372,793.9
11,779.0	0.0	4.5	0.0	867.2	0.1	2.5	834.1	15.1	0.0	19,245.0

Source: Own aggregation based on the Scottish 2019 Input Output Table.

IV. Results and discussion

The starting point of the analysis is the decrease in the final demand that the accommodation and food service activities faced at the beginning of the lockdown period. As shown in Figure 3 the final demand for the sector contracted substantially by about 60 per cent. This had not only impact on it is own sector but also through its connections with other sectors to the rest of the economy.

Figure 3 – Evolution of the final demand of the accommodation and food service activities (£ millions)



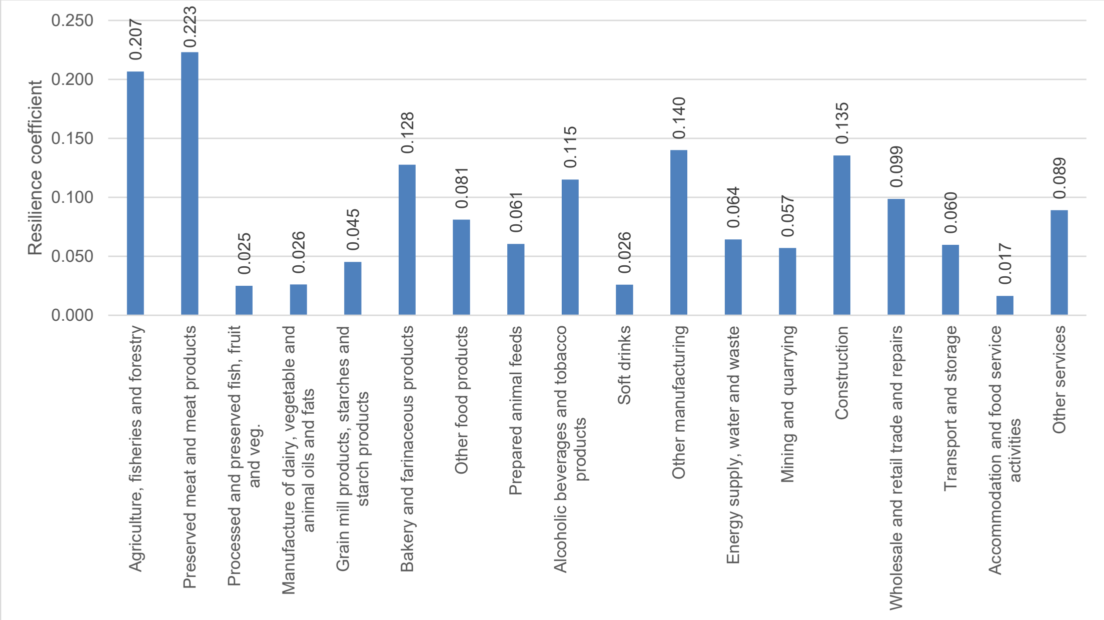
Source: Scottish Government.

The next step of the work consists of the estimation of the resilient coefficients for all sectors. Table A.1 in the Annex presents the information used for the computation. It should be mentioned that in order to isolate the impact of the Ukraine-Russia conflict, the ending period was fixed after 10 months of the period 0, set in most of the cases in April 2020. Going beyond January 2021 would have implied also to consider the effects of the conflict.

Concentrating on the food and drink sectors, as shown in Figure 4, 'Processing of meat and meat products' and 'Agriculture, fisheries and forestry' were the sectors with the highest resilience coefficient, i.e., the ones to reach faster the steady state. However, the other food processing industries and the soft drink industry showed small resilient coefficients, all of them (with the exception of the bakery sector) less than 0.1.

The processed fish and fruit and vegetables, dairy and vegetable oils and soft drink industry appear as particularly in a sensitive position given their relationship with the accommodation and food sector. It is interesting to note that at least the dairy and vegetable oil sector would have been further shocked by the effects of the Ukraine-Russia conflict.

Figure 4 – Estimated resilience coefficient by productive sector



The next step of the recovery analysis, which is presented in Figure 5. For this analysis the interdependence matrix (presented in the Annex in Table A.2) is crucial because it represents the interrelation of the different sectors. The evolution of the sectors is given by the difference equation represented by (8).

As shown by the figures and anticipated from the analysis of the resilience coefficients, the soft drink and the dairy and vegetable oil sector are the ones that with the slowest recovery paths. As shown, agriculture and processed meat are less affected. An interesting aspect of all the sectors is that all the sectors follow a convergent path to the steady state, this is slow in all the cases, indicating that the shocks are persistent on the sector.

Figure 5 – Inoperability dynamic recovery path by productive sector

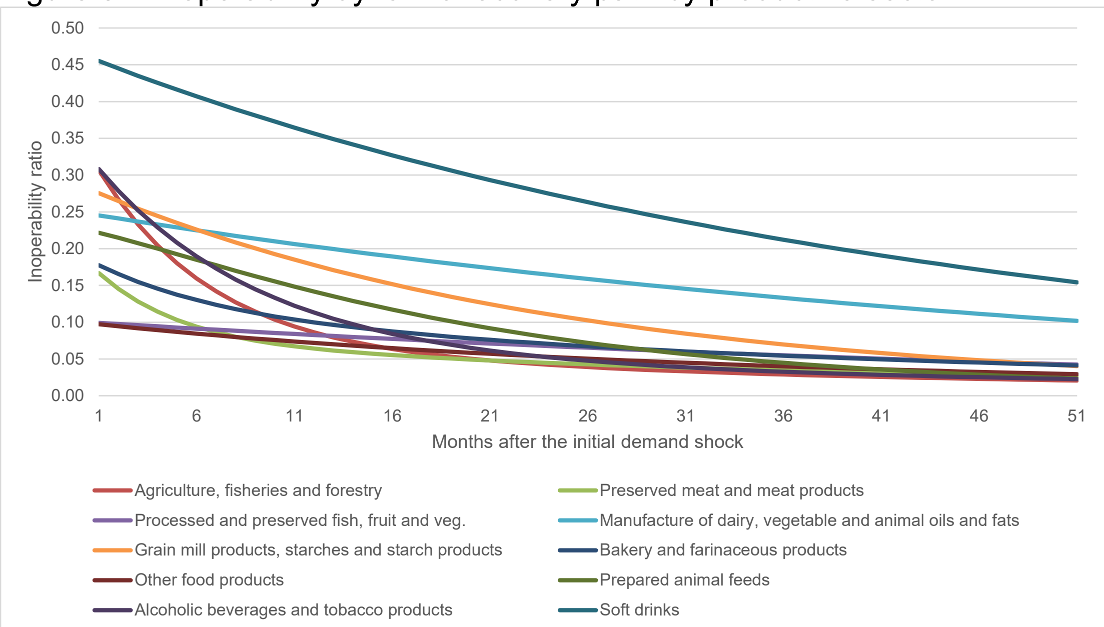
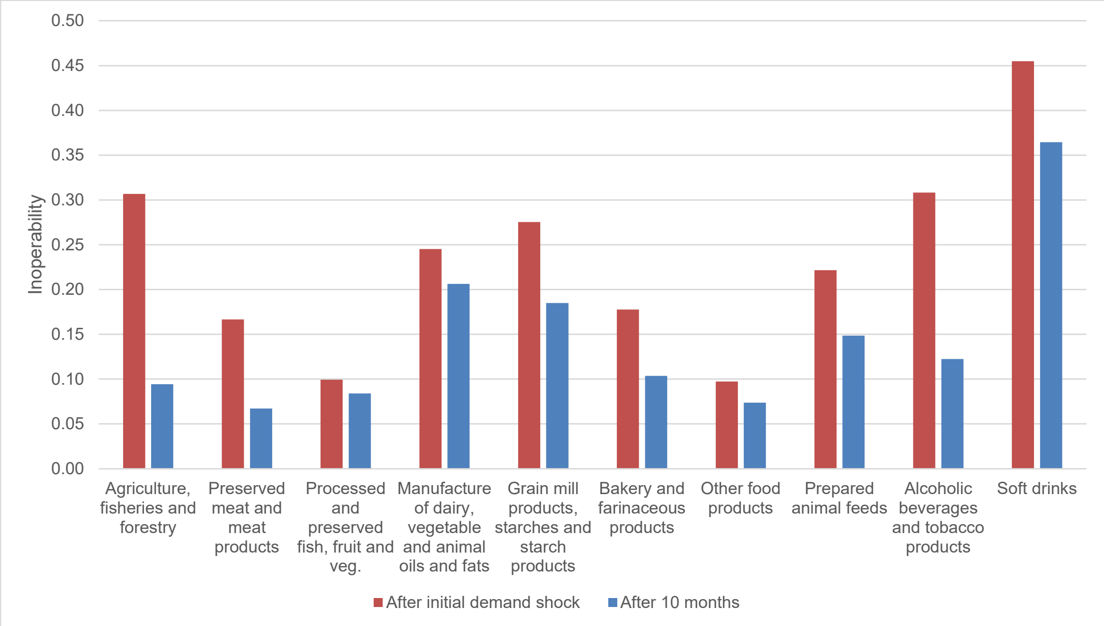


Figure 6 was produced in order to clarify how fast the sector converge. As shown in the Figure, Agriculture, Preserve meats and Alcoholic beverages inoperability is reduced by half after 10 months, which in all the other cases is not the case.

Figure 6 – Initial and after 10 months inoperability by sector



The last part of the calculation is the estimation of economic losses, which follows equation (14) and it is presented in Table 2.

Table 2 - Estimated economic losses for the first 10 months (£ million)

	Planned output	Sum q(t) 1/	Economic losses	Losses 2/
Agriculture, fisheries and forestry	497.9	1.93	962.2	1.93
Preserved meat and meat products	107.5	1.13	121.7	1.13
Processed and preserved fish, fruit and veg.	140.4	1.01	141.2	1.01
Manufacture of dairy, vegetable and animal oils and fats	31.9	2.48	79.1	2.48
Grain mill products, starches and starch products	7.8	2.50	19.6	2.50
Bakery and farinaceous products	95.7	1.48	141.4	1.48
Other food products	55.8	0.93	52.1	0.93
Prepared animal feeds	37.8	2.04	76.9	2.04
Alcoholic beverages and tobacco products	409.6	2.20	899.8	2.20
Soft drinks	31.9	4.49	143.3	4.49
Other manufacturing	2,187.0	2.25	4,929.1	2.25
Energy supply, water and waste	1,367.2	1.46	1,993.1	1.46
Mining and quarrying	302.4	3.34	1,010.3	3.34
Construction	1,737.0	3.78	6,560.9	3.78
Wholesale and retail trade and repairs	1,949.8	3.11	6,068.4	3.11
Transport and storage	1,001.4	3.46	3,461.3	3.46
Accommodation and food service activities	693.9	8.98	6,233.1	8.98
Other services	11,706.6	1.38	16,113.6	1.38

Note: 1/ Sum of inoperability from period 0 to 10. 2/ Share of the planned output.

Table 2 shows the losses in monetary term and also in relative terms (as a share of the plan output of the sector. In monetary terms, from the food and drink sector; Agriculture, fisheries and forestry and Alcoholic beverages and tobacco products showed the greater losses (£962.2 and £899.8, respectively). However, the relative losses provide a more easy to visualise the losses. For instance, whilst Accommodation and food service activities has losses that are similar to Wholesale and retail trade and repairs, in relative terms, the former is above two times the latter. Moreover, the soft drinks sector show a ratio above 4 showing the importance of the losses for the sector.

V. Conclusions

Various sectors of the economy have become very interconnected. As a results disruption to one sector has cascading effects on the national supply chain network. The goal of the present work is to show how disruptions to final demand in the accommodation and food services sector could potentially render the entire national Scottish supply chains inoperable using input-output tables. The entire Scottish economy was affected by the covid-19 pandemic however, the degree of vulnerability is proportional to the degree to which sectors relied on human inputs and the extent of interconnectedness between sectors. We show in this analysis that 1) Covid-19 pandemic disrupted all sectors of the economic with the accommodation and food sectors being the most affected; 2) temporary reduction in final demand in the accommodation and food service due to the pandemic had cascading effect on interconnected sectors of the economy; 3) economic sectors have different coefficient of resilience (resistant to/recovery from shocks) and dynamic recovery rates when exposed to the same disruption; and finally economic losses vary across different sectors.

The accommodation and food service sector was the most affect by the covid-19 pandemic lockdown contracting by about 60 per cent. The DIIM shows that the disruption to this sector had cascading effect on the remaining 17 sectors of the economy.

We used the resilience coefficient to show the speed with which these sectors return to full operation. The results show that the Processed and preserved fish, fruits and vegetable sector is the least resilient whilst Preserved meat and meat products sector is the most resilient to final demand disruption in the accommodation and food service sector. The dynamic recovery curve shows that recovery is quicker for agricultural, fishery and forestry sector after 10 months compared to the remaining sectors especially the soft drinks sector. The least economically affected sector was the other food products sector whilst the other services sector had the highest economic loss. Despite the fact that the soft drinks sector had a slow recovery rate, economic losses were lower compared to the agricultural, fishery and forestry sector.

From the policy perspective, we have shown that the most disrupted sector by the covid-19 pandemic is the accommodation and food service sector. Stakeholders in the accommodation and food service sector should re-examine the sector and develop capacity against future pandemics. In addition, since pandemics affect interconnected sectors, it is important for economic sectors to collaborate either vertically or horizontally by sharing information and risk to reduce the burden of future disruptions. The most vulnerable sector of the economy i.e. other services sector should form a major part of government policy decision making when planning against future pandemics.

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Annex

Table A.1 – Computation of resilience coefficients

Resilience coefficients		Max	Min	Date	Max-after	Date	q(0)	q(T)	T	(1-aii)	ki
1	Agriculture, fisheries and forestry	110.988	76.940	Apr-2020	105.433	Jan-2021	0.307	0.050	10	0.877	0.207
2	Preserved meat and meat products	121.200	101.000	Apr-2020	118.600	Jan-2021	0.167	0.021	10	0.919	0.223
3	Processed and preserved fish, fruit and veg.	103.800	93.500	Apr-2020	95.700	Jan-2021	0.099	0.078	10	0.956	0.025
4	Manufacture of dairy, vegetable and animal oils and fats	111.820	84.400	Mar-2020	90.440	Dec-2020	0.245	0.191	10	0.953	0.026
5	Grain mill products, starches and starch products	147.400	106.800	Feb-2020	123.800	Jan-2021	0.275	0.160	12	0.998	0.045
6	Bakery and farinaceous products	114.300	94.000	Apr-2020	108.600	Jan-2021	0.178	0.050	10	0.995	0.128
7	Other food products	102.800	92.800	Apr-2020	98.300	Jan-2021	0.097	0.044	10	0.984	0.081
8	Prepared animal feeds	123.200	95.900	Apr-2020	107.300	Dec-2020	0.222	0.129	9	0.993	0.061
9	Alcoholic beverages and tobacco products	106.100	73.400	Apr-2020	95.500	Jan-2021	0.308	0.100	10	0.979	0.115
10	Soft drinks	123.300	67.200	Apr-2020	80.000	Jan-2021	0.455	0.351	10	0.999	0.026
11	Other manufacturing	102.561	69.416	Apr-2020	92.341	Jan-2021	0.323	0.100	10	0.840	0.140
12	Energy supply, w ater and w aste	106.824	91.611	Apr-2020	97.568	Jan-2021	0.142	0.087	10	0.772	0.064
13	Mining and quarrying	115.997	73.647	Apr-2020	91.278	Jan-2021	0.365	0.213	10	0.944	0.057
14	Construction	100.298	45.049	Apr-2020	81.484	Jan-2021	0.551	0.188	10	0.795	0.135
15	Wholesale and retail trade and repairs	100.813	60.101	Apr-2020	85.281	Jan-2021	0.404	0.154	10	0.977	0.099
16	Transport and storage	102.367	64.211	Apr-2020	80.052	Jan-2021	0.373	0.218	10	0.899	0.060
17	Accommodation and food service activities	107.821	20.506	Apr-2020	33.737	Jan-2021	0.810	0.687	10	0.992	0.017
18	Other services	102.494	85.260	Apr-2020	94.646	Jan-2021	0.168	0.077	10	0.882	0.089

Source: Ow n elaboration based on Scottish Government and Office for National Statistics data

Table A.2 - Interdependency matrix - average: 1998 – 2019

Products	Industry	Agriculture fisheries and forestry	Preserved meat and meat products	Processed and preserved fish, crustaceans molluscs fruit and vegetables	Manufacture of dairy vegetable and animal oils and fats	Grain mill products, starches and starch products	Bakery and farinaceous products	Other food products	Prepared animal feeds	Alcoholic beverages & Tobacco products	Soft drinks	Other manufacture	Energy supply water and waste	Mining and quarrying (Section B)	Construction (Section F)	Wholesale and retail trade and repairs	Transport and storage	Accommodation and food service activities	Other services
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Agriculture, fisheries and forestry	0.1231	0.1319	0.0534	0.0608	0.0075	0.0003	0.0089	0.0085	0.0059	0.0007	0.0451	0.0051	0.0003	0.0045	0.0053	0.0011	0.0059	0.0092
2	Preserved meat and meat products	0.0049	0.0813	0.0003	0.0005	0.0000	0.0048	0.0092	0.0004	0.0004	0.0004	0.0093	0.0002	0.0001	0.0005	0.0116	0.0032	0.0495	0.0255
3	Processed and preserved fish, fruit and veg.	0.0004	0.0012	0.0443	0.0024	0.0006	0.0060	0.0023	0.0013	0.0018	0.0023	0.0033	0.0003	0.0001	0.0005	0.0028	0.0012	0.0248	0.0147
4	Manufacture of dairy, vegetable and animal oils and fats	0.0004	0.0038	0.0027	0.0471	0.0005	0.0318	0.0110	0.0044	0.0007	0.0007	0.0118	0.0006	0.0002	0.0014	0.0078	0.0043	0.0608	0.0305
5	Grain mill products, starches and starch products	0.0037	0.0049	0.0023	0.0003	0.0020	0.0284	0.0008	0.0102	0.0363	0.0000	0.0070	0.0002	0.0002	0.0013	0.0018	0.0004	0.0167	0.0044
6	Bakery and farinaceous products	0.0007	0.0012	0.0022	0.0003	0.0001	0.0054	0.0023	0.0003	0.0016	0.0014	0.0079	0.0007	0.0002	0.0011	0.0102	0.0037	0.0815	0.0301
7	Other food products	0.0007	0.0145	0.0066	0.0019	0.0006	0.0204	0.0162	0.0019	0.0109	0.0151	0.0109	0.0006	0.0002	0.0016	0.0036	0.0023	0.0404	0.0250
8	Prepared animal feeds	0.3106	0.0009	0.0004	0.0019	0.0000	0.0008	0.0003	0.0073	0.0008	0.0001	0.0146	0.0005	0.0004	0.0029	0.0019	0.0009	0.0021	0.0122
9	Alcoholic beverages and tobacco products	0.0009	0.0004	0.0003	0.0002	0.0000	0.0003	0.0001	0.0001	0.0213	0.0001	0.0148	0.0005	0.0004	0.0030	0.0021	0.0010	0.0425	0.0085
10	Soft drinks	0.0003	0.0001	0.0005	0.0001	0.0000	0.0002	0.0001	0.0001	0.0003	0.0011	0.0043	0.0002	0.0001	0.0009	0.0013	0.0010	0.0701	0.0287
11	Other manufacturing	0.0073	0.0010	0.0013	0.0005	0.0001	0.0012	0.0007	0.0007	0.0062	0.0010	0.1601	0.0098	0.0051	0.0321	0.0124	0.0127	0.0023	0.0449
12	Energy supply, w ater and w aste	0.0089	0.0023	0.0028	0.0008	0.0004	0.0017	0.0008	0.0010	0.0078	0.0005	0.0749	0.2278	0.0053	0.0161	0.0348	0.0071	0.0192	0.0956
13	Mining and quarrying	0.0032	0.0011	0.0015	0.0008	0.0002	0.0009	0.0006	0.0006	0.0041	0.0004	0.0582	0.0441	0.0558	0.1214	0.0329	0.0126	0.0010	0.0365
14	Construction	0.0015	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0066	0.0150	0.0024	0.2049	0.0141	0.0027	0.0021	0.0761
15	Wholesale and retail trade and repairs	0.0098	0.0047	0.0033	0.0024	0.0003	0.0035	0.0015	0.0012	0.0074	0.0010	0.1376	0.0037	0.0030	0.0248	0.0228	0.0123	0.0115	0.0537
16	Transport and storage	0.0086	0.0029	0.0040	0.0024	0.0007	0.0022	0.0016	0.0018	0.0118	0.0013	0.0802	0.0067	0.0095	0.0081	0.1305	0.1014	0.0052	0.1811
17	Accommodation and food service activities	0.0002	0.0001	0.0001	0.0001	0.0000	0.0003	0.0001	0.0001	0.0006	0.0000	0.0273	0.0019	0.0007	0.0034	0.0051	0.0039	0.0078	0.0460
18	Other services	0.0016	0.0003	0.0003	0.0002	0.0000	0.0004	0.0003	0.0002	0.0025	0.0002	0.0222	0.0046	0.0021	0.0102	0.0217	0.0097	0.0062	0.1177

Source: Own elaboration based on the Scottish Input-Output tables.