The system-wide impact of healthy eating: assessing emissions and economic impacts at the regional level

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Abstract: Encouraging consumers to shift their diets towards a lower meat/lower calorie alternative has been the focus of food and health policies across the world. The economic impacts of such changes on regions have been less widely examined, but are likely to be significant, especially where agricultural and food production activities are important for the region. In this study we use a multi-sectoral modelling framework to examine the environmental and economic impacts of such a dietary change, and illustrate this using a detailed model for Scotland. We find that if household food and drink consumption follows healthy eating guidelines, it would reduce both Scotland's "footprint" and "territorial" emissions, and yet may be associated with positive economic impacts, generating a "double dividend" for both the environment and the economy. The economic impact however depends critically upon how households use the income previously spent on higher meat/ higher calorie diets. Furthermore, the likely (but not modelled) benefits to health suggest the potential for a "triple dividend".

Keywords: Diet; Emissions; Economic impact; Scotland.

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1. *Introduction*

There is an increasing focus on encouraging individuals to undertake actions that would improve their health. Rates of obesity across the western world have risen sharply in recent decades (Ng et al, 2014), while 29% of Scottish adults were classified as obese[1] in 2016, with a further 36% overweight (Scottish Government, 2017a). Obesity rates for Scottish Men and Women have increased between 2003 and 2016 from 22% to 29% and 24% to 29% respectively. Almost one in three Scottish children has a BMI outwith the healthy range, with one in seven at risk of obesity (a BMI above the 95th percentile).

In response, the Scottish diet has been examined (Food Standards Scotland, 2018) and a number of proposals made to improve food and diet choices, including reducing consumption of certain goods. The Scottish Government's "Revised Dietary Goals" (Scottish Government, 2016) set out that individuals should seek to reduce daily calorie intake by 120 kcals, eat more than 400g of fruit and vegetables per day while limiting their intake of red and processed meat to no more than 90g/day (p.3). Increased rates of obesity lead to a number of negative outcomes for individuals, such as increasing the chance of developing cancers, diabetes and cardiovascular disease (see for instance, Wang et al, 2011).

[1] Obesity is typically defined using Body Mass Index (BMI) measures, which is calculated as an individual's weight (kg) divided by the square of their height (metres). A BMI of more than 30 indicates "Obese", while between 25.0 and 29.9 is classified as "Overweight" and a "normal weight" defined as a BMI between 18.5 and 24.9. (Baker, 2018).

The private benefits of moving towards a healthy diet are therefore clear, and the kinds of interventions which could encourage this shift are widely understood (including education, pricing and regulation)[2]. Currently omitted from this discussion however – and the focus of this paper - is an assessment of the possible *economic* impacts of such a change in individuals' diets.

It is to this debate that the current paper contributes. We seek to explore three issues. First, what are the economic impacts on Scotland of a shift in consumer demands consistent with healthier eating? Specifically, we identify the extent to which economically important sectors of the Scottish economy are affected by a reduction in meat and food and drink consumption consistent with this healthier diet.

Second, we identify the impact on emissions associated with both Scottish production ("territorial") and Scottish consumption ("footprint") following the change in diet and expenditure patterns. This permits us to quantify both the economic and environmental consequences of healthier eating for the region. As part of the motivation for a move towards a lower meat diet is the environmental benefits, being able systematically to evaluate whether policies designed to improve in this domain, also might have economic consequences is likely to be highly valuable to policymakers. Our proposed framework adds

[2] The "Supporting Healthy Choices" programme seeks to "rebalance" the Scottish diet through education as well as voluntary action to support healthy living, the promotion of healthier products and encouraging food producers to formulate healthier products.

environmental detail within an economic model to capture the interdependence between economic outcomes and (in this case) emissions.

Third, our methodological contribution is to identify the *net* economic and environmental impacts of a positive shift in consumer demands in line with improved dietary choices. That is to say, reductions in household expenditure consistent with reduced calories and meat consumption, will not necessarily reduce the total amount of household spending. The profile of household spending across products will change, however, with increases in spending on discretionary (and non-food) items acting to maintain total household consumption. Neither the aggregate nor sectoral results on economic and environmental measures of this change in consumption patterns can be known in advance.

The paper proceeds as follows. Section 2 discusses previous literature on the consequences – including economic and environmental impacts - of a shift to a healthy diet and the modelling frameworks which have been employed to analyse these consequences. Section 3 presents our proposed regional multisectoral modelling framework, the data requirements, and the simulation strategy employed in alternative scenarios around consumption "re-spending". Section 4 presents the results of our analysis, including the sectoral and aggregate economic and emissions impacts of each scenario. Section 5 provides some brief conclusions and directions for future research.

2. Literature review

Red meat production and consumption matters for climate change, as well as economic activity. It is acknowledged that red meat is a particularly inefficient and carbon intensive way of generating calories for human consumption (see, for example, Scarborough et al, 2014). For each calorie of meat produced, many calories of grain and other vegetable crops have to be grown to feed livestock. To the extent that arable farming has a certain emissions consequence per human calorie supplied, livestock production clearly multiplies these emissions per calorie produced. And this is before we take into consideration the methane produced by livestock, which further adds to climate change emissions. Springmann et al (2016) found that "transitioning toward more plant-based diets that are in line with standard dietary guidelines could reduce global mortality by 6–10% and food-related greenhouse gas emissions by 29–70% compared with a reference scenario in 2050" (p. 4146).

This suggests the prospect of a policy win-win: if diets improve in accordance with healthy eating guidelines (i.e. reducing calorie intake generally, but especially from red meat consumption) then not only will it help meet health policy outcomes, it could also lead to reduced emissions, with consequential environmental benefit.

The economic impacts of such a change are however unclear. For instance, a healthy diet will mean lower food consumption – in line with lower calories - and in particular, lower expenditures on food and drink types higher in saturated fats, sugars, salts and other indicators of less healthy eating choices, such as red meat. If expenditure on food, and especially red meat, falls - and in the absence of any increases in demand for other goods – economic activity is likely to contract. It might be expected that reductions in activity would be felt in red meat producing and sales sectors, as well as ripple effects on the downstream activities in food production.

Economic activity attributable to food consumption is especially significant in Scotland where food production and related activity are important sectors in the economy. Food and Drink is one of the Scottish Government's "Growth Sectors" (Scottish Government, 2015) and the focus of policy actions[3]. The recent strategy for the Food and Drink sector set the ambition to double turnover in "farming, fishing, and food and drink" to £30 billion by 2030 (Scottish Food and Drink Partnership, 2017)[4]. There is of course potential for a conflict between ambitions for these sectors growing through increasing exports (Scottish Food and Drink Partnership, 2014) at a time of heightened global concern about healthy eating[5].

However, the *net* economic impact of reducing spending on "bad" diets depends on both the extent to which the spending which was previously made on these diet choices is then spent on other products, as well as differences in the scale of food production systems in the host

[3] The Scottish Government's "Food & Drink" growth sector is defined using Standard Industrial Classifications (SIC), and includes: Agriculture; Fishing; Aquaculture; Meat Processing; Fish & fruit Processing; Dairy Products, Oils & Fats Processing; Grain Milling & Starch; Bakery & Farinaceous; Other Food; Animal Feeds; Spirits & Wines; Beer & Malt; and, Soft Drinks.
[4] On the most recent data, this broadly defined sector generates £5.2 billion of Gross Value Added (GVA), and direct employs 111,000 people, approximately 4% of total employment in Scotland (Scottish Government, 2018).
[5] Scottish Food and Drink Partnership (2014) envisages that the future global consumer "will be seeking out" Scottish produce, including dairy and red meat.

region and their linkages to the rest of the regional economy, relative to that for the areas which see increases in spending. The overall impact might be either positive or negative depending on the extent to which the gross effect of the reduced spending on poor diets was offset by the positive effect of increased expenditure on alternative uses. Understanding the factors affecting the *net* economic – as well as environmental - impacts of changes in diet is the major focus of this paper, which we analyse here through focusing on the expenditure effects of the diet change[6].

There is a large literature on the environmental consequences of particular household diet choices. For example, McCarthy et al (2018) use survey data to examine the relationship between diet and emissions in Irish adults, finding that excessive and meat-heavy diets have undesirable emissions consequences and that adherence to dietary guidelines "can viably attenuate dietary environmental impact". Arrieta and Gonzalez (2018) link dietary choices in Argentina to greenhouse gas emissions, exploring the reductions in emissions which could be obtained through various dietary scenarios. Additionally, Hallstrom et al (2014) examine impacts on emissions and land use of reductions in meat consumption. Like Arrieta and Gonzalez (2018) however, their framework describes the scale of reductions in emissions associated with lower meet or food consumption, and not the net (economic or emissions) impacts of these changes. Reynolds et al (2015) use Input-Output modelling to look at food

[6] It has been argued that better diets could also have positive fiscal benefits through both reduced medical costs and fewer absences from work related to obesity. A report for the Scottish Parliament noted prior estimates that healthcare cost of treating overweight and obesity was £363 million in 2007/8 while lost earnings from obesity-relate sickness in Scotland were estimated at between £860 million and £970 million (Castle, 2015). To be clear, an improved diet would be expected to lead to a further supply-side stimulus; a healthier and more productive labour force, with reduced expenditures on public health actions; however the additional economic impacts through this health mechanism, are not examined in this paper.

expenditure patterns across income groups in Australia, again evaluating the impact of dietary choices upon greenhouse gas (GHG) emissions.

IO tables and models are widely used in applied economic statistics as well as impact analysis. IO tables show the destination of sales and source of inputs for all sectors of an economy and thus reveal the interconnectedness between sectors of the economy. This feature accounts for the widespread use of IO models in economic "impact" (or "multiplier") analysis – such as the impact on the economy of specific disturbances, or to identify the contribution of different sectors of the economy[7]. Past examples for the Scottish economy include a study of Higher Education Institutions (Hermannsson et al, 2013) or the forestry sector (McGregor and McNicoll, 1992).

The key strength of the IO accounts and models is that they are multisectoral in nature, and so permit a detailed analysis of industries across the economy. This feature is critical for the derivation of economic impacts, but also for determining changes in employment and emissions at a sectoral level, where sectors have considerable heterogeneity in the employment- or emissions-intensity of production. These features permit the use of IO modelling to set out the impacts of changes in diet on economic (including GDP and

[7] The conventional IO modelling specification expresses sectoral gross output (X) as the product of the Leontief inverse matrix ($(I-A)^{-1}$) and a vector of final demand, Y. Economic disturbances are expressed as changes in demand (ΔY), producing changes in output through the equation ($\Delta X = (I-A)^{-1} \Delta Y$). Changes in employment, GDP and emissions at the aggregate and sectoral level make use of fixed relationships (coefficients) between each variable and output at the sectoral level. For more details on IO modelling, see Miller and Blair (2009).

employment) as well as emissions (and other environmental) indicators, in a growing literature.

Joyce et al (2014) survey the literature on dietary choices and their emissions consequences, with some of the papers surveyed employing multi-sectoral modelling approaches, including IO modelling techniques, to comprehend these impacts. Meat intensive diets are associated with higher GHG emissions, but there is cross country variation. However, this survey focuses on the climate change impacts of dietary choices; the associated economic consequences are not part of their focus (in contrast to the present paper). What Joyce et al (2014) do provide is a discussion of the policy actions which can generate a change in dietary choices: regulations; economic incentives or disincentives; or information orientated tools. In our paper on the other hand, we simply explore the likely impact of a policy that successfully alters dietary choices so as to reduce red meat consumption.

One of the papers in the Joyce et al (2014) survey, Stehfest et al (2009), examines the global level climate consequences of diet changes, finding that moving towards diets involving less meat consumption could have major implications for global emissions. Their findings include that a switch towards a lower meat diet could reduce the costs of mitigation by 50% in 2050 compared to the reference case, with significant changes in land use away from crops for feed, and animal production. They intriguingly suggest that, as well as positive health benefits, dietary changes have an "important role in future climate change mitigation policies" (p. 83).

No system-wide economic impacts are provided in this analysis, however, unlike studies for the EU and UK[8].

Tukker et al (2011) undertake a major study for the EU, which focusses on changes in demand for food, with a particular emphasis on the emissions impacts. In their approach, the E3IOT input-output model captures the environmental impacts of different food products, so that when there are dietary changes, the consequences for a range of environmental indicators are captured. The partial equilibrium "CAPRI" model - solely focusing on the agricultural sector - is additionally used in this paper to capture the adjustments within the demand for agricultural products which produce price effects that are not captured in the E3IOT model[9].

For the UK, Audsley et al (2011) examines the consequences of a switch towards plant-based products and away from livestock products, and finds that this can have beneficial impacts not only on greenhouse gas emissions but also for the availability and use of land. In all cases, reductions in consumption of meat reduce the UK grassland areas previously used for animals and crops for animal feed. Their report considers the possible consequences of reductions in land use for animals, opening up opportunities for expansion of tillable land, including production of livestock for export, or "biofuel crops, planted woodland and re-wilding".

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[8] Stehfest et al (2013) undertake a comparison of two global models, both of which are "coupled" to the IMAGE integrated assessment model to explore the importance of model choice in driving results. As with the 2009 paper described in the text, discussion of economic results are limited to the impacts of specific agricultural commodities and their prices.

[9] Specifically, the change in diet is translated in the E3IOT model into a demand change across specific categories. These were entered into the CAPRI model as relative demand changes, which produces a new set of equilibrium demands for each product taking into account adjustments in prices. This adjusted set of demands for imported and domestically produced products is subsequently entered to the E3IOT model.

Discussing the economic impacts of the consequences, Audsley et al (2011) note that these would likely be unevenly distributed across the UK, with output contraction for “almost all” farmers in Northern Ireland, Scotland and Wales, and “output growth in the south and east of England”[10].

In addition to emissions, other environmental indicators can be linked to food production and consumption, including water. For example, Hess et al (2016) examine the impact on (global) emissions and blue water scarcity of different carbohydrate products consumed in the UK, while Hess et al (2015) examine the level and distribution of blue water scarcity changes resulting from changes in UK diet. Both papers show the critical nature of extra-national water impacts and the potential unintended consequences of reducing meat consumption domestically in the UK[11].

Further, some have examined the health consequences of dietary change, including Milner et al (2015). To date however, there is limited examination of the economic consequences of improvements in household diet. It is to this gap that the current paper contributes. In order

[10] It is noted that “the farm-level economic impact of a [50% reduction in livestock product consumption] will depend crucially on what replacement output is found for the land released and on market effects that are beyond the scope of this study” (Audsley et al (2011) p. 6).

[11] As Hess et al (2015, p. 7) note, “From this perspective, the impact of policies designed to promote healthier eating on global blue water scarcity may appear benign. However, the alternative dietary scenarios considered show differing regional impacts – with all but the most extreme dietary scenario producing increases in the potential contribution to domestic blue water scarcity (due largely to increased consumption of dairy products) and potentially large impacts on blue water scarcity in other countries associated with increased imports of irrigated fruit and vegetables from countries with an already high level of water stress (e.g. Spain, South Africa, Israel).”.

to capture the economic consequences, as well as the emissions consequences, of a dietary shift, we utilise Input-Output modelling.

The approach that we choose to employ, that of scenario analysis of a switch in consumer tastes away from red meat in an environmentally-augmented Input Output model, can be motivated by appealing to the conclusions from Garnett (2011). This finds that efficiency-focused technological measures in the food production system are not capable of reducing emissions to the degree required. Large emissions reductions require a shift in the pattern of consumption. We assume that a successful Government information campaign persuades the public of the health and environmental benefits and so results in a switch in consumption away from red meat (Joyce et al, 2014). In this paper we analyse the economic and emissions consequences of such a shift in consumption.

3. Data and methods

To undertake the empirical evaluation of the economic and emissions consequences of changes in Scottish diet, we use an Input-Output (IO) model, calibrated on IO accounts for Scotland in 2014. The meat production sector is separately identified, using a novel disaggregation of the agriculture sector as a whole, and the model is further extended to incorporate emissions. In principle, the modelling approach set out in this paper could be employed for any region or nation for which such data are available.

This section begins by describing the economic data that we use and the approach to disaggregation of the agriculture sector (Section 3.1). We then discuss the emissions data which form the basis for Scotland's territorial and footprint-based emissions (Section 3.2). The dietary change scenarios are then outlined (Section 3.3).

3.1 Economic data, including disaggregation of the Red Meat production sector

The Scottish Government produces Input-Output (IO) tables on an annual basis. These show the structure of production and consumption in the economy at a highly disaggregated level of industrial detail (see, for example, Miller and Blair, 2009). The columns of the IO tables show what each industry purchases from all other sectors in Scotland and imports for use in production, plus the wages, profits and taxes that these industries/sectors pay. The rows of the IO tables show the destination for output of each industry, either to other industries for use in production (i.e. as intermediate inputs to the production of other sectors' outputs), and sales by each industry to consumers, either domestic – e.g. households, governments – or to external markets (i.e. Scottish exports). In the published accounts the Scottish economy is disaggregated into 98 industrial sectors, and the characteristics of sectors in the economy, and links between industries can be observed directly from these tables.

The Scottish IO tables show that there are strong links among the industries which make up the Scottish Food & Drink sector. For example, "Meat Processing" purchases inputs from the "Agriculture" sector, which in turn purchases inputs from "Animal Feeds", which purchases inputs from "Agriculture" (such as plant foods), and so on. But there are also links between the industries that constitute the Food & Drink sector and those in the wider economy. For example, Restaurants purchase meat products from the Meat Processing sector, which sources inputs from meat production activities within the Agriculture sector.

Hence, this means that any reduction in consumer expenditure on the output of one industry – such as Meat Processing - will have spillover effects to the levels of activity in other industries from which the sector sources inputs, especially (but not limited to) the other industries that comprise the Food & Drink sector (e.g. Meat Production). In addition, those sectors providing inputs to the directly impacted sectors will reduce their demand for intermediate inputs, and so on (e.g. transport).

Given the differential carbon intensity of red meat consumption as compared to the carbon intensity of other foods, it is essential to disaggregate the agriculture sector in the IO table into "red meat" and "other agriculture" sub-sectors. Fortunately, Moxey (2016) has done much of the required work in a report for Quality Meat Scotland. Our research expands this disaggregation of the Agriculture sector to help distribute total "food and drink" carbon emissions between red meat consumption and other food and drink consumption[12].

Using an IO model calibrated on the (now 99 sector) IO table for the Scottish economy in 2014, we calculate a range of "multipliers" which demonstrate the interconnectedness between different sectors and the rest of the economy. These are reported in Table 1, where

[12] Full details are given in Appendix A.

we focus on key economic and environmental multipliers for the Primary sectors. GVA-output multipliers show the impact on Gross Value Added (GVA) across the whole economy of unit changes in the final demand for the output of each sector, while employment-output and CO2e-output multipliers show the impact of a unit change in final demand on employment and CO2e emissions respectively.

The most striking feature from Table 1 is that Meat production has a high carbon impact; indeed of all 99 sectors, it has the highest CO2e-output multiplier (of 4.781)[13]. Thus, an additional £1 million of final demand for the output of the Meat production sector increases total emissions across all sectors of the Scottish economy by 4.781 kTCO2e.

Table 1: Some sectoral Type 1 multipliers in the disaggregated IO tables for 2014, Scotland

Sector	*GVA-Output multiplier*	*Rank, n = 99*	*Employment-output multiplier*	*Rank, n = 99*	*CO2e-output multiplier*	*Rank, n = 99*
Meat production	0.626	58	22.366	15	4.781	1
Other agriculture	0.530	83	13.063	37	2.111	6
Fishing	0.653	54	15.153	30	0.285	34
Meat processing	0.464	92	12.928	39	1.438	8

[13] In all analysis, we use Type 1 multipliers (Miller and Blair, 2009).

Fish and fruit processing	0.466	91	10.279	60	0.374	27
Dairy products, oil and fats processing	0.469	89	10.452	58	1.179	10
Food and beverage services	0.695	42	24.670	10	0.212	43

Source: Authors' calculations.

3.2 Emissions data

The scale of carbon emissions at a regional level can be measured using two alternative perspectives: production-oriented territorial emissions and the consumption-oriented carbon footprint. Territorial emissions are those actually produced within a region and therefore include the emissions generated from the production of goods which are exported and consumed outside that region.

The carbon footprint conversely seeks to measure the emissions associated with all goods consumed by the residents of a territory, irrespective of where these goods are produced. Accordingly, emissions associated with goods and services imported into Scotland for consumption by Scottish residents are included in the footprint measure, while emissions associated with the production of Scottish exports are omitted[14].

Scotland's estimated carbon footprint, at 76.8MtCO_2e, is much higher than its territorial emissions of 49.5MtCO_2e (Scottish Government, 2017b). This reflects the facts that: Scotland imports more than it exports (both to/from the rest of the UK and international destinations), and that its imports are much more carbon intensive than its exports (as is normally the case for an advanced, service-sector dominated economy, like Scotland).

Table 2 shows how we reconcile Scotland's territorial emissions with its carbon footprint. In this calculation, we assume that Scotland's exports are as carbon intensive as its consumption from domestic production, and that economic activity in the rest of the UK has the same carbon intensity as Scotland.

Table 2: Scotland's Territorial Carbon Emissions and Carbon Footprint, 2014

	Values (£m)	Emissions (MtCO_2e)	
Gross Output	233,147	49.5	Territorial Emissions
rUK Intermediate Imports	29,297	11.9	
International Intermediate Imports	15,725	16.8	

[14] Scottish Government (2017c) provides an assessment of the carbon footprint of Government spending in Scotland, including emissions outside of Scotland in the production of goods and services imported to Scotland.

Less Total Intermediates	(102,591)		
Total Final Goods	175,577	78.3	
Exports	(70,926)	(17.1)	
rUK Final Good Imports	24,184	7.1	
International Final Good Imports	12,041	8.6	
National Income	140,876	76.8	Carbon Footprint

Source: Scottish Government (2017c) and authors' calculations.

Productive economic activity in Scotland (in combination with international aviation and shipping emissions and emissions from land use changes) is associated with Scottish territorial emissions of 49.5MtCO_2e. However, from a consumption-oriented perspective, this activity relies on imported intermediate goods, which also cause emissions in their production – although outwith Scotland - and these emissions must be added given their association with Scottish consumption. Furthermore, not all Scottish production is consumed in Scotland, and we subtract the emissions associated with Scotland's exports. Conversely, we must add in the emissions associated with final goods imports into Scotland in order to reach the Carbon Footprint total of 76.8MtCO_2e[15].

The territorial emissions, and the emissions associated with imported intermediate goods and services, can then be allocated to economic activity in specific sectors, while emissions

[15] This requires certain assumptions about the composition and carbon intensity of international trade. The assumptions made for this are detailed in Appendix B.

associated with final goods imports can be associated with consumer demand for specific goods.

3.3 Method, including scenarios

In this paper we are interested in the economic and emissions impacts of a change in consumer expenditures on Food & Drink, in line with healthy eating guidelines. We model this using the Input-Output framework extended to incorporate sectoral emissions. Here we describe two scenarios that represent the extremes of what households can do with the income that they now do not spend on food and drink: that is they either save all of this income (Scenario 1) or they spend all of it on other goods and services (Scenario 2). Both scenarios, however, feature the same reduction in expenditure on the output of the sectors providing food and drink to Scottish households.

We use the healthy eating guidelines described in Springmann et al (2016), which approximate to a 38.8% reduction in calories from red meat and a 2.7% reduction in calories from other foods and drinks[16]. Assuming that there is a one to one correspondence between expenditure and calories, the healthy eating scenario is assumed to involve a 38.8% reduction in household expenditure on the output from the "Red Meat" and "Meat Processing" industries (SIC2007 10.1), a 2.7% reduction in Scottish household expenditure upon the

[16] Overall, the healthy eating scenario considered here implies that calories should fall by 5.1% and that meat consumption should fall by 38.8%. Given an estimate of how many calories come from meat, this implies a non-meat calorie reduction of 2.7%.

output of all the other Food & Drink sector industries and a 1.4% reduction on spending on the “Food and beverages services” sector[17]. Lower calories therefore translate to lower spending, with demand for domestic products falling by £277 million, and a reduction in food and drink imports of £437 million. Thus, total spending is reduced by £713 million. Given the assumptions we have made on the composition of imports, roughly one-third of this fall in expenditure is on domestic Scottish production.

The two scenarios differ in terms of what these consumers are assumed do with the income they save from their reduction in food and drink expenditures. In Scenario 1 household expenditure on food and drink is reduced as described above and nothing else changes (i.e. the unspent income is saved). Accordingly, this scenario is associated with a reduction in total household expenditure.[18]

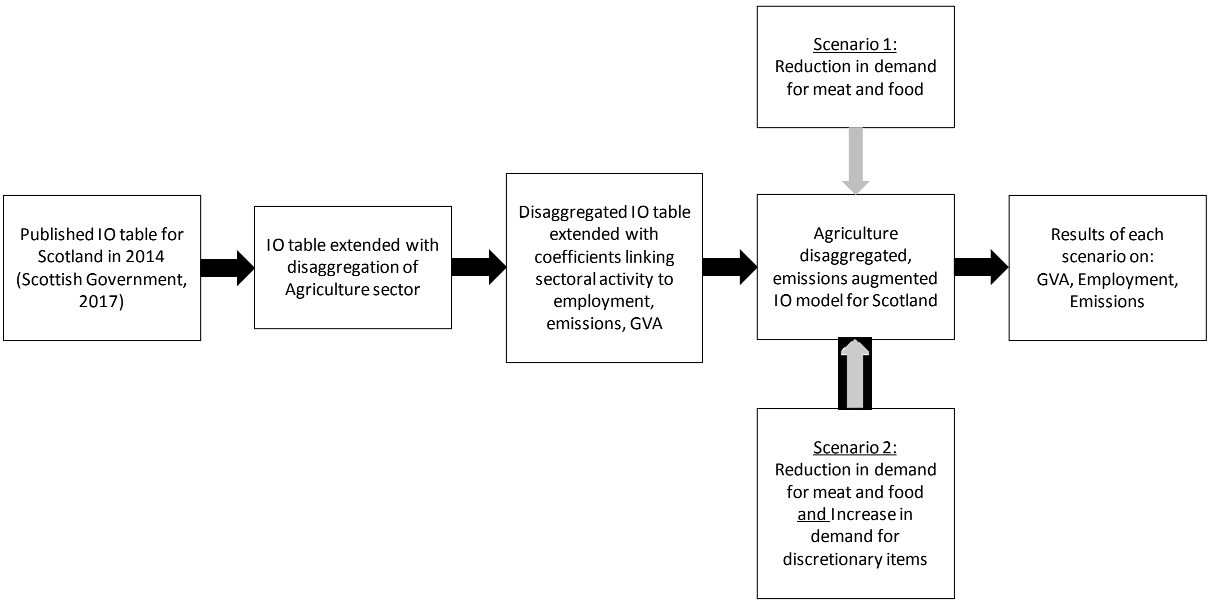
Scenario 2 assumes that household expenditure in total is unaltered, with the reduction in food and drink expenditure being accompanied by an increase in expenditure across all other (non-food[19]) discretionary goods (in proportion to current households’ expenditure on these items) including imports to Scotland. Discretionary goods are identified as all those goods in the economy other than public services, accommodation costs and legal and financial

[17] These are the nine sectors comprising SICs 10 and 11, specifically “Fish and Fruit processing”, “Dairy products”, “Grain milling”, “Bakery”, “Other food”, “Animal feeds”, “Spirits and Wines”, “Beer and Malt”, and “Soft Drinks”. The reduction in spending on the “Food and Beverages” sector is calculated from the 5.1% reduction in calories and information that around 27% of inputs to the Food and Beverages sector is from food and drink ingredients.
[18] In making this assumption, we are following the IO literature in assuming that only changes in demand produce economic impacts. There are therefore assumed to be no macroeconomic response to the additional savings thus generated. This is equivalent to households using additional savings to pay down debts, for instance.
[19] Spending on food and drink is reduced overall, so there is assumed to be no substitution towards alternative food items.

services. (So the assumption is that, just because food expenditure has gone down, this does not mean that, for example, rent or insurance costs have gone up, or that the government starts taxing households more in order to fund and spend more on public services). Figure 1 summarises our modelling approach under both scenarios.

As described earlier, we can use the IO modelling framework to identify the economic consequences of these implied changes in demand for the outputs of Scottish sectors, and our environmental extension permits the analysis of changes in Scotland's territorial emissions and carbon footprints.

Figure 1: Methodological approach in each scenario



Source: Authors elaboration

4. Results

4.1 System-wide impacts on the economy and emissions

Our headline economic and environmental results are set out in Table 3. Recall that in Scenario 1 the reduced expenditure associated with lower consumption of calories is not offset by any reallocation of expenditure to discretionary goods; rather, savings increase. We consequently expect the reduction in economic activity in this Scenario observed in the first main row of Table 3. In Scenario 2 there is a reallocation of spending away from food and drink consumption and towards a mixed basket of "discretionary" expenditures. The net effect of both the (reduced) demand for food and drink and (increased) discretionary expenditure is shown in the second row of Table 3.

Table 3: Changes in headline economic and emissions indicators (absolute values and % changes from base year).

	GVA		Employment (no. employees)		Income		Emissions: Territorial		Emissions: Footprint	
	(£m)	%	%		(£m)	%	($ktCO_2e$)	%	($ktCO_2e$)	%
Scenario 1	-156	-0.1%	-4,896	-0.2%	-83	-0.1%	-635	-1.1%	-2,880	-3.8%
Scenario 2	+189	+0.1%	+2,212	+0.1%	+115	+0.2%	-450	-0.8%	-2,522	-3.3%

Source: Authors calculations

Scenario 1

In Scenario 1, households reduce their spending on food and drink, and this leads to a reduction in GVA and employment associated with the food production and distribution sectors, and in the sectors that supply inputs to the food sectors through the “multiplier” process.

Looking at the whole economy, GVA falls by 0.1% (£156 million), employment falls by 0.1% (around 4,900 FTE jobs), and carbon emissions generated within the Scottish economy fall by 1.1% (slightly more than 0.6MtCO_2e). Exports are assumed to be unchanged, but various sectors of the Scottish economy now have reduced import demand (because of the reduced economic activity) and consumers have also reduced their expenditure on food imports.

The combination of these two effects improves Scotland’s trade balance by £552 million, and reduces the emissions generated outwith Scotland, but on behalf of Scottish residents, by 2.2MtCO_2e. The combination of reduced emissions within and outwith Scotland is to reduce Scotland’s carbon footprint by 3.8%.

Scenario 2

In Scenario 2, total household expenditure is unchanged, with the reduction in spending on food and drink offset exactly by an equivalent increase in discretionary household expenditures, defined above. At the aggregate level we can see the net economic and environmental impacts of this change in the sectoral distribution of spending: GVA rises by

£189 million (+0.1%) with employment also increasing, up by just over 2,200 FTE jobs. The trade balance improves with lower imports (down £193 million) and (assumed) unchanged exports. Of course, the net aggregate outcome of the reallocation of expenditures reflects the different characteristics of the impacted sectors: on average, discretionary household expenditures are more value-added and employment-intensive than e.g. expenditure on Meat Production.

Carbon emissions generated within the Scottish economy fall by 0.8% (around 0.45MtCO2e), and emissions generated outwith Scotland, but on behalf of Scottish consumers, are reduced by 2.1MtCO2e. Scotland's carbon footprint falls by slightly less than in Scenario 1, down by 3.3%.

This smaller reduction in both territorial and consumption-oriented emissions is partly explained by the stimulus to the economy under this Scenario and a commensurate increase in emissions from Scottish production. However, total carbon emissions still fall in this case, because spending (and therefore activity) has been reallocated from high emission sectors (including "Red meat production" etc.) to lower emission sectors.

4.2 Sectoral results

We highlight the sectoral results from both Scenarios by showing the sectors with the largest (in absolute terms) changes in GVA, employment and emissions in Figures 2 and 3 respectively. We can clearly see the "winners" and "losers" across the economy of this reallocation of household spending.

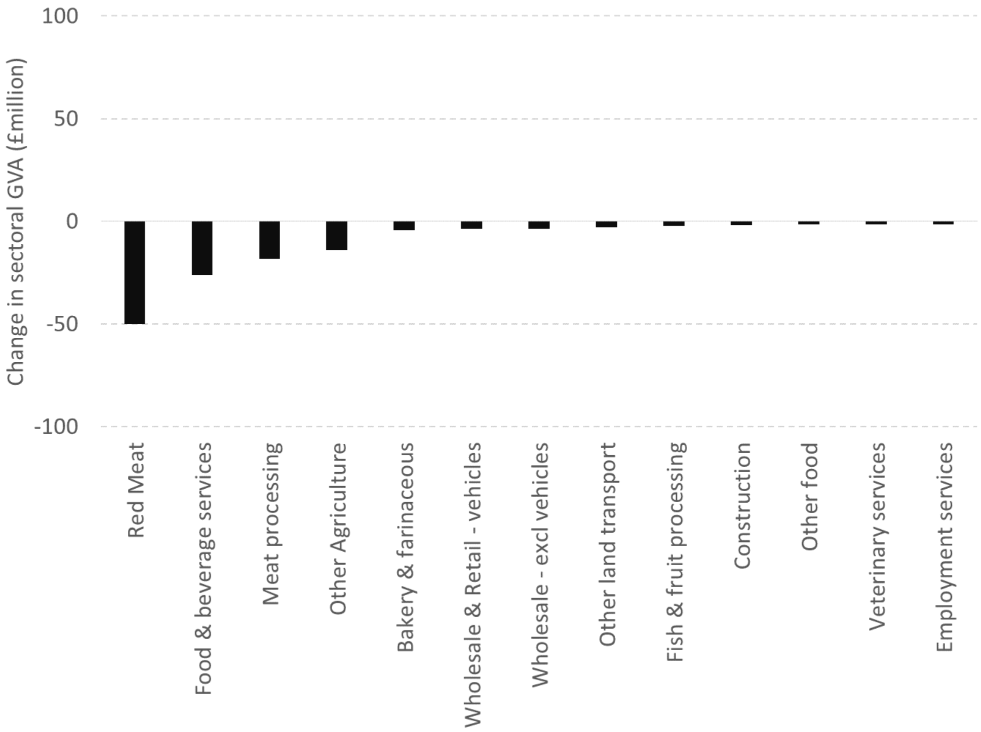
The largest absolute reductions in economic activity are seen in "Red meat production", which experiences reductions of approximately 2,150 jobs and £50million in GVA. This is similar in both Scenarios, as there is an assumed identical reduction in demand for the output of this sector in Scenarios 1 and 2 and in the latter none of the discretionary spending is allocated to this sector. Other notable reductions occur in the directly affected sectors of "Food and beverage services", "Meat processing" and "Other agriculture" and small reductions occur in those sectors with backward linkages to these sectors, including "Land transport" and "Veterinary services".

While in Scenario 1 all sectors are negatively impacted, in Scenario 2 positive changes are experienced by sectors benefitting from the increased demand for their outputs. In particular those sectors where a high portion of households' discretionary spending is concentrated benefit, notably the "Retail" sector - where employment and GVA increase by 2,600 FTE jobs and £97 million respectively – as well as in "Other personal services" and "Wholesale" sectors. There is similarly an increase (decrease) observed in emissions from those sectors seeing demand and therefore economic activity increasing (decreasing) in Scenario 2. Emissions rise in electricity in part through the need for electricity in the production of goods and services, and the overall emissions intensity of this activity[20].

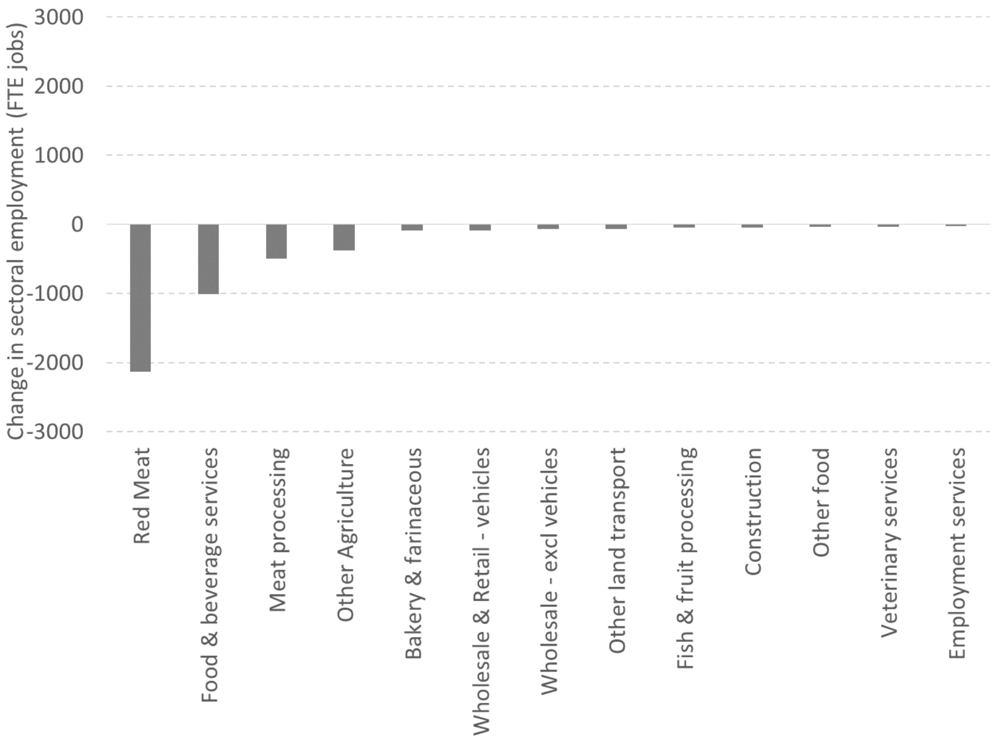
[20] Note that the carbon intensity of electricity generation in 2014 – and therefore used in this analysis - is higher than at time of writing (2018) with, for example, the final Scottish plant generating electricity from Coal closing in March of 2016. This would be reflected in increased emissions on a territorial basis. Any stimulus to economic activity in Scotland would also increase demand for inputs from outside Scotland, including in the rest of the UK, and any resulting emissions from that indirect and induced demand for products which take place outside of Scotland would be reflected in the footprint measure of emissions.

Figure 2: Scenario 1 - Changes in GVA, employment and CO2e emissions from base year, absolute change, £m, FTE jobs and tonnes CO2e, selected industries

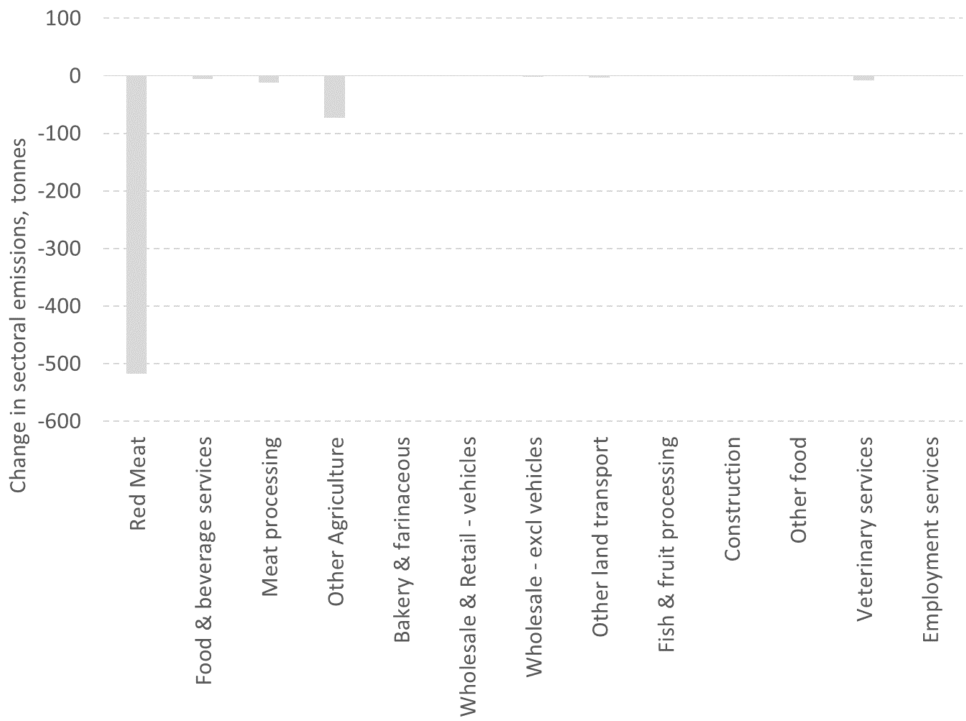
a) GVA



b) Employment



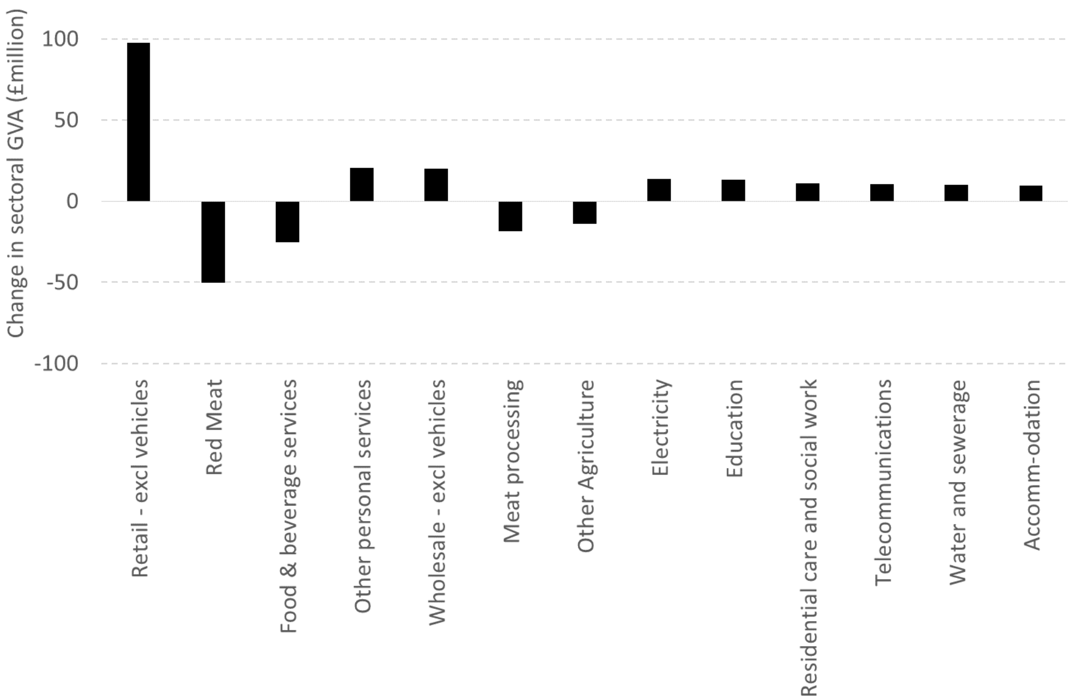
c) Emissions



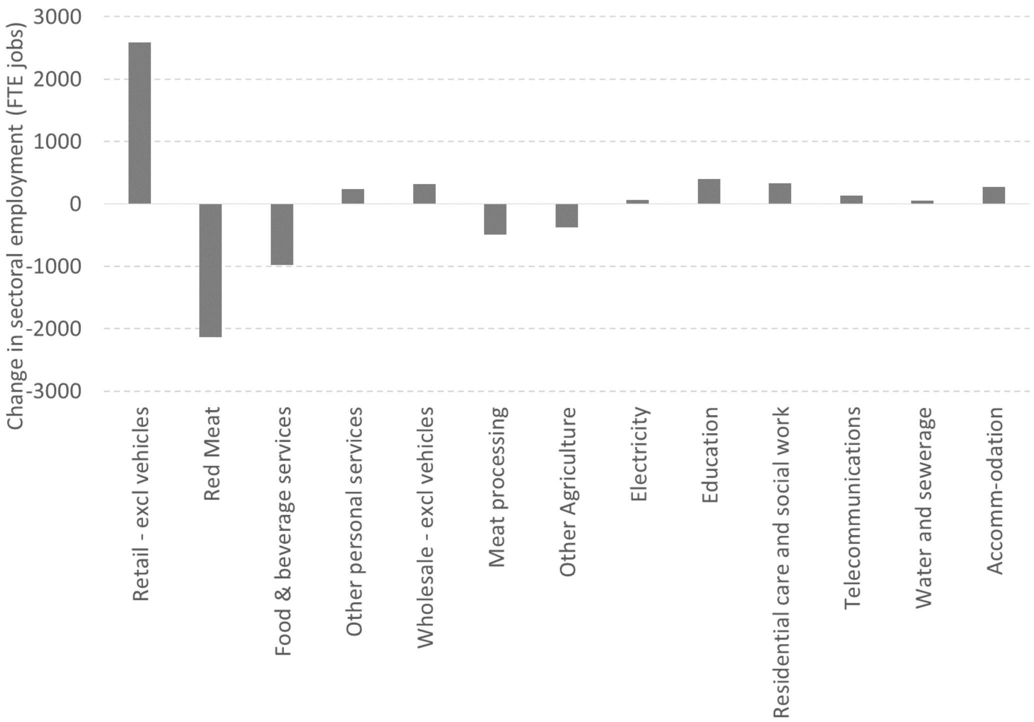
Source: Authors' calculation.

Figure 3: Scenario 2 - Changes in GVA, employment and emissions from base year, absolute change, £ m, FTE jobs and tonnes CO2e, selected industries

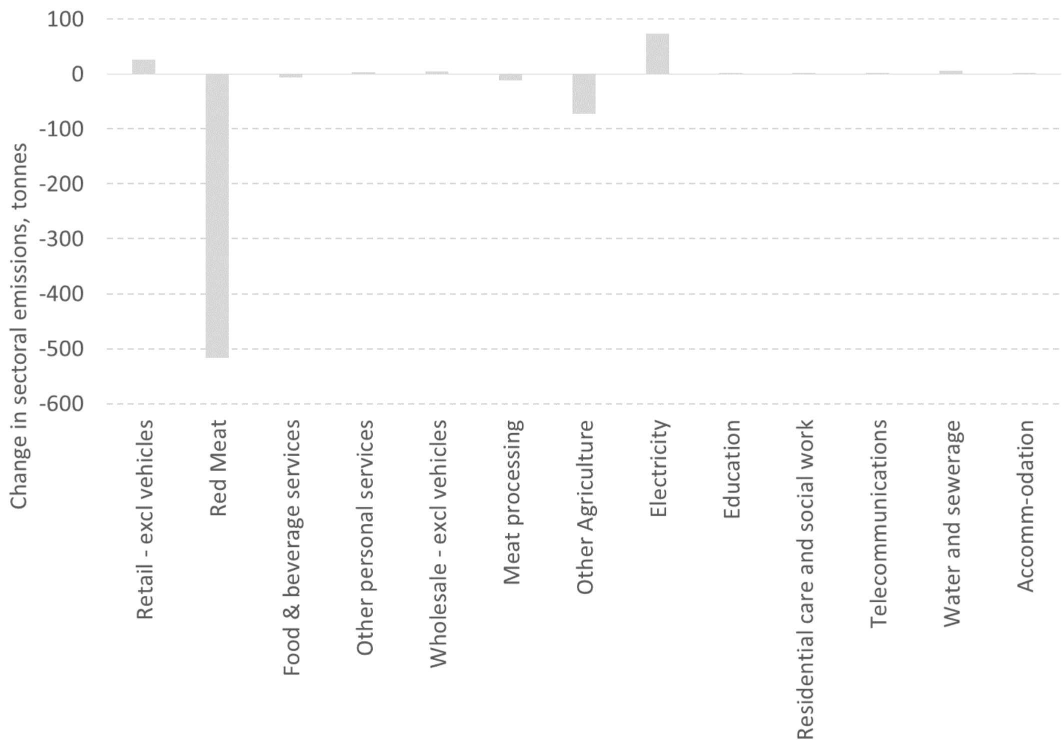
a) GVA



b) Employment



c) Emissions



Source: Authors' calculations.

5. *Discussion and Conclusions*

Our objective in this paper is to identify the system-wide economic and emissions consequences for Scotland of a switch away from red meat, in particular, to a healthier diet. We explore these issues using a purpose-built environmentally extended Input-Output (IO) model of Scotland that separately identifies the “red meat” sector and its linkages to the rest of the economy.

We use IO modelling, including a novel disaggregation of the Agriculture sector, to explore the economic and environmental consequences of a reduction in expenditure on calories by Scottish households in line with a healthier diet. Importantly, we capture the net impact in Scenario 2 by considering the role of “reallocation” of expenditure away from food and drink consumption and towards “discretionary” spending. Thus, a lower calorie diet does not necessarily mean reduced household spending, and our results confirm that – under one possible scenario – the reallocation of household spending can have a positive impact on economic activity while preserving the environmental benefits associated with a healthier diet.

In using an IO approach, we are able to capture intersectoral linkages as well as report activity and emissions changes at the sectoral level, reflecting differences in emissions at this detailed level. The approach shares common limitations with other IO studies in that it is assumed that sectors’ marginal changes in purchases reflect average levels of inputs in the base year (i.e.

that there are fixed "technical coefficients" in production), which is consistent with no changes in relative prices, such as would be the case with an entirely passive supply side of the economy. If prices were to change, then a Computable General Equilibrium (CGE) approach may be superior as sectors' input mixes adjust to price changes generated by the interaction of demand and a non-passive supply side. Further, our analysis assumes an exogenous change in demand due to a government information campaign, while future research could consider alternative mechanisms to generate the resulting changes in food consumption[21], such as taxation policies[22]. Among recent work on the consequences of environmental taxes linked to meat consumption, Säll (2018) suggests that meat taxes may be regressive – hitting lower income households more than those with higher incomes – and Dogbe and Gill (2018) who show that revenue neutral tax policies aimed at food products based on their emissions could improve environmental as well as dietary outcomes.

Our results are driven by the nature of both the disaggregated model used, and the assumptions around the construction of both scenarios. Further extensions to the methodological approach which should be considered in future research, relate to two elements of our modelling: the change in demand, and alternative patterns of re-spending. First, it may be the case that changes in the level of calories could be achieved through the reallocation of spending from meat to lower calorie alternatives. To be able to model this appropriately would require significantly greater detail on both domestic and imported food

[21] Apostolidis and McLeay (2016) find other factors, in addition to price, which appear to influence demand for meat substitutes and suggest actions, "including labelling, financial incentives, educational campaigns and new product development" (p. 74).
[22] Indeed, our Scenario 1 might be considered to reflect the outcome of such a taxation policy in which revenues are used by the Government to pay down debts and do not have further demand-side impacts on the economy.

products, and their (international) supply chains. The results of the analysis would depend on the precise nature of the shift towards a healthier diet. Such a change, of course, always results in a reduction in households spending on "unhealthy" goods and services. However, if households simply save that part of their income which was previously spent on red meat, total consumption expenditure falls. In this case our IO model identifies a contraction in aggregate economic activity, with falls in value-added and employment. The impact is concentrated in the red meat and related sectors. However, there is also a significant drop in CO2 emissions.

Second, our Scenario 2 assumes that money saved on food products is spent on "discretionary" items. However there is currently limited available evidence on the extent of this switching of expenditure. The (positive) economic impact of re-spending in Scenario 2 dominates the negative impact of the reduction in spending on meat and food and drink, but the precise nature of re-spending determines whether an economic and environmental "double-dividend" is likely, and so should be the focus of further study.

From a policy perspective, the results of Scenario 1 are mixed. First, emissions fall, contributing to the achievement of a key environmental goal of policy, namely emissions targets. Furthermore, not only do territorial emissions fall, but so too does the Scottish carbon footprint, so that territorial emissions are not improving by effectively redistributing emissions to trading partners; an important outcome given that the ultimate objective of climate policy is to reduce global emissions. Second, economic activity however contracts due to the reduction in consumption expenditure. It seems the shift to a healthier diet, while unambiguously benefiting the environment and population health, may – in the absence of re-spending of saved income - be bad news for another key policy goal, economic growth.

However, this result is not general, and is, at least in part, a feature of the assumptions underlying the first scenario. In particular, it seems more likely that households who decide to shift to a healthier diet would choose simply to reallocate their spending, rather than reduce it overall. In this case the income not spent on red meat would instead be spent on other discretionary goods and services. In this case there are clearly countervailing effects on the economy: the contractionary impact of reduced spending on red meat and the expansionary effects of reallocating this spending to other goods and services. The net economic and environmental effects are not known *ex ante*, and this motivates Scenario 2.

In this alternative scenario we find that, for the Scottish case, the reallocation of spending actually stimulates aggregate economic activity slightly (indicating that the expanding sectors are more value-added and employment-intensive than the contracting sectors, including "Meat Production"). Emissions still fall – according to both production and consumption-oriented measures, but by less than in the first scenario because of the stimulus to economic activity that occurs in this case[23].

[23] Others have analysed the emissions impacts following energy efficiency policies targeted at households, including Chitnis et al (2014) and Grabs (2014). These papers offer a sophisticated framework for considering how cost savings from energy efficiency measures translate to expenditure on different items, and the resulting "rebound" effects on emissions – where emissions are reduced by less than would be anticipated without acknowledging the feedback between energy efficiency and additional households' incomes. As such policies targeted at households will change households incomes as well as prices of goods and services, a computable general equilibrium analysis may be particularly useful (e.g. Figus et al, 2017). We are grateful to an anonymous referee for this comment.

The results of both Scenarios reinforce the widespread finding of existing literature (e.g. Stehfest, 2009; Springman et al, 2016; MCarthly et al, 2018) that a shift to a healthy diet, away from red meat, improves emissions as well as health outcomes, and so generates a policy "double dividend". However, our analysis extends the existing literature to allow an analysis of the likely economic impact of a shift to healthier eating. On plausible assumptions we find that a "triple dividend" is possible, with the improvement in healthy eating also stimulating the economy. However, this result is not inevitable and depends on what consumers choose to do with any income saved as a consequence of reduced consumption of red meat.

So a shift to a healthier diet can simultaneously: stimulate economic activity, and reduce emissions. Although we do not seek to model the effects here, we know that a shift to a more healthy diet can have substantial health benefits for the individual (and reduced costs to society). A move towards a healthier diet therefore represents a potential "triple dividend" from a policy perspective in that three key objectives of policy are favourably impacted. Furthermore, our IO framework can only identify the expenditure effects of switching to a healthier diet: many of the health benefits would be expected to stimulate the supply side of the economy e.g. increase in labour supply (through greater longevity) and productivity (through reduced absenteeism and presenteeism). Future research should systematically explore the impact of these potential supply side impacts, and could usefully draw from studies using CGE models, in which the supply side of the economy is explicitly modelled. Furthermore, in comparing the static scenarios in which spending is adjusted, we do not attempt to predict the dynamic impacts of changes to meat and food consumption. This could also be considered in future research, most naturally in the context of an energy-economy-environment Computable General Equilibrium (CGE) model.

What are the implications for policy? First, and most importantly, our analysis suggests that policies that successfully induce a shift in consumption away from unhealthy diets are likely to improve health, emissions and, probably, the economy (though the latter depends, in general on the structure of the target economy since this impact is the net effect of countervailing forces). This suggests the desirability of pursuing such policies. However, our analysis simply analyses the impact of an exogenous shift towards a healthier diet.

How might government induce such a change in behaviour? Government-sponsored information campaigns and moral suasion are one such policy instrument that may induce a shift in tastes towards healthy eating. Health-oriented taxation policies are another, but proper analysis of this would necessitate a framework that can handle impacts on relative prices. Future research should examine such policies explicitly. Futhermore, these policies should be explored in a framework where the supply side impacts of improved health on the economy and health-motivated taxation impacts, including the use of recycled tax revenues, can be explicitly addressed.

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Appendix A: Disaggregation

The Agriculture sector comprises many heterogeneous activities: types of farming, quality of land, etc.; the detail of which is lost when considering agriculture as a single sector. Further, in terms of climate change policy, both the emissions intensity and the putative policy instruments vary by farm type. In particular, red meat production has a higher emissions contribution per calorie produced than the production of other food, and as a result, we disaggregate the Agriculture sector in the IO accounts to separately identify the red meat and non-red meat sub-sectors. A more complete disaggregation may be desirable for other applications, but is in no way precluded by starting with a simple 'Red Meat–Non-red Meat' disaggregation.

Moxey (2016) provides a starting point for disaggregating the Agriculture sector into Red Meat and Non-red Meat. This work draws upon the June 2016 Agricultural Census, the Farm Accounts Survey, and Input-Output tables, as well as data from the Quality Meat Scotland (QMS) trade association who commissioned that report.

Red Meat purchase shares from other sectors (as a share of the (IO table) Agriculture sector purchases from other sectors) is based on figures from Table C5 of Moxey (2016). This table reports the estimated GVA "beyond farmgate arising from suppliers" to the Agriculture sector as a whole, and to Red Meat farms. Allocating Agriculture purchases (i.e. the Agriculture column in the IO table) to Red meat/Non-red Meat, based on these GVA figures is therefore akin to assuming that each sector supplies a homogenous good to both Red Meat and Non-red Meat sectors. The level of purchases from each sector by each of these two sub-sectors would therefore be linearly related to the GVA arising.

Then we need to make an assumption about how to divide Agriculture's spending on Agriculture output into Red Meat and Other Agriculture. The assumption used is to assume that the red meat sector sells its output to red meat and to other agriculture in same proportions as Meat Processing does. Other agriculture then sells the balance to red meat and other agriculture in the same proportions as agriculture sells to meat processing and agriculture.

Tables B3 & B5 of Moxey (2016) allows us to split the total intermediate input purchases, subsidies (assuming that subsidies can be divided into "on products" or "on production" using the Agriculture sector proportions for both red meat and for other agriculture), GVA, and gross output of the Agriculture sector into Red Meat/Non-red Meat. This allows us to infer the split of imports by these sectors. Further, we assume a common wage rate across Agriculture, using Table D3 of QMS to divide employment numbers, and so split wages. The profit split is then a balancing item.

The Red Meat sector is assumed to sell the same proportion of its gross output to domestic final consumers and to other sectors as Meat Processing does, with the exception of what we label as "high red meat input sectors": Meat Processing, Dairy Products Oils & Fats, and Food & Beveridge Services. For these, we assume 80% of Agriculture's sales to Meat Processing were actually from Red Meat, and for the other two sectors we split Agriculture's sales by the Red Meat-Other Agriculture gross output shares.

Tables B3 & B5 of Moxey (2016) gives us to the capital consumption for Agriculture and for Red Meat. We use this to split Agriculture sales to Gross Fixed Capital Formation, Valuables, and Change in inventories, into sales from Red Meat and from Other Agriculture. Export sales are then the balancing item of final demand (we use the Agriculture split between Non-resident households, Rest of UK exports, and Rest of world exports).

Appendix B: Assumptions

Certain assumptions have to be made to close the model that we use. In particular around the composition and carbon intensity of international trade. We use the UK Input-Output table which, as well as a domestic product by product table, which also includes the sectoral composition of international imports. The basic assumptions that are then made are that:

- Scottish imports from the rest of the UK have a sectoral composition that looks like UK domestic consumption.
- Scottish imports from the rest of the world have a sectoral composition that looks like UK international imports.
- Agriculture in the UK domestic table has been disaggregated using proportions from the Scottish disaggregation, except that share of sales from Red Meat are multiplied by a factor of 0.76.
- Agriculture in the UK international imports table has been disaggregated using proportions from the Scottish disaggregation, except that share of sales from Red Meat are multiplied by a factor of 3.70.
- The multipliers, 0.76 and 3.70, have been calibrated so that UK meat consumption is composed of 45% from international imports (see International Meat Trade Association, 2016) and so that Scottish Red Meat production is 18.3% of UK Red Meat production (figures from p18 of QMS (2018) applied to Scottish and UK agricultural output).

- We have CO2e/Output sectoral coefficients at the UK level. We assume that the Scottish sectoral coefficients are as the UK coefficients except in specific cases of agriculture (including red meat) and energy, for which we use Scottish specific data. We then require a multiplier of 1.06 applied to all the sectoral coefficients in order for the implied Scottish territorial emissions calculated within our model to reconcile with the Scottish Government figure.

- Finally, the sectoral carbon intensity of international imports are as the UK intensity multiplied by a factor of 2.78, calibrated so that the implied Scottish carbon footprint calculated within our model reconciles with the Scottish Government figure.