ABSTRACT

Title: Environmental and economic impacts of Brexit in the consumption of vegetables and fruits in the UK

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S.14 Modelos input-output y de equilibrio general para el análisis de la sostenibilidad medioambiental de las regiones

Abstract: *(minimum 300 words)*

Brexit, particularly depending on its final version, is bound to have important effects on trade as well as on other socio-economic and environmental issues. Trying to give an assessment on these questions, we apply a multi-regional input-output model, extended with international trade data, to evaluate the economic and environmental impacts from Brexit in terms of consumption of fruits and vegetables in the UK. To this aim, we followed the methodology already applied to Spanish fresh produce consumption developed in Tobarra et al. (2018). Detailed trade data from customs (HM Revenue & Customs database) allow us to include an accurate demand vector for the current situation and future potential scenarios.

Certainly, a no-deal Brexit will reduce the availability of fruits and vegetables imported into the UK from EU countries and different regions of the world economy. Therefore, this reduction will generate a substitution effect, being these goods potentially replaced either by domestic production or by imports from other regions. Among other effects, this change in trade patterns, would affect where the production is located, and consequently where the jobs are created and how much resources are needed in the process. Additionally, as a by-product, this would imply also a change in the levels of CO_2. In this paper, we calculate the footprint balance linked to these import changes as the difference between the footprint from imported fruits and vegetables from the EU and the footprint using a substitute origin (UK or third countries/regions). A positive sign in that avoided footprint balance would indicate a positive result, since the trade substitution outcome is linked with a lower footprint. On the contrary, a negative sign would be linked to a negative impact (increasing the footprint) caused by the trade diversion.

A second objective in our paper is to analyse economic vs. environmental impacts from the potential Brexit trade substitution effect. In other words, we aim to identify the potential synergies or trade-offs between the economic and environmental results. These include carbon and water footprints for assessing environmental impacts and employment footprint for economic effects.

Keywords: *(maximum 6 words)* Multiregional input-output models, Environmental footprints, Brexit, trade patterns

JEL codes: C67, F18, Q56

1. Introduction

The trade disruption that Brexit may engender in the economic activity of the United Kingdom will likely lead to important effects in the production and consumption of agricultural products (Hubbard et al., 2018). Among others, the causes that may explain this disruption can be found in the funding support to farmers from the Common Agricultural Policy (CAP)[1], in the tariffs to agricultural products (11% in average) and the important international dependence of this sector in the United Kingdom, which imports around 70% of their consumption (DEFRA, 2018). Given this situation, the *British Retail Consortium* sent a letter to the European Parliament in January 2019 warning that, due to the complex value chain in the food industry, the availability to fruits and vegetables will be heavily disrupted in the extreme case of a no-deal Brexit (https://brc.org.uk/brexit-campaign).

The Brexit impact will vary across sectors and be largely dependent on whether the UK is a net importer or net exporter of the relevant commodity. Among the agricultural products, the consumption of fresh fruit and vegetables is the most affected by Brexit, due to their high dependence to European imports. In the case of fruits, European imports reach values of around 50% in the case of EU oranges and 56% in the case of EU apples imports. Among vegetables, values of around 88% can be found in the EU imports of tomatoes and around 80% in the case of EU imports of other vegetables (such us onions, garlic or lettuce). Brexit will cause a reduction in the availability of fruits and vegetables in the UK at different points in the year due to seasonality and, together with a reversion to WTO tariffs, would lead to a significant increase in food prices. Poorer households and the restaurant industry are among the consumers that are going to be most affected as they spend a higher proportion of their consumption in

[1] The current annual payments to farmers (totalling £2.5bn per year to the UK) are the remnants of the protectionist CAP. A further £0.8bn per year is spent in the UK under the CAP for environmental conservation and rural development schemes. These payments (£3.3bn per year) form the major part (90%) of the financial benefit to the UK of EU membership, offset by the UK's contribution to the rest of EU spending (Hubbard et al., 2018).

food. This scenario is similar to other situations in the past when the reductions were caused by extreme weather conditions in the countries of origin (Spain in 2017). However, in this case these trade-substitution effects will also be affected by changes in the exchange rate, possible labour market changes and other non-tariff barriers.

In order to overcome this trade disruption, UK consumers potentially will have to adjust the situation by substituting imported fresh fruits and vegetables with different fruits and vegetables produced locally in the United Kingdom; with other similar fruits and vegetables produced outside the European Union; or by increasing the consumption of other different types of food such as augmenting the consumption of fish, meat or processed food over fresh foods and vegetables. The aim of this paper is to evaluate the environmental as well as socio-economic effects of these potential substitution effects in the consumption patterns of fruits and vegetables in the agricultural sector of the United Kingdom due to Brexit related effects. The analysis will document these effects in terms of the changes in the carbon, water and labor footprint.

Given the importance of the agriculture sector in the United Kingdom in terms of land use (70%), water consumption and emissions, our analysis is important because these substitution effects will potentially have important long-term effects in the environment as well as the quality of life and heath perspectives of the UK citizens (Springmann and Freund, 2018). These potential negative consequences of the Brexit consumption substitution effects are linked with the consensus in the literature that it is advisable to follow a low calorie diet with higher proportion of fruits, vegetables and dry fruits over meats and fats associated with longer life expectancy and a reduction of greenhouse gases (Tilman and Clark, 2014; Springmann et al., 2016).

This analysis uses as a reference framework the environmental extension of the multiregional input-output (MRIO) model. In particular, the methodology for the calculation of the footprint becomes useful to draw out the impact that the changes in the household consumption can have over all of the global value chain. This methodology has also been used to evaluate how these decisions may affect the diet (Behrens et al., 2017), population ageing (Shigetomi et al., 2014), income distribution (López et al., 2016) or the effect on poverty (Hubacek et al., 2017), etc.

In the case of trade substitution-effect analyses, the methodology that has been more commonly used is regarding the *balance of avoided footprints* (Dietzenbacher and Mukhopadhyay, 2007; López et al., 2013; Tan et al., 2013; Arto et al., 2014; Liu et al., 2016a; Lopez et al., 2017). Among them, Tobarra et al. (2018) focuses its attention to the consumption of fruits and vegetables. In this methodology, the sign of balance of the Balance of Avoided Footprints indicates if the effect in the environment, which is associated to a substitution of imported goods by domestic goods, is beneficial (balance is negative) or detrimental (balance is positive). The sign of the effect is not directly linked to the volume of trade, but is linked to the resource intensity and pollution in the countries of origin. This balance can be used to evaluate the impact of any other factor such as physical resources (water, energy, land or materials), social impacts (labor, work accidents – employment injuries, etc.) or waste generation (greenhouse emissions, nitrogen, etc.) or other environmental damages (reduction in the biodiversity).

The impact of Brexit in the agriculture sector

Few analyses have been published on the impact of Brexit on the agricultural sectors. Chen et al. (2018) employ an extension of the World Input-Output Database (WIOD) with regional detail for EU countries to study the degree to which EU regions and countries are exposed to negative trade-related consequences of Brexit. They develop an index of this exposure, which incorporates all effects due to geographically fragmented production processes within the UK, the EU and beyond. The results for the primary industry vary across regions, with UK regional shares of local GDP exposed to Brexit from 13 to 34%.

Los et al. (2017) computes the industry’s exposure to Brexit using the 2016-release of WIOD. The estimates indicate how much the industry has to restructure its supply chains and employees to mitigate against the losses caused by reduced post-Brexit trade and movement with the EU. The results show that crop and animal production industries present exposure levels of the 12% of value added at risk.

Hubbard et al. (2018) estimate the potential effects of UK agricultural and trade policy scenarios following Brexit. This article reports preliminary results from employing a Computable General Equilibrium Model, a Partial Equilibrium Model and Farm Level Models to explore selected trade and domestic policy scenarios post-Brexit. Their preliminary results show that Brexit would have significant implications for UK agriculture, a sector with strong trade links to the EU and reliance on CAP income support. Trade scenario effects depend on the net trade position, and/or world prices. Under a Free Trade Agreement (FTA) with the EU, agricultural impacts are relatively modest. By contrast, unilateral removal of import tariffs (UTL) has significant negative impacts on prices, production and incomes. Adoption of the EU's WTO tariff schedule for all imports (including from the EU) favours some net importer sectors (e.g. dairy) and harms exporter sectors (e.g. sheep). These trade effects, however, might be overshadowed by the exchange rate and possible labour market changes and other non-tariff barriers (not addressed in this article).

The fruit and vegetable trade market

According to the data of the 2017 UK Supply and Use Tables (SUTs) provided by the ONS, the production of "Processed and preserved fish, crustaceans, molluscs, fruit and vegetables" (the most disaggregated product classification that includes fruits and vegetables available in the UK I-O framework) is quite dependent from the foreign countries. This product appears in the top 25 out of 105 of the ones where imports represent a higher part of the total supply, with 40.49% of the production coming from abroad. From the demand side, fruits and vegetables are basically consumed by households (90.12% of the final demand) and just a small part of it is exported outside the UK (9.84%).

Among households, the ones that spend more in fresh fruits and vegetables are the richest ones with 6.4£ and 6.9£ per week in average (see Table 1), respectively. Based on data from Living Costs and Food Survey, in relative terms, it represents a largest part of the budget of the low-income households (2.90% of their total expenditure) while it just represents the 1.88% of the high-income households, as expected from a basic product. The difference between the share for fruits and vegetables of the low and high-income households is larger in the case of Potatoes, and other tubers, but in general, for the poorest households fruits and vegetables means 20% more in their budgets than the average UK household, while for the richest ones it means 22% less than the average. Therefore, any changes in the price of these products would affect to a greater extent to the poorest households reducing their disposable budget and consequently their welfare too, since the demand of these products is quite inelastic.

Table 1. Average weekly household expenditure (£) in fruits and vegetables (F&V) in 2017

Code	Product	Low dec	2nd dec	3rd dec	4th dec	5th dec	6th dec	7th dec	8th dec	9th dec	Highdec	All HHs
1.1.19	Fresh fruit	1.6	2.2	2.8	3.0	3.7	3.9	4.4	4.7	5.6	6.4	3.8
1.1.20	Other fresh, chilled or frozen fruits	0.2	0.2	0.3	0.5	0.5	0.4	0.5	0.5	0.6	0.7	0.5
1.1.21	Dried fruit and nuts	0.4	0.4	0.5	0.6	0.7	0.9	0.9	1.2	1.3	1.5	0.8
1.1.22	Preserved fruit and fruit based products	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.1
1.1.23	Fresh vegetables	1.7	2.2	2.7	3.3	3.9	4.1	5.0	5.2	6.3	6.9	4.1
1.1.24	Dried vegetables	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1
1.1.25	Other preserved or processed vegetables	0.7	0.8	1.1	1.4	1.3	1.6	1.7	2.1	2.3	2.4	1.5
1.1.26	Potatoes	0.4	0.6	0.7	0.8	0.8	0.8	0.8	0.9	1.0	0.9	0.8
1.1.27	Other tubers and products of tuber vegetables	0.9	1.2	1.2	1.5	1.7	1.8	1.6	1.9	2.1	1.9	1.6
	Total expenditure (all categories)	207	265	337	424	506	553	611	702	820	1117	554
	Percentage of F&V over total expenditure (%)	2.90	2.91	2.79	2.66	2.55	2.49	2.46	2.39	2.38	1.88	2.40

As can be seen in Table 2, if we compare the UK imports and exports of fresh fruits and vegetables, it has a clear trade deficit in general. By products, this negative trade balance result holds for all except for the case of the Potatoes, where the UK actually export more than what it imports. It is worth mentioning the important value of imported Tomatoes, Other Vegetables, Oranges, Apples and Other fruits from the European Community countries; Edible Nuts from Asia; Bananas and Other fruit from Latin America and the Caribbean; Leguminous and Edible nuts from North America; and Grapes and Other fruits from Sub-Saharan Africa. By regions, 51.7% of the imports come from the European Community countries, which anticipates large effects related to changes in the patterns of trade due to Brexit.

Table 2. UK Imports and Exports of fresh fruits and vegetables in 2017 (Millions of £)

		Imports								Exports	
Code	**Commodity**	**EC**	**Asia and Oc.**	**E Europe**	**Latin Amer.**	**Mid. E and N Afri.**	**N Amer.**	**Sub-Sah. Afri.**	**W Europe exc EC**	**Total**	**Diff (M – E)**
0.54.1	Potatoes	55.2	0.0	0.0	0.0	22.1	0.0	0.0	0.0	95.0	-17.6
0.54.2	Leguminous vegetables	24.2	44.2	5.5	6.8	4.1	84.8	5.8	10.7	81.4	104.8
0.54.4	Tomatoes	435.8	0.4	0.0	0.0	55.9	0.0	1.2	0.6	7.6	486.3
0.54.5	Other vegetables	1348.3	44.5	1.3	79.9	50.8	35.6	135.7	3.1	95.5	1603.7
0.57.1	Oranges	214.7	1.1	0.0	49.1	69.1	1.7	113.9	3.0	16.2	436.4
0.57.2	Other citrus	88.0	2.2	0.0	23.7	5.9	11.3	33.1	2.7	6.1	160.7
0.57.3	Bananas	26.3	1.7	0.0	501.8	0.0	5.5	92.2	0.0	40.9	586.7
0.57.4	Apples	203.0	54.0	0.2	35.3	0.0	2.5	63.9	0.0	13.9	344.9
0.57.5	Grapes	194.9	23.4	0.0	115.5	41.1	29.7	155.2	95.5	16.2	639.1
0.57.6	Figs	6.2	0.2	0.0	1.4	1.5	0.1	1.8	12.0	1.1	22.1
0.57.7	Edible nuts	149.8	193.8	4.8	38.2	1.0	143.6	11.5	9.2	62.6	489.5
0.57.9	Other fruit	930.1	44.4	2.3	483.8	94.6	55.3	183.4	29.8	74.4	1749.4
	Total	**3676.7**	**409.9**	**14.0**	**1335.5**	**346.3**	**370.0**	**797.7**	**166.7**	**510.9**	**6605.9**

The rest of the paper is structured as follows. The next section highlights the methodology and databases used in the analysis including the balanced of avoided footprint methodology by imports. The following section discussed the main findings of our analysis. The final section offers some concluding remarks.

2. Methodology and databases

Balance of avoided footprint by imports

The literature of the balance of avoided emissions was be used to evaluate the positive or negative impact of international trade in the evolution of global carbon emissions: (Arto et al., 2014; Dietzenbacher and Mukhopadhyay, 2007; Liu et al., 2016a; Liu et al., 2016b; López et al., 2013; Tan et al., 2013; Zhang, 2012). In this research line, (Tobarra et al., 2018) developed the seasonal avoided footprint by imports to evaluate the impact of the substitution fruit and vegetables imported of Spain for products produce local and seasonal. In this research, we adapt this balance to evaluate the environmental impact of Brexit in the trade fresh vegetables and fruits of UK.

The balance of avoided footprint by imports (*BAFM)* is defined by the difference between embodied footprint in fruits and vegetables from imports for region *r*, UK, minus domestic avoided footprint for this region *r*, UE countries. This domestic avoided footprint measure the footprint required to domestically/locally produce the alternatives fresh vegetables and fruits necessary to substitute the imports make by this region.

Under a multiregional input-output model with three different regions (*r*, *s*, *n*), the balance of avoided footprint by imports for region *r* due to its trade products with region *s* is shown by equation (1):

$$BAFM^{rs} = \begin{pmatrix} f^r & 0 & 0 \\ 0 & f^s & 0 \\ 0 & 0 & f^n \end{pmatrix} \begin{pmatrix} L^{rr} & L^{rs} & L^{rn} \\ L^{sr} & L^{ss} & L^{sn} \\ L^{nr} & L^{ns} & L^{nn} \end{pmatrix} \left[\begin{pmatrix} 0 & 0 & 0 \\ y^{sr} & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} - \begin{pmatrix} 0 & y^{*sr} & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \right]$$

$$BAFM^{rs} = \hat{f}[I - A]^{-1}\hat{y}^{sr} - \hat{f}[I - A]^{-1}\hat{y}^{*sr} \qquad (1)$$

where $\hat{f}$ is the diagonal matrix of environmental factor coefficients, A is defined as the matrix of input coefficients, I is the identity matrix and $L = (I - A)^{-1}$ the Leontief inverse. While $\hat{y}^{sr}$ is the diagonalized vector of exports imports by *r* from *s*, the vector $\hat{y}^{*sr}$ is defined as a diagonalized vector of domestic avoided imports and includes the imported agricultural products from *s* that can be substituted by the alternative domestic products generate in *r* economy. A positive sign of *BAFM* will indicate that imported fruits and vegetables generate more footprint use than produce domestically its products and that therefore trade is environmentally harmful. Then, the substitution of imported fruits and vegetables by domestic production generate a better environmental result. Otherwise, a negative sign of *BAFM* will imply that importing those products is better for the environment as the footprint embodied are lower than those that would result from producing domestically. In this case, the substitution of imported fruits and vegetables by domestic production is environmentally harmful.

A relevant advantage for BAFM compared to other emission balances is that the first allows us to evaluate trade effects on the environment, as it depends on differences in intensity in global pollution or in terms of footprint among the trading partners. Unlike the emission balances for a country, that depends both on emission intensity and volume of trade, the BAFM does not depend on the amount of trade as we assume that imports are substituting for the same volume of local production. The *BAFM* can be calculated by any factor content (emissions, water, materials, energy, employment, etc.) and although it is possible evaluate the terms of prices, kg or calories, we evaluate the substitution in value terms because this assumption ensuring that consumers spend the same amount of income on domestic and imported products.

Balance of avoided footprint by diversion of imports

Insofar as Brexit may hamper British imports from the EU, a trade diversion to non-EU countries could result. In this case, the expression $BAFDM^{rn}$ would then quantify the balance of avoided footprint by diversion of imports. In particular, it measures the footprint impact that would take place if imports by country *r*, the UK in this case, from region *s*, the EU, are now provided by region *n*, non-EU countries.

$$BAFDM^{rn} = \begin{pmatrix} f^r & 0 & 0 \\ 0 & f^s & 0 \\ 0 & 0 & f^n \end{pmatrix} \begin{pmatrix} L^{rr} & L^{rs} & L^{rn} \\ L^{sr} & L^{ss} & L^{sn} \\ L^{nr} & L^{ns} & L^{nn} \end{pmatrix} \left[\begin{pmatrix} 0 & 0 & 0 \\ y^{sr} & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} - \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ y^{*sr} & 0 & 0 \end{pmatrix} \right]$$

$$BAFDM^{rs} = \hat{f}[I-A]^{-1}\hat{y}^{sr} - \hat{f}[I-A]^{-1}\hat{y}_D^{*sr} \qquad (2)$$

Where $\hat{y}_D^{*sn}$ is a diagonalized vector of domestic avoided imports and includes the imported agricultural products from *s* that can be substituted by the same fresh fruits and vegetables imported form region *n*. In order to obtain that vector we assume that imports from the EU for each product are allocated to non-EU countries proportionally to the weight of each country on total imports. A negative balance would imply that the trade diversion is environmentally harmful, as imports from region *n* show a higher footprint than imports from *r*. Conversely, a positive balance would be environmentally beneficial as it implies than imports from country/region *r* are more footprint intensive than new imports from region *n*.

Databases

We have used the extended environmentally multi-regional input-output (EE-MRIO) provided by EXIOBASE version 2.2. for the year 2007 (Exiobase Consortium, 2015; Tukker et al., 2013; Tukker and Dietzenbacher, 2013; Wood et al., 2015), provided for 163 industries and 48 countries and regions. For the satellite accounts of carbon, we used CO_2e emissions by Global Warming Potential 100: kg CO_2e = 1x kg CO_2 + 25 x kg CH_4 + 298 x kg N_2O + 22800 x kg SF_6. We utilize the blue water data, ground and surface water, and green water, precipitation that is stored in the root zone of the soil and evaporated, transpired or incorporated by plants.

Information about the origin and value of the imported fresh fruits and vegetables was taken from the HM Revenues and Customs (HMRC), which publishes the “Overseas Trade Statistics (OTS) of the UK”. This database provides information on international trade in goods collected from UK Customs import and export entries made by importing/exporting businesses, predominantly via the Customs Handling of Import and Export Freight (CHIEF) system. It offers both value and net mass of the commodities (SITC 1-5 digit) from 1996 onwards, monthly. In our particular case, we have used 2017 figures of four different types of fresh vegetables (potatoes, leguminous, tomatoes and other vegetables) and eight different fresh fruits (oranges, other citrus, bananas, apples, grapes, figs, nuts and other fruits), as shown in Table 3.

Table 3. Commodities used in the analysis

Code SITC	Commodity name
0.54	*Vegetables, fresh, chilled, frozen or simply prs; roots, tubers & other edible veg products, nes, fresh or dried*
0.54.1	Potatoes, fresh or chilled (not including sweet potatoes)
0.54.2	Leguminous vegetables, dried, shelled, whether or not skinned or split
0.54.4	Tomatoes, fresh or chilled
0.54.5	Other fresh or chilled vegetables (onions, garlic, lettuce, etc.)
0.57	*Fruit and nuts (not including oil nuts), fresh or dried*
0.57.1	Oranges, mandarins, clementines and similar citrus hybrids, fresh or dried
0.57.2	Other citrus fruit, fresh or dried
0.57.3	Bananas (including plantains), fresh or dried
0.57.4	Apples, fresh
0.57.5	Grapes, fresh or dried
0.57.6	Figs, fresh or dried
0.57.7	Edible nuts (exc. nuts chiefly used for the ext. of oil), fresh or dried, whether or not shelled or peeled
0.57.9	Other fruit, fresh or dried, nes (melons, pears, apricots, etc.)

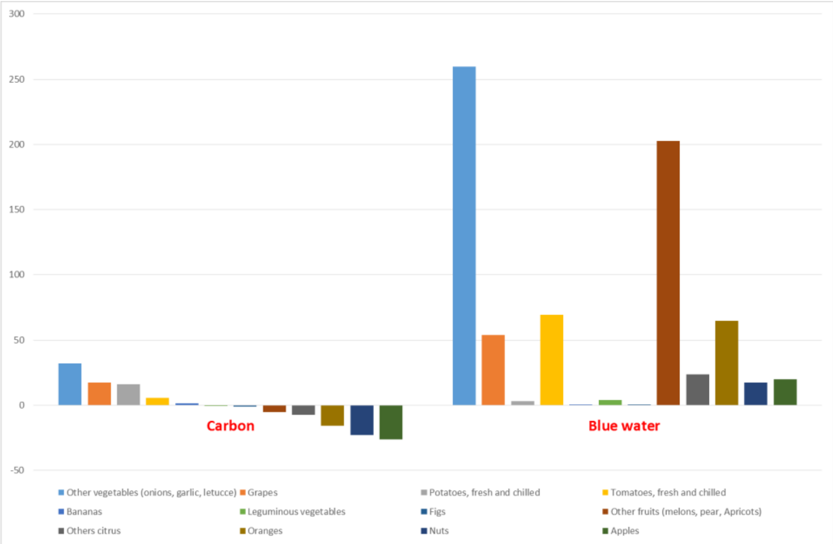
The HMRC also contains detailed information of the origin and destination of the trade, including 27 EU countries and countries from other rest of the World areas (divided between Asia and Oceania, Eastern Europe, Latin America and the Caribbean, Middle East and North Africa, North America and Sub-Saharan Africa). **3. Main Results**

2.1. Substitution of imported fruits and vegetables from the EU by UK local production

From the balance of avoided emissions for 2017 we learn that UK imported fresh fruits and vegetables imply net savings in carbon footprint of -0.22% of total embodied carbon in imports (Figure 1). Savings are highly significant for some fruits, like apples, nuts and oranges. Nevertheless, for some fruits and vegetables, imports generate a higher carbon footprint (onions, lettuces, garlic, grapes and potatoes) and import substitution would be environmentally beneficial. As long as a no-deal Brexit entails progressively substituting UK imported fruits and vegetables by local agricultural production, Brexit would have a non-significant effect in terms of carbon footprint, as it only represents an increase of 0.22%. Savings in carbon could nevertheless be significant if trade is displaced towards an increased consumption of some local produce for which the UK has a lower carbon footprint. In these cases both trade and environmental policies would concur and result up in greater savings.

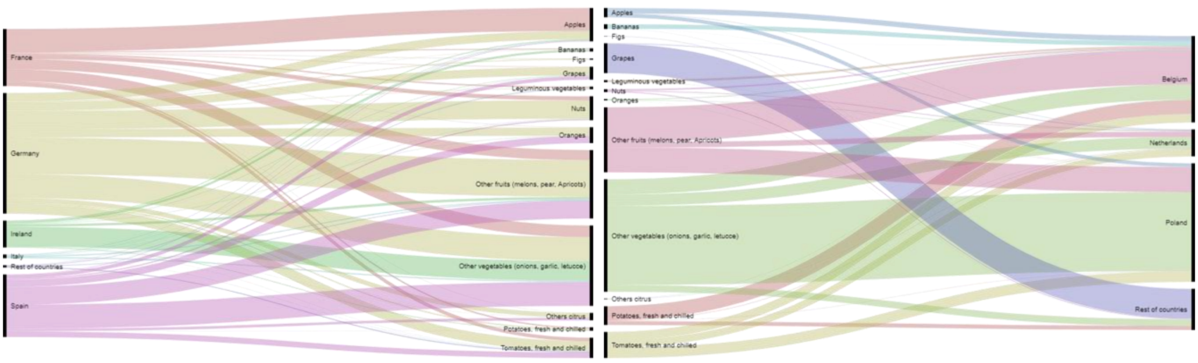
As for blue water footprint, the balance of avoided blue water by imports shows that imported fruits and vegetables generate a net increase in blue water of 96% of total embodied blue water in imports (Figure 1). As a result, a no-deal Brexit that discourages these imports would save water, particularly for some vegetables (onions, lettuce, garlic) and fruits (melons, pears, peaches). These results for both balances are dependent on differences in intensity for carbon and water footprint among the different countries providing fruits and vegetables to the UK and intensity for the UK. The UK requires less blue water per monetary unit of fruits and vegetables than its international providers. The relative carbon intensity however, depends on the countries of origin considered.

Figure 1. Balance of avoided carbon (KtCO$_2$) and blue water (Mm^3) from imported fruits and vegetables by domestic production in the UK, 2017



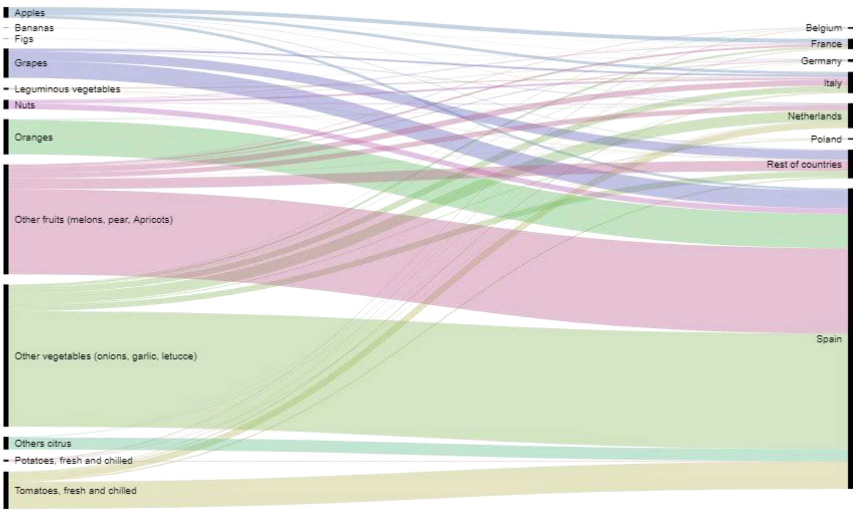
When we delve into differences among countries and types of fresh fruits and vegetables, we find that British imports generate in some cases important reductions in carbon footprint (left side in Figure 2) as well as some significant increases (right side in Figure 2). Main savings are found in imports from Germany, France, Spain and Ireland, and by products in imported other vegetables and fruits and, to a lesser extent, apples and nuts. On the other hand, the greatest increases are found in imports from Poland and Belgium and other vegetables and fruits as well as grapes. The coincidence in other vegetables and fruits shows that the relevant factor for carbon footprint is the country of origin and therefore trade changes could generate significant CO_2 savings than a no-deal Brexit (-0.22% of total footprint).

Figure 2. Balance of avoided carbon footprint from imports by UK domestic production, by country of origin and type of fruit and vegetable, 2017. Negative balance to the left and positive balance to the right.



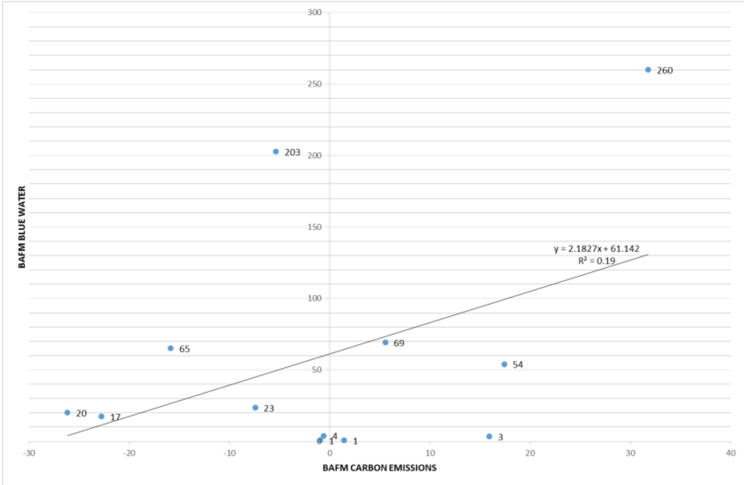
As for blue water, the UK imported fruits and vegetables generate significant increases in blue water use for all countries of origin and they amount to 722 Mm^3 (Figure 3), with the exception of small savings in the trade with Ireland (-2.6 Mm^3). Furthermore, increases are concentrated in imports from Spain (77% of total water increases, over 553 Mm^3), followed, a long way behind, by imports from the Netherlands, Italy and France. By products, important water increases are due to imports of other vegetables and fruits, but also oranges, tomatoes and grapes. The lesser water availability in Spain, particularly green water, implies a greater blue water use (irrigation) than the UK and therefore higher blue water intensity. Nevertheless, when we compared both BAFM for Spain, the British trade generates a negative balance for CO_2 and a positive sign for blue water. The warmer and sunnier Spanish weather implies a lower power use and higher solar energy to grow fruits and vegetables, but on the other hand, its lower rainfall explains the reduced availability of green water and the need for blue water use. Similar results can be found for trade with France and Germany. On the contrary, for other countries like Poland and Belgium, both the carbon and blue water BAFM are positive, as production in those countries is more carbon and blue water intensive than in the UK.

Figure 3. Balance of avoided blue water from imports by UK domestic production by country and type of fruit and vegetable, 2017. Only countries with positive balance.



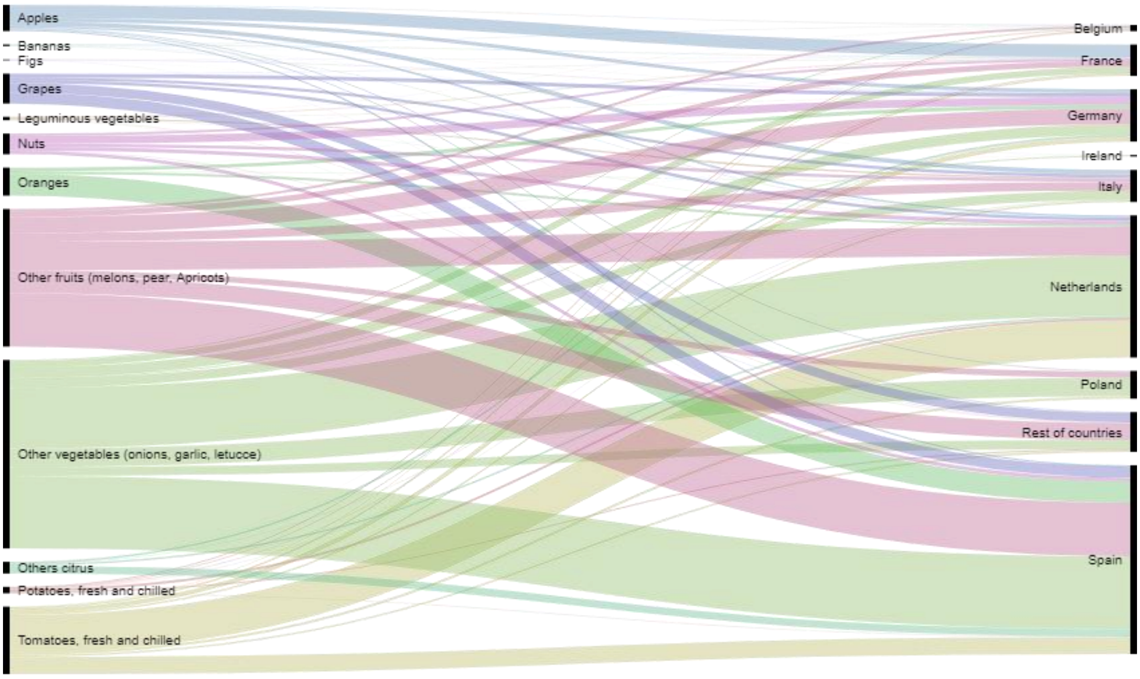
In general we can also point to some positive link or complement between the avoided carbon and blue water balances. Imported fruits and vegetables that save blue water also reduce carbon and conversely those requiring more blue water also generate more emissions. This could be related to the energy requirements for irrigation and associated carbon emissions, regardless of the different energy mix among countries.

Figure 4. Balance of avoided carbon ($KtCO_2$) versus blue water (Mm^3) from imported fruits and vegetables by UK domestic production, 2017



The balance of avoided employment from imported fruits and vegetables by the UK shows a positive result of 101,089 people. This indicates that imports imply a net (direct and indirect) job creation as the total employment coefficient for the UK is significantly lower than those of its EU providers (Figure 3, and Table 4 in Annex). The top countries for employment creation are Spain, Germany and France. By products, we can highlight the net job creation in other vegetables, other fruits and tomatoes and, to a lesser extent, grapes, apples and nuts. A hard Brexit, provided it increases agriculture production in the UK, it would imply 88,797 new jobs while reducing EU employment by 189,868 jobs and Spanish jobs by 72,075 (this concurs with predictions by the Bank of Spain that rank Spanish agriculture as one of the top affected sectors by a no-deal Brexit for the Spanish economy, Banco de España, 2019).

Figure 5. Net job reduction if imported fruits and vegetables are substituted by UK domestic production, 2017

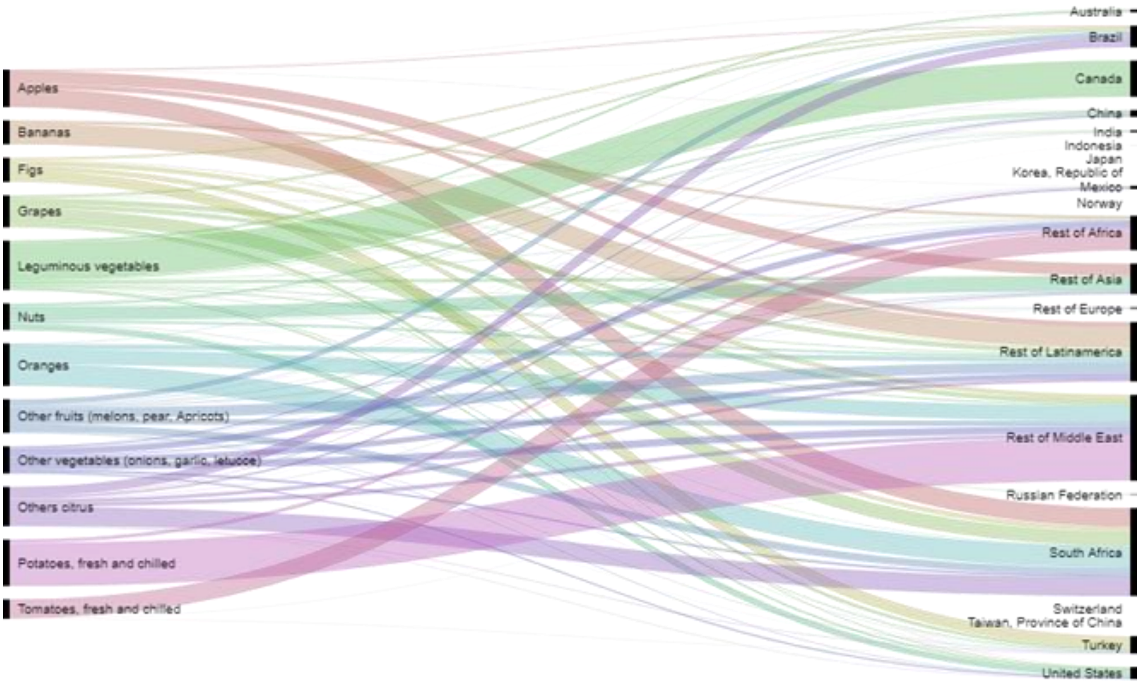


2.2. Substitution of imported fruits and vegetables from the EU by production from non-EU countries

Substitution by domestic production would reduce choices for consumers, as British agriculture is not capable of providing the same amount and types of fruits and vegetables as imports from the EU. Furthermore, the UK agriculture will face the challenge of increasing capacity to provide for that new demand, requiring new farming land when 70% of all UK land is already allocated to agriculture (Defra, 2018), or changing production to cultivating produce with increase demand. Simultaneously, rising prices for fruits and vegetables are also expected if domestic production show higher costs than imported produce. As a result, a no-deal Brexit is expected to divert trade to imported fruits and vegetables from third countries in order to avoid those limitations from domestic production.

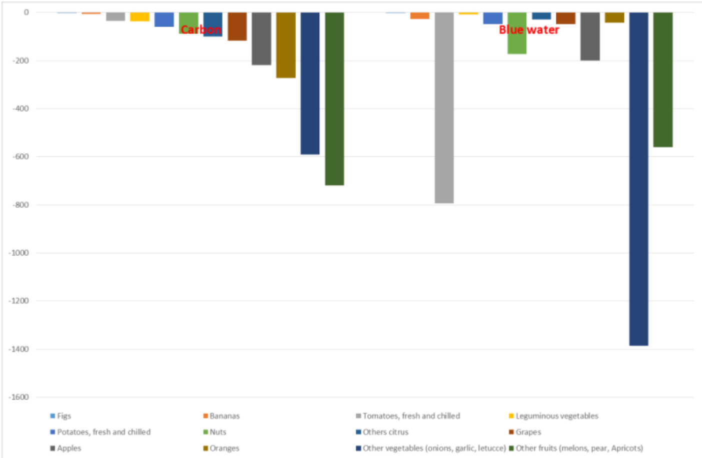
In this section we assume that trade is proportionally diverted towards present providers of fruits and vegetables to the UK for each considered product (Figure 6). By regions and countries of origin, imports would be concentrated in big regions (Rest of Middle East, South Africa, Rest of Latin America) and countries like Canada, Brazil and Turkey. By products, we find Canada as main provider for leguminous vegetables, Rest of Middle East for potatoes, South Africa and Rest of Latin America for oranges and Rest of Africa for tomatoes.

Figure 6. Trade diversion for UK imported fruits and vegetables to non-EU countries, 2017(€)



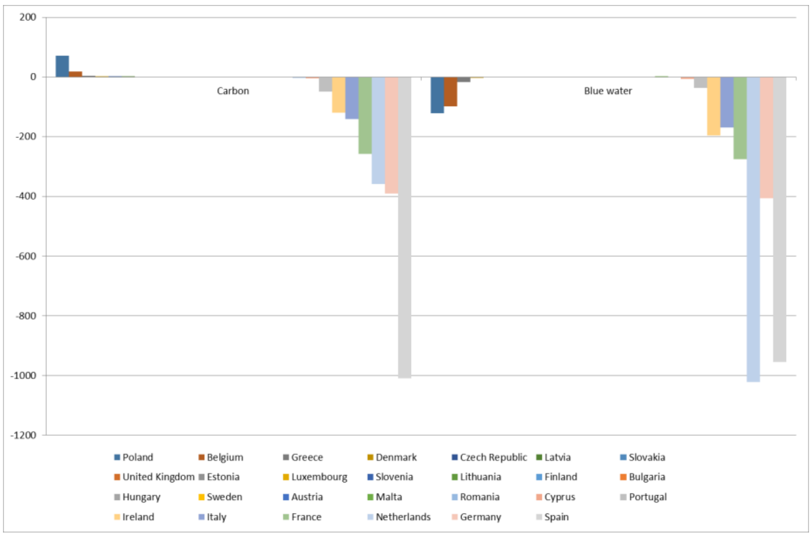
Our results show that this trade diversion would generate significant negative effects on carbon and blue water footprint for all currently UK imported fruits and vegetables from the EU (Figure 7). This amounts to a net increase of 74% for carbon footprint and 555% for blue water footprint, relative to embodied emissions and water in imports from EU. Regarding carbon footprint, the top increases from this substitution are linked to other fruits (melons, pears, peaches), other vegetables (onions, lettuces, garlic), oranges and apples. As for water footprint other vegetables (onions, lettuces, garlic), tomatoes and other fruits (melons, pears, peaches) generate the highest increases. These increases result from the lower footprints of produce imported form the EU compared to those from countries outside the EU, reflecting a negative sign in the balance of avoided emissions/blue water use (Figure 2). Similarly to the substitution of imports from EU by domestic production, this balance implies a significantly lower intensity for EU carbon and water footprints relative to other countries trading with the UK.

Figure 7. Balance of avoided carbon and blue water in UK imported fruits and vegetables diverted to non-EU countries, 2017



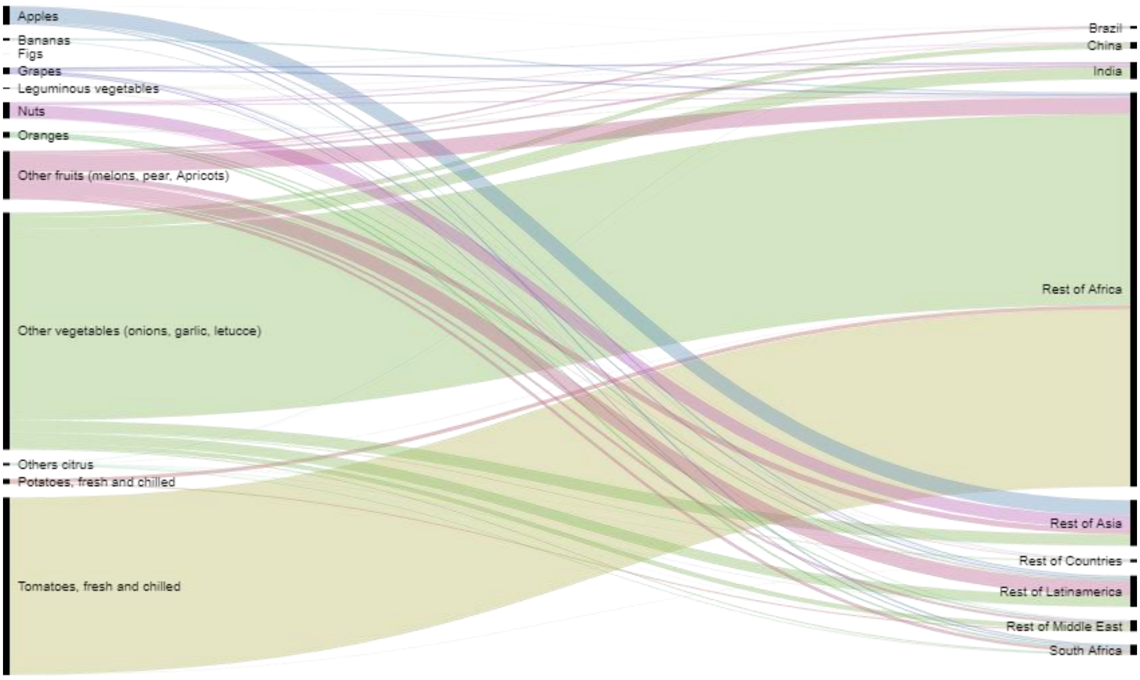
By country of origin, the trade diversion from a no-deal Brexit would entail an increase in both carbon and blue water footprint from British consumption of fruits and vegetables as the balance is negative for most countries (Figure 8). The ranking is very similar for both types of environmental impact, being particularly relevant the increases due to reducing imports from Spain, Germany, France and Italy. In most cases, the carbon and blue water intensities for EU countries is lower than that of the alternative non-EU providers for the UK. Therefore, the trade diversion from Brexit would be environmentally harmful. There is however a reduced number of countries, representing a relatively small amount of imports, that are less efficient in carbon footprint terms than the alternative providers and show a positive BAFDM. Trade diversion from these countries (Poland, Belgium, Greece, Denmark, Czech Republic, Latvia) due to a no-deal Brexit would then generate some savings for carbon footprint, but not for blue water.

Figure 8. Balance of avoided carbon and blue water from UK imported fruits and vegetables diverted to non-EU countries, 2017



Diverting trade of fruits and vegetables to non-EU countries would generate 5,138,000 net jobs in the world economy (Figure 9, and Table 5 in Annex). Job generation would be due mostly to diverted trade of other vegetables (46%) and tomatoes (35%), while other fruits (9%) are far less relevant than for jobs embodied in imports from the EU. Most of the employment generated would be concentrated in the region Rest of Africa that accounts for 75% (despite corresponding to only 25% of total imports), followed by Rest of Asia with 8.8% (5.5% of imports) and Rest of Latin America, 6% (23,9% of imports). South Africa also plays a relevant role in the employment impact from trade diversion, as it represents 13.6% of imports, but only 2.2% of total new employment. Job increases, mostly in Rest of Africa and Rest of Asia as stated above, result from far higher total employment coefficients in those regions (3,582 thousand workers per million euros in Rest of Africa, 0.306 for Rest of Latin America and 0.021 for the UK) and the volume of agricultural imports.

Figure 9. Employment generation if UK imports of fruits and vegetables are diverted to non-EU countries, 2017



3. Discussion and conclusions

Our results for environmental impacts using our balance of avoided carbon emissions and water use for fresh fruits and vegetables show that UK imports from EU countries in 2017 cause a significant increase in green and blue water footprints (96%) and a close-to-zero saving in carbon emissions (-0.22%). A no-deal Brexit, so far as it makes more difficult to import and leads to a progressive substitution by domestic production, will save water footprint by a maximum of that 96% and have no significant effect on

CO_2 emissions. However it might be difficult for the British agriculture to provide the required fruits and vegetables, particularly at a similar price, and therefore we can expect some trade diversion directed to non-EU countries. In that case, our balance of avoided footprint by trade diversion indicates that imported fresh fruits and vegetables would significantly increase both carbon and blue water footprints, as much as 74% and 555%, respectively. We can conclude that consumption of fresh fruits and vegetables in the UK after a no-deal Brexit would cause an important increase in carbon and water consumer footprints.

As regards employment changes from a hard Brexit, because of the high direct work intensity in the agriculture of developing countries (due to the existing underemployment and lack of mechanisation), the diversion of UK imports from EU to non-EU countries would increase employment by more than 5 million jobs. However, one job in a EU country is not equivalent to one job in a developing country in terms of working conditions and wages, or social risks. Agricultural activities in developing countries are basic for food and economic sustenance for a significant share of the population that has no other alternative means (FAO, 2018). Accordingly, analyses on changes in consumption in developed countries should jointly take into account both social and environmental impacts on developing countries, with particular reference to the United Nations Sustainable Development Goals.

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Annex

Table 4. Balance of avoided footprint for fresh UK imported fruits and vegetables from the EU substituted by domestic production, 2017

		Potatoes, fresh and chilled	Leguminous vegetables	Tomatoes, fresh and chilled	Other vegetables (onions, garlic, letucce)	Oranges	Others citrus	Bananas	Apples	Grapes	Figs	Nuts	Other fruits (melons, pear, Apricots)	Total	% BAE/MCO2
Carbon footprint	Kt CO_2	160	-6	56	318	-158	-74	15	-261	175	-9	-227	-54	-67	-0.22%
	% BAE/M	26%	-3.01%	1.53%	2.77%	-9.79%	-11.30%	6.32%	-18.44%	9.77%	-21.86%	-22.47%	-0.70%	-0.22%	
Green and Blue footprint	Mm3	11.3	10.8	164.0	556.6	116.9	43.8	2.8	55.6	99.6	1.5	43.5	419.1	1525.4	79%
	% BAE/M	64%	80%	77%	78%	83%	81%	48%	71%	82%	68%	72%	80%	79%	
Blue Footprint	Mm3	3.2	3.7	69.2	259.8	64.9	23.5	0.6	19.8	53.9	0.6	17.2	202.7	719.1	91%
	% BAE/M	76%	89%	89%	91%	94%	93%	56%	84%	94%	83%	86%	92%	91%	
Scarce Blue Footprint	Mm3	1.0	1.1	21.9	83.5	21.8	7.9	0.2	5.2	14.6	0.1	5.3	62.8	225.4	96%
	% BAE/M	86%	94%	95%	96%	97%	97%	72%	90%	96%	88%	92%	96%	96%	
Employment Footprint	Thousands of people	1.2	0.6	13.1	36.5	5.4	2.3	0.3	5.1	5.8	0.2	4.0	26.6	101.1	53%
	% BAE/M	48%	52%	55%	53%	51%	52%	33%	51%	55%	52%	53%	54%	53%	

Table 5. Balance of avoided footprint for fresh UK imported fruits and vegetables from the EU substituted by production from non-EU countries, 2017

		Potatoes, fresh and chilled	Leguminous vegetables	Tomatoes, fresh and chilled	Other vegetables (onions, garlic, letucce)	Oranges	Others citrus	Bananas	Apples	Grapes	Figs	Nuts	Other fruits (melons, pear, Apricots)	Total	% BAE/MCO2
Carbon footprint	Kt CO_2	-602	-374	-346	-5902	-2720	-990	-66	-2186	-1169	-29	-880	-7188	-22452	-74.0%
	% BAE/M	-97.75%	-192.07%	-9.45%	-51.44%	-168.13%	-151.39%	-28.22%	-154.18%	-65.44%	-69.75%	-86.96%	-94.08%	-73.98%	
Green and Blue footprint	Mm3	-110.3	-23.5	-3742.4	-5314.1	-120.1	-173.0	-96.2	-483.2	-203.4	-3.5	-382.1	-2310.5	-12962.3	-668%
	% BAE/M	-629.21%	-173%	-1754%	-749%	-85%	-322%	-1678%	-615%	-167%	-163%	-632%	-441%	-668%	
Blue Footprint	Mm3	-48.5	-8.7	-793.9	-1385.4	-41.7	-29.0	-26.6	-199.3	-48.3	-1.4	-173.2	-560.2	-3316.2	-421%
	% BAE/M	-1154%	-207%	-1027%	-486%	-60%	-116%	-2364%	-843%	-84%	-203%	-867%	-255%	-421%	
Scarce Blue Footprint	Mm3	-30.7	-1.8	-490.2	-630.3	-15.4	-0.5	-5.6	-25.0	-9.3	-0.4	-25.3	-75.5	-1310.0	-555%
	% BAE/M	-2685%	-158%	-2115%	-721%	-69%	-6%	-2078%	-435%	-61%	-241%	-442%	-115%	-555%	
Employment Footprint	Thousands of people	-48.6	-10.7	-1725.0	-2264.2	-46.7	-20.2	-23.5	-175.9	-56.2	-0.6	-153.0	-424.2	-4948.6	-2606%
	% BAE/M	-1892%	-869%	-7312%	-3279%	-440%	-460%	-2476%	-1763%	-537%	-178%	-2007%	-864%	-2606%	