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Eating local and in-season fruits and vegetables: Carbon-water-employment trade-offs and synergies

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Abstract

What would the effect on the employment and environmental footprint be if Spanish households substituted imported fresh fruits and vegetables with local production? Are the impacts similar over the entire year? Is it possible to find a general pattern that allows for straightforward household consumption decisions promoting sustainability? In this paper, we answer these questions using an innovative concept, the seasonal avoided footprint by imports (SAFM), to understand the interactions among carbon emissions, scarce water use, and employment linked to imports and domestic production.

Our study shows that decisions regarding local and seasonal consumption of fruits and vegetables by citizens in rich regions of the global economy, such as Spain, can lead to a conflict of objectives between the environment and social development in poor regions. The inter-country trade of fruits and vegetables generates relevant negative environmental hotspots, as the imports from developing countries are often more carbon- and water-intensive. However, the substitution of imports by local production implies vast job losses in these developing countries.

Therefore, we suggest the implementation of certification systems that jointly consider the appropriate levels of social, economic, and environmental development and provide a useful guide for consumer decisions that reinforce social and environmental synergies.

Keywords

Seasonal avoided footprint by imports; Food-Energy-Water Nexus; Environment-Employment trade-off; Multiregional input-output model

1. Introduction

The agricultural sector is of particular relevance to human welfare, as it provides living means for most of the poor households in the world and represents the backbone of the fight against famine (FAO, 2018). In the last 20 years, agriculture in developing countries has had to adapt to the rising globalisation of production (MacDonald et al., 2015), which has generated global food crises at times due to spiking agricultural prices (Berazneva and Lee, 2013). These phenomena have allowed only a few developing countries to implement efficient land use practices (Lambin and Meyfroidt, 2011).

Nevertheless, the environmental impacts in terms of water, energy, or other inputs, can vary by as much as 50 times among producers for the same type of food and can thus provide effective options for mitigation along global production chains (Poore and Nemecek, 2018). Food, energy, and water (FEW) are the basic needs for which the demand is increasing, and challenges to satisfy them arise in an interrelated manner, as have been studied notably since the work of Hoff (2011). They are closely linked to emissions and climate, as discussed in this paper, and have been explicitly stated, e.g., in the World Economic Forum (WEF, 2011). Progress has been made in recognising these needs and new approaches are being developed to manage their scarcity (Conway et al., 2015; Liu et al., 2017; Schyns et al., 2019). It has been highlighted that successfully facing these challenges is more likely if a transdisciplinary approach is used, e.g., focusing on how sustainable supply chains influence the FEW nexus from a commerce and industry perspective (Bergendahl et al., 2018) and how research should be conducted by using a "web" (rather than a "linear tree") model that addresses interdisciplinary complexity (Liu et al., 2019).

Sustainable Development Goals (SDGs) have become the reference to achieve economic, social, and environmental sustainability in the least-favoured regions of our planet (United Nations, 2015). These conflicts have sometimes been neglected, as the indexes included in the SDGs do not consider the impacts along the global value chain (Wiedmann and Lenzen, 2018). The progress until 2018 in implementing those measures, which are included in the SDGs, has not prevented the existence of critical gaps regarding the nexus and synergies between goals (Allen et al., 2018). Therefore, the trade-offs between the generation of value added, employment, and environmental impacts have often caused the increasing destruction of precious natural resources (Newbold et al., 2015; Zoumides et al., 2014), loss of biodiversity (Lenzen et al., 2012), and changes in land use in the developing countries due to their trade with developed countries (Weinzettel et al., 2014). In addition, the trade-offs differ significantly among nations, and the interactions appear to show higher disparities in terms of land and water resources than in terms of carbon emissions (Scherer et al., 2018).

The easily identifiable trade-offs are derived from the intensive use of natural resources in the developing countries that export a limited number of agricultural products, such as the soy products of Brazil, Argentina, and Cameroon (MacDonald et al., 2015), or for reducing carbon storage, habitat provision or other ecosystem services by converting grasslands and forest into croplands (Johnson et al., 2014). This has exhausted the scarce natural resources, e.g., water in the Middle East and North Africa (MENA) (Hoekstra and Mekonnen, 2012). However, other not-so-evident FEW trade-offs may be hidden in ordinary household consumption decisions, as our analysis helps to reveal. Other papers have shown that imported products, such as soy, not only deteriorate the environments of the producing countries but also those of the importing countries because the conversion of soybean lands to corn fields and rice paddies has led to N pollution in China. (Sun et al., 2018).

Concurrently, there is growing concern in developed regions regarding the impacts from different diets on their citizens' state of health and their environmental footprints. The main recommendations attempt to direct consumption towards increasing the intakes of fruits, vegetables, and nuts, lowering meat and fat consumption, and reducing calorie intake. This is the case that is discussed by Tukker et al. (2010) and Tukker et al. (2011), who found a potential reduction of approximately 9% in CO_2e emissions when the population moves to a vegetarian diet, while Pairotti et al. (2015) and Cazcarro et al. (2012) showed potential reductions of 12.7% in CO_2e emissions and 9% in the water footprint, respectively, due to shifts to healthy diets. Behrens et al. (2017) showed that the recommended diets in the richer countries, when compared to the usual diets, imply reductions in greenhouse gases, eutrophication, and land use (e.g., approximately 13-24%, 9,8-21.3%, and 5.7-17.6%, respectively). This advice is also useful in terms of aligning the goals for improving individual health, particularly in rich countries and for lowering the dietary GHG footprint (Springmann et al., 2016; Tilman and Clark, 2014). Real choices do not always follow the recommended pattern, for example, in emerging countries such as China, where the increased consumption of dairy, eggs, and shellfish improves the nutrition for its population at the expense of the environment (He et al., 2018).

The consumption of local (zero-kilometre) and in-season products has also become a useful slogan that can be used to simplify the choices regarding fresh fruits and vegetables in affluent regions. This rule should help to reduce the environmental footprint and improve health, as it implies decreasing the intake of processed food while favouring the integration of local agriculture and shortening global food chains. In addition, as substitution decreases imports from other countries, which are often emerging or developing countries, this substitution might compromise the economic and social development of these nations. A specific reason for this effect is their economic structures, in which agricultural income and employment still represent a significant share of their economies, and this is even more so for some of their most vulnerable people. This argues for the inclusion of a measure of employment in the FEW nexus.

While considering all of these factors and examining how the decisions made by Spanish consumers may have global effects, the objective of this paper is to measure the impacts on the social and environmental footprints that are a consequence of the hypothetical substitution of imported, in-season and out-of-season fruits and vegetables by other local or domestic alternatives in Spain (for example, substituting pineapples from Costa Rica in December with domestic oranges). The term footprint is associated with the undesirable negative impacts that accompany production and distribution supply value chains, whereas the social attribute could be related to any social aspect (Alsamawi et al., 2014b; García-Alaminos et al., 2020; Xiao et al., 2017). For our case, the social footprint is measured by the changes in total employment that are directly and indirectly required along the global production chains when the final demand substitution is made. The environmental impact measures are the same when using greenhouse gas emissions (CO_2 equivalent, CO_2e) and scarce blue water as the dimensions.

Specifically, we use and enhance the concept of the seasonal avoided footprint by imports (i.e. the change in total requirements when the final imports are replaced by domestic seasonal products), which was previously developed in (Tobarra et al., 2018), to compare the CO_2e, water and, as a novelty, employment impacts between imported and local or domestic products on a monthly basis. By doing so, we can identify the particular months, products, and regions for which substituting imported fruits and vegetables implies trade-offs between the environmental and social footprints, which reduce the environmental impacts while reducing employment in the developing countries. Furthermore, we examine the presence of positive potential synergies, for which the environmental and social objectives may align positively, and negative potential synergies, for which the environmental and social objectives may simultaneously worsen.

2. METHODS AND MATERIALS

Multiregional input-output models (MRIOs) (Miller and Blair, 2009) have been extended to assess the impact of international trade on different factors (Wiedmann, 2015) from production factors such as employment (Alsamawi et al., 2014a) or value added (Koopman et al., 2014) to natural resources. Among the studies that deal with environmental impacts, we highlight water (Cazcarro et al., 2016), materials (Wiedmann et al., 2013), energy (Arto et al., 2016) and environmental impacts, such as CO_2 emissions (Liu et al., 2016; López et al., 2015) or nitrogen pollution (Oita et al., 2016).

Additionally and more closely related to social factors, we highlight the study of "bad labour footprints" (Simas et al., 2014) and the general conceptualisations of labour footprints under these frameworks (Gómez-Paredes et al., 2016). The analysis of employment that is embodied in international trade reveals that wealthy countries outsource (essentially low-skilled) labour to developing countries, which is similar to the displacement of environmental impacts (Alsamawi et al., 2014a; Alsamawi et al., 2014b; Portella-Carbó, 2016). Several of these studies have highlighted the magnitude of risk and forced hazardous or child labour footprints; on the other hand, there is a vast body of economic literature that also examines the positive aspects of these processes in terms of triggering job creation (Feenstra and Sasahara, 2018) and income generation (Baldwin, 1992). Before the studies on footprint impacts, other concepts have discussed the trade-offs between economic and social effects and environmental impacts: the environmental Kuznets curve (Grossman and Krueger, 1995) and the pollution haven hypothesis (Copeland and Taylor, 2004). Recently, the methodology of the pollution haven hypothesis has been studied by using multiregional input-output models, which has allowed to examine this hypothesis by considering the trade footprint by considering all of the emissions that are incorporated in global production chains (López et al., 2018).

The primary use of the MRIO framework is to integrate full global supply chains and implicitly identifies the key inter-linkages of the FEW elements, as well as additional social and environmental aspects and the pressures across them. For example, food demand (as in this case) triggers the need for transport and production in several regions with different inputs, direct and indirect water requirements, energy needs and technologies (e.g., the CO_2e emissions differences captured here can be due to different levels of energy use and/or of technologies).

The typical expression of these extended MRIO models for *r* regions in the period of time *t* (usually a year) is shown in (1):

$$F = \hat{f}(I - A)^{-1}\hat{y} = \hat{f}L\hat{y} = P\hat{y} \quad (1)$$

where F shows the total impact dimension or content of factor *f* by sector and region of origin and destination that is embodied in the production at the world level (where $\hat{f}$ is the corresponding diagonal matrix); A is the matrix of technical coefficients (which measure the inputs in every country in every sector that are required per unit of output in a specific sector in one country) and are integrated by A^{rr} on the main diagonal (i.e., the domestic technical coefficient matrix of country *r*, where all of the inputs are produced within the same country r), and by A^{sr} for the off-diagonal positions (the imported technical coefficient matrix of country *r* from country *s*). The diagonal matrix of final demand, $\hat{y}$, includes the diagonal matrix of the domestic final demand products (on the main diagonal, $\hat{y}^{rr}$) and the imported final demand products from each country *s* (at the off-diagonal positions, $\hat{y}^{sr}$) of country r. $L = (I - A)^{-1}$ is the Leontief Inverse, where I is the identity matrix and P is the matrix of the multipliers where P^{sr} shows the total, direct and indirect, impacts of factor *f* of country *s* that are embodied in one unit of final demand that is consumed in country *r*. In the empirical application, we consider three-factor types: employment (social sphere of sustainability), greenhouse gases (carbon dioxide equivalent emissions, CO_2e), and scarce blue water (both in the environmental sphere). For the sake of simplicity, to clarify the multiregional character of expression (1), equation (2) expresses this calculation for an economy with two sectors (i, j) and two regions (*r*, *s*).

$$F = \begin{pmatrix} f_i^r & 0 & 0 & 0 \\ 0 & f_j^r & 0 & 0 \\ 0 & 0 & f_i^s & 0 \\ 0 & 0 & 0 & f_j^s \end{pmatrix} \begin{pmatrix} L_{ii}^{rr} & L_{ij}^{rr} & L_{ii}^{rs} & L_{ij}^{rs} \\ L_{ji}^{rr} & L_{jj}^{rr} & L_{ji}^{rs} & L_{jj}^{rs} \\ L_{ii}^{sr} & L_{ij}^{sr} & L_{ii}^{ss} & L_{ij}^{ss} \\ L_{ji}^{sr} & L_{jj}^{sr} & L_{ji}^{ss} & L_{jj}^{ss} \end{pmatrix} \begin{pmatrix} y_i^{rr} & 0 & y_i^{rs} & 0 \\ 0 & y_j^{rr} & 0 & y_j^{rs} \\ y_i^{sr} & 0 & y_i^{ss} & 0 \\ 0 & y_j^{sr} & 0 & y_j^{ss} \end{pmatrix} \quad (2)$$

MRIO with seasonal final demand

We intend to develop an MRIO model with a seasonal final demand for fruits and vegetables. Every season and each country or region will import and export different amounts of these agricultural products depending on its own production of fruits and vegetables (which will be very different depending on the season and hemisphere) and the consumption patterns of the populations involved. The lack of multiregional data on the production technology and emissions for each type of fruit and vegetable forces us to assume that they are similar within each country but differ between countries and by following the model that was previously developed in (Tobarra et al., 2018), the carbon footprint of region *r* in season *z* can be expressed as shown in equation (3):

$$F_z^r = \hat{f} \ \ [I - A]^{-1} \hat{y}_z^1 \quad (3)$$

For every season *z* and for every product *i*, we find domestic consumption that is represented by the diagonal vector $\hat{y}_{iz}^{rr}$, exports ($\hat{y}_{iz}^{rs}$) and imports ($\hat{y}_{iz}^{sr}$). The sum of the demands for all seasons provides the final demand in the conventional MRIO model. For instance, if we take *z* as the months of the year, the annual domestic final demand is $y_i^{rr} = \sum_{z=1}^{12} y_{iz}^{rr}$, which is valid for both imports and exports.

Balance of the seasonal avoided footprint through imports (SAFM)

We define the Balance of the Seasonal Avoided Footprint through iMports (SAFM) for region *r* as the impacts in terms of the factor types (e.g., carbon emissions, water, and employment) that are caused by substituting imported agricultural products (in season or month *z*) from country *s* by domestic produce in region *r* ($SAFM_{iz}^r$). The expressions for this balance are shown in equations (4a) and (4b).

$$SAFM_{iz}^r = \hat{f} \ \ [I - A]^{-1} \hat{y}_{iz}^{sr} - \hat{f} \ \ [I - A]^{-1} \hat{y}_{iz}^{*sr} \quad (4a)$$

$$SAFM_z^r = \begin{pmatrix} f_i^r & 0 & 0 & 0 \\ 0 & f_j^r & 0 & 0 \\ 0 & 0 & f_i^s & 0 \\ 0 & 0 & 0 & f_j^s \end{pmatrix} \begin{pmatrix} L_{ii}^{rr} & L_{ij}^{rr} & L_{ii}^{rs} & L_{ij}^{rs} \\ L_{ji}^{rr} & L_{jj}^{rr} & L_{ji}^{rs} & L_{jj}^{rs} \\ L_{ii}^{sr} & L_{ij}^{sr} & L_{ii}^{ss} & L_{ij}^{ss} \\ L_{ji}^{sr} & L_{jj}^{sr} & L_{ji}^{ss} & L_{jj}^{ss} \end{pmatrix} \left[\begin{pmatrix} 0 & 0 \\ 0 & 0 \\ y_{iz}^{sr} & 0 \\ 0 & y_{jz}^{sr} \end{pmatrix} - \begin{pmatrix} y_{iz}^{sr} & 0 \\ 0 & y_{jz}^{sr} \\ 0 & 0 \\ 0 & 0 \end{pmatrix} \right] \quad (4b)$$

where $\hat{y}_{iz}^{sr}$ indicates the exports from region *s* to *r* (i.e., imports of *r* from *s*) and $\hat{y}_{iz}^{*sr}$ shows the avoided imports in sector *i* in season *z*, which allows us to quantify the total avoided factor content (footprint) for the agricultural products that are imported from region *s* when substituted by the domestic production of region r (as shown in expression 4b, this implies changing the imported amounts of *r* from *s* by *r*'s domestic production).

To interpret these formulas, a positive sign for the SAFM balance indicates that the production of imported fruits and vegetables in season *z* requires a higher amount of factors than domestic production and, as a result, import substitution by domestic production is environmentally more efficient. In terms of employment, although a positive sign can also be interpreted as an increase in efficiency, it conversely implies that substituting imports by local production causes a further reduction in jobs (in the exporting region *s*) than creation (in consuming region *r*) (see Table 1). In contrast, a negative sign for the SAFM balance implies that the factors that are embodied in the imports are lower than those required for domestic production. In this case, changes in diets to local seasonal consumption increase carbon emissions and water use because imports are more environmentally efficient. Again, in terms of employment, a negative sign can also be interpreted as a lower level of employment reduction (in *s*) than job creation (in *r*) due to the substitution of imports by local products. Consequently, synergies arise from local seasonal consumption between the environmental and social goals when the SAFM shows opposite signs for the environmental metrics and employment, while there is a trade-off when the SAFM has the same sign for all factors. The demand for fruits and vegetables could either be used for final consumption or as intermediate goods since the impact of the substitution and the possible trade-offs and synergies that would arise are identical. Nevertheless, if these fruits and vegetables were processed by firms, more downstream emissions would be incorporated.

Table 1. Impacts and interactions depending on the sign of the Balance of Seasonal Avoided Footprint of imports (SAFM).

		Imports substitution by local production consumption			
		Sign of the balance – same sign		Sign of the balance – combination of signs	
		SAFM < 0 [CO2 water labour]	SAFM > 0 [CO2 water labour]	SAFM < 0 [CO2 water] SAFM>0 [labour]	SAFM > 0 [CO2 water] SAFM < 0 [Labour]
Footprint	Carbon	↑	↓	↑	↓
	Water	↑	↓	↑	↓
	Labour	↑	↓	↓	↑
Consequences	International trade	Good for environment /Bad for employment creation	Bad for environment / Good for employment creation	Good for environment /Good for employment creation	Bad for environment / Bad for employment creation
	Local production consumption	Bad for environment / Good for employment creation	Good for environment /Bad for employment creation	Bad for environment / Bad for employment creation	Good for environment /Good for employment creation
Interactions	Synergies	Carbon emissions Water use		Carbon emissions Water use Employment	
	Trade-offs	Employment		*None*	

Note: The yellow headings indicate a negative sign for the SAFM, and the white headings indicate a positive sign for the SAFM. The SAFM sign for employment has been changed in the figures 3 to 7 for presentation purposes.

The limited available information requires the use of the annual average in the previous expressions (3) and (4) for both the technical coefficients and factor intensities instead of the actual technical coefficients and factors depending on the season (so, both A and f are the same throughout the year). This assumption means that we do not include the impacts on the balances of different inputs of production or carbon emissions or water used depending on the season. The results are a first estimation of these balances. However, at the same time, the assumption implies that the results show the impacts of changes in origin (e.g., imports or local production) and destination (e.g., exports) on the trade of agricultural products and, as a result, we are isolating the "country effect" of the seasonal consumption of vegetables and fruits. As long as every country imports a different basket of products every season (or every month) and the products contained in this basket come from different countries, the seasonal consumption of fruits and vegetables embodies different productive structures and separate factor content intensities on average. In addition, another advantage of the proposed balance calculation is that, for each season, it allows us to identify the signs of the balance for countries and products, which enables decisions that are dependent on the season, which is hidden information when considering annual data.

Expression (4) shows the equation for the total factor content that is linked to the international trade of fruits and vegetables. However, as the agricultural sector is the most labour-intensive sector in most countries, it is also relevant to calculate the direct employment that is embodied in internationally traded fruits and vegetables. The resulting expression for the directly embodied employment in the SAFM is shown in equation (5).

$$dSAFM_{iz}^{r} = \hat{f} \;\; \hat{y}_{iz}^{sr} - \hat{f} \;\; \hat{y}_{iz}^{*sr} \tag{5}$$

The difference between expressions (4) and (5) provides the indirect labour that is generated through global production chains.

Data Sources

The input-output data for the MRIO model were obtained from EXIOBASE version 2.2. for 2007 (Tukker et al., 2013). This database provides data for an extended environmentally multiregional input-output (EE-MRIO) model for 163 industries and 48 countries and regions. We chose this data source instead of the other available multiregional databases because it has a specific category for "fruits and vegetables".

A summary of data sources and characterisations can be found in Table 2. We use satellite accounts, supplementary statistics provided by the same database for particular aspects of the economy, for the factor contents of carbon emissions, employment, and water. For the last factor, we use the data for both blue water (e.g., ground and surface water) and green water (e.g., from precipitation that is stored in the root zone of the soil and evaporates, transpires, or is incorporated by plants). We focus on the effects on "scarce water", and find of particular interest the impact on "scarce blue water". In order to assess the volume of scarce blue water, the ratio of freshwater withdrawal is applied to the total renewable water resources (FAO, 2017; Lenzen et al., 2013). By following the data from the Spanish Ministry of Agriculture, which provides different references for the calendars of fruits and vegetables, we classified the months of harvest and best consumption times in Spain for the various fruits and vegetables (MAGRAMA, 2017)). The data for the traded (imported/exported) agricultural products were provided by the Spanish Customs Office for 2011, which included details of the weight, value, country of origin/destination, and mode of transportation (Aduanas, 2011). The data on international trade are available monthly at the 8-digit level, so that we could distinguish the vegetables and fruits that were directed to final consumption from those that were allocated to intermediate consumption by following the Broad Economic Categories (BEC). Seasonal figures have been calculated by the addition of the corresponding months. In addition, to isolate the fresh products, we extracted the dried, frozen, and/or temporarily preserved products.

Table 2. Data sources and characterisations

Data		Source	Transformations	Resolution
MRIO coefficients	Production	EXIOBASE v2.2.2	Not required	163 industries, 48 regions Annual data
	CO_2e	EXIOBASE v2.2.2 Satellite accounts (GHG emissions)	CO_2 equivalent emissions are calculated to include all relevant GHG, following IPCC (2013) definition for Global Warming Potential 100 (GWP100): kg CO_2e = 1x kg CO_2 + 25 x kg CH_4 + 298 x kg N_2O + 22800 x kg SF_6	163 industries, 48 regions Annual data
	Blue scarce water	EXIOBASE v2.2.2 Satellite accounts and AQUASTAT (FAO, 2017)	The blue water coefficient from Exiobase (Hoekstra et al., 2009, 2011) is multiplied by the ratio of water withdrawals by each activity in each region to the total renewable freshwater resources in that region, following Lenzen et al. 2013. Coefficients for fruits and vegetables were published in Tobarra et al., 2018.	163 industries, 48 regions Annual data
	Employment	EXIOBASE v2.2.2 Satellite accounts	Not required	163 industries, 48 regions Annual data
Final demand (imports and exports)		Spanish Customs Office	Data in euros. We select only fresh fruits and vegetables for final use, using the Broad Economic Categories classification (consumption goods). We use the calendar of the Spanish Ministry of Agriculture, Fisheries, Food and the Environment (2013) to consider each particular product as in- or out-season for our country.	8-digit level for products, finally aggregated to fruits or vegetables, in- and out-season. Monthly data

Limitations and Assumptions

Our proposed methodology, combining an MRIO with seasonal final demand, allows us to reveal relevant information, that is totally missed in the yearly data, particularly when advising potential changes in consumer behaviour and their effects. Ideally, a monthly disaggregation for technology and factor requirements could be introduced in order to calculate a fully seasonal MRIO model. This would, however, entail obtaining monthly data for every production and resource coefficients for all goods and services (not only the agricultural produce but with an obvious focus on that) for all relevant countries. According to our current knowledge, there is no database that allows for this level of disaggregation. A discussion of potential options and limitations can be found in the supplementary information in Tobarra et al. (2018). Nevertheless, by using a seasonally disaggregated final demand, we capture differences in technology and resources use per month, as we change the mix of countries (each with its own production and factor coefficients) in the final demand (imports). We understand that we therefore capture the most substantial part of the seasonality, as technology coefficients are supposed to be more stable in time and different inputs are produced during the whole year. Final demand, exports and imports in our empirical application, is far more volatile and clearly reflects changes in product availability for fresh fruits and vegetables.

It must be emphasised that the above-described model is built on hypothetical scenarios, in which consumers are willing to change their consumption patterns, and the production and distribution value chains are able to respond. The analysis of the reasons that lead to changes towards sustainable food consumption patterns shows inextricably intertwined factors (Hoek et al., 2021) ranging from individuals' actions and behaviour to complex environmental dynamics (e.g., immediate, indirect, and macro-environment, including institutional, political or general economic settings). These factors are complex and should be approached jointly from different perspectives to ensure a sustainable food demand. Additionally, other related considerations, such as the interactions among import substitutions and prices, quality, and income distribution, should be analysed. On the other hand, if these changes were to take place, a detailed analysis of the time required for the supply to adapt, in terms of logistical transformation or even production adjustments, is required.

The import substitutions that are reflected in the SAFM mean that we are replacing the monetary value of imports with local products of the same value, keeping constant the share of fruits and vegetables in the 'consumers' basket in terms of expenditures. In some cases, replacement implies that consumers buy lower (higher) amounts of fruits and vegetables (in terms of kg) if the average prices of imported products are lower (higher) than those of domestic products. In this sense, other possibilities could be further explored, for instance, keeping constant the physical amounts or calories instead of the monetary values. The main advantage of the value measure is that it ensures that import substitution is affordable for households since the total expenditures remain fixed. Although the calculations change depending on the chosen measure (monetary versus physical amounts), the conclusion remains unaffected since the results show differences in their intensities but not in their signs (Tobarra et al., 2018). However, there are other possibilities that require further analysis, i.e. if imported fruits and vegetables are cheaper, the consumer may need to increase the share of fruits and vegetables in her basket, reducing the purchases of other goods and services, or substitute imported fruits and vegetable for cheaper domestic alternatives. The economic and environmental impact of these options would require detailed analysis of income elasticity for goods and services in the consumers' basket.

For our calculations, we consider the terms local and domestically produced (i.e., produced within the country borders) to be equivalent. This is a simplifying assumption that entails no distinctions of the regional differences that a country may have (from logistics, distance to final consumers, type of soil, or climate) that are expected to be higher the larger a country. The development of multiregional models with regional detail, such as the EUREGIO for Europe (Thissen et al., 2018) (with the appropriate satellite accounts), would help to overcome this assumption.

We must also note that in this paper, we have not explicitly accounted for the distances or means of transport for the international transport of fruits and vegetables. EXIOBASE includes transport as the average for all products in a category for all origins and transport modes. In two previous works, Cadarso et al. (2010) and López et al. (2015), we provide some evidence regarding this issue. However, it is important to note that this only affects CO_2 emissions and that our conclusions would not be significantly affected, as this would increase the emissions, in particular, for imported products that are transported from distant countries that generally present higher emission coefficients than Spain for fruits and vegetables. The increase for EU imports, where the coefficients are much more similar to the Spanish coefficients, would be much lower. This would reinforce our results rather than reverse them.

For the case of water, we also obtained the monthly consumption (blue) of water use by using the information by basins of the monthly blue water consumption shown in (Hoekstra et al. 2012), but these data were not ultimately used in the analysis due to the possible introduction of mismatches or biases with other data that were unavailable for such temporality (especially to construct the water coefficients, which is in accordance with the entire MRIO temporal structure). This poses a limitation, but the key here was to not focus on the changes in economic structures of the MRIOs, since these (at least the "production recipes") and multipliers tend to be quite constant over time as the "stability of input-output coefficients" literature shows (Bezdek, 1984; Bon, 1986, 1988; Bon and Bing, 1993; Dietzenbacher and Hoen, 2006; Moses, 1955; Teigeiro and Solís, 2005; Wood, 2011; Zaman et al., 2010); however we state that the absolute trade values are more seasonally volatile, and their study (ceteris paribus) already shows the ways in which these can be relevant for a number of environmental and social aspects. Without ignoring either the aforementioned temporality (e.g., not immediacy) in which the changes in pressures and employment may occur, it does hint that the nature of trade in fruits and vegetables has, for example, great trade-offs in terms of the employment levels across countries/regions, or in the pressures, which potentially may have stronger effects if they are critical (i.e., on employment if that requires seasonal movement of workers and on the biophysical side, e.g., water consumption in scarce water countries in areas with low precipitation during certain months of production).

3. MAIN RESULTS AND DISCUSSION

3.1 Seasonal Avoided Labour Footprint.

The results of the seasonal avoided labour footprint (SAFM for labour) show significantly positive values for both in-season and out-of-season products, as shown in Table 3. Table results are coloured so that SAFM results range from bright red (positive values), cases of higher labour reduction due to the substitution of imports by domestic production, to bright green (negative values), cases of higher labour creation, with yellow tones for intermediate values. As a summary, domestic production, as an alternative to imported fruits and vegetables, leads to net global reductions in employment of 787,492 workers (summing totals in Table 3). This result implies high productivity levels for Spanish agricultural labour, as confirmed by Table 3, where Spain is ranked 17th (out of 48) in terms of labour productivity.

The high levels of Spanish labour productivity entail a relevant reduction in net employment in the SAFM measure, namely, 135,339 workers for in-season fruits, 194,700 for out-of-season fruits, 411,523 for in-season vegetables, and 45,929 for out-of-season vegetables. The employment reductions are mainly concentrated in Latin America and Africa, and both are regions with high total employment coefficients (especially in Africa, with 3.582 thousand workers/million € and the Latin America, with 0.306 thousand workers/million €, compared to the Spanish level of 0.043 thousand workers/million €) and the outstanding position as Spanish produce providers. The net positive employment reduction that is generated as a result of domestic production replacing imports occurs for all months and in most regions, but with a few exceptions, such as France, Belgium and the United Kingdom, which total 824 net employment increases due to domestic production replacing in-season imported vegetables at their higher points. The results shown in Table 3 are net results, that is, they provide the difference between job creation and reduction due to imports substitution. If all Spanish imports of fruits and vegetables were to be replaced by domestic production, an increase of 66,298 new jobs would be generated in Spain, together with a total reduction of 853,790 jobs worldwide, particularly in the poorest regions. Deeper analysis of labour market conditions is required to know whether these jobs could be covered with domestic supply or imported labour is required, or how wages in the agri-food sector would be affected.

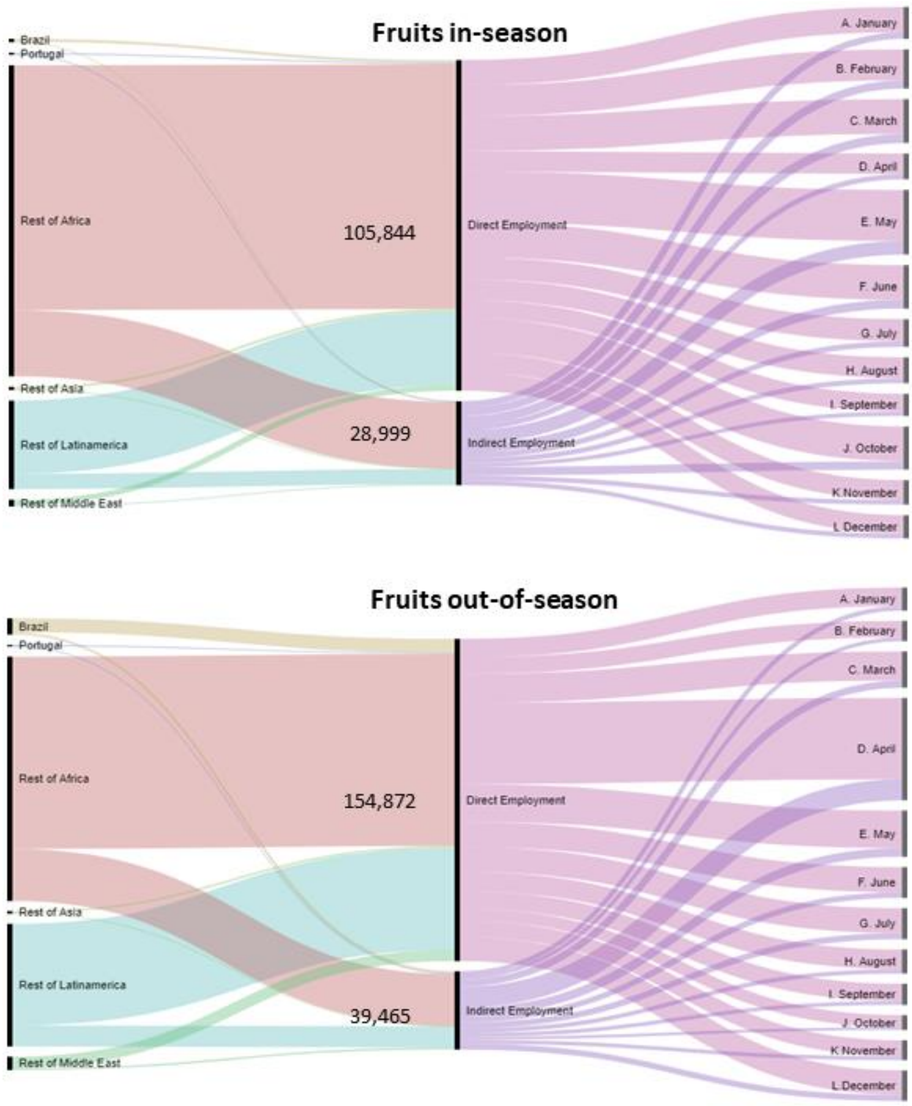
Table 3. Impact on labour due to substitution of imported seasonal fruits and vegetables by domestic production, 2011.

	Employment coefficient (1000 workers /Million €)		SAFM (workers)			
			Fruits		Vegetables	
	Total	Direct	In-season	Out-of-season	In-season	Out-of-season
Austria	0.0500	0.0351	2	2	3	0
Belgium	0.0320	0.0085	-275	-232	-193	-91
Bulgaria	0.0136	0.0048	-1	-8	-12	-2
Cyprus	0.0483	0.0186	0	0	4	2
Czech Republic	0.0544	0.0238	0	1	6	0
Germany	0.0433	0.0304	3	5	2	1
Denmark	0.0241	0.0120	-2	-14	-20	-4
Estonia	0.0412	0.0228	0	0	0	0
Spain	**0.0430**	**0.0266**	0	0	0	0
Finland	0.0231	0.0127	0	0	0	0
France	0.0411	0.0127	-124	-87	-256	-223
Greece	0.0575	0.0300	34	18	1	1
Hungary	0.0878	0.0500	1	4	36	35
Ireland	0.0227	0.0167	0	0	-1	-2
Italy	0.0481	0.0245	355	199	34	11
Lithuania	0.1280	0.0782	0	1	20	0
Luxembourg	0.0583	0.0265	0	0	2	0
Latvia	0.0267	0.0026	0	0	0	0
Malta	0.0220	0.0167	0	0	0	-1
Netherlands	0.0505	0.0060	48	182	183	104
Poland	0.0665	0.0426	9	26	20	2
Portugal	0.0745	0.0503	619	746	808	271
Romania	0.2611	0.1816	17	5	31	11
Sweden	0.0238	0.0132	0	-1	-13	-134
Slovenia	0.0721	0.0547	0	0	0	12
Slovakia	0.0198	0.0037	0	0	0	-27
United Kingdom	0.0212	0.0087	-173	-69	-375	-235
United States	0.0259	0.0134	-4	-38	-17	-9
Japan	0.0739	0.0503	4	1	0	0
China	0.8490	0.7866	611	1,217	5,045	3,881
Canada	0.0497	0.0223	0	3	0	0
Korea, Republic of	0.0822	0.0659	0	0	12	0
Brazil	0.1839	0.1471	1,085	7,703	21	28
India	1.4091	1.3397	0	459	130	0
Mexico	0.1462	0.1368	401	243	150	24
Russian Federation	0.0891	0.0551	0	9	3	0
Australia	0.0321	0.0120	0	0	-35	0
Switzerland	0.0388	0.0210	0	0	0	0
Turkey	0.0659	0.0559	3	5	5	0
Taiwan	0.1176	0.0868	0	0	0	0
Norway	0.0235	0.0119	0	0	0	0
Indonesia	0.7770	0.7147	0	119	0	0
South Africa	0.1784	0.1391	371	2,816	5	1
Rest of Asia	1.9639	1.6753	979	1,127	241	254
Rest of Latinamerica	0.3068	0.2453	28,594	58,023	8,438	9,552
Rest of Europe	0.2014	0.1198	86	319	17	83
Rest of Africa	3.5823	2.8110	100,518	115,603	396,539	32,368
Rest of Middle East	0.2282	0.1834	2,179	6,317	690	13
SAFM Total (net employment)			**135,339**	**194,700**	**411,523**	**45,929**
Gross employment embodied in imports			151,283	218,228	428,623	55,655
Gross employment embodied in domestic production			15,944	23,528	17,100	9,726

Note: The countries with technical coefficients greater than those of Spain are highlighted in red. Negative signs in SAFMs (green tones) imply net employment increases due to domestic production replacing fruits and vegetables imports (or losses due to imported fruits and vegetables), while positive signs in SAFMs (red tones) imply net employment losses due to domestic production replacing imports (or increases due to imports). SAFM results are in net terms, that can be obtained as the difference between gross employment embodied in imports and gross employment embodied in domestic production, also.

A comparison between the Direct (fruits and vegetable workers) and Total (all workers along the production chain) columns in Table 3 reveals that the differences in agricultural productivity are the main reason behind the increased net employment. The differences in the direct coefficients are higher than those of the total coefficients and, as a result, the labour productivity for fruits and vegetables explains approximately 70% of the SAFM differences for the rest of Africa and rest of Latin America. These regions are characterised by high labour intensities and low levels of production mechanization, together with an agricultural sector that is the only income option for broad segments of their populations (FAO, 2018). In addition, employment is highly concentrated in terms of its origin (the rest of Africa represents 74% and 60%, for in-season fruits and out-of-season fruits, respectively, while the rest of Latin America represents 21% and 30%, respectively). When comparing the in-season fruits and out-of-season fruits (Figure 1), the employment that is generated by imports is similar and the direct effect is dominant in both cases and is evenly spread throughout the months (except for April for out-of-season fruits).

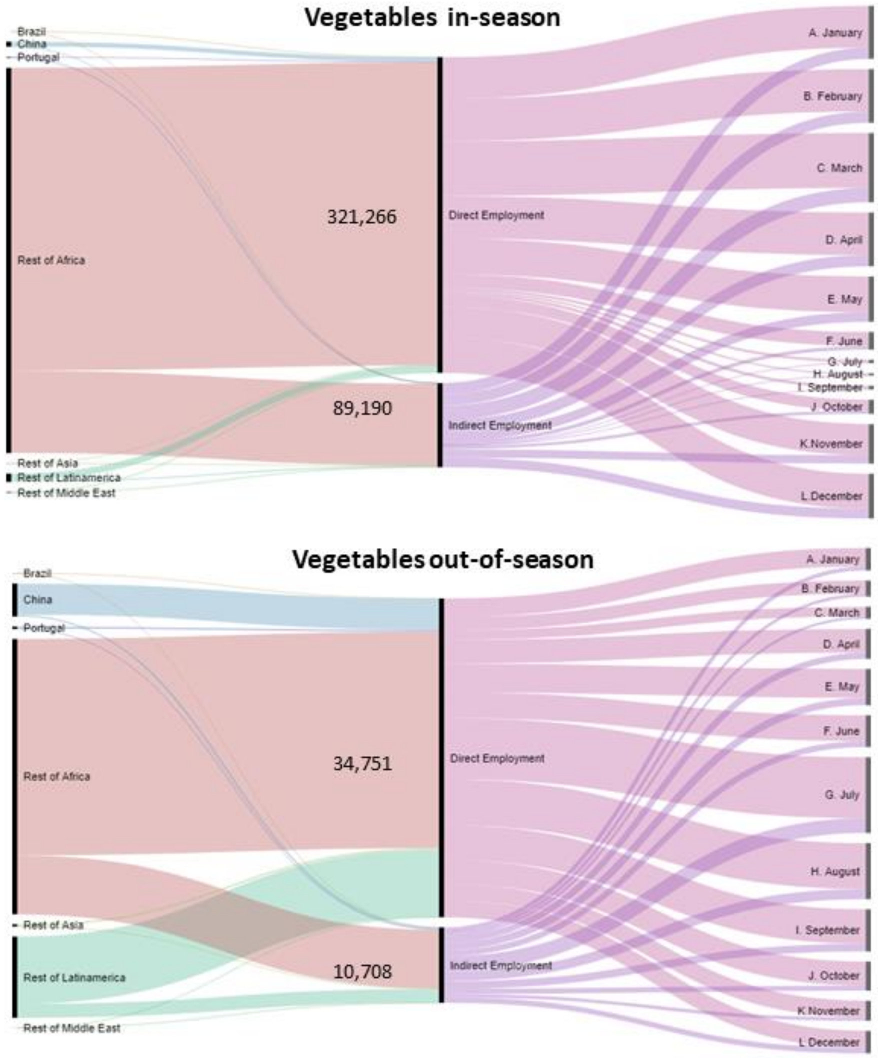
Figure 1. Reduction in direct and indirect employment due to fruits' imports substitution by domestic production, main countries with positive signs, 2011 (workers).



Note: The flows represent the reduction in employment associated with the substitution of imports of fruits by domestic production). The flows on the left report the employment reduction in the region from which the imports originate. The middle flows indicate if the employment reduction is direct or indirect, and the flows on the right show the months in which these imports take place.

For vegetables, in-season is the source of most labour increases, which would cause a net reduction of 411,523 jobs if the amount of imported production were to be replaced by domestic production and would mainly be located in the rest of Africa (over 96%). The amount of labour induction due to imported fruits and vegetables is lower in summer (e.g., from June to September) and is mainly due to the increased Spanish production for in-season vegetables, in contrast to out-of-season vegetables for which the months with the highest employment linked to Spanish imports are July, August and September (see Figure 2). The added employment from imported out-of-season vegetables is remarkably lower and is due mainly to the low import volumes. The main values are concentrated in the summer season in the rest of Africa (69%), with a smaller contribution from the rest of Latin America (20%).

Figure 2. Reduction in direct and indirect employment due to vegetables' imports substitution by domestic production, main countries with positive signs, 2001 (workers).



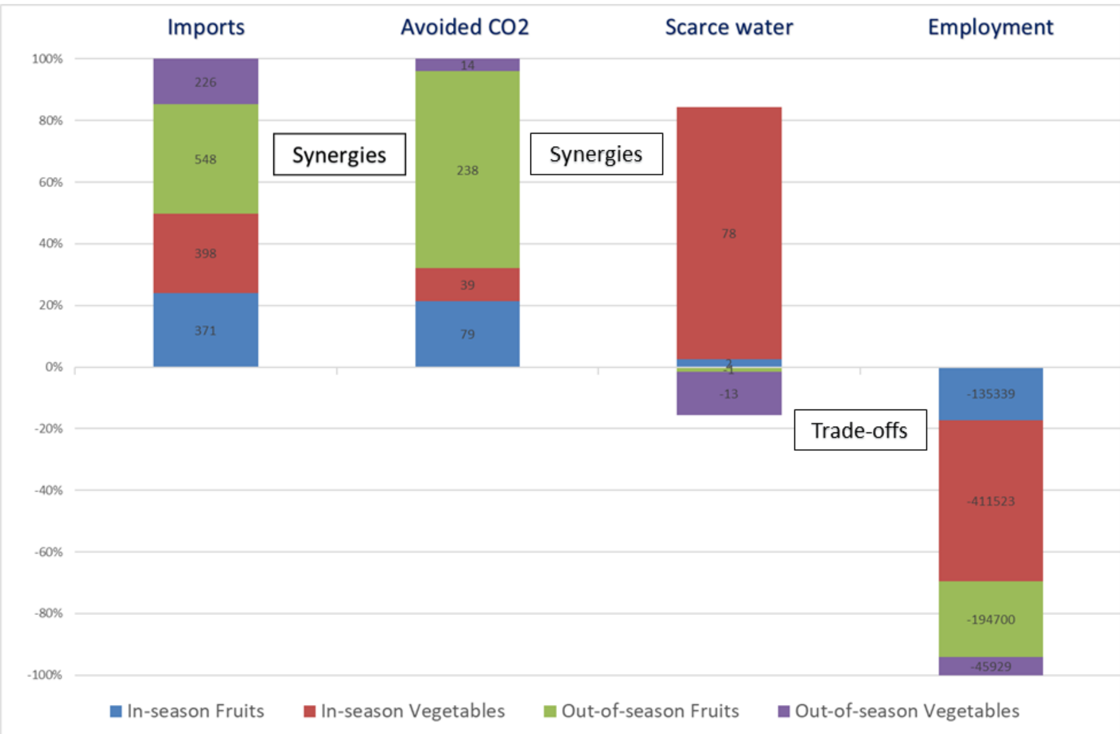
Note: The flows represent the reduction in employment associated with the substitution of imports of vegetables by domestic production. The flows on the left report the employment reduction in the region from which the imports originate. The middle flows indicate if the employment reduction is direct or indirect, and the flows on the right show the months in which these imports take place.

The jobs that are created in the developed and developing countries have markedly different characteristics in terms of the work and pay conditions and of social risk, which are factors that should be kept in mind if labour substitution is to be considered. The possibilities of the MRIO models to allocate undesired social footprints, by drawing links among the final consumers and producers, have been recognised by previous studies (García-Alaminos et al., 2020; Wiedmann and Lenzen, 2018; Xiao et al., 2017). Although the identification of such indecent labour footprints is beyond the scope of this study, previous research has revealed some cases. An important source of social risk that is associated with the exports from developing countries to developed countries takes place in agriculture, e.g., Moroccan exports of tomatoes and molluscs, which are products with high gender inequality in their production conditions (Xiao et al., 2017). Other countries and products with high social risk include rice in India, dried fruits in Pakistan, fish and sugar in Yemen, and tomatoes and sugar in Syria. In general, forced labour is a significant issue worldwide in the primary sector in both Africa and Latin America (USBILA, 2016).

3.2 Trade-off versus synergies due to fruit and vegetable imports.

The joint analysis of the avoided factor balances in monetary and physical terms sheds some light on the real impacts of changes in household consumption patterns (Figure 3). For the total imports of Spanish fruits and vegetables, the results show that a conflict is present among the social and environmental goals for all groups when confronting the employment impact with one or both of the environmental impacts. This is because, throughout the year, the substitution of imported fruits and vegetables for domestic production implies reductions in the carbon and scarce blue water footprints. However, there is an important trade-off between the environmental and social footprints since import substitution would lead to a reduction in employment of 787,492 jobs (as seen in Table 2).

Figure 3. Imports (millions of euros), avoided CO_2e (tCO_2), avoided scarce blue water (Km^3) and job reductions (workers) due to import substitution by domestic production (SAFM), 2011



Note: The sign of the SAFM for employment has been changed from positive to negative in this figure for presentation purposes to clarify that the results obtained if imports are substituted by domestic production imply a net reduction in overall employment (fewer jobs in Spain than would have been in other countries for the same production of fruits and vegetables).

In- and out-of-season imported fruits, comprise 59% of total imports, and only 58% of net-generated employment. However, these imports account for 88% of the net generated CO_2 emissions that could be caused by international trade in 2011 (Table 4). On the other hand, in- and out-of-season imported vegetables, account for only 41% of imports, 42% of generated net employment abroad, and only a 12% increase in net emissions. Therefore, although the labour intensity is only slightly lower for imported fruits than for imported vegetables, imported fruits have a much higher carbon intensity than vegetables. In particular, out-of-season fruits account for 64% of the CO_2e emissions for all groups considered, even though they only account for 35% of the imports, so they are a focus for controlling negative trade impacts.

Regarding water, fruit import substitution does not significantly change water use, with in-season and out-of-season fruits accounting for less than 5% of the avoided scarce blue water measure. However, the vegetable trade implies important virtual data flows that have particular patterns, with a positive sign for in-season vegetables, which induce a notable increase in water use if the imported products were to be replaced by domestic production and a potential reduction if the substitution were for out-of-season vegetables. A small relative efficiency in Spanish agriculture in the production of out-of-season fruits and vegetables in terms of water, especially in the case of vegetables, points to imports as a way to reduce the use of this resource.

Table 4. Fruit and vegetable imports, avoided CO_2e, scarce water, and employment reduction due to import substitution by domestic production, 2011

		Imports (euros)		Avoided CO_2 (kCO_2)		Avoided scarce blue water (m^3)		Employment reduction (workers)	
Fruits	In season	371,016,223	24%	79,285,574	22%	56,646	4%	135,339	17%
	Out-of-season	547,503,825	35%	237,712,902	66%	1,244	0%	194,700	25%
Vegetables	In-season	397,935,273	26%	33,695,726	9%	1,452,848	107%	411,523	52%
	Out-of-season	226,323,947	15%	9,121,550	3%	-151,084	-11%	45,929	6%

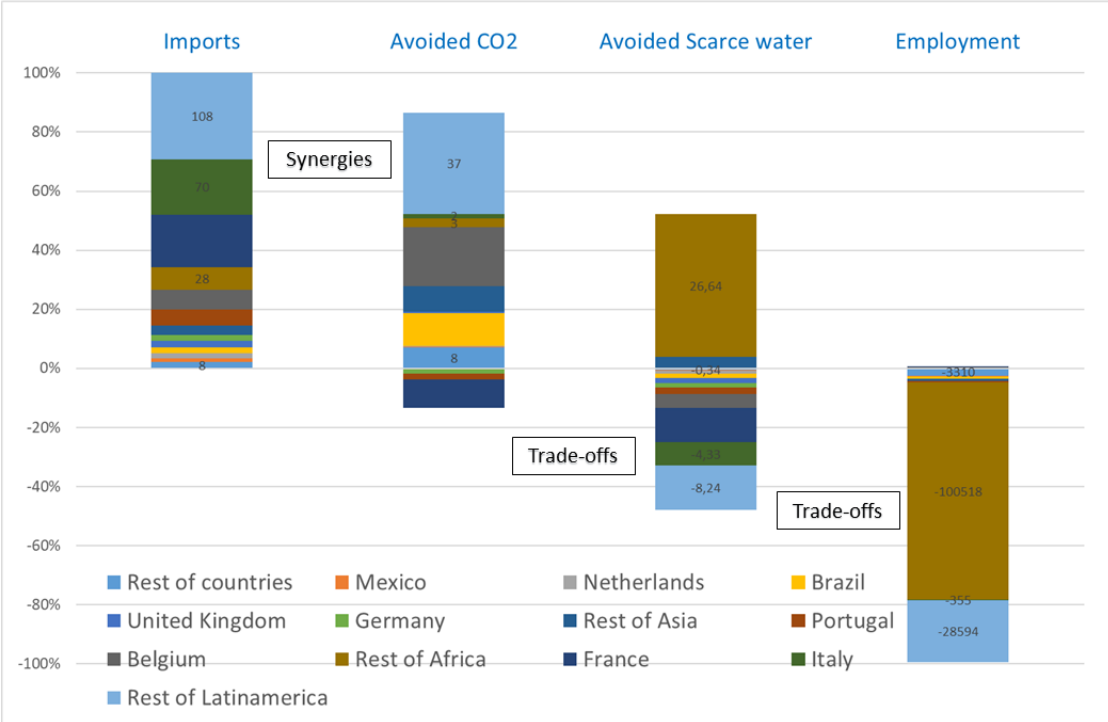
3.3. Hotspots associated with the consumption of imported fruits by country

The objective of this section is to identify the countries in which the SAFM presents negative (or positive) hotspots in terms of emissions, water, or employment. This leads to a discussion regarding whether it would be beneficial to modify (or maintain) the trade relationships (see Figures 4 and 5), especially if these relationships represent a significant share of total Spanish imports. These two extreme cases lead to a consideration of the negative and positive synergies that are defined in Table 1, which identify those countries for which fruit and vegetable import substitution is undesirable (column 3) or recommended (column 4), respectively. More complex cases are, however, common in our results and examining those situations where import substitution would improve the environmental metrics (social) while worsening the social (environmental) metrics. More complicated cases can also be mentioned, since although the water and carbon footprints go hand in hand for many countries, this is not always the case.

The clearest case where a goal conflict occurs is for the rest of Africa (WF), since the elimination of imports represents a slight reduction in the total imports of in-season and out-of-season fruits and implies a difficult trade-off since it would mean significant savings of scarce blue water while leading to a reduction of more than 300,000 jobs in that area. For the case of the scarce blue water balance of in-season fruits, the imports from the rest of Africa (WF) account for 7.7% of imports and 92.4% of the total increase in the avoided balance of scarce blue water. However, these imports only represent 4.3% of the CO_2e growth. We also highlight that 44% of Africa's imports come from Morocco (melons, watermelon, papayas, grapes, dates and pineapples) and 15% from Cameroon (bananas). The substitution by imports from the rest of Africa involves a strong conflict of the objectives or trade-offs between promoting the planet's environmental sustainability (e.g., reducing water consumption) and the social and economic sustainability of the developing regions due to the great reductions in employment that are generated.

In the rest of Latin America, a conflict occurs between the increased CO_2 emissions and the significant reduction in employment when imports of in-season fruits and, especially, out-of-season fruits are replaced by local consumption. Specifically, the imports of out-of-season fruits from Brazil (e.g., melons, watermelon, papayas) make up 10% of the total, yet its CO_2 emissions SAFM represents 35.9% of the increased emissions. However, this conflict does not occur for water since the region has significant resources. For the case of water, the imports from Latin America (as hinted at in the introduction, e.g., from Costa Rica, which is the main provider of tropical fruits for Spain, approximately 23% of those imports, mainly pineapple and banana, or from Perú, mainly avocado) present a synergy between job creation and water use, since they represents a large addition of jobs in the relatively poorer regions of the planet and a net reduction in the consumption of scarce blue water (the savings for out-of-season fruits are much greater than for in-season fruits).

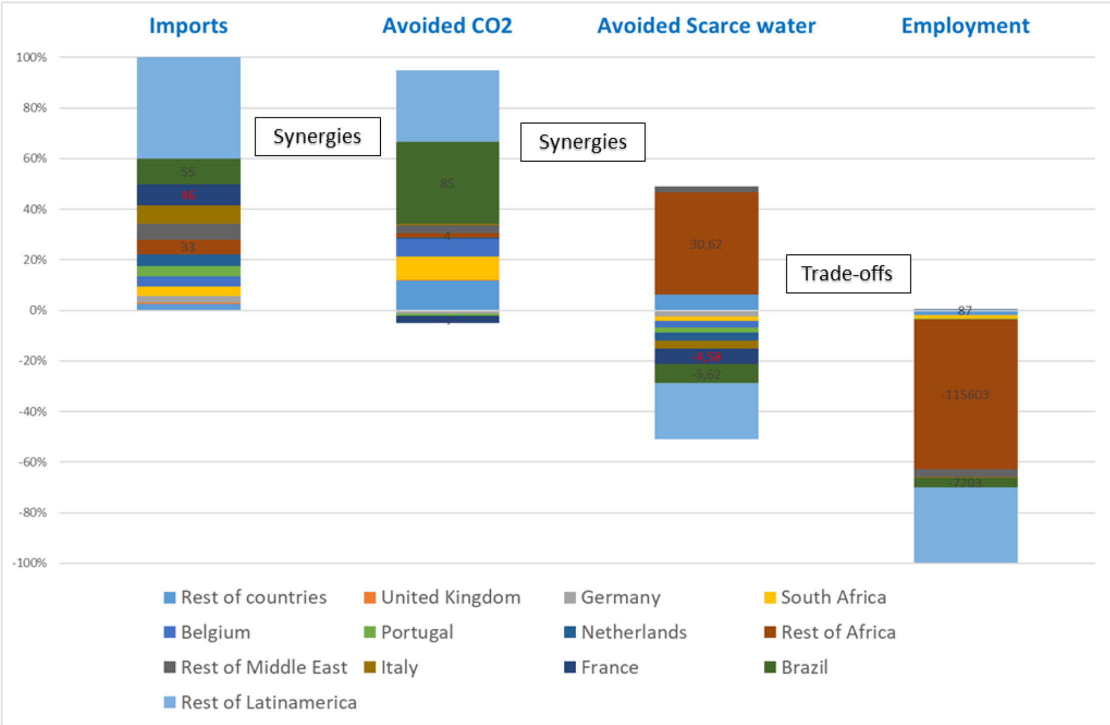
Figure 4. Imports (millions of euros), avoided CO_2e (tCO_2), avoided scarce blue water (Km^3) and job reductions (workers) due to in-season fruits' import substitution by domestic production (SAFM), 2011



Note: The sign of the SAFM for employment has been changed from positive to negative in this figure for presentation purposes to clarify that the results obtained if imports are substituted by domestic production imply a net reduction in overall employment (fewer jobs in Spain than would have been in other countries for the same production of in-season fruits).

Regarding the replacement of in-season and out-of-season fruits that are produced in Spain by imports from France and Portugal (and other similar EU countries), the environmental effects of these substitutions would be negative since they would increase both emissions and the amounts of scarce water used. The changes in employment are minimal when dealing with EU countries, especially if we compare them with those observed for countries in Africa and South America, and therefore, their impact is more a matter of environmental rather than social sustainability. For the in-season fruits, imports from Belgium (e.g., apples, pears, and quinces) can also be highlighted since their imports are 6.8% of the total and lead to an increase in emissions that is 27% of the total.

Figure 5. Imports (millions of euros), avoided CO_2e (tCO_2), avoided scarce blue water (Km^3) and job reductions (workers) due to of out-of-season fruits' import substitution by domestic production (SAFM), 2011



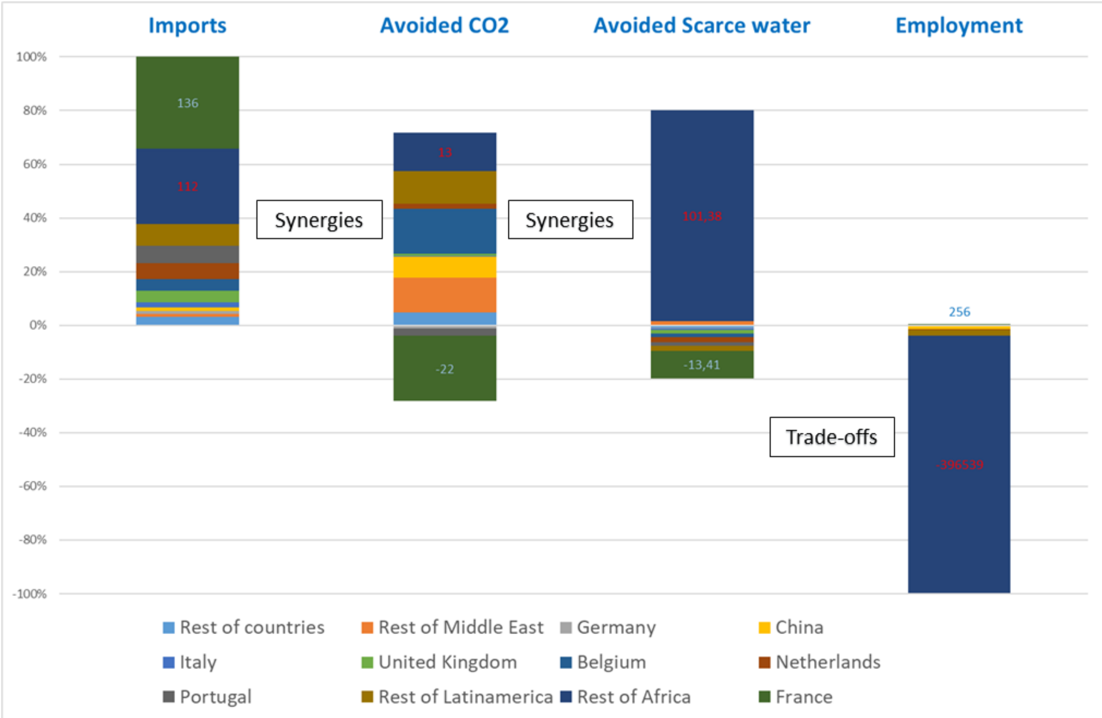
Note: The sign of SAFM for employment has been changed from positive to negative in this figure for presentation purposes to clarify that the results obtained if imports are substituted by domestic production imply a net reduction in overall employment (fewer jobs in Spain than would have been in other countries for the same production of out-of-season fruits).

3.4 Hotspots associated with the consumption of imported vegetables by country

The most important import volumes from Africa consist of in-season vegetables, as these come from Northern Africa, which has the same seasonal cycle as Spain. The imports from the rest of Africa represent 28% of the total, and their replacement for domestic production encompasses a strong trade-off since it would allow a reduction in the use of scarce blue water that would total 101 km^3 (i.e., 130% of the total net scarce blue water savings) and a reduction in carbon emissions of 13 tCO2 (i.e., 33% of net avoided emissions) but would nevertheless result in a reduction of 396,539 net jobs in Africa (.96% of the total net loss). In other words, there are economic and environmental synergies that are associated with the substitution of vegetables from Africa but there is an important trade-off in terms of employment, as is also found for fruits. The importance of imported vegetables from Latin America is much less than that of fruits, which has a lower weight in the total imports.

In terms of emissions, Belgium is a hotspot in economic and carbon terms. The imports into Spain of in-season vegetables from this country represent 4.4% of the total value and 38% of net emissions. Hence, reducing the imports of vegetables from Belgium would lead to a significant reduction in the global carbon footprint of in-season vegetables, while the effects on scarce water and employment are minor. In France, the significant imports of in-season vegetables lead to significant savings in emissions and scarce blue water, with little impact on employment. In this case, the substitution of imports from France would mean a significant increase in the global impacts in terms of carbon and scarce blue water.

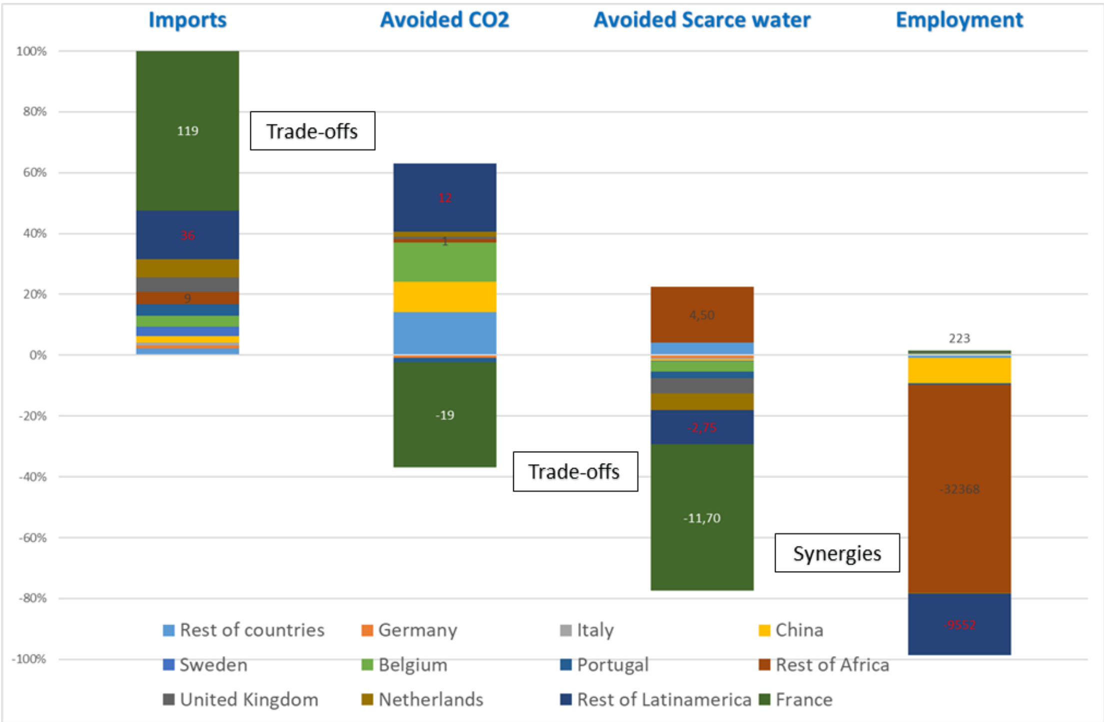
Figure 6. Imports (millions of euros), avoided CO_2e (tCO_2), avoided scarce blue water (Km^3) and job reductions (workers) due to in-season vegetables' import substitution by domestic production (SAFM), 2011



Note: The sign of SAFM for employment has been changed from positive to negative in this figure for presentation purposes to clarify that the results obtained if imports are substituted by domestic production imply a net reduction in overall employment (fewer jobs in Spain than would have been in other countries for the same production of in-season vegetables)..

In the out-of-season vegetable trade, the imports from the rest of Africa represent 4% of the total (e.g., 90% from Morocco, legumes and tomatoes and 7% from Egypt). These imports also are also associated with a net increase in the scarce blue water footprint of 4.5 km^3 (78.5% of the increase), a small effect in terms of emissions, and the creation of 32,368 jobs (70% of the net creation) (Figure 7). Therefore, its replacement in monetary terms would be feasible and would have a significant synergy in terms of water but would also be a trade-off in terms of employment. On the other hand, imports from France maintain a positive hotspot, since they represent 52% of the total imports and lead to great savings in emissions (49% of the total net savings) and in water (-11.7 km^3, which represents 88% of the net savings), while the net generated employment is 223 workers.

Figure 7. Imports (millions of euros), avoided CO_2e (tCO_2), avoided scarce blue water (Km^3) and job reductions (workers) due to out-of-season vegetables' import substitution by domestic production (SAFM), 2011



Note: The sign of SAFM for employment has been changed from positive to negative in this figure for presentation purposes to clarify that the results obtained if imports are substituted by domestic production imply a net reduction in overall employment (fewer jobs in Spain than would have been in other countries for the same production of out-of-season vegetables)..

4. CONCLUSIONS

The study has been framed around global social and environmental effects, especially regarding the food-energy-water (FEW) impacts of national actions, in particular fruit and vegetable import substitution. This substitution trend has become popular in thinking, discourses, and action (based on health, environmental, and local employment concerns), such as the consumption of local (zero-kilometre) and in-season products, especially in affluent regions.. Additionally, security concerns related to availability of food, energy, and water (and now health equipment due to the COVID-19 crisis) are increasingly present on the agenda at a wider scale.

Our study allows us to conclude that decisions regarding the local and seasonal consumption of fruits and vegetables by citizens in rich regions of the global economy, as in Spain, can lead to a conflict of objectives between the economic and social development in the poor regions of the world and the related environmental impacts. This highlights the complexity of communicating a clear message to consumers in rich regions that would allow them to make consumption decisions that support the achievement of balanced global sustainability and the sustainable development objectives of poor regions on the planet.

The trade in fruits and vegetables between Spain and other developing countries creates relevant negative environmental hotspots, as the imports from these countries are often more carbon- and water-intensive: The rest of Africa (e.g., Morocco, Cameroon, Senegal, Tunisia, and Cote d'Ivore) for water and the rest of Latin America and Brazil for carbon. For the imports from Africa, the most significant volumes consist of in-season vegetables, as they mostly originate in the north of the continent, which shares the same season as the Iberian Peninsula. Nevertheless, these imports are problematic due to their requirements of large amounts of scarce blue water but at the same time, that they generate the most jobs by means of imports. On the other hand, most of the imports from South America into Spain consist of out-of-season fruits that result in a significant increase in CO_2e emissions along with a relative decrease in scarce blue water use and a rise in net employment. For all of these imports, a focus on environmental objectives would lead to advising against their consumption in favour of using domestic produce in Spain, as they present environmental synergies. However, they show a strong conflict in terms of employment reductions. By considering all factors, we should instead provide information about some negative social effects compared to the other effects and suggest a reduction in their consumption.

Whenever employment in developing countries is considered as an argument, together with in-season and proximity consumption, it becomes an increasingly complex task to draft clear patterns to guide decision-making by consumers. Local produce reduces imports and impairs development in developing regions. Their high direct employment intensity in agriculture, which is partly due to subemployment, implies vast job losses if imports from these countries are replaced by local or domestic production. The trade-off between improving the environment and creating jobs in emerging countries should cause us to consider alternatives to measure both types of impacts simultaneously. Most existing certification and labelling processes (e.g., "fair trade", "carbon footprint", "recycled", and “no plastic use”) focus on separately identifying how adequate those products are in either social or environmental terms. Our results suggest that we should search for certification systems that jointly consider the appropriate social, economic, and environmental development factors.

From the perspective of Spanish trade policy with developing countries, this would entail establishing trade agreements with countries that generate important environmental impacts under the conditions of cultivation technology transfer that saves water and reduces carbon emissions in those regions to reduce environmental pressure while sustaining local economies. Other solutions that advocate taxing products from developing countries to include the negative externalities into their prices through embodied carbon or water taxes should also consider the lower level of development in these countries as well as the job concentrations in agriculture. In this sense, the income from those taxes should be returned to these countries by means of a Clean Development Mechanism or as technology transfers that reduce resource use and reduce energy intensity.

As a collateral benefit of our analysis, we find that footprint calculations can also be used to evaluate the impacts of developing countries on achieving the SDGs in the poorest regions of the world. This must start by quantifying the consumption weights of the developed countries in terms of employment, value-added, carbon or water in the developing countries. By using this information, rather than by focusing on the absolute levels of those variables, incentives should be more precisely directed to reduce the carbon and water intensities of exports and to increase job quality, i.e., with higher wages per new job.

Another path to evaluate how the import of fruits and vegetables from developing countries can improve social sustainability in the origin countries, without undermining family welfare in rich countries and their substitution via price elasticity, would involve calculating the degree to which the wages in the developing countries could increase, so that imports would have the same price per unit as the domestically produced produce. In practice, this calculation is akin to a substitution in terms of quantity rather than value, as in this study, as it guarantees the same price for domestic and imported produce.

The Spanish trade in fruits and vegetables with developed countries also creates some positive environmental hotspots, as some imports reduce both CO_2 emissions and the use of scarce blue water, namely, France, and Portugal. The environmental synergies and few social trade-offs characterise this trade due to the similarity in employment coefficients and the cleaner and more efficient production processes in these countries. For instance, for the case of imports from France, these imports are mostly in-season (followed by out-of-season) vegetables, and they generate significant CO_2 and scarce blue water savings while barely reducing jobs. In such cases, appropriate environmental certifications for imported products that inform consumers about the water and carbon footprints, when compared to alternative Spanish produce, would inform consumers about the benefits of these imports. In contrast, for the imports from developing countries, the social (job) impacts are less extreme, while the environmental effects, especially water rather than carbon, are more relevant. For this reason, when promoting local and seasonal consumption, environmental considerations are more important than job creation or local and regional integration. Consequently, imports should include a positive environmental certification rather than a job-based certification.

The obtained positive or negative FEW synergies provide a tentative result to guide policies with great development and mitigation potential, and they should be understood as an early approximation to orient further studies. The accuracy of the results would benefit from a lower level of disaggregation of the environmental coefficients for different fruits and vegetables. By working with agricultural products, the results would also improve with seasonalized production coefficients for the products, since they are not expected to be similar if production conditions change throughout the year in terms of the water and temperature conditions. This is also the case for the production coefficients, which could be determined in detail by using specific regional characteristics, since national borders cannot be incorporated into the climate conditions for agricultural produce.

ACKNOWLEDGEMENTS

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