Vulnerability of exporting nations to the development of a carbon label in the United Kingdom

G. Edwards-Jones a,*, K. Plassmann a, E.H. York a, B. Hounsome b, D.L. Jones a, L. Milà i Canals c

a School of the Environment and Natural Resources, Bangor University, Bangor, Gwynedd, N Wales, LL57 2UW, United Kingdom
b Centre for Economics and Policy in Health, Institute of Medical and Social Care Research, Dean Street Building, Bangor University, Bangor, Gwynedd LL57 1UT, United Kingdom
c Centre for Environmental Strategy, University of Surrey, Guildford, Surrey GU2 7XH, United Kingdom

1. Introduction

Concern about climate change has stimulated interest in estimating the total amount of greenhouse gases (GHGs) emitted during the production, processing, retailing and use of many consumer goods, including food products (e.g. Smith et al., 2005; Tzilivakis et al., 2005; Nonhebel, 2006). The outcome of these calculations is the carbon footprint, which reports the total amount of GHGs produced for a given activity (Carbon Trust, 2007). The carbon footprint of a product is expressed in terms of its global warming potential (GWP), which relates to the impact of different GHGs on global warming. In order to simplify discussion of the impacts of different mixes of GHGs, the global warming potential of 1 kg of each GHG is compared to that of 1 kg of carbon dioxide. IPCC (2007) suggests that the impact of 1 kg of methane on global warming is equivalent to that of 25 kg of carbon dioxide, while 1 kg of nitrous oxide is equivalent to 298 kg of carbon dioxide. After making the impact of all the GHGs equivalent to that of carbon dioxide, their impacts can be summed and the overall impact can be expressed as kg of CO2-equivalents.

Carbon labels inform consumers about the amount of greenhouse gases (GHGs) released during the production and consumption of goods, including food. In the future consumer and legislative responses to carbon labels may favour goods with lower emissions, and thereby change established supply chains. This may have unintended consequences.

We present the carbon footprint of three horticultural goods of different origins supplied to the United Kingdom market: lettuce, broccoli and green beans. Analysis of these footprints enables the characterisation of three different classes of vulnerability which are related to: transport, national economy and supply chain specifics.

There is no simple relationship between the characteristics of an exporting country and its vulnerability to the introduction of a carbon label. Geographically distant developing countries with a high level of substitutable exports to the UK are most vulnerable. However, many developing countries have low vulnerability as their main exports are tropical crops which would be hard to substitute with local produce.

In the short term it is unlikely that consumers will respond to carbon labels in such a way that will have major impacts in the horticultural sector. Labels which require contractual reductions in GHG emissions may have greater impacts in the short term.
Currently businesses can utilise carbon footprints in order to inform their internal environmental management. In addition there is the possibility that in the future they may be used to inform market based pollution control schemes such as carbon trading (Jochen Gassner, pers. com.). A further possible outcome from the carbon footprinting process is a ‘carbon label’, which communicates a summary of the carbon footprint of a product to consumers (Carbon Trust, 2006). Carbon labels can appear on the packaging of the product, or alternatively they can be made available to stakeholders by other means, such as on a website or in company literature (e.g. http://www.walkerscarbonfootprint.co.uk, http://www.innocent.co.uk).

If consumers in the United Kingdom (UK) were to utilise a carbon label on food to guide their purchase decisions then, all other things being equal, a rational consumer would purchase lower carbon rated items in preference to higher rated ones. As transport can be one of the major sources of greenhouse gas emissions in any supply chain (Sim et al., 2007), consumer responses to carbon labels bring the potential to impact the competitiveness of exports from countries which are distant from the UK (or any other market). The loss of these export markets may then in turn have impacts on a range of social and environmental factors in the exporting nations (Edwards-Jones et al., 2008).

The purpose of this paper is to consider the potential impact on exporting countries of UK consumers making food purchasing decisions based on a carbon label. Of particular concern is the issue as to whether poor countries will suffer disproportionately from any impact of a carbon label. In order to achieve this aim, the paper will consider the carbon footprint of four different horticultural products supplied to the UK from a range of countries. These examples will then be used to identify the factors which influence the vulnerability of exporting nations to any impacts of a carbon label. Finally the overall vulnerability of some case study economies and supply chains will be identified and discussed. The focus in this analysis is on horticultural products because the airfreight of such products has stimulated a high level of public attention in issues such as ‘food miles’ in recent years (The Guardian, 2003; Kelly, 2004; Frith, 2005; Smith et al., 2005). As a result of scientists’ response to this public attention there are more relevant data on international supply chains for horticultural products than for other groups of product.

2. Methods

Two types of study are reported here. Firstly, two case studies present primary data collected as part of a larger research project which have not been reported previously; these relate to the supply of green beans from Kenya and Uganda and broccoli from Spain to the UK market. A third case study on lettuce supplied to the UK from Spain was undertaken as part of the same research project and has been reported previously (Mila i Canals et al., 2007a). In addition to these primary case studies, the case of supplying roses to the UK from Kenya and The Netherlands is also discussed (Williams, 2007). This study has been reported elsewhere and is presented here in order to broaden the perspective offered by the three primary case studies. As the purpose of the case studies presented is to highlight issues which will influence the vulnerability of exporting nations to a carbon label it is not possible to present the results of the full life cycle assessments (LCA) here. Rather only summary results of the GHG emissions are reported here and further details of the LCA of the three primary case studies will be reported elsewhere.

2.1. Data collection for the primary case studies: beans, broccoli and lettuce supply chains

Between 2006 and 2008 vegetable farms in the UK, Spain, Uganda and Kenya were asked to participate in a research project which was concerned with exploring a range of issues related to the production of ‘local’ and ‘non-local’ food. As part of this project farms helped with research covering a range of topics such as greenhouse gas emissions from production, soil quality, nutritional quality of produce, social and economic studies (Cross et al., 2008) and LCA. The sampling strategy for participating farms was opportunistic. For example, in Spain and the UK all commercial horticultural farms in specific regions were approached by a letter followed up with a phone call (Lincolnshire, Hereford and Worcester in UK and Murcia in Spain). The purpose of the project was explained to the farmer in these communications, and interested farms were then visited by project staff for further discussion. Once the farms were recruited data collection took place via regular, sometimes monthly, visits over the 3 year period.

Farms in Uganda were recruited via direct contact made from collaborators in Makerere University, Kampala. In Kenya the research was undertaken on large commercial farms which were approached directly by UK based staff and asked to participate. Field work in Uganda was undertaken in 2006 and 2007 and in Kenya in 2007.

In order to obtain a statistically valid sample of farms and/ or supply chains it would be necessary to adopt a two stage process. First would be a need to understand the variability in carbon footprint of a product produced from different farms/ supply chains. Second would be the utilisation of a sampling procedure that ensured adequate representation of farms from across the entire range of carbon footprints (e.g. some form of random stratified sample). There is currently a poor understanding of the variability of producers’ carbon footprints, and as a result there is insufficient knowledge available to enable the construction of a valid sampling frame. For this reason the sampling procedure adopted here was pragmatic as it provided good coverage of regions within a country and ensured farms were clear as to their commitment to the project. However, it was not a statistically representative sample of farms in these regions. So while the sample farms appeared to be qualitatively typical of their type, the results cannot be extrapolated to all farms in a region or country.

2.2. LCA methods

The scope of the LCA studies for beans and broccoli included the assessment of vegetable production and delivery to UK consumers, as well as food storage, preparation and consumption at home. The GHG emissions of each product were
estimated from the application of standard life cycle assessment methods (to be reported in full elsewhere). The analysis utilised the Ecoinvent 2000 database (http://www.ecoinvent.ch) (Althaus et al., 2004; Dones et al., 2004; Frischknecht et al., 2004; Nemecek et al., 2004; Spielmann et al., 2004), and the impact assessment phase was performed using the CML 2001 method (Guine´ e et al., 2002). As discussed above farm level data were collected directly from farms in the UK, Spain, Kenya and Uganda. More generic data were used for upstream production of farm inputs and some downstream activities. Data relating to the production of ancillary materials and machinery were obtained from existing databases.

3. Results

3.1. Case study 1 – green beans (Phaseolus vulgaris) from the UK, Uganda and Kenya for the UK market

3.1.1. Description of farms and supply chains

Data collection in the UK focused on one large farm specialised in runner beans. The farm had high levels of mechanisation; but also used manual labour for planting and harvesting. Applications of fertilisers and pesticides were tailored to the crop’s needs through soil analyses and pest monitoring. Early crops were protected with a plastic cloche for the first weeks to prevent frost damage. Later crops did not require a cloche, but irrigation was occasionally required. Yields were normally round 12 tonnes/ha. The carbon footprint of both fresh and frozen bean supply chains was estimated.

In Uganda, five different bean growers were studied. Most of them grew crops on fields recently (less than 5 years) cleared from secondary growth forest. In some parts of Uganda the abandonment of fields and their subsequent clearing is a form of rotation and does not constitute clearance of primary forest. All farms had a very low level of mechanisation, with only two reporting the use of hired ploughs for soil preparation. The beans have a short growing cycle (about 4 months from sowing to next crop) and a yield of ca. 9.5 tonnes/ha. Most operations on the farm were undertaken manually and while most crops were rain fed some manual watering was required during dry periods. Beans were transported to the UK by air. Some farmers sold produce directly to exporters who then sold the produce to Europe or Asia (India), others sold to a mixture of exporters and local markets.

In Kenya, one large farm growing runner beans for export to the UK was assessed. This farm had an integrated growing, packing, transport and export system, and was responsible for all of these stages up to delivery in the retail distribution centre (RDC) in the UK. All beans were air freighted from Kenya to the UK in freight planes. The level of mechanisation was low, with planting, weeding, installation and removal of crop support, coiling and harvesting operations all being carried out manually. Yields were typically 36–38 tonnes/ha. The growing period for runner beans was 5 months; in between crops, a cover crop was planted and left in the ground for 12–15 months. New fields were planted throughout the year. Irrigation was used for 4 months per crop; however, irrigation needs varied throughout the year depending on rainfall. Fertilisation was mainly through the irrigation drench as fertigation. Lighting was required for 10 weeks per crop.

3.1.2. Carbon footprint

The GWP of the two African supply chains was substantially greater than the UK supply chains, and was dominated by the air freighting stage (Fig. 1). Home processing was the dominant life cycle stage for the UK supply chains, and this highlights the important impacts of storage and cooking on the life cycle of many goods. The cropping stage for fresh beans, and the transport and retail stage for frozen produce, were the next most important life cycle stages in terms of GWP.

3.2. Case study 2 – flowers from Kenya and The Netherlands brought to the UK market place (Williams, 2007)

This study estimated the carbon footprint of producing cut roses supplied to the UK market place from one company in Kenya and a separate company in The Netherlands. The supply chains differed in two significant ways. Firstly delivery from Kenya included a long flight by freight aircraft, whereas delivery from The Netherlands was by road. Secondly electricity and heat used in Kenyan greenhouses were derived from geothermal energy, while in The Netherlands heating came from burning natural gas, and electricity was generated from a primary energy mix dominated by fossil fuel.

The study used a traditional LCA approach and estimated emissions of GHGs associated with the manufacture of all inputs, and their use in the supply chain. This involved tracing emissions back to primary sources of energy and material. The system boundary included production and transport up to the retail distribution centre (RDC) in Hampshire, southern England. The functional unit for the analysis was 12,000

![Fig. 1 – Comparative results for Global Warming Potential (GWP) (kg CO2 equiv per 1 kg of beans) for five alternative bean supply chains: Kenya (KE), Uganda (UG), United Kingdom first crop (UK1), second crop (UK2) and frozen (UK frozen). The relative contributions of different elements of the supply chains are shown by the shading.](image-url)
marketable quality cut stem roses. All data on production systems were provided to the analyst by the company and associated consultants.

The annual yields of marketable stems were 1,350,000 and 2,285,000 per hectare in the Dutch and Kenyan operations respectively. The production and delivery to the RDC from Kenya incurred 68,000 MJ primary energy and emitted 6000 kg CO₂ equiv GHGs. Delivering the same amount of flowers to the same RDC from the Dutch company incurred 550,000 MJ primary energy and emitted 37,000 kg CO₂ equiv GHGs.

3.3. Case study 3 – lettuce production in Spain and the UK for the UK market (Mila` i Canals et al., 2007a)

3.3.1. Description of farms and supply chains
In order to provide lettuce to UK consumers all year round several different supply chains have been developed. These include UK field grown lettuce in the summer, imports from Spain (delivered by road) during the UK winter, and also UK based protected cultivation in the UK winter. Outdoor production practices change through the seasons to respond to weather conditions; e.g. UK early crops (harvested May to mid July) are protected with fleece to prevent frost damage during the first 6 weeks in the field, while early Spanish crops (planted in August–September) generally require more water for irrigation. Mila` i Canals et al. (2007a) undertook an LCA of lettuce production from these three different supply chains. The functional unit was 1 kg of lettuce delivered to a UK RDC. Data on farm production practices, post-harvest cooling and transport to the RDC were collected directly from individual producers in the UK (3 open field, 2 under-glass) and Spain (2 producers). Data related to the production of cos, iceberg and green oak leaf lettuces and fine endives, but no distinction was made on the basis of lettuce variety or nutritional content.

3.3.2. Carbon footprint
Results highlighted the important contribution of fertiliser use to GWP in all supply chains. Refrigerated transport was an important contributor to GWP during transport from Spain to the UK, while energy for heating in protected cultivation dominated the results of winter production in the UK. Of particular note was the fact that growing and transporting lettuce from Spain in the UK winter had a lower GWP than growing the lettuce in protected environments in the UK (Fig. 2). Also of note was the variation in GWP of different farms in the same country, which on average were at least as large as differences between farms from different countries.

3.4. Case study 4 – broccoli production in Spain and the UK for the UK market

3.4.1. Description of farms and supply chains
The analysis considered two UK farms, one of which was a large business which produced a range of vegetables. It had its own on-farm processing and packing plant, where produce was cooled and processed according to customers’ requirements. Produce was distributed directly to supermarkets. The second farm was much smaller. It utilised collective processors who in turn sold to supermarkets. Both farms practiced sequential cropping of broccoli which served to lengthen the season (here termed first and second crops). The supply of both fresh and frozen broccoli was considered in the LCA for both farms.

Two large broccoli producers were assessed in Spain. Their main market for broccoli was the UK, although they also produced other vegetables mostly orientated to the Spanish market. Broccoli is irrigated in Spain due to the low rainfall in the region. One farm used gravity irrigation and had higher water inputs (20% higher in the first crop and twice as much in the second) than the second farm, which used drip irrigation.
Both farms had on-site cooling and packing facilities. In general, product was sold loose and transported in reusable and foldable plastic crates. Although one farm often used cardboard boxes to send the produce to the UK; LDPE film was also commonly used to wrap the broccoli heads individually and prevent moisture loss during transport. Broccoli was transported to the UK by truck.

3.4.2. Carbon footprint

The majority of the GHG emissions were related to home processing, particularly to energy use for cooking; which represented between 50% and 70% of overall GHG emissions (Fig. 3). Not surprisingly emissions from transport and retail were greatest for Spanish product, and because of this Spanish produce tended to have a greater carbon footprint than fresh UK product. Frozen UK product had a greater carbon footprint than fresh produce from one Spanish farm, and was similar to the other.

4. Consumer responses to carbon labels

As discussed above carbon footprints could have several uses within a business and commercial context. Not all of these uses would necessarily have a direct impact on supply chains and international trade. However, there are at least three possible mechanisms by which carbon footprinting could impact trade: consumer-facing carbon labels, social contracts with producers to reduce footprints and a carbon tax on all imported goods. The latter suggestion is not a real option at the moment, but if it did become a real prospect then much of the analysis undertaken on the impact of carbon footprints would also be relevant, as to a large extent their impacts would be the similar to those discussed here. Social contracts which required producers to reduce GHG emissions are a part of the Carbon Trust’s carbon labelling scheme (Carbon Trust, 2006), but to date few producers have declared the level of reduction they have implemented as a result of participating in the scheme. Quantitative consumer-facing carbon footprints are also part of the Carbon Trust label, and if these became widespread then we can postulate at least four potential responses consumers could make to these labels:

a) Seek substitute goods with lower carbon labels
b) Make a less direct substitution, e.g. UK chicory instead of lettuce, local cider instead of imported wine
c) Stop buying goods with high carbon footprints altogether
d) Ignore the carbon label and base purchasing decisions on some other attribute

If consumers adopted responses (a) or (b) then it could be expected that producers offering products favoured by consumers would respond to the increased demand by increasing production. Conversely those companies responsible for supplying goods with a higher carbon footprint would see a decrease in sales. As a result they would be obliged either to innovate in order to develop a competitive carbon footprint, or alternatively to adapt to the lower revenues.

It is also possible that some consumers may respond as described in (c). It is hard to predict how widespread this behaviour would be, but already there are consumer movements against buying bottled water in restaurants on environmental grounds, the substitute being a jug of tap water (Siegle, 2008). So for particularly environmentally aware consumers this behaviour may occur. It is also possible that consumers may not respond to the carbon label at all, but may simply purchase goods according to a suite of other criteria, like price and freshness (IGD, 2006).

It is extremely difficult to predict either company responses to carbon footprints or consumer responses to any carbon label. Indeed it is possible that different consumers will adopt different responses, or even that individual consumers may adopt all four behaviours for different goods. However, for the purposes of the remaining analysis it is assumed that the only
response to carbon labels will be through consumers adopting behaviour (a), i.e. they will seek substitute goods with the lowest carbon footprints.

5. Insights from the case studies

The case studies provide several insights which help determine the potential vulnerability of exporting nations to the development of a carbon label. For example, it is evident from the lettuce case study that

- GHG emissions from UK produced food grown in protected cropping can be greater than production and transport from distant field based production.
- The trade-offs consumers will have to make between similar goods may vary with season, however when there are seasonally differentiated products consumers do not need to make any trade-offs (i.e. Spanish produce has lowest carbon footprint in winter, but it is not found in the UK market in the summer).

The broccoli case study also considered Spanish and UK food and this suggested that

- When field based crops are considered, UK food may have lower carbon footprints than food from Europe, but storage of UK produced food can significantly increase the overall footprint and this may make imported goods more ‘carbon competitive’ than stored ‘local’ produce.

Consideration of the green beans supply chains clearly showed that

- Airfreighting dominates the carbon footprint and renders African produce very ‘carbon uncompetitive’ with UK based production.

However, as shown by the roses case study

- It is possible to compensate for the emissions from airfreighting by employing technologies elsewhere in the supply chain that have low GHG emissions.

5.1. Identifying vulnerable supply chains

In addition to noting the direct observations from the case studies, it is possible to identify attributes of supply chains which would determine the probability of existing supply chains from exporting countries being replaced by more local carbon efficient supply chains:

- Biophysical practicality of production: Substitution of supply chains could only occur if it were biophysically possible to produce the goods in some other country or region. Many crops require certain meteorological conditions (e.g. hours of sunshine, high average temperature and no temperature below freezing) and these conditions do not occur everywhere. So it is not possible to produce all crops in all regions, and for this reason some level of trade will be necessary.

- Financial returns to farmers: Even if it were possible to grow a crop in a locality, it may not offer a positive financial return to farmers. Unless this occurs there will be no substitution of supply chains.

- Relative profitability of enterprise: Even if there were a positive financial return to farmers, they may not adopt the new enterprise if it offers a lower financial return than other potential enterprises.

- Quality: The quality of the produce from any new local supply chain will need to be acceptable to consumers. For example, it may be possible to grow crops in north-western Europe which are not native to the continent, but the quality of the final product may not be high enough to meet consumer needs. This is often the case for crops which need certain sunshine and temperature regimes.

- Seasonality: Even if produce of the correct quality can be produced in a locality, in order to achieve acceptable returns it may be necessary to bring them to market at particular times of year. This may be biologically difficult for crops which are not native to the region.

In addition to the nature of the supply chain, there are also aspects of geography and economy which can render a particular nation more or less vulnerable to the introduction of a carbon label (Table 1). For example, nations which are distant from the target market and depend on air freight to

<table>
<thead>
<tr>
<th>Vulnerability class</th>
<th>Specific form of vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply chain</td>
<td>Exporting goods which are can be produced closer to the target market.</td>
</tr>
<tr>
<td></td>
<td>Exporting goods which offer farmers local to the target market a high level of profitability compared to other potential land uses.</td>
</tr>
<tr>
<td></td>
<td>Exporting goods of a quality that is easy to achieve in other countries/regions.</td>
</tr>
<tr>
<td></td>
<td>Exporting goods which have no seasonal differentiation from those produced in the target market.</td>
</tr>
<tr>
<td></td>
<td>Having no potential for substitution of high emitting processes which occur during local production.</td>
</tr>
<tr>
<td></td>
<td>Being dependent on a natural resource that is distant from the source of food production.</td>
</tr>
<tr>
<td>Transport</td>
<td>Being a long way from the target market.</td>
</tr>
<tr>
<td></td>
<td>Having exports with a high dependence on air transport.</td>
</tr>
<tr>
<td></td>
<td>Having poor access to carbon efficient forms of transport, e.g. shipping.</td>
</tr>
<tr>
<td>Economy</td>
<td>High dependence on exports to one particular market.</td>
</tr>
<tr>
<td></td>
<td>High value of exports in relation to Gross Domestic Product.</td>
</tr>
<tr>
<td></td>
<td>Export product portfolio of similar character.</td>
</tr>
</tbody>
</table>
transport goods to that market are more vulnerable to import substitution than are countries which are closer and/or utilise other forms transport. Similarly countries with high value exports and a high dependence on one type of export are more vulnerable to changes in the market than are countries with a lower dependence on exports and/or a more diverse portfolio of export goods. Having identified the potential aspects of vulnerability, it is now possible to enquire if developing countries will be disproportionately more vulnerable to a carbon label in the UK than other countries.

6. Will a carbon label have a disproportionate impact on developing nations?

It is not possible here to consider all possible forms of vulnerability identified in Table 1 for all developing countries. However, in order to explore the potential vulnerability of developing countries some initial analyses of horticultural products are presented below.

6.1. Transport

As transport is a contributory factor to the carbon footprint of goods, distance itself is a contributor to vulnerability. There is a weak tendency for the poorer countries, as measured by Gross Domestic Product (GDP) per capita, to be further from the UK than richer countries (regression analysis of GDP (y) against distance from London (x) for all countries in the CIA (2008) database suggests \( y = -0.8875x + 19699, \ r^2 = 0.0438 \). Given that the UK is geographically close to several other rich countries in north-western Europe, then the same trend will hold true for these countries and entry into this potentially lucrative market from many of the poorest nations in Africa and south Asia will require produce to be transported thousands of kilometres. This element of the supply chain is therefore of particular importance for developing countries.

6.2. Economy

Three forms of vulnerability identified in Table 1 are related to economy: high value of exports in relation to wealth, as measured by GDP, high dependence on exports to one particular market and a restricted range of products in the export product portfolio.

Countries like Japan have a high GDP and a low level of horticultural import to the UK (Figs. 4 and 5). So the fact that they are distant to the UK market is not important, and even if they were excluded from the UK market it would not have a major impact on the horticultural sector or the economy as a whole. Conversely, countries like Kenya are also distant from UK markets, have a low GDP and a high dependence on imports to the UK (Figs. 4 and 5). Further the fact that the horticultural portfolio of Kenya itself is relatively narrow, i.e. focusing around tea, coffee and beans tends to exacerbate their vulnerability. These types of country are therefore in the highest vulnerability class of those analysed.

There is a third class of countries like Spain which are relatively close to the UK, have a high GDP and export a wide range of horticultural goods to the UK which are of high value (Figs. 4 and 5). The diversity of produce exported means that even if certain supply chains are vulnerable, the sector overall is very resilient to the development of lower carbon footprint substitutes. Indeed even if all Spanish horticultural products were excluded from the UK market through import substitution, given the wealth of the country its overall economic impact would be relatively low.
6.3. Supply chain differences

Although these broad level analyses are interesting, analysis of each individual supply chain reveals another level of complexity (Table 2). For example, although the Kenyan green bean sector has a high vulnerability, the tea and coffee exports, which are both of higher value than the bean exports have a low vulnerability. A similar situation occurs for Guatemala where pea and bean exports may be vulnerable, but coffee will not be. Conversely all three of the major exports from Uganda have low vulnerability, as none could be substituted by local (i.e. UK or EU) production. New Zealand on the other hand has at least two highly vulnerable supply chains – apples and onions. Both of these products can be produced in the UK and EU, and both have the potential to be stored between seasons. So while there may be loss of quantity and quality during storage, technological developments in post-harvest technology could reduce these significantly. Further as current analyses suggest that the carbon footprint of both crops is either higher than UK produced products all year round (Saunders et al., 2006 for onions), or is only lower for some months of the year (apples – Milà i Canals et al., 2007b) then these supply chains must be classed as highly vulnerable.

Another interesting situation concerns the Mediterranean rim countries, represented in Table 2 by Israel and Egypt. Both countries can supply goods when they are out of season in north-west Europe, however technological advances in post harvest technology of potatoes, or in extending the season of table grapes could offer the potential for import substitution. Similarly the supply of tomatoes and chillies from Israel is vulnerable to any technological developments in north-west Europe which would render greenhouse production much more carbon efficient. One impact of a carbon label may be to stimulate research efforts into such technical innovations. This in turn may lead to import substitution as these technologies become adopted at some future time. So the vulnerability of these supply chains may increase over time.

7. Discussion

At its simplest level this analysis suggests that geographic distance does present some challenges to developing countries. Further, their relatively weak economic situation and limited portfolio of export goods suggests that the economic and social impacts of losing any of their major exports may be larger than in more developed nations. However, generally the major exports of developing countries by value, tend to be crops that cannot be grown in Europe (i.e. tea, coffee and tropical fruits). For this reason no substitution by local produce is possible. This does not preclude the possibility of future competition between different countries altering their market share (i.e. amongst the coffee growing nations of the world), but it does suggest that the introduction of a carbon label would not necessarily strongly discriminate against all developing countries.

However, the reality of any future impacts depends entirely on the exact functioning of carbon labels. If carbon labels act to inform consumers about relative GHG emissions of goods, then their impact will depend upon consumers being able to preferentially choose one product over another. For this to happen they must be presented with a genuine choice between substitutable products. For example, they must have the choice between buying similar apples from different supply chains at a similar price. It is unclear how often this situation will occur. This is because the fresh produce supply chains into major retailers in the UK are generally very well differentiated by season and product. For this reason it is unlikely that consumers would be presented with the choice of purchasing new potatoes from Israel and the UK on the same day. Rather the Israeli potatoes would be available several weeks earlier than those.
from the UK. So a more realistic choice facing consumers on a typical shopping day in late spring may be Israeli new potatoes or UK ware potatoes (i.e. potatoes harvested several months earlier that had been kept in store). The question then arises as to whether these two different types of potato are really directly substitutable goods, i.e. are consumers indifferent between them? The acceptability of substitute goods will probably vary with product and also with consumer, and it is not at all clear that total substitution will occur across all product lines. Similarly,

<table>
<thead>
<tr>
<th>Country</th>
<th>Main horticultural exports product by value to the UK</th>
<th>Vulnerability of supply chain to a carbon label</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spain</td>
<td>Tomatoes</td>
<td>Medium – low</td>
<td>Field grown tomatoes are vulnerable to technological advances in UK greenhouse technologies.</td>
</tr>
<tr>
<td></td>
<td>Lettuce</td>
<td>Low</td>
<td>They have seasonal advantages and a lower carbon footprint than UK lettuce grown in winter with protection.</td>
</tr>
<tr>
<td></td>
<td>Oranges</td>
<td>Low</td>
<td>All oranges are produced at a distance and local substitution is not possible.</td>
</tr>
<tr>
<td>Israel</td>
<td>Potatoes</td>
<td>Medium – low</td>
<td>They have a seasonal advantage, but substitution is possible.</td>
</tr>
<tr>
<td></td>
<td>Tomatoes</td>
<td>Medium – high</td>
<td>Substitution is possible as the carbon footprint is technology dependent.</td>
</tr>
<tr>
<td></td>
<td>Chilies &amp; peppers</td>
<td>Medium – high</td>
<td>As above.</td>
</tr>
<tr>
<td>Egypt</td>
<td>Oranges</td>
<td>Low</td>
<td>All oranges are produced at a distance and local substitution is not possible.</td>
</tr>
<tr>
<td></td>
<td>Grapes</td>
<td>Medium – low</td>
<td>They have a small seasonal advantage and some substitution may be possible.</td>
</tr>
<tr>
<td></td>
<td>Potatoes</td>
<td>Medium – low</td>
<td>They have a seasonal advantage, but substitution is possible.</td>
</tr>
<tr>
<td>Kenya</td>
<td>Tea</td>
<td>Low</td>
<td>All tea is produced at a distance and local substitution is not possible.</td>
</tr>
<tr>
<td></td>
<td>Coffee (green)</td>
<td>Low</td>
<td>As above.</td>
</tr>
<tr>
<td></td>
<td>Green beans</td>
<td>High</td>
<td>Although there are seasonal advantages they are freighted and have a high public profile. Substitution is possible.</td>
</tr>
<tr>
<td>Uganda</td>
<td>Coffee (green)</td>
<td>Low</td>
<td>All coffee is produced at a distance and local substitution is not possible.</td>
</tr>
<tr>
<td></td>
<td>Bananas</td>
<td>Low</td>
<td>As above.</td>
</tr>
<tr>
<td></td>
<td>Cocoa beans</td>
<td>Low</td>
<td>As above.</td>
</tr>
<tr>
<td>India</td>
<td>Tea</td>
<td>Low</td>
<td>All tea is produced at a distance and local substitution is not possible.</td>
</tr>
<tr>
<td></td>
<td>Grapes</td>
<td>Low</td>
<td>They have a seasonal advantage and substitution is not possible. They are shipped.</td>
</tr>
<tr>
<td></td>
<td>Mangoes</td>
<td>Low</td>
<td>All mangoes are produced at a distance and local substitution is not possible.</td>
</tr>
<tr>
<td>Phillipines</td>
<td>Mangoes</td>
<td>Low</td>
<td>All mangoes are produced at a distance and local substitution is not possible.</td>
</tr>
<tr>
<td>Japan</td>
<td>Tea</td>
<td>Low</td>
<td>All tea is produced at a distance and local substitution is not possible.</td>
</tr>
<tr>
<td></td>
<td>Mushrooms</td>
<td>Medium</td>
<td>A knowledge dependent sector – vulnerable to developments in the EU.</td>
</tr>
<tr>
<td></td>
<td>Tea</td>
<td>Low</td>
<td>All tea is produced at a distance and local substitution is not possible.</td>
</tr>
<tr>
<td>China</td>
<td>Tea</td>
<td>Low</td>
<td>As above.</td>
</tr>
<tr>
<td></td>
<td>Apples</td>
<td>Medium</td>
<td>Some advantages related to season and volume, but EU substitution is possible.</td>
</tr>
<tr>
<td></td>
<td>Sunflower seeds</td>
<td>Medium</td>
<td>As above.</td>
</tr>
<tr>
<td>Guatemala</td>
<td>Coffee green</td>
<td>Low</td>
<td>All coffee is produced at a distance and local substitution is not possible.</td>
</tr>
<tr>
<td></td>
<td>Peas</td>
<td>High</td>
<td>Although there are seasonal advantages they are freighted and have a high public profile. Substitution is possible.</td>
</tr>
<tr>
<td></td>
<td>Beans</td>
<td>High</td>
<td>As above.</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Apples</td>
<td>High</td>
<td>Although they have a seasonal advantage, the carbon footprint advantage is small and positive for only a few months in late summer. Vulnerable to technological advances in the EU apple industry.</td>
</tr>
<tr>
<td></td>
<td>Onions/shallots</td>
<td>High</td>
<td>Have a higher carbon footprint than EU produce and are vulnerable to technological advances in the EU industry.</td>
</tr>
<tr>
<td></td>
<td>Kiwi fruit</td>
<td>Low</td>
<td>All kiwi fruit are produced at a distance and local substitution is not possible.</td>
</tr>
</tbody>
</table>
there remains uncertainty as to how consumers will trade-off differences in price and carbon labels. While there is evidence that some labelled food attracts a price premium (e.g. certified organic produce), as yet there is no suggestion that price will systematically vary according to the level of GHG emissions declared on the carbon label. So consumers will probably be faced with the same level of price variation that occurs today. Thus the choice faced by consumers can be categorised as being between product A with price X and carbon label Y, and product B with price J and carbon label K, where the level of substitutability between products A and B will vary with consumer and product.

When the level of variation in product characteristics (price, carbon label and substitutability) is combined with the complexity of consumer choice it becomes very difficult to predict major changes in supply chains as a result of the introduction of a carbon label. Indeed in the first instance there may be very little change at all. However, to date there has been no overall analysis of the impacts of such a consumer driven mechanism on GHG emissions or supply chains and so no overall conclusions can be made at this time.

It is possible that carbon labels may operate in other ways, as described earlier, when companies enter into a social contract which commits them to reduce the GHG emissions related to a specific product over time. Within the Carbon Trust’s scheme producers are obliged to reduce emissions on labelled products or risk losing the right to use the label. Whilst this scheme does not directly depend upon consumer choice to bring about change, it does presume that there is commercial advantage associated with having a labelled product (InSight, 2008). So ultimately the impact of the label on GHG emissions does depend upon consumer attitudes and behaviour, albeit in a more indirect way.

If companies worked vigorously to minimise their GHG emissions then there could be a rapid impact on supply chains. For this reason, exporting countries may be more vulnerable to this type of response than to a consumer-oriented response. However, given that adoption of the Carbon Trust label remains voluntary, it is unclear how quickly change could be achieved across the whole food sector. It is also unclear if all future carbon labels would actively require producers to continuously reduce GHGs.

There is no simple relationship between the characteristics of an exporting country and its vulnerability to the introduction of a carbon label. Geographically distant developing countries with a high level of exports to the UK are most vulnerable; however the highest value exports of many developing countries are tropical crops which would be hard to substitute with production from within the UK/EU. Some countries which are geographically closer to the UK are vulnerable in other ways which are related to the development of new production and storage technologies in the UK/EU. These developments could reduce the seasonal advantage certain developing countries currently enjoy. However, in the short term it seems unlikely that carbon labels that depend on consumer action to bring about change will have major impacts in the horticultural sector. Labels which require contractual reductions in GHG would probably have greater impacts in the short term, but could not continue to deliver GHG reductions over a longer period.

In conclusion, it is worth noting three further points. Firstly, this analysis has only considered exports to the UK. Nearly all other developed countries will also receive substantial levels of horticultural imports, so when taken in the round the introduction of a carbon label in the UK alone may have very little impact on the patterns of world trade or GHG emissions. However, the UK is not the only country with carbon labelling initiatives. Similar initiatives are emerging in France (Casino et al., 2007), Switzerland, USA and at EU level (Byrne, 2008) (see Brenton et al. (2008) for a review of schemes). As a result suppliers in developing countries may be subjected to a range of different schemes relating to different export markets. It is unclear how these different schemes will impact developing economies and a more complete analysis is needed to understand the impacts of carbon labels on world markets.

Secondly, the carbon footprints of horticultural products tend to be low compared to other food items (Barrett et al., 2002), so even if carbon labels brought about major reductions in the GHGs released during the production of these products they may not have a major impact on the overall rate of climate change.

Thirdly, this analysis has only been concerned with carbon labels and the emissions of greenhouse gases. There are a range of other issues which may affect consumer purchasing decisions, e.g. animal welfare, impacts on biodiversity, use of inputs (like pesticides and water) and social issues such as worker health and fair trade. Some existing labels communicate information about these characteristics singly (e.g. animal welfare), while others communicate a more holistic approach to production (e.g. certified organic). It is unclear both how consumers currently trade off between the different aspects of labelled food (e.g. water use and impacts on biodiversity), and also how individual farmers respond to the different requirements of the different schemes (if at all). Against this background it could be suggested that the introduction of a carbon label will have little impact on consumer behaviour as they are already confused by the profusion of labelling schemes relating to food (Edwards-Jones et al., 2008). Conversely, given the growing political and commercial importance of the climate change agenda it could be argued that carbon footprints will become the predominant factor influencing choice between alternative goods.

Regardless of these issues, it is clear that if developing countries wish to maintain their exports to the UK then they may consider a range of activities which include

- Invest in renewable energy sources
- Develop enterprises with low energy requirements
- Develop enterprises with low dependency on carbon intensive inputs
- Develop supply chains which minimise emissions from transport
- Consider the carbon footprint of the inputs to the enterprise, as inputs with high carbon footprints themselves will increase the carbon footprint of the final product.
Acknowledgements

This work was part of a larger project entitled ‘Comparative assessment of environmental, community and nutritional impacts of consuming fruit and vegetable produced locally and overseas’ (RES-224-25-0044) which was funded under the UK Research Councils Rural Economy and Land Use (RELU) Programme. We thank the RELU programme for all their support. We are grateful for fruitful collaborations with colleagues in Uganda, particularly Philip Nyeko and Kenya, particularly Maggie Opondo. We are also very grateful to the horticultural businesses who participated in the project and gave so freely their time and expertise.

REFERENCES


Gareth Edwards-Jones is Professor of Agriculture and Land Use at Bangor University. He led an interdisciplinary project which inves-
tigated a range of issues relating to local and non-local food. This study provided much of the data used in this paper.

Dr Katharina Plassmann is a post-doctoral researcher specialising in carbon footprinting of food systems.

Liz York is a PhD student working on modelling greenhouse gas emissions from food crops.

Dr Barry Hounsome is an economist and was the manager of the large interdisciplinary project.

Davey Jones is Professor of Applied Ecology and specialises in soil science and environmental microbiology.

Dr Llorenc Milà i Canals is a specialist in life cycle assessment and now works in industry.