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Is Local Food More Environmentally Friendly? The GHG Emissions Impacts of Consuming Imported versus Domestically Produced Food

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Abstract With the increased interest in the 'carbon footprint' of global economic activities, civil society, governments and the private sector are calling into question the wisdom of transporting food products across continents instead of consuming locally produced food. While the proposition that local consumption will reduce one's carbon footprint may seem obvious at first glance, this conclusion is not at all clear when one considers that the economic emissions intensity of food production varies widely across regions. In this paper we concentrate on the tradeoff between production and transport emissions reductions by testing the following hypothesis: Substitution of domestic for imported food will reduce the direct and indirect Greenhouse Gas (GHG) emissions associated with consumption. We focus on ruminant livestock since it has the highest emissions intensity across food sectors, but we also consider other food products as well, and alternately perturb the mix of domestic and imported food products by a marginal (equal) amount. We then compare the emissions associated with each of these consumption changes in order to compute a marginal emissions intensity of local food consumption, by country and product. The variations in regional ruminant emissions intensities have profound implications for the food miles debate. While shifting consumption patterns in wealthy countries from imported to domestic livestock products reduces GHG emissions associated with international trade and transport activity, we find that these transport emissions reductions are swamped by changes in global emissions due to differences in GHG emissions intensities of production. Therefore, diverting consumption to local goods only reduces global emissions when undertaken in regions with relatively low emissions

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intensities. For non-ruminant products, the story is more nuanced. Transport costs are more important in the case of dairy products and vegetable oils. Overall, domestic emissions intensities are the dominant part of the food miles story in about 90 % of the country/commodity cases examined here.

Keywords CGE model · Emissions intensity · Food miles debate · Livestock emissions · Transport emissions

JEL Classification F18 · Q17 · Q18 · Q56 · Q58

Abbreviations

CDE	Constant difference of elasticities
CES	Constant elasticity of substitution
CGE	Computable general equilibrium
GHG	Greenhouse gas
GTAP	Global Trade Analysis Project
GWP	Global warming potential
LCA	Life cycle analysis

> …Locavorism can only result in higher costs and increased poverty, greater food insecurity, less food safety, and much more significant environmental damage… Only through greater technological advances, economies of scale and international trade can we achieve the locavores' worthy goals of improving nutrition while diminishing the environmental impact of agricultural production…
>
> - Desrochers and Shimizu (2012).

1 Introduction

The impact of food consumption on greenhouse gas emissions has attracted greater interest as the broader question of climate change has drawn more serious debate. The primary anthropogenic greenhouse gas, CO_2, has risen in atmospheric concentration from an estimated 260 ppm nearly 150 years ago to over 380 ppm today. It is estimated that levels of 550 ppm will be reached within 50 years, mainly due to the use of fossil fuels as our primary energy source. While the impact of this rise in CO_2 levels on the global ecosystem is not definitively known, it is reasonable to expect that global temperatures will rise. According to the International Panel on Climate Change, world mean temperatures can potentially increase above their pre-industrial equilibrium[1] (based on "best estimate" climate sensitivity[2]) by 2.4–2.8 °C by 2020, with potentially severe consequences for human welfare (IPCC 2007). World Bank and IPCC estimates suggest that agriculture and transportation sectors are responsible for 15 % (World Bank 2008) and 23 % (IPCC 2007) of global emissions, respectively. The

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[1] The equilibrium climate sensitivity is a measure of the climate system response to sustained radiative forcing. It is not a projection but is defined as the global average surface warming following a doubling of carbon dioxide concentrations (IPCC 2007).

[2] Note that the "best-estimate" climate sensitivity (3 °C) represents the value with the highest probability (IPCC 2007).

majority of industrialized nations agree that action should be taken, but the key question is how much such reductions will cost and how they will affect the level and distribution of global economic activity.

With the increased attention paid to global emissions, civil society, governments and the private sector are questioning the impact which traded goods have on climate change. In particular, critics are calling into question the wisdom of transporting agricultural products and food across continents instead of consuming locally produced food. Indeed, consumers in wealthy countries have become more concerned with their 'carbon footprint'. While the proposition that local consumption will reduce one's carbon footprint may seem commonsensical, this is not at all clear when one considers that the intensity of input use in food production varies widely across regions. The use of greenhouses for fruit and vegetable production, the application of chemical inputs, and the use of electricity and fuels inputs in production all show considerable variation across countries. For this reason, it is important to combine estimates of emissions associated with the production and transportation of food products in order to offer a more comprehensive assessment of the carbon footprint associated with food consumption. This issue has been dubbed the "food miles" debate. In its simplest form "food miles" refers to the distance traveled by food from the farm producer to the consumer (Kasterine and Vanzetti 2010).

Research on this subject remains fragmented with no firm methodology for examining the "food miles" issue. Currently, most, if not all, research focuses on "micro" level analysis—emissions resulting from the production and international transport of single traded commodities between two distant locations using a large array of different methods. Furthermore, since 2009, many new market requirements, mainly in the form of standards on 'product carbon footprinting' (PCFs) have emerged. Comparison between the results from different studies and schemes is difficult and often leads to contradictory findings.

Building on the global data base maintained by the Global Trade Analysis Project (GTAP), alongside state of the art general equilibrium modelling, this research proposes moving away from piecemeal, micro analyses of the food miles issue to more comprehensive, multi-country[3] and sectoral analysis. The aim of this exercise is to re-evaluate the food miles debate in the context of a comprehensive analysis of the GHGs emissions engendered during the production and transport of internationally traded food products.

The first and second sections of this paper explore the "food miles" debate, evaluating the current literature, setting the scene for the analysis, and validating the importance of the inclusion of production and international transport emissions in the "food miles" realm. Section 3 gives a brief description of the modified GTAP model used in this study, focusing on the relationship between emissions and economic activities in the model. Section 4 describes the experimental design. The Sects. 5 and 6 focus on the analysis of the results. Finally, Sec. 7 reports our conclusions from the analysis.

2 The Food Miles Debate and Literature Review

The concept of "food miles" is based on the fact that domestic and international transport activities are important users of energy, and hence sources of GHG emissions. It is therefore intuitive to reason that the further a product travels to market from the production site, the greater its environmental damage and contribution to global warming. However, the issue is clearly more complex than this. King et al. (2010), find that fuel use is more affected by

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[3] See Peters et al. (2011).

supply chain structure (e.g. size and number of segments) than by the distance traveled by the food product itself. Furthermore, the same study finds that fuel use per unit product is often smaller in supermarket supply chains than in local supply chains. In a study of organic vegetables, Coley et al. (2009) find that a supply chain in which consumers travel to the farm to purchase their vegetables produces more GHG emissions, as compared to a large-scale home-delivery supply chain operated by a large food retailer.

The food miles approach is clearly an over-simplified way to address the environmental problem of carbon emissions associated with food consumption.[4] It is a very crude indicator of environmental damage as it ignores differences in emissions between different forms of transport and energy use intensity in other stages of the supply chain. USDA (2002) estimates that 14.4 % of total US energy consumption was accounted for by the food sector. Out of this total, 0.6 % was accounted by food-related transport, 2.0 % by agriculture and 4.1 % by households' kitchen related appliances. Processing, packaging, selling of food represented together roughly 10 times the energy used by food related transport. This figure is even more surprising, given estimates that the average US-consumed food item travels more than 5,000 miles from farm to fork (Bomford 2011). Nonetheless, there are individual cases cited in the literature (see below) in which transport does play a critical role in overall emissions, partially due to increased use of emissions intensive air transport for 'just in time' delivery of various goods, including agricultural products (Cristea et al. 2013).

Partly as a response to the food miles debate, there has been an emerging local food movement which aims to counter-act the increasing globalization, centralization and industrialization of the agri-food system. However, Ballingall and Winchester (2010) point out, in their study of UK, French and German consumption shifts towards food sourced from neighbouring countries, that such changes would result in significant welfare losses for many developing regions, among which Sub-Saharan Africa would be the most hit. Weber and Matthews (2008) conclude that altering household diets would be a more effective strategy for reducing GHG emissions than localizing food supply chains.

Life cycle analyses (LCAs) have become an increasingly popular way to calculate the energy and emissions associated with the consumption of particular products. For example, Jones (2006) offers a comparative study of UK and Kenyan green bean production. The energy requirements for the production systems were similar (UK 0.82–1.38 MJ/kg and Kenya 0.69–1.72 MJ/kg) and the same for packaging (3.92 MJ/kg). The key point of difference was the airfreight element which meant the total energy footprint for Kenyan beans (62.51–63.54 MJ/kg) was 12–13 times greater than that for UK produce (4.74–5.30 MJ/kg). Sim et al. (2007) reached an even more dramatic conclusion in evaluating Kenyan and Guatemalan beans consumed in the UK. He finds that these imports entail a global warming impact 20–26 times greater than UK beans, once airfreight was factored into the analysis.

These findings contrast with the LCA analysis of Williams (2007) focusing on cut roses supplied to the UK market from a company in Kenya, as compared with a supplier in the Netherlands. Interestingly enough, unlike the beans example, cut flowers is more energy demanding during the production stages for countries due to the need for heat and sunlight. Williams found that, even after taking into account the emissions from air transport, roses produced in Kenya generated considerably lower emissions than roses produced in the Netherlands. The emissions from aviation transport from Kenya to the UK were less than the higher emissions in the production stage in the Netherlands. The latter arising from the fact that electricity and heat used in Kenyan greenhouses was derived from geothermal energy, while

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[4] See for example Edwards-Jones (2006), Lawson (2008), McKie (2007), ITC/UNCTAD/UNEP (2007), Wynen and Vanzetti (2008).

in the Netherlands heating and electricity were generated by burning fossil fuels. Clearly, the increasing use of air freight for agricultural products has played an important role in stimulating the food miles debate.

When investigating studies making reference to road- or sea-freighted goods, the debate remains very open. According to UK Department for Environment, Food and Rural Affairs (2007), 9 % of total food and vegetables imported into the UK is sourced by air freight, leaving the remaining share transported by road and/or sea. Carlsson-Kanyama et al. (2003) argue that the production system can be an important contributor to total energy inputs as indicated in the comparison between Swedish greenhouse produced tomatoes (66 MJ/kg) and open grown Southern European tomatoes (5.4 MJ/kg). Hauwermeiren et al. (2007) analysis, based on previous research completed by Maertens et al. and Georges et al., also reached a similar conclusion, calculating GHG emissions of growing tomato under heated greenhouses to 26.73 MJ/kg and emitting 1,459.4 g of CO_2/kg. Greenhouse tomatoes use 10–18 times more energy than open grown crops. Such analyses underscore the point that locally produced goods are not always the least emitting.

For goods that are less dependent on climate related emissions, Fogelberg and Carlsson-Kanyama (2006) review the emissions resulting from the production of broccoli in Sweden against broccoli imported from South and Central America. They find that Swedish production is heavily dependent on the use of diesel whereas the other South and Central America's agricultural technologies are less mechanized and less dependent on primary fossil fuel consumption. Similarly, they also provide interesting results regarding those products which encapsulate emissions in their production resulting from the import of given inputs for a weight loss product. Their analysis also investigated the trade off between transporting wheat from Brazil and raising chickens in Sweden and emissions resulting from Brazil's direct imports of chicken. According to their analysis, differences in emissions between the two sourcing options are very small.

Canals and his colleagues at the University of Surrey offer a comparative study of domestic and imported apples, investigating the primary energy use for the production, transport and storage life cycle stages for UK, EU and Southern Hemisphere sourced fruit. The Canals et al. (2007) study also considered seasonality and the loss of product during storage to enable a more comprehensive comparison of the systems. In contrast to Sim et al. (2007), the authors did not find clear support that a local (UK) supply scenario would necessarily be superior to an alternative European and Southern Hemisphere supply scenario. The period of supply and therefore relative storage period was an important variable as was the road transport element of European sourced fruit. Blanke and Burdick (2005) estimate that energy to store apples is almost as great as energy needed to transport apples from overseas, should apples be available all year round. UK sourced fruit had the lowest energy use during its supply to market in the months of January and October, and the highest in August where the energy use overlaps with apples sourced from the Southern Hemisphere.

The Saunders et al. (2006) study uses LCA methodology to assess the greenhouse gas emissions and energy impact from the production and transport of apples, onions, lamb, and dairy products. They concluded that, in the case of 3 of the 4 products considered, emissions were lower when produced in New Zealand and transported by sea to the UK than when produced in the UK and sold domestically. In agreement with Canals et al. (2007) findings, but refuting Sim et al. (2007) conclusion, the LCA study found that sea freighted apples from New Zealand had lower associated emissions (185 kg CO2/tonne) than UK grown apples stored for 6 months (271.8 kg CO2/tonne). However, UK grown and stored (9 months) onions were found to have slightly lower CO2 emissions compared to sea freighted New Zealand produce (170 kg CO2/tonne vs. 184.6 kg CO2/tonne). Interestingly this study showed the importance of including storage in the analysis and that the energy and emissions associated with storage can be greater than shipping. For example, the energy associated with 6 months cold storage for UK apples required 2,069 MJ/tonne (41 % of total product energy) and emitted 85.8 kg CO2/tonne (35.6 % of total CO2). In the case of onions, the energy associated with 9 months controlled atmosphere storage for UK product required 3,020 MJ/tonne (80 % of total product energy) and emitted 125.2 kg CO_2/tonne (73.6 % of total CO_2).

Needless to say, Life Cycle carbon accounting is becoming increasingly difficult in today's globalised economy where value chains are fragmented and goods often transit through multiple countries before arriving in destination markets. In an attempt to be more comprehensive in capturing these linkages, input-output analysis is increasingly being used to assessing the carbon footprint of various activities. One of the early studies in the LCA literature to incorporate these intersectoral linkages is that of Hendrickson et al. (1998) who introduce the concept of an economic input-output (EIO) LCA methodology with a system boundary that includes the whole economy. Most of their subsequent applications have focused on the manufacturing sector, and do not employ a global input-output table. In contrast to these national or regional studies, Peters et al. (2011) employ a global input-output table based on the GTAP data base in order to assess the carbon footprint of various activities.

Tukker et al. (2006) utilize an EU input-output analysis to determine the Global Warming Potential (GWP) contribution made by various sectors within the EU-25. Food (including alcohol and tobacco) was found to account for 31 % of the EU-25 GWP, whilst vegetables accounted for 0.7 % and fruit 0.5 % of GWP.

Input-output analyses are notably void of economic behavior. A natural extension of this work is to use a global applied general equilibrium model for assessing such linkages. Zhu et al. (2006) employ a global applied general equilibrium model to analyze the impacts of a change in consumption preferences for novel protein foods and the effects of environmental policies. They find that, although the increased consumption of novel protein foods decreases global nitrous oxide and methane emissions from agriculture, the reduction in emissions does not take place in regions with increased food consumption due to international trade. The authors also suggest that the reduction in emissions is insignificant, since a growing number of moderate income consumers increase their consumption of meat.

In this paper, we extend this line of literature by using a newly constructed global CGE model of economic activity and GHG emissions in order to assess the impacts of 'food miles' policies on regional and global emissions for a variety of different food products.

3 Methodology and Data

Household decisions on the sourcing of food consumption depends on many factors, including consumer preferences, government policies, environmental impact of food consumption and transportation. In this paper we concentrate on the tradeoff between emissions reductions and international trade by analyzing the following hypothesis: Substitution of domestic for imported food will reduce the direct and indirect GHG emissions associated with consumption. Such tradeoffs can be well analyzed through computable general equilibrium (CGE) economic models, which are widely used by researchers working on climate change issues. Unfortunately, given the prominence of non-CO_2 emissions in global agricultural production, the absence of these data from many existing CGE models has limited attempts to estimate the relationship between emissions and associated drivers and economic activity. This research is the first one to provide a comprehensive assessment of the GHG emissions impacts of food consumption, utilizing the GTAP data base and modelling framework, supplemented

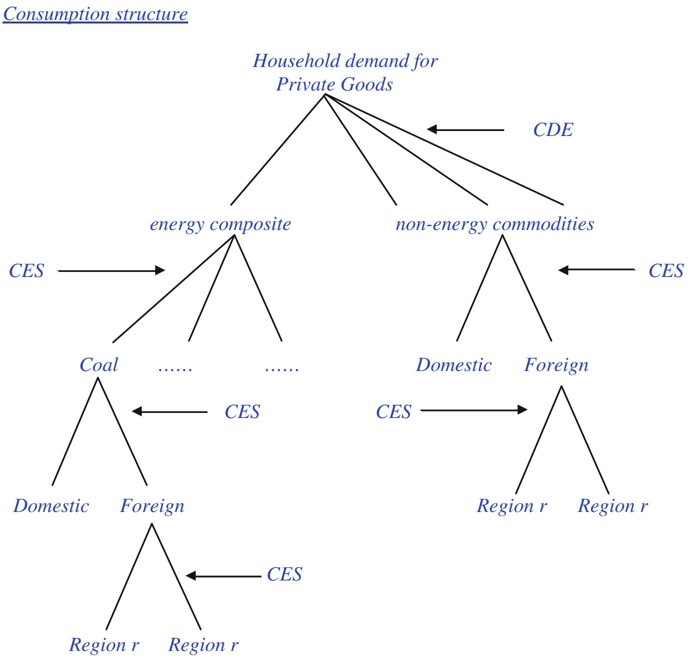

Fig. 1 Consumption structure of the GTAP model

with data on CO_2emissions from fossil fuel combustion (Lee 2007) and non-CO_2emissions associated with agricultural production (Rose and Lee 2009; Avetisyan et al. 2011). The former are linked to the consumption of fossil fuels in the GTAP model, while the latter are linked to specific drivers in the model (e.g., N_2O emissions are linked to the use of fertilizer in crop and grazing activities, and methane emissions are linked to land use in paddy rice production). Together, these data bases account for emissions associated with the production of agricultural and food products and provide an appropriate basis for comparison of the global emission associated with domestic and imported foods.

In this paper we work with a modified version of the GTAP model (Hertel 1997) which incorporates land use by agro-ecological zone, as well as CO_2 and non-CO_2 GHG emissions from production and international transportation of food commodities (Hertel et al. 2009).

To better describe the relationship between emissions and different economic activities in the model we focus on the consumption and production structure of the GTAP model (Figs. 1, 2).

Consumption structure: The structure of household consumption in the model is depicted in Fig. 1 and is based on the constant-difference of elasticities (CDE) functional form which permits calibration of the model to own-price and income elasticities of demand for composite consumption goods. Calibration of this function is based on international cross section estimates of elasticities as documented in Reimer and Hertel (2004). In the case of energy demands, this composite is formed by aggregating different types of energy commodities. For non-energy goods, such as food, these composite goods are formed directly from CES aggregates of domestic and imported goods, with the latter being formed from a CES aggregate of imports from different regions—the so-called Armington specification. This is the margin at which the domestic-import decision is made. Consumers in any given region of the model may be induced to substitute domestic for imported goods by changing the relative price of

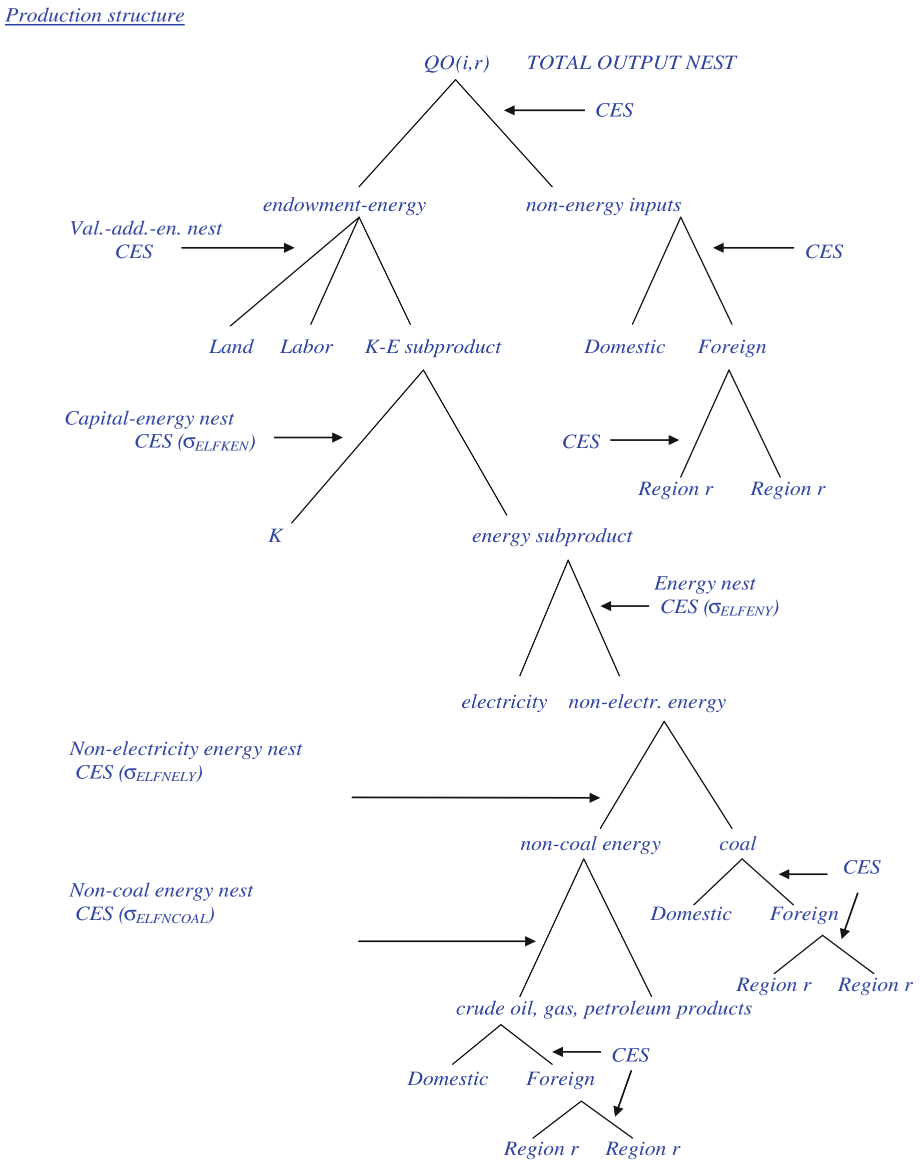

Fig. 2 Production structure of the GTAP model

these commodities via taxation. These Armington elasticities are based on the econometric estimates documented in Hertel et al. (2007). Given the critical importance of these parameters for the sourcing of commodities across different exporting regions, we will undertake a systematic sensitivity analysis of the results with respect to the estimated standard errors of these elasticities of substitution.

Production structure: As with most CGE models, the production structures in GTAP are of the nested CES form. At the top level of the production function, the value-added/energy composite is combined with composite intermediate inputs, including agricultural commodities, assuming fixed proportions. The non-energy, composite commodities are formed from domestic and imported goods using the same Armington structure (and parameters) as are used on the consumption side of the model.[5] The elasticities of substitution amongst the components of the capital-labor-land-energy nest and between different energy types are taken from Burniaux and Truong (2002).

3.1 Trade and Transport in GTAP

International trade and transport activities in GTAP are represented through margins services, i.e. shipping services or transport costs which are bundled (in fixed proportion) with merchandise goods. The trade margins account for the difference between exports at *fob* values and imports at *cif* values and are supplied by individual country exports of transport services which substitute imperfectly in the production of global trade and transport activity.

3.2 Greenhouse Gas Emissions in the Model

There are six main emissions components in the model which are linked to economic drivers—either inputs (e.g., fertilizer, petroleum) or outputs under the assumption that they are emitted in fixed proportion to these underlying drivers in the model. The equations describing the link between emissions and economic drivers are presented in Appendix 8.

In this study we use the non-CO_2 greenhouse gas emissions database (Rose and Lee (2009)) developed by USEPA and Purdue University's Global Trade Analysis Project, designed specifically for use in the GTAP model. The database contains highly disaggregated information about emissions by four types of activities, each of which is mapped to countries and sectors based on activity and input quantity data. This careful mapping is critical to the validity of subsequent, model-based inferences about the global emissions impacts of food miles policies.

According to Rose and Lee (2009), land use and land based activities are one of the important drivers of non-CO_2 GHG emissions, accounting for nearly 50 and 75 % of world emissions of methane (CH_4) and nitrous oxide (N_2O), respectively. Together, they represent approximately 14 % of global GHG emissions in carbon dioxide equivalent units. About 60 % of global non-CO_2 GHG emissions are generated by land based activities, with the largest contribution of ruminant livestock production at 25 %, followed by paddy rice at 8 %, and then various crops and non-ruminant livestock.

We supplement the non-CO_2 emissions data base with the CO_2 emissions data documented in Lee (2007), representing carbon emissions from fossil fuel combustion by sector, in every region of the world. The latter are computed using the GTAP energy volume data and by adopting the Tier 1 method of the revised 1996 IPCC Guideline (IPCC/OECD/IEA 1997). As can be seen from Table 1, the non-agricultural sectors are dominant in CO_2 emissions. Within agriculture, the largest share of CO_2 emissions belongs to fruits and vegetables, which are often grown in greenhouses requiring supplementary heat and light.

For this analysis we aggregate the CO_2 emissions discussed in Lee (2007) and the non-CO_2 greenhouse gas emissions into a common measure: MMTCO2e = Million metric tons of carbon dioxide equivalent, as described in Rose and Lee (2009). GTAP activity is then aggregated to the level of 19 regions and 29 sectors, which allows comparing emission changes associated with changes in trade patterns in different geographic regions with differing levels of

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[5] In practice only composite imports are sourced by agent in the model. The import-import substitution occurs "at the border". Since this sourcing decision is an important part of the model's consumption and production activities, we have portrayed them as part of those activities in Figs. 1 and 2.

Table 1 Global land related non-CO_2 and CO_2 emissions, MMTCO2e

Sector	Non-CO_2	CO_2
Paddy rice	730	11
Wheat	209	22
Cereal grains	246	24
Fruits, vegetables, nuts	550	74
Oil seeds	180	13
Sugar cane, sugar beet	66	5
Plant-based fibers	114	13
Crops nec	202	48
Bovine cattle, sheep and goats, horses	2,233	19
Animal products nec	499	46
Raw milk	488	17
Forestry	0	27
Total land-use related sectors	5,518	321
Other sectors	3,579	22,998

Source Rose and Lee (2009) and GTAP version 6 data base

economic development—a factor which we find to be important in determining emissions intensity. There are 15 food sectors in this aggregation.

In our subsequent analysis, we will pay special attention to the *emissions intensities* of individual sectors. If production expands in a sector/region with relatively high emissions intensity, then we expect global emissions to rise, *ceteris paribus*. And conversely, the food miles experiment causes production to expand in a sector exhibiting relatively low emissions intensity. Table 2 reports global emissions intensities by sector and gas (MKgCO2e = Metric kilograms of carbon dioxide equivalent per dollar of output). We can see that the highest emissions intensity is in the ruminants sector. This makes it a particularly interesting sector to analyze in greater detail.

Avetisyan et al. (2011) analyze the variation in emissions intensities of ruminant meat production across regions in considerable detail. They decompose the sources of regional differences and find that the largest portion of these international differences is due to variations in the value of output per animal, as opposed to differences in emissions per animal. These differences in value of output per animal are, in turn, driven by differences in biophysical yields, which are predominant in dairy production, as well as differences in the price of output, which are predominant in the case of beef.

4 Experimental Design

Our goal in this study is to evaluate the impact of substituting domestically produced goods for imported commodities produced in the same sector. In so doing, we must assess the competing effects of shifting patterns of production on the one hand, and diminished demands for international trade and transport services on the other. A key question in our experimental design is: How can we induce the prescribed shift in consumption associated with a 'food miles experiment'? The application of a tariff on imports may seem like the natural vehicle for inducing a shift in consumption from imported to domestic goods. However, because many imported goods are destined for intermediate uses (recall Fig. 2), this is not an effective vehicle for shifting consumption patterns. Indeed, if imported goods were predominately

Table 2 Global emissions intensities by sector and gas (MKgCO2e/$)

Sector	CO_2	N_2O	CH_4	FGAS
Paddy rice	0.109	0.990	6.409	0
Wheat	0.225	1.393	0.017	0
Cereal grains	0.232	1.989	0.021	0
Oil seeds	0.173	1.636	0.015	0
Sugar cane, sugar beet	0.150	1.498	0.020	0
Other agriculture goods	0.196	1.047	0.017	0
Forestry	0.208	0.001	0.002	0
Dairy farms	0.099	0.987	2.079	0
Ruminant livestock	0.132	3.661	10.461	0
Non-ruminant livestock	0.155	1.067	0.469	0
Processed dairy products	0.073	0.001	0	0
Processed ruminant meat products	0.064	0	0	0
Processed non-ruminant meat products	0.048	0	0	0
Vegetable oils and fats	0.122	0.001	0	0
Beverages, tobacco, sugar	0.099	0.001	0	0
Processed rice	0.123	0.001	0	0
Food products nec	0.093	0.001	0	0
Other primary: fishery and mining	0.399	0.002	0.001	0
Coal	0.603	0.001	3.767	0
Crude oil	0.618	0.001	0.627	0
Natural gas	1.180	0.004	1.332	0
Petroleum, coal products	0.877	0.042	0.211	0
Electricity	8.366	0.018	0.002	0.027
Energy intensive Industries	0.342	0.032	0.002	0.042
Other transport	1.190	0.032	0.186	0
Water transport	1.125	0.024	0.005	0
Air transport	1.970	0.064	0.008	0
Other industry and services	0.065	0	0	0.005
Services generating Non-CO_2 emissions	0.048	0.010	0.139	0

used as intermediate inputs for domestically produced products (e.g., imported soybeans used to produce domestic pork), then such a tariff could result in a reduction, rather than in increase, in consumption of domestically produced food. For this reason, we apply a tax directly on consumers. The size of this tax is designed to be just enough to induce the desired shift in consumption from imported to domestically produced food commodities.[6]

There is yet another important consideration in the design of our experiment, and that has to do with the measurement of consumption. How do we establish the volume of domestically produced commodity equivalent to the displaced imported good? If products were

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[6] In order to ensure tax neutrality, we adjust the overall level of consumption taxation so as to keep constant the share of total tax receipts in net national income.

homogeneous, then there would be no question—simply measure the weight of the product and replace (e.g.) 1,000 metric tons of imported goods with the equivalent volume of domestically produces commodity. However, even in the world of relatively disaggregated agricultural products, goods are far from homogeneous. Just as there are high quality cars and low quality cars, there is high quality beef and low quality beef, specialty rice and bulk rice. Higher quality products require more inputs and command a higher price in the marketplace. In a world of differentiated products, measurement of volume in tons makes little sense, which is why we measure it in US$, evaluated at initial period prices. Hence our experiment involves replacing $50M in imported food product with $50M in domestic food product from the same sector.[7]

We must also decide which products to examine in the context of the food miles debate. By their very nature, raw agricultural products are less likely to be consumed by private households—particularly those in developed economies where the food miles debate is currently active. Therefore, we focus our attention on the processed food product categories in the data base, including livestock products (ruminants, dairy and non-ruminants), vegetable oils and fats, processed rice. We do not focus on the more aggregate categories of food products, given the challenges of understanding what is driving the results there. In light of the importance of ruminants in the global agricultural emissions picture, we begin there, and develop the analysis in great detail, before moving on to a summary of the results for the other sectors.

In order to keep the exposition tractable, we choose two of the world's largest economies, the EU and China, for our detailed food miles analysis. With these sectoral and regional foci, we begin by discussing two experiments: **EURUMINANTS**, in which we increase EU consumption of domestically produced ruminant products and decrease the imported consumption by the same absolute amount, without changing total consumption of ruminant products in a particular region and **CHNRUMINANTS** in which we do the same in the China/Hong Kong region of the model. Following the detailed examination of ruminant products trade, we move on to a concise summary of the food miles experiments for the other food products and other regions.

5 Results

5.1 Emissions from International Trade and Transport

We first analyze the changes in transport emissions, which have been central to the "food miles" debate, and then turn to changes in total emissions and output. Within our analytical framework, we can distinguish between transport emissions by mode: water, air and land (i.e. other), and by disposition of the services: domestic vs. international. Table 3 breaks down the change in global transport emissions along these two dimensions. Note first of all, that for both experiments, global transport emissions fall when domestic consumers substitute domestic for imported ruminant products in the EU and in China. And, in both cases, both international and domestic transport-related emissions fall at the global level. In the case of EU substitution of domestic for imported ruminant products, the decline in international emissions is relatively more important. However, China's ruminant substitution has a much

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[7] A legitimate concern associated with this experimental design is that it might favor high quality goods, with relatively lower tonnage, and hence potentially lower transportation costs. However, this is a fundamental feature of the global economic geography and hence cannot be ignored.

Table 3 Change in global GHG emissions from transport, by mode and disposition of services (MTCO2e)

Disposition	EURUMINANTS				CHNRUMINANTS			
	Air	Water,	Other	Total	Air	Water	Other	Total
Domestic	−10	−36	−739	−785	−56	−424	−4,675	−5,155
International	270	−191	−1,366	−1,287	537	−872	40	−295
Total	260	−227	−2,105	−2,072	481	−1,296	−4,635	−5,450

larger impact on domestic transport emissions worldwide. These reductions occur in the major China-exporting regions (Table 4), including US, EU, Brazil and Oceania (Australia and New Zealand). However, there is also a reduction in domestic transport emissions in China. Overall, these two experiments reinforce the conclusion that sourcing food locally will reduce overall emissions from transportation, although this will not be the case in every region.

It is interesting that international air transport emissions rise in both cases. This can be explained by the fact that food is transported mostly by water and land transport. With the substitution of domestic for imported ruminant products the trade in other goods, transported by air, grows, and results in increased air transport emissions.

We now add emissions associated with production to this picture. The results are summarized in Table 4, alongside the transport emissions which are now disaggregated into those generated by domestic transport activity and those generated by international transportation. The results for the **EURUMINANTS** scenario show that the transport emissions decline of 2,070 MTCO2e is dominated by the change in production related emissions, which fall by 82,642 MTCO2e. This production effect is due to the substitution of domestically sourced consumption in a region with relatively low emissions intensities. Specifically, in the European Union the emissions intensities in the ruminant meat sector is 5.74 MkgCO2e/$, whereas the EU import-weighted emissions intensity of exporters' production is 8.11MkgCO2e/$ (Table 5). Thus the substitution of local for global food in this case reduces the emissions intensity of final consumption in the EU.

The results under scenario **CHNRUMINANTS** are quite different. Firstly, emissions from global transportation decrease by 5,451 MTCO2e, which is quite a bit more than under the EU scenario. Nonetheless, global emissions rise sharply (by 302,773 MTCO2e) when Chinese consumers shift consumption in favor of domestic goods. This follows from the very high emissions intensity of China's ruminant production (Table 5) which is 24.63 Mkg CO2e/$ vs. 11.84 MkgCO2e/$ in the regions exporting to China (weighted by China's import shares). There are also changes in emissions from other sectors, which are relatively small compared to that from the ruminant meat sector.

5.2 Ruminant Products: Changes in Total Emissions, by Region

Nitrous oxide and methane emissions rise in the EU under scenario **EURUMINANTS.** The former is driven by increased production of feedstuffs in the EU, including wheat and cereal grains, increases nitrous oxide emissions from fertilizer applications, as well as fertilizer applications on grazing lands. The increase in ruminant animal numbers and output boosts methane emissions in the EU. However, as noted previously, global emissions decline significantly under this scenario (by 84,503 MTCO2e) as a result of substituting domestic for imported ruminant products. Overall, both nitrous oxide and methane emissions fall, with

Table 4 Change in ruminant meat, transport and total emissions (MTCO2e)

Regions	EURUMINANTS emissions					CHNRUMINANTS emissions				
	Ruminant meat	Transport		Other sectors	Total	Ruminant meat	Transport		Other sectors	Total
		Domestic	Internat.				Domestic	Internat.		
United States	−1,548	−33	381	−717	−1,917	−13,623	−678	522	−4,139	−17,918
European Union	30,581	−60	−756	1,796	31,561	−7,889	−109	−557	−1,598	−10,153
Brazil	−68,777	−208	−129	−974	−70,088	−58,108	−179	−65	−1,143	−59,495
Canada	−1,142	2	−68	−96	−1,304	−11,073	12	49	−330	−11,342
Japan	−42	−5	−4	−153	−204	−156	−30	131	29	−26
China and Hong Kong	−1,423	3	−96	−587	−2,103	507,541	−2,276	54	−27,045	478,274
India	−258	−6	−11	87	−188	2,880	−19	33	465	3,359
Central and Caribbean Americas	−637	−4	30	−52	−663	−2,141	−1	−26	−109	−2,277
South and Other Americas	−10,639	19	−11	−231	−10,862	−8,818	12	−25	−569	−9,400
East Asia	−94	−3	−169	−124	−390	−330	−24	−169	−161	−684
Malaysia and Indonesia	−247	1	−1	120	−127	−694	7	−59	132	−614
Rest of South East Asia	−776	−3	−63	76	−766	−1,403	−9	−124	98	−1,438
Rest of South Asia	−77	1	−10	−35	−121	0	2	2	−132	−128
Russia	−65	5	−106	47	−119	−302	17	−79	29	−335
Other East Europe	−111	−30	−234	337	−38	−109	−33	−200	19	−323
Rest of European Countries	−379	−8	−16	−6	−409	−98	−7	−30	−53	−188

Table 4 continued

Regions	EURUMINANTS emissions					CHNRUMINANTS emissions				
	Ruminant meat	Transport		Other sectors	Total	Ruminant meat	Transport		Other sectors	Total
		Domestic	Internat.				Domestic	Internat.		
Middle Eastern and North Africa	−250	−23	−71	25	−319	−1,137	−62	−92	−245	−1,536
Sub Saharan Africa	−13,048	−81	−7	96	−13,040	−2,670	−16	−17	−200	−2,903
Oceania countries	−13,713	−352	53	606	−13,406	−60,840	−1,762	357	2,146	−60,099
Total	−82,642	−785	−1,287	211	−84,503	341,032	−5,155	−295	−32,809	302,773

Table 5 Change in world ruminant meat, transport and total emissions under "food miles" experiment in different regions

Region with "food miles" experiment	Change in world emissions, MTCO2e			Ruminant meat emissions intensity, MkgCO2e/$	Ruminant meat import-weighted emissions intensity, MkgCO2e /$
	Ruminant meat	Transport	Total		
Japan	−78,029	−1,730	−37,746	1.47	12.69
Rest of European Countries	−40,171	−1,835	−37,661	3.91	10.12
United States	−130,113	−713	−114,601	4.45	8.07
Other East Europe	−82,509	−17,785	−148,750	4.95	8.27
East Asia	−41,167	−6,092	1,457	5.15	14.03
Middle Eastern and North Africa	−273,353	−14,264	−305,239	5.28	8.77
European Union	−82,642	−2,070	−84,503	5.74	8.11
Canada	20,089	−6,326	16,603	6.06	5.05
Russia	110,143	−9,818	103,699	10.44	7.58
Oceania countries	20,935	−2,657	10,771	11.42	10.62
Central and Caribbean Americas	−5,696	−2,928	−19,231	12.75	7.63
South and Other Americas	−151,646	−6,230	−159,103	17.91	19.37
China and Hong Kong	341,032	−5,451	302,773	24.63	11.84
Sub Saharan Africa	610,098	−4,838	599,864	41.82	37.00
Malaysia and Indonesia	245,830	−4,676	214,119	49.72	13.30
Brazil	813,044	−447	821,779	54.05	15.31
World	–	–	–	14.25	–

the latter accounting for about three-quarters of the total as the reduction in imports of ruminant products into the EU market decreases demand for foreign produced ruminants with relatively higher emissions factors (Table 5).[8]

The largest reductions in emissions under scenario **EURUMINANTS** takes place in Brazil and Oceania, both of which have strong export sales to the EU market in the base period 615 US$ million and 802 US$ million, respectively, as well as having relatively high emissions factors (Table 5). As previously mentioned, Other Eastern European countries experience the smallest reduction in emissions under scenario **EURUMINANTS.** Given their relatively high emissions intensity, we would expect to see more abatement in this region. The main reason this doesn't occur is due to the bilateral trade pattern. The initial level of exports of ruminant products from Other Eastern European countries to the EU is quite modest (30 US$ million).

As noted above, under scenario **CHNRUMINANTS,** ruminant production rises in China, while declining in nearly every other region, and given the relatively high emissions intensity

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[8] The factors that affect the output of ruminant products are discussed in detail in Appendix 8.

in China, it is hardly surprising that total emissions rise in this case. Of the global increase, by 302,773 MTCO2e, most is attributable to methane from ruminant meats. Indeed, methane accounts for about six-sevenths of the total increase. Thus, the implications of sourcing food locally are very different compared to those in **EURUMINANTS**.

Having seen that the reductions in GHG emissions from international trade and transport following local food substitution are dominated by changes in global output emissions in the cases of the EU and China, it is worthwhile to investigate: How pervasive is this phenomenon? And how frequently is it the case that local food substitution fails to reduce global emissions? We pursue this, first for ruminant products consumption in other regions, and then for other types of food products.

5.3 Ruminant Products in Other Regions

Table 5 reports the emissions impacts of implementing the same 50 US$ million food miles experiment undertaken above for the EU and China regions, for all of the other available regions in the global model.[9] We can see that the shift to domestic food consumption of ruminant products in other regions boosts global emissions in many developing country regions beyond China, including: Brazil, China, East Asia, Malaysia and Indonesia, and Sub Saharan Africa. Canada, Russia and Oceania also fall into this category. However, not all of these countries exhibit high absolute emissions intensities. To see this, compare them to the WORLD row in the table. Canada, for example, has a lower than average emissions intensity in ruminant meat production. However, its imports tend to come from the US, which has an even lower intensity. Therefore, displacing imports from the US (its main trading partner in ruminant products) with Canadian domestic production results in higher production-based emissions.

On the other hand, Other South America (outside of Brazil) has an absolutely high emissions factor, but, because this is still lower than its import-weighted average (dominated by Brazil), food miles in that region reduces global emissions. Indeed, comparison of the final two columns of Table 5 shows that in most cases, whenever the domestic emissions intensity dominates the import-weighted intensity for a given region, global emissions rise under a food miles scenario. The one exception is Central America and the Caribbean. Although the domestic emissions intensity of the ruminant meat sector is greater than the import-weighted emissions intensity in the Central and the Caribbean region, global emission decrease mainly due to a large reduction in global cereal grains emissions by 7,864 MTCO2e. Also, there is some reduction in global non-ruminant meat emissions by 3,745 MTCO2e. Another interesting case is the East Asia region. Despite the lower domestic emissions intensity in the ruminant meat sector of this region, global emissions increase due to increasing emissions mainly in the non-ruminant meat (by 42,463 MTCO2e) and electricity sectors (by 4,935 MTCO2e).

Overall, the $50 million “food miles” substitution policy in the Middle East and North Africa region (which has relatively low emissions intensity per dollar of ruminant meat output, 5.28 MkgCO2e/$), is the one which generates the largest reduction in world emissions. In contrast, the Brazilian policy yields the largest increase in world emissions due to very high emissions intensity per dollar of ruminant meat output in that region (54.05 MkgCO2e/$) across considered regions.

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[9] We redo the same 50 US$ million food miles experiment only in regions where the change in consumption patterns of ruminant products does not make its imports negative in the GTAP data base.

Table 6 Share of global emissions change accounted for by transport related emissions

Region with "food miles" experiment	Food product in "food miles" experiment[a]			
	Dairy products	Non-ruminant products	Vegetable and oil products	Processed rice products
United States	–	–	–	–
European Union	0.51	0.09	–	0.10
Brazil	0.17	–	–	0.11
Canada	0.71	0.88	–	–
Japan	0.04	0.00	–	0.00
China and Hong Kong	0.08	–	–	0.41
India	–	0.14	–	–
Central and Caribbean Americas	0.46	0.09	–	0.19
South and Other Americas	–	0.06	–	0.58
East Asia	0.12	–	–	–
Malaysia and Indonesia	0.03	–	–	–
Rest of South East Asia	0.42	–	–	–
Rest of South Asia	–	–	–	–
Russia	–	0.11	0.64	–
Other East Europe	0.16	0.12	0.69	–
Rest of European Countries	0.43	0.07	–	–
Middle Eastern and North Africa	0.34	–	0.51	0.11
Sub Saharan Africa	–	–	–	–
Oceania countries	–	–	0.06	–

[a] We report missing only the cases where total emissions increase

5.4 Food Miles for Other Food Products

The high overall emissions intensity of ruminant production makes that sector an interesting case to consider, but it also biases the results in the direction of production-related emissions dominating the story. Therefore, it is important to consider the food miles experiment for other categories of food products. Here, we choose four other categories of foods which are both primarily destined for final consumption and are also readily identifiable in the GTAP data base: dairy products, non-ruminant livestock products, vegetable oils and fats, and processed rice. From Table 2, we see that, with the exception of paddy rice, which has a very high methane emissions intensity, the other primary sectors underlying these food products show much smaller economic emissions intensities (emissions/$ output).

Table 6 reports the share of the total emissions change that derives from transport related emissions in each region, for each of these food products. (Complete results are reported in Appendix 10 Tables 8, 9, 10 and 11.) From this it can be seen that the food miles story is indeed driven in some cases by transport related emissions in the less emissions intensive sectors. This is most obvious for the change in consumption of dairy products in the European Union and non-ruminant products in Canada. Unlike the changes in emissions from increased domestic ruminant meat consumption, the changes in the consumption patterns of other food products in some cases generate larger reductions in global transport emissions than for production-related emissions. We conclude that the food miles story is more nuanced and that, in some regions, for some food products, the substitution of local for imported food products may reduce global GHG emissions due to the reduction in international transport emissions. These cases are indeed consistent with the commonly assumed food miles story.

6 Robustness to Parameter Uncertainty

As with any economic model, the results presented here are sensitive to the model parameters. Of special importance are the so-called “Armington” parameters governing international trade. For an individual product, a low trade elasticity means that any reduction in aggregate imports will be reflected in more or less proportional reductions in purchases from all exporters to the ‘food miles’ region. In contrast, a high Armington elasticity will permit this pattern of import sourcing to vary, depending on changes in relative prices. Since production emissions intensities vary greatly across regions, any such change in the pattern of import sourcing could have a significant impact on both the transport and production related emissions changes. For this reason, we undertake a systematic sensitivity analysis (SSA) of our results with respect to the trade elasticities used in the model.

We begin by specifying the distribution of Armington elasticities of substitution for all five food products based on the estimated standard errors for these elasticities of substitution (Hertel et al. 2007). We then solve the model repeatedly using the Gaussian Quadrature (GQ) approach to sampling. This is more efficient than Monte Carlo, and has been shown to provide unbiased estimates of the distribution of CGE model results with respect to parameter uncertainty (DeVuyst and Preckel 1997). The SSA results are reported in Appendix 11 Tables 12, 13, 14, 15, 16, 17, 18, 19, 20 and 21. We focus on the coefficient of variation (the standard deviation divided by the mean) for the emissions estimates. Assuming the results are normally distributed, we use ±2 standard deviation to construct 95 % confidence intervals for changes in trade elasticities and world emissions, so that all values of CV smaller than 0.5 indicate a statistically robust result. We find that most of our results are robust with respect to this parameter uncertainty. Exceptions are: the change in total emissions in Japan following a ruminant meat ‘food miles’ policy in either China or the EU; emissions in Brazil, Malaysia and Indonesia, Other East Europe, Sub Saharan Africa following a paddy rice ‘food miles’ policy in China; and finally, emissions in Sub Saharan Africa following a paddy rice ‘food miles’ policy in the EU.

6.1 Limitations

The results of this study have an important limitation owing to the relative high level of aggregation employed here. When a “food miles” policy is applied to aggregate food products, the changes in emissions will be different from cases when the consumption of a very specific food product category is adjusted by such policy. A good example is provided by the ruminant meats sector in our model, which includes not only cattle, but also sheep and goats. This may well explain, for example, the large reductions in GHG emissions in the Middle East and North Africa in the wake of a food miles policy, since this region tends to produce sheep and goats domestically, while importing more cattle meat products, the latter which have a higher emissions intensity. There is little we can do short of further disaggregation of the sector, which is beyond the scope of this study, but would be a useful contribution in future research.

7 Conclusions

While advocates of a ‘food miles’ policy suggest that shifting consumption patterns towards domestic foods will reduce the carbon footprint of food consumption, we find that this is more nearly the exception, rather than the rule in today’s globalized economy. Once non-CO2 emissions are taken into account, many food products have very high GHG emissions intensities associated with their on-farm production and variations in these intensities can dwarf any change in international transport emissions under a food miles policy. In order to forcefully make this point, we focus on ruminant livestock production. This is the sector with the highest emissions intensity of all, and it also exhibits considerable variation across regions. As a result, under a food miles policy, changes in production related emissions dominate the ensuing changes in transport emissions in every region of our model. Therefore, with only a few exceptions, one can predict the consequences of a food miles policy simply by comparing the policy region’s ruminant meats emission intensity with the import-weighted average of this same intensity in the rest of the world. And these results are largely robust to key parameter uncertainties in the model. Consequently, we conclude that redirecting consumption to domestically sourced ruminant products only reduces global GHG emissions when implemented in regions with relatively low emissions intensities.

We also consider the impact of a food miles policy for other food products, including non-ruminant meats, dairy, vegetable oils and rice. In the majority of cases, the change in production emissions dominates the change in transport emissions following the policy intervention. However, there are some notable exceptions, including: dairy products in the EU and Canada, non-ruminants in Canada, vegetable oils in three of the four regions considered, and rice in the case of a South American food miles policy.

In summary, we conclude that the ‘food miles’ advocates are generally mistaken in their conclusion that reducing the global shipment of food products will always reduce GHG emissions. Indeed, in most cases where a local food policy does reduce GHG emissions, this arises due to differences in the emissions intensity of production, not reductions in transport related emissions. Those interested in food miles policies would be well-advised to shift their attention to an analysis of the technologies used to produce food across the globe.

8 Appendix A

8.1 The Linkage of Emissions and Economic Drivers

The following equations are used to link emissions to economic drivers in the model (all variables are expressed as percentage changes in the corresponding levels variables):

$$qemo_{jr} = qf_{ijr} \tag{1}$$

where, the change in ***output related emissions*** in region r $qemo_{jr}$ is linked to qf_{ijr}, which is the change in the demand for commodity i for use by j in r.

$$ghgff_{gijr} = qfe_{ijr} \tag{2}$$

where, the change in ***firm's factor-related emissions*** in region r $ghgff_{gijr}$ is linked to qfe_{ijr}, which is the change in the demand for endowment i for use in ind. j in region r.

$$ghgfd_{gijr} = qfd_{ijr} \tag{3}$$

where, the change in ***emissions from firms' usage of domestic product*** $ghgfd_{gijr}$ is linked to qfd_{ijr}, which is the change in the domestic good i demanded by industry j in region r.

$$ghgfm_{gijr} = qfm_{ijr} \tag{4}$$

where, the change in ***emissions from firms' usage of imports*** $ghgfm_{gijr}$ is linked to qfm_{ijr}, which is the change in the demand for i by industry j in region r.

$$ghgpd_{gir} = qpd_{ir} \tag{5}$$

where, the change in ***emissions from private consumption of domestic product*** $ghgpd_{gir}$ is linked to qpd_{ir}, which is the change in private household demand for domestic i in region r.

$$ghgpm_{gir} = qpm_{ir} \tag{6}$$

where, the change in ***emissions from private consumption of imports*** $ghgpm_{gir}$ is linked to qpm_{ir}, which is the change in private household demand for imports of i in region r.

8.2 Decomposition of the Change in the Ruminant Products Output

To analyze the change in the output of ruminant products we refer to the linearized market clearing condition for merchandise commodities in GTAP:

$$qo_{ir} = SHRDM_{ir} * qds_{ir} + \sum_{s} SHRXMD_{irs} * qxs_{irs} \tag{7}$$

where:

qo_{ir} is percent change in industry output of commodity i in region r;
qds_{ir} is percent change in domestic sales of commodity i in r;
qxs_{irs} is percent change in exports of commodity i from r to region s;
$SHRDM_{ir}$ is the share of domestic sales of i in r;
$SHRXMD_{irs}$ is the share of export sales of i to s in r.

Under scenario **EURUMINANTS** the decomposition of output in the EU reveals that the dominating portion of the change in ruminant products comes from domestic sales (−0.06 %). Next, we decompose the domestic sales using its market clearing condition:

$$qds_{ir} = \sum_{j} SHRDFM_{ijr} * qfd_{ijr} + SHRDPM_{ir} * qpd_{ir} + SHRDGM_{ir} * qgd_{ir} \tag{8}$$

where:

qfd_{ijr} is percent change in domestic product i demanded by industry j in region r;
qpd_{ir} is percent change in private household demand for domestic product i in region r;
qgd_{ir} is percent change in government demand for domestic product i in r;

$SHRDFM_{ijr}$ is share of domestic product i used by sector j in r at market prices;
$SHRDPM_{ir}$ is share of domestic product i used by private household in r;
$SHRDGM_{ir}$ is share of imports of product i used by government in r.

The results show that most of the change in domestic sales of ruminant products in the EU is due to increase in private consumption (0.08 %). To further analyze the factors that cause the increase in the output of ruminant products we decompose its domestic demand using the Eq. (9):

$$qfd_{ijs} = qft_{ijs} - ESUBD_i * (pfd_{ijs} - pft_{ijs}) \tag{9}$$

where:

qft_{ijs} is percent change in demand for commodity i for use by j in region s;
$ESUBD_i$ is region-generic elasticity of subst. domestic/imported for all agents;
pfd_{ijs} is percent change in price index for domestic purchases of commodity i by j in s;
pft_{ijs} is percent change in firms' price for commodity i for use by j in s.

The outcome shows that the demand component of ruminant products dominates the substitution effect. Hence, we validate that the change in ruminant products is due to increased domestically sourced ruminant product consumption in the EU.

9 Appendix B

9.1 Trade Elasticities of Substitution

The following trade elasticities of substitution are used in the model simulations (Table 7).

Table 7 Armington elasticities of substitution for different sectors in the GTAP model

Sector	Elasticity of substitution between domestic and imported goods	Elasticity of substitution among imports in Armington structure
Paddy rice	10.1	5.1
Wheat	8.9	4.5
Cereal grains	2.6	1.3
Oil seeds	4.9	2.5
Sugar cane, sugar beet	5.4	2.7
Other agriculture goods	4.9	2.3
Forestry	5.0	2.5
Dairy farms	7.3	3.7
Ruminant livestock	6.7	2.5
Non-ruminant livestock	2.6	1.3
Processed dairy products	7.3	3.7
Processed ruminant meat products	7.7	3.9
Processed non-ruminant meat products	8.8	4.4
Vegetable oils and fats	6.6	3.3
Beverages, tobacco, sugar	2.8	1.4

Table 7 continued

Sector	Elasticity of substitution between domestic and imported goods	Elasticity of substitution among imports in Armington structure
Processed rice	5.2	2.6
Food products nec	4.0	2.0
Other primary: fishery and mining	1.9	1.0
Coal	6.1	3.1
Crude oil	10.4	5.2
Natural gas	33.0	11.0
Petroleum, coal products	4.2	2.1
Electricity	5.6	2.8
Energy intensive industries	6.9	3.4
Other transport	3.8	1.9
Water transport	3.8	1.9
Air transport	3.8	1.9
Other industry and services	7.0	2.5
Services generating Non-CO_2 emissions	3.8	1.9

10 Appendix C

10.1 "Food miles" Experiments for Other Food Products in Different Regions of the Global Model

For the robustness of our analysis of the food miles issue we perform additional "food miles" experiments focusing on changes in consumption patterns of dairy and non-ruminant products, vegetable oils and fats, and processed rice, where available,[10] and then summarize the results in Tables 8, 9, 10 and 11. In particular, we impose taxes on private consumption (while maintaining tax neutrality) of both locally produced and imported dairy and non-ruminant products, vegetable oils and fats, and processed rice, to increase domestic purchases in the region by 50 US$ million, and reduce their import sourced consumption by the same amount.

As can be noted from Tables 8, 9, 10 and 11, substitution of local for imported food products may reduce global GHG emissions due to lower use of international transport and not because of changes in production patterns of these food products. This is especially true for dairy products in the European Union and non-ruminant products in Canada.

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[10] We redo the same 50 US$ million food miles experiment only in regions where the change in consumption patterns of dairy and non-ruminant products, vegetable oils and fats, and processed rice, does not make their imports negative in the GTAP data base.

Table 8 Change in world dairy farms, transport and total emissions under “food miles” experiment in different regions

Region with “food miles” experiment	Change in world emissions, MTCO2e			Dairy farms emissions intensity, MkgCO2e/$	Dairy farms import-weighted emissions intensity, MkgCO2e /$
	Dairy farms	Transport	Total		
Japan	−36,985	−1,529	−34,244	0.996	4.06
Rest of European countries	−5,440	−5,962	−13,755	1.700	4.03
Canada	3,119	−5,428	−7,686	1.752	4.04
East Asia	−35,967	−3,849	−31,151	1.758	4.03
United States	−14,896	320	−5,071	2.218	4.06
Middle Eastern and North Africa	−15,173	−8,928	−26,213	2.244	4.04
European Union	317	−2,265	−82	2.542	4.04
Other East Europe	−23,210	−15,396	−93,410	2.810	4.10
Central and Caribbean Americas	−5,128	−2,080	−4,564	3.392	4.05
China and Hong Kong	−39,648	−5,669	−71,408	4.187	4.03
Malaysia and Indonesia	−54,917	−2,507	−91,321	4.322	3.99
South and Other Americas	15,469	−3,855	28,328	4.374	4.03
Rest of South East Asia	25,958	−4,358	−10,485	4.701	4.05
Oceania countries	30,566	−4,018	23,187	5.542	4.03
Russia	88,201	−10,414	88,753	8.374	3.62
Rest of South Asia	−2,843	1,747	4,036	10.115	4.01
Brazil	120,300	−2,726	−15,833	12.562	4.00
Sub Saharan Africa	259,857	−8,457	199,269	46.504	3.95
World	–	–	–	3.165	–

Table 9 Change in world non-ruminant meat, transport and total emissions under “food miles” experiment in different regions

Region with “food miles” experiment	Change in world emissions, MTCO2e			Non-Ruminant meat emissions intensity, MkgCO2e/$	Non-Ruminant meat import- weighted emissions intensity, MkgCO2e /$
	Non-Ruminant meat	Transport	Total		
Rest of European countries	−11,401	−1,820	−24,559	0.619	2.369
Other East Europe	−29,518	−14,419	−124,741	0.768	2.436
Central and Caribbean Americas	−11,004	−3,698	−42,895	1.524	2.452
Canada	16,265	−5,400	−4,680	1.625	2.563
Japan	−38,428	−150	−46,856	1.796	2.988
East Asia	1,180	−3,014	32,724	2.036	2.590

Table 9 continued

Region with "food miles" experiment	Change in world emissions, MTCO2e			Non-Ruminant meat emissions intensity, MkgCO2e/$	Non-Ruminant meat import- weighted emissions intensity, MkgCO2e /$
	Non-Ruminant meat	Transport	Total		
European Union	−6,243	−2,040	−21,675	2.081	2.677
India	−14,007	−1,911	−14,072	2.101	4.969
United States	−15,738	1,865	3,819	2.404	2.875
Russia	−1,318	−13,745	−127,612	3.021	2.199
Middle Eastern and North Africa	35,425	8,692	181,081	3.359	3.041
China and Hong Kong	58,695	−6,014	7,235	3.594	2.948
Oceania countries	−31,575	314	82,530	3.735	3.567
Rest of South East Asia	55,905	−6,108	2,375	4.338	4.326
South and Other Americas	−20,355	−6,618	−112,751	4.383	4.003
Rest of South Asia	−2,950	−6,520	16,127	7.603	5.725
Malaysia and Indonesia	76,223	−6,109	42,646	5.707	3.732
Sub Saharan Africa	117,940	−6,081	361,505	13.466	6.440
World	–	–	–	3.034	–

Table 10 Change in world oilseeds, transport and total emissions under "food miles" experiment in different regions

Region with "food miles" experiment	Change in world emissions, MTCO2e			Oilseeds emissions intensity, MkgCO2e/$	Oilseeds import-weighted emissions intensity, MkgCO2e/$
	Oilseeds	Transport	Total		
Japan	47,069	−654	46,437	0.304	0.953
India	−3,277	−689	6,274	0.361	1.585
Middle Eastern and North Africa	−22,790	−9,508	−18,821	0.467	2.003
Rest of South East Asia	−546	−6,258	1,443	0.712	0.604
Sub Saharan Africa	−11,164	−5,672	162,092	0.821	1.481
Oceania countries	−13,139	−608	−9,551	0.821	1.170
Other East Europe	−12,686	−7,450	−10,748	0.830	1.369
Central and Caribbean Americas	21,779	−5,215	16,187	0.989	2.130
East Asia	−1,012	−755	12,043	1.055	1.575
Rest of South Asia	12,633	−2,403	26,885	1.114	1.763
European Union	2,099	−1,881	2,300	1.289	1.160

Table 10 continued

Region with "food miles" experiment	Change in world emissions, MTCO2e			Oilseeds emissions intensity, MkgCO2e/$	Oilseeds import-weighted emissions intensity, MkgCO2e/$
	Oilseeds	Transport	Total		
Russia	10,234	−10,183	−15,942	2.100	1.525
China and Hong Kong	18,884	−2,657	70,602	2.339	0.977
United States	31,929	2,511	43,111	2.431	1.487
Rest of European countries	25,660	−2,902	26,011	2.608	1.247
South and Other Americas	9,126	−3,717	6,789	3.215	2.875
Brazil	89,451	899	54,458	5.093	2.055
World	–	–	-	1.825	–

Table 11 Change in world paddy rice, transport and total emissions under "food miles" experiment in different regions

Region with "food miles" experiment	Change in world emissions, MTCO2e			Paddy rice emissions intensity, MkgCO2e/$	Paddy rice import-weighted emissions intensity, MkgCO2e /$
	Paddy rice	Transport	Total		
Japan	1,083	−5	−6,611	0.544	7.183
Other East Europe	−52,078	−23,121	99,622	1.295	15.438
Middle Eastern and North Africa	−106,675	−18,907	−169,638	2.948	7.931
European Union	−41,737	−3,612	−36,518	3.389	7.235
Central and Caribbean Americas	−74,666	−10,394	−54,142	3.600	7.900
Rest of South Asia	−8,121	−8,299	21,457	5.558	10.266
United States	−191,829	6,438	−173,970	7.218	7.875
Brazil	8,341	−7,834	−70,245	7.336	12.962
Sub Saharan Africa	183,767	−13,399	167,470	10.380	6.458
Malaysia and Indonesia	99,700	−13,044	76,283	10.750	12.138
South and Other Americas	−13,856	−7,149	−12,232	13.039	9.446
Rest of South East Asia	156,336	−10,540	130,527	13.338	11.029
China and Hong Kong	−65,480	−11,176	−27,210	13.831	7.912
Russia	27,272	−1,389	48,648	30.701	7.630
World	–	–	–	7.508	–

11 Appendix D

See Tables 12, 13, 14, 15, 16, 17, 18, 19, 20 and 21.

Table 12 EURUMINANTS—change in world ruminant meat, transport and total emissions (MTCO2e)

Region	Confidence interval and coefficient of variation											
	Ruminant meat				Other transport				Water transport			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	−2,202	−1,548	−894	−0.21	26	46	66	0.22	3	4	5	0.17
European Union	18,084	30,581	43,078	0.20	−568	−404	−240	−0.20	−286	−206	−126	−0.20
Brazil	−96,163	−68,777	−41,391	−0.20	−527	−377	−227	−0.20	34	58	82	0.21
Canada	−1,566	−1,142	−718	−0.19	−104	−75	−46	−0.19	−1	−1	−1	0.00
Japan	−69	−42	−15	−0.32	0	0	0	0.00	−7	−5	−3	−0.20
China and Hong Kong	−2,006	−1,423	−840	−0.20	−76	−54	−32	−0.20	−43	−31	−19	−0.19
India	−356	−258	−160	−0.19	−20	−15	−10	−0.17	−2	−2	−2	0.00
Central and Caribbean Americas	−893	−637	−381	−0.20	16	16	16	0.00	2	2	2	0.00
South and Other Americas	−14,881	−10,639	−6,397	−0.20	−50	−36	−22	−0.19	8	12	16	0.17
East Asia	−138	−94	−50	−0.23	−222	−158	−94	−0.20	−21	−15	−9	−0.21
Malaysia and Indonesia	−354	−247	−140	−0.22	4	8	12	0.25	−12	−8	−4	−0.25
Rest of South East Asia	−1,097	−776	−455	−0.21	−80	−58	−36	−0.19	−15	−12	−9	−0.13
Rest of South Asia	−109	−77	−45	−0.21	−12	−8	−4	−0.25	0	0	0	0.00
Russia	−87	−65	−43	−0.17	−129	−92	−55	−0.20	0	0	0	0.00
Other East Europe	−154	−111	−68	−0.20	−370	−264	−158	−0.20	1	1	1	0.00
Rest of European Countries	−531	−379	−227	−0.20	−24	−18	−12	−0.18	−6	−4	−2	−0.20
Middle Eastern and North Africa	−366	−250	−134	−0.23	−103	−72	−41	−0.22	−27	−19	−11	−0.21
Sub Saharan Africa	−18,270	−13,048	−7,826	−0.20	−135	−97	−59	−0.20	1	1	1	0.00
Oceania countries	−19,069	−13,713	−8,357	−0.20	−623	−447	−271	−0.20	0	0	0	0.00

Table 12 continued

Region	Confidence interval and coefficient of variation							
	Air transport				Total			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	179	298	417	0.20	−2,724	−1,917	−1,110	−0.21
European Union	−290	−206	−122	−0.20	18,671	31,561	44,451	0.20
Brazil	−26	−18	−10	−0.21	−97,995	−70,088	−42,181	−0.20
Canada	8	10	13	0.13	−1,791	−1,304	−817	−0.19
Japan	−4	−4	−4	0.00	−738	−204	330	−1.31
China and Hong Kong	−13	−8	−3	−0.33	−2,964	−2,103	−1,242	−0.20
India	0	0	0	0.00	−256	−188	−120	−0.18
Central and Caribbean Americas	4	8	12	0.25	−931	−663	−395	−0.20
South and Other Americas	19	32	45	0.21	−15,193	−10,862	−6,531	−0.20
East Asia	0	0	0	0.00	−564	−390	−216	−0.22
Malaysia and Indonesia	0	0	0	0.00	−182	−127	−72	−0.22
Rest of South East Asia	1	4	7	0.33	−1,082	−766	−450	−0.21
Rest of South Asia	0	0	0	0.00	−172	−121	−70	−0.21
Russia	−12	−8	−4	−0.25	−157	−119	−81	−0.16
Other East Europe	0	0	0	0.00	−53	−38	−23	−0.20
Rest of European Countries	−1	−1	−1	0.00	−571	−409	−247	−0.20
Middle Eastern and North Africa	−4	−4	−4	0.00	−459	−319	−179	−0.22
Sub Saharan Africa	5	8	11	0.17	−18,257	−13,040	−7,823	−0.20
Oceania countries	91	149	207	0.20	−18,643	−13,406	−8,169	−0.20

Table 13 CHNRUMINANTS—change in world ruminant meat, transport and total emissions (MTCO2e)

Region	Confidence interval and coefficient of variation											
	Ruminant meat				Other transport				Water transport			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	−15,568	−13,623	−11,678	−0.07	−383	−338	−293	−0.07	−72	−64	−56	−0.06
European Union	−8,897	−7,889	−6,881	−0.06	−85	−78	−71	−0.05	−483	−429	−375	−0.06
Brazil	−65,335	−58,108	−50,881	−0.06	−291	−260	−229	−0.06	27	31	35	0.06
Canada	−12,337	−11,073	−9,809	−0.06	32	36	40	0.06	0	0	0	0.00
Japan	−225	−156	−87	−0.22	159	174	189	0.04	−59	−53	−47	−0.06
China and Hong Kong	428,087	507,541	586,995	0.08	−1,885	−1,576	−1,267	−0.10	−503	−435	−367	−0.08
India	2,361	2,880	3,399	0.09	13	20	27	0.18	−6	−6	−6	0.00
Central and Caribbean Americas	−2,441	−2,141	−1,841	−0.07	−10	−8	−6	−0.14	−9	−7	−5	−0.13
South and Other Americas	−9,875	−8,818	−7,761	−0.06	−31	−27	−23	−0.07	−2	−2	−2	0.00
East Asia	−410	−330	−250	−0.12	−81	−73	−65	−0.06	−94	−83	−72	−0.07
Malaysia and Indonesia	−815	−694	−573	−0.09	6	6	6	0.00	−47	−41	−35	−0.07
Rest of South East Asia	−1,609	−1,403	−1,197	−0.07	−54	−48	−42	−0.06	−45	−39	−33	−0.07
Rest of South Asia	0	0	0	0.00	10	13	16	0.13	0	0	0	0.00
Russia	−348	−302	−256	−0.08	−12	−11	−10	−0.06	−32	−28	−24	−0.07
Other East Europe	−119	−109	−99	−0.05	−242	−213	−184	−0.07	−15	−13	−11	−0.08
Rest of European Countries	−114	−98	−82	−0.08	−6	−6	−6	0.00	−27	−23	−19	−0.08
Middle Eastern and North Africa	−1,301	−1,137	−973	−0.07	−60	−52	−44	−0.07	−97	−86	−75	−0.07
Sub Saharan Africa	−3,073	−2,670	−2,267	−0.08	−14	−12	−10	−0.10	−13	−11	−9	−0.09
Oceania countries	−68,003	−60,840	−53,677	−0.06	−2,452	−2,182	−1,912	−0.06	−7	−7	−7	0.00

Table 13 continued

Region	Confidence interval and coefficient of variation Air transport				Total			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	199	246	293	0.10	−20,396	−17,918	−15,440	−0.07
European Union	−180	−159	−138	−0.07	−11,394	−10,153	−8,912	−0.06
Brazil	−17	−15	−13	−0.07	−66,877	−59,495	−52,113	−0.06
Canada	22	25	28	0.06	−12,632	−11,342	−10,052	−0.06
Japan	−22	−20	−18	−0.05	−58	−26	6	−0.62
China and Hong Kong	−261	−211	−161	−0.12	404,195	478,274	552,353	0.08
India	0	0	0	0.00	2,756	3,359	3,962	0.09
Central and Caribbean Americas	−15	−12	−9	−0.11	−2,591	−2,277	−1,963	−0.07
South and Other Americas	14	16	18	0.06	−10,518	−9,400	−8,282	−0.06
East Asia	−42	−37	−32	−0.07	−827	−684	−541	−0.10
Malaysia and Indonesia	−19	−17	−15	−0.05	−719	−614	−509	−0.09
Rest of South East Asia	−52	−46	−40	−0.06	−1,643	−1,438	−1,233	−0.07
Rest of South Asia	−11	−9	−7	−0.13	−141	−128	−115	−0.05
Russia	−26	−23	−20	−0.07	−363	−335	−307	−0.04
Other East Europe	−9	−7	−5	−0.14	−362	−323	−284	−0.06
Rest of European Countries	−8	−8	−8	0.00	−216	−188	−160	−0.07
Middle Eastern and North Africa	−19	−16	−13	−0.08	−1,747	−1,536	−1,325	−0.07
Sub Saharan Africa	−12	−10	−8	−0.08	−3,327	−2,903	−2,479	−0.07
Oceania countries	688	784	880	0.06	−67,176	−60,099	−53,022	−0.06

Table 14 EUDAIRYFARMS—change in world dairy farms, transport and total emissions (MTCO2e)

Region	Confidence interval and coefficient of variation											
	Dairy farms				Other transport				Water transport			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	−150	−127	−104	−0.09	0	0	0	0.00	−40	−35	−30	−0.07
European Union	3,953	4,790	5,627	0.09	−618	−525	−432	0.00	−409	−348	−287	−0.09
Brazil	−37	−31	−25	−0.10	0	0	0	0.00	−14	−12	−10	−0.09
Canada	−84	−72	−60	−0.08	−90	−76	−62	0.00	−4	−4	−4	0.00
Japan	−2	−2	−2	0.00	0	0	0	0.00	−38	−32	−26	−0.10
China and Hong Kong	2	2	2	0.00	−92	−78	−64	0.00	−59	−50	−41	−0.09
India	0	0	0	0.00	−9	−8	−7	0.00	−19	−15	−11	−0.14
Central and Caribbean Americas	−101	−85	−69	−0.09	0	0	0	0.00	−2	−2	−2	0.00
South and Other Americas	−66	−56	−46	−0.09	−15	−13	−11	0.00	−13	−11	−9	−0.11
East Asia	−12	−10	−8	−0.10	−234	−198	−162	0.00	−63	−54	−45	−0.08
Malaysia and Indonesia	−1	−1	−1	0.00	18	23	28	0.00	−40	−35	−30	−0.07
Rest of South East Asia	−22	−18	−14	−0.12	−129	−110	−91	0.00	−34	−29	−24	−0.08
Rest of South Asia	−17	−12	−7	−0.20	0	0	0	0.00	0	0	0	0.00
Russia	−216	−184	−152	−0.09	−109	−92	−75	0.00	−19	−17	−15	−0.07
Other East Europe	−154	−131	−108	−0.09	−310	−263	−216	0.00	−3	−3	−3	0.00
Rest of European Countries	−702	−596	−490	−0.09	−13	−10	−7	0.00	−12	−10	−8	−0.11
Middle Eastern and North Africa	−36	−30	−24	−0.10	−85	−72	−59	0.00	−78	−67	−56	−0.08
Sub Saharan Africa	−273	−232	−191	−0.09	−63	−55	−47	0.00	−15	−12	−9	−0.14
Oceania countries	−3,400	−2,888	−2,376	−0.09	−45	−38	−31	0.00	2	2	2	0.00

Table 14 continued

Region	Confidence interval and coefficient of variation							
	Air transport				Total			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	0	0	0	0.00	−333	−282	−231	−0.09
European Union	−110	−95	−80	0.00	3,260	3,950	4,640	0.09
Brazil	−2	−2	−2	0.00	−20	−17	−14	−0.09
Canada	−4	−4	−4	0.00	−120	−102	−84	−0.09
Japan	0	0	0	0.00	−49	−49	−49	0.00
China and Hong Kong	4	4	4	0.00	−641	−545	−449	−0.09
India	0	0	0	0.00	−161	−138	−115	−0.09
Central and Caribbean Americas	0	0	0	0.00	−148	−124	−100	−0.10
South and Other Americas	0	0	0	0.00	−2	−2	−2	−0.09
East Asia	0	0	0	0.00	−335	−284	−233	−0.09
Malaysia and Indonesia	0	0	0	0.00	−125	−108	−91	−0.08
Rest of South East Asia	0	0	0	0.00	−314	−267	−220	−0.09
Rest of South Asia	0	0	0	0.00	−20	−16	−12	−0.13
Russia	−11	−8	−5	0.00	−396	−336	−276	−0.09
Other East Europe	3	3	3	0.00	311	377	443	0.09
Rest of European Countries	3	5	7	0.00	−506	−430	−354	−0.09
Middle Eastern and North Africa	0	0	0	0.00	−265	−225	−185	−0.09
Sub Saharan Africa	0	0	0	0.00	−455	−387	−319	−0.09
Oceania countries	64	78	92	0.00	−1,296	−1,100	−904	−0.09

Table 15 CHNDAIRYFARMS—change in world dairy farms, transport and total emissions (MTCO2e)

Region	Confidence interval and coefficient of variation											
	Dairy farms				Other transport				Water transport			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	−3,096	−2,662	−2,228	−0.08	−39	−34	−29	−0.07	−135	−116	−97	−0.08
European Union	−16,399	−14,133	−11,867	−0.08	−299	−264	−229	−0.07	−1,399	−1,205	−1,011	−0.08
Brazil	−110	−92	−74	−0.10	26	31	36	0.09	−50	−44	−38	−0.07
Canada	−524	−448	−372	−0.08	56	67	78	0.09	−16	−14	−12	−0.07
Japan	−75	−61	−47	−0.11	53	64	75	0.09	−156	−134	−112	−0.08
China and Hong Kong	21,648	26,203	30,758	0.09	−2,310	−1,949	−1,588	−0.09	−905	−774	−643	−0.08
India	−57	−48	−39	−0.09	36	46	56	0.11	−33	−29	−25	−0.07
Central and Caribbean Americas	−336	−278	−220	−0.10	−37	−31	−25	−0.10	−21	−19	−17	−0.05
South and Other Americas	−379	−322	−265	−0.09	−21	−19	−17	−0.06	−44	−38	−32	−0.08
East Asia	−231	−193	−155	−0.10	−102	−89	−76	−0.07	−292	−252	−212	−0.08
Malaysia and Indonesia	−395	−339	−283	−0.08	−94	−81	−68	−0.08	−137	−119	−101	−0.08
Rest of South East Asia	−1,992	−1,706	−1,420	−0.08	−86	−76	−66	−0.07	−120	−104	−88	−0.08
Rest of South Asia	−90	−69	−48	−0.15	10	10	10	0.00	−4	−4	−4	0.00
Russia	−117	−98	−79	−0.10	−44	−38	−32	−0.08	−82	−70	−58	−0.09
Other East Europe	−111	−96	−81	−0.08	−173	−148	−123	−0.08	−39	−33	−27	−0.09
Rest of European Countries	−234	−202	−170	−0.08	8	12	16	0.17	−69	−59	−49	−0.08
Middle Eastern and North Africa	−147	−119	−91	−0.12	0	0	0	0.00	−292	−251	−210	−0.08
Sub Saharan Africa	−487	−404	−321	−0.10	−14	−14	−14	0.00	−33	−29	−25	−0.07
Oceania countries	−51,749	−44,581	−37,413	−0.08	−585	−505	−425	−0.08	40	48	56	0.08

Table 15 continued

Region	Confidence interval and coefficient of variation							
	Air transport				Total			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	−66	−61	−56	−0.04	−7,363	−6,358	−5,353	−0.08
European Union	−1	−1	−1	−0.10	−22,816	−19,686	−16,556	−0.08
Brazil	−1	−1	−1	0.00	−2,420	−2,084	−1,748	−0.08
Canada	0	0	0	0.00	−1,436	−1,238	−1,040	−0.08
Japan	−30	−26	−22	−0.08	−133	−105	−77	−0.14
China and Hong Kong	−454	−384	−314	−0.09	−24,611	−19, 885	−15,159	−0.12
India	0	0	0	0.00	213	290	367	0.13
Central and Caribbean Americas	−14	−12	−10	−0.08	−884	−755	−626	−0.09
South and Other Americas	−11	−9	−7	−0.10	−1,188	−1,021	−854	−0.08
East Asia	−68	−58	−48	−0.08	−665	−573	−481	−0.08
Malaysia and Indonesia	−20	−18	−16	−0.06	−259	−228	−197	−0.07
Rest of South East Asia	−64	−56	−48	−0.08	−2,409	−2,078	−1,747	−0.08
Rest of South Asia	−10	−8	−6	−0.11	−310	−262	−214	−0.09
Russia	−20	−17	−14	−0.10	142	171	200	0.09
Other East Europe	−4	−4	−4	0.00	−107	−92	−77	−0.08
Rest of European Countries	−2	−2	−2	0.00	−303	−262	−221	−0.08
Middle Eastern and North Africa	−39	−35	−31	−0.06	−1,437	−1,231	−1,025	−0.08
Sub Saharan Africa	0	0	0	0.00	−2,012	−1,726	−1,440	−0.08
Oceania countries	1,083	1,292	1,501	0.08	−16,542	−14,284	12,026	−0.08

Table 16 EUNRUMINANTS—change in world non-ruminant meat, transport and total emissions (MTCO2e)

Region	Confidence interval and coefficient of variation											
	Non-Ruminant meat				Other transport				Water transport			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	−509	−437	−365	−0.08	7	8	9	0.08	−36	−32	−28	−0.07
European Union	6,002	7,287	8,572	0.09	−615	−526	−437	−0.08	−186	−160	−134	−0.08
Brazil	−6,256	−5,366	−4,476	−0.08	−181	−156	−131	−0.08	17	21	25	0.09
Canada	−69	−59	−49	−0.08	−81	−70	−59	−0.08	−3	−3	−3	0.00
Japan	−16	−14	−12	−0.07	0	0	0	0.00	−14	−13	−12	−0.06
China and Hong Kong	−886	−759	−632	−0.08	−63	−54	−45	−0.08	−17	−15	−13	−0.07
India	−5	−4	−3	−0.14	3	4	5	0.07	−2	−2	−2	0.00
Central and Caribbean Americas	−59	−51	−43	−0.08	0	0	0	0.00	−4	−4	−4	0.00
South and Other Americas	−465	−398	−331	−0.08	−9	−8	−7	−0.07	−4	−4	−4	0.00
East Asia	−54	−47	−40	−0.08	−194	−166	−138	−0.09	−41	−35	−29	−0.09
Malaysia and Indonesia	−2,204	−1,890	−1,576	−0.08	−18	−16	−14	−0.07	−20	−16	−12	−0.11
Rest of South East Asia	−4,143	−3,553	−2,963	−0.08	−83	−71	−59	−0.08	−10	−8	−6	−0.10
Rest of South Asia	−42	−36	−30	−0.08	0	0	0	0.00	0	0	0	0.00
Russia	−24	−20	−16	−0.10	−106	−92	−78	−0.08	−7	−6	−5	−0.10
Other East Europe	−3	−3	−3	0.00	−311	−267	−223	−0.08	−5	−5	−5	0.00
Rest of European Countries	−28	−24	−20	−0.08	−21	−19	−17	−0.06	−11	−9	−7	−0.11
Middle Eastern and North Africa	−225	−193	−161	−0.08	−93	−79	−65	−0.09	−51	−43	−35	−0.09
Sub Saharan Africa	−748	−642	−536	−0.08	−64	−54	−44	−0.09	−6	−6	−6	0.00
Oceania countries	−41	−35	−29	−0.08	−64	−55	−46	−0.09	0	0	0	0.00

Table 16 continued

Region	Confidence interval and coefficient of variation							
	Air transport				Total			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	−109	−93	−77	−0.09	−1,458	−1,253	−1,048	−0.08
European Union	−75	−64	−53	−0.09	7,294	8,848	10,402	0.09
Brazil	0	0	0	0.00	−20,220	−17,346	−14,472	−0.08
Canada	−4	−4	−4	0.00	−174	−150	−126	−0.08
Japan	0	0	0	0.00	−51	−42	−33	−0.11
China and Hong Kong	−2	−2	−2	0.00	−1,174	−1,006	−838	−0.08
India	0	0	0	0.00	30	36	42	0.08
Central and Caribbean Americas	0	0	0	0.00	−126	−107	−88	−0.09
South and Other Americas	4	5	6	0.13	−966	−828	−690	−0.08
East Asia	0	0	0	0.00	−345	−296	−247	−0.08
Malaysia and Indonesia	5	6	8	0.13	−2,172	−1,863	−1,554	−0.08
Rest of South East Asia	30	35	40	0.07	−4,678	−4,013	−3,348	−0.08
Rest of South Asia	5	5	5	0.00	−109	−94	−79	−0.08
Russia	0	0	0	0.00	−104	−104	−104	0.00
Other East Europe	−2	−2	−2	0.00	−206	−178	−150	−0.08
Rest of European Countries	1	1	1	0.00	−54	−46	−38	−0.09
Middle Eastern and North Africa	0	0	0	0.00	−199	−170	−141	−0.08
Sub Saharan Africa	−5	−5	−5	0.00	−2,527	−2,167	−1,807	−0.08
Oceania countries	32	37	42	0.07	−1,046	−898	−750	−0.08

Table 17 CHNRUMINANTS—change in world non-ruminant meat, transport and total emissions (MTCO2e)

Region	Confidence interval and coefficient of variation											
	Non-Ruminant meat				Other transport				Water transport			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	−9,758	−8,392	−7,026	−0.08	−575	−494	−413	−0.08	−130	−112	−94	−0.08
European Union	−7,380	−6,346	−5,312	−0.08	−469	−404	−339	−0.08	−1,098	−944	−790	−0.08
Brazil	−18,221	−15,674	−13,127	−0.08	−373	−321	−269	−0.08	40	48	56	0.08
Canada	−1,651	−1,419	−1,187	−0.08	−36	−30	−24	−0.10	−10	−8	−6	0.00
Japan	−101	−87	−73	−0.08	107	127	147	0.08	−121	−105	−89	−0.08
China and Hong Kong	99,297	118,786	138,275	0.08	−1,955	−1,678	−1,401	−0.08	−735	−631	−527	−0.08
India	−13	−11	−9	−0.08	14	16	18	0.08	−21	−19	−17	−0.06
Central and Caribbean Americas	−105	−89	−73	−0.09	6	7	8	0.09	−14	−12	−10	−0.08
South and Other Americas	−1,794	−1,542	−1,290	−0.08	15	15	15	0.00	−25	−21	−17	−0.10
East Asia	−2,000	−1,720	−1,440	−0.08	−195	−167	−139	−0.08	−223	−191	−159	−0.08
Malaysia and Indonesia	−20,144	−17,324	−14,504	−0.08	−177	−152	−127	−0.08	−132	−114	−96	−0.08
Rest of South East Asia	−7,344	−6,316	−5,288	−0.08	−33	−29	−25	−0.07	−86	−74	−62	−0.08
Rest of South Asia	−51	−43	−35	0.00	6	8	10	0.11	0	0	0	0.00
Russia	−188	−160	−132	−0.09	28	34	40	0.09	−63	−54	−45	−0.08
Other East Europe	−75	−65	−55	−0.08	−141	−122	−103	−0.08	−26	−22	−18	−0.10
Rest of European Countries	−12	−10	−8	−0.10	−17	−13	−9	−0.14	−56	−48	−40	−0.08
Middle Eastern and North Africa	−569	−488	−407	−0.08	−82	−71	−60	−0.07	−214	−184	−154	−0.08
Sub Saharan Africa	−476	−407	−338	−0.08	−9	−8	−7	−0.07	−28	−24	−20	−0.09
Oceania countries	2	4	6	0.25	−224	−192	−160	−0.08	−6	−6	−6	0.00

Table 17 continued

Region	Confidence interval and coefficient of variation							
	Air transport				Total			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	139	167	195	0.08	−20,220	−17,391	−14,562	−0.08
European Union	−38	−32	−26	−0.10	−13,151	−11,309	−9,467	−0.08
Brazil	−11	−11	−11	0.00	−58,719	−50,510	−42,301	−0.08
Canada	28	33	38	0.07	−2,301	−1,979	−1,657	−0.08
Japan	−9	−8	−7	−0.07	8	12	16	0.17
China and Hong Kong	−371	−319	−267	−0.08	104,971	125,501	146,031	0.08
India	2	2	2	0.00	130	158	186	0.09
Central and Caribbean Americas	12	12	12	0.00	−733	−630	−527	−0.08
South and Other Americas	15	18	21	0.10	−4,066	−3,496	−2,926	−0.08
East Asia	−27	−23	−19	−0.09	−3,950	−3,397	−2,844	−0.08
Malaysia and Indonesia	43	52	61	0.08	−19,442	−16,721	−14,000	−0.08
Rest of South East Asia	4	4	4	0.00	−8,340	−7,174	−6,008	−0.08
Rest of South Asia	−5	−5	−5	0.00	−144	−123	−102	−0.09
Russia	1	1	1	0.00	100	120	140	0.09
Other East Europe	2	2	2	0.00	271	320	369	0.08
Rest of European Countries	0	0	0	0.00	−105	−90	−75	−0.08
Middle Eastern and North Africa	0	0	0	0.00	−937	−803	−669	−0.08
Sub Saharan Africa	0	0	0	0.00	−2,185	−1,875	−1,565	−0.08
Oceania countries	72	86	100	0.08	−3,928	−3,379	−2,830	−0.08

Table 18 EUOILSEEDS—change in world oilseeds, transport and total emissions (MTCO2e)

Region	Confidence interval and coefficient of variation											
	Oilseeds				Other transport				Water transport			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	−590	−502	−414	−0.09	0	0	0	0.00	−62	−53	−44	−0.09
European Union	2,181	2,623	3,065	0.08	−309	−265	−221	−0.08	−781	−667	−553	−0.09
Brazil	854	1,025	1,196	0.08	5	8	11	0.17	−25	−21	−17	−0.10
Canada	−9	−7	−5	−0.14	−90	−78	−66	−0.08	−7	−5	−3	−0.17
Japan	0	0	0	0.00	−72	−62	−52	−0.08	−71	−61	−51	−0.08
China and Hong Kong	−50	−42	−34	−0.10	−72	−62	−52	−0.08	−122	−104	−86	−0.09
India	−108	−92	−76	−0.09	−10	−8	−6	−0.11	−11	−10	−9	−0.07
Central and Caribbean Americas	−22	−18	−14	−0.11	0	0	0	0.00	−8	−6	−4	−0.17
South and Other Americas	−641	−547	−453	−0.09	−95	−80	−65	−0.09	−15	−13	−11	−0.08
East Asia	−1	−1	−1	0.00	−196	−167	−138	−0.09	−136	−116	−96	−0.08
Malaysia and Indonesia	−202	−172	−142	−0.09	264	317	370	0.08	30	37	44	0.09
Rest of South East Asia	−12	−10	−8	−0.10	0	0	0	0.00	−39	−33	−27	−0.09
Rest of South Asia	−11	−9	−7	−0.11	6	8	10	0.10	0	0	0	0.00
Russia	8	10	12	0.11	−124	−107	−90	−0.08	−32	−27	−22	−0.10
Other East Europe	−32	−28	−24	−0.07	−541	−461	−381	−0.09	−20	−16	−12	−0.11
Rest of European Countries	−9	−7	−5	−0.14	−21	−19	−17	−0.06	−38	−32	−26	−0.09
Middle Eastern and North Africa	−57	−49	−41	−0.08	−56	−48	−40	−0.08	−129	−110	−91	−0.09
Sub Saharan Africa	−94	−80	−66	−0.09	−52	−44	−36	−0.09	−13	−11	−9	−0.10
Oceania countries	5	5	5	0.00	−65	−55	−45	−0.09	−4	−4	−4	0.00

Table 18 continued

Region	Confidence interval and coefficient of variation							
	Air transport				Total			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	142	171	200	0.09	−879	−746	−613	−0.09
European Union	−148	−127	−106	−0.08	2,660	3,208	3,756	0.09
Brazil	4	4	4	0.00	734	881	1,028	0.08
Canada	8	8	8	0.00	−107	−89	−71	−0.10
Japan	3	4	5	0.11	−115	−98	−81	−0.09
China and Hong Kong	2	2	2	0.00	−804	−656	−508	−0.11
India	4	4	4	0.00	−57	−49	−41	−0.09
Central and Caribbean Americas	−4	−4	−4	0.00	−113	−100	−87	−0.07
South and Other Americas	11	13	15	0.08	−613	−524	−435	−0.08
East Asia	12	15	18	0.09	−308	−262	−216	−0.09
Malaysia and Indonesia	177	214	251	0.09	2,672	3,218	3,764	0.08
Rest of South East Asia	35	42	49	0.08	188	227	266	0.09
Rest of South Asia	5	5	5	0.00	3	3	3	0.07
Russia	9	11	13	0.10	236	285	334	0.09
Other East Europe	9	11	13	0.11	83	101	119	0.09
Rest of European Countries	−2	−2	−2	0.00	−72	−61	−50	−0.09
Middle Eastern and North Africa	17	20	23	0.07	−276	−236	−196	−0.08
Sub Saharan Africa	11	13	15	0.08	−3,871	−3,303	−2,735	−0.09
Oceania countries	75	90	105	0.08	415	501	587	0.09

Table 19 CHNOILSEEDS—change in world oilseeds, transport and total emissions (MTCO2e)

Region	Confidence interval and coefficient of variation											
	Oilseeds				Other transport				Water transport			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	1,606	1,946	2,286	0.09	−55	−48	−41	−0.08	−207	−177	−147	−0.08
European Union	−64	−56	−48	−0.07	−465	−400	−335	−0.08	−2,235	−1,920	−1,605	−0.08
Brazil	246	320	394	0.11	−265	−229	−193	−0.08	−73	−63	−53	−0.08
Canada	358	432	506	0.09	−76	−65	−54	−0.08	−26	−22	−18	−0.10
Japan	1	1	1	0.00	1	1	1	0.08	−225	−193	−161	−0.08
China and Hong Kong	12,540	15,105	17,670	0.08	−209	−169	−129	−0.12	−723	−620	−517	−0.08
India	−151	−125	−99	−0.10	34	42	50	0.09	−45	−38	−31	−0.09
Central and Caribbean Americas	3	3	3	0.00	11	15	19	0.14	−28	−24	−20	−0.08
South and Other Americas	1,693	2,053	2,413	0.09	−100	−86	−72	−0.08	−67	−57	−47	−0.09
East Asia	22	26	30	0.08	−130	−112	−94	−0.08	−434	−372	−310	−0.08
Malaysia and Indonesia	−901	−773	−645	−0.08	1,274	1,524	1,774	0.08	183	219	255	0.08
Rest of South East Asia	−23	−19	−15	−0.11	83	101	119	0.09	−139	−119	−99	−0.08
Rest of South Asia	−89	−73	−57	−0.11	12	14	16	0.07	−5	−5	−5	0.00
Russia	13	15	17	0.07	−9	−8	−7	−0.08	−133	−115	−97	−0.08
Other East Europe	6	6	6	0.00	−352	−303	−254	−0.08	−60	−52	−44	−0.08
Rest of European Countries	0	0	0	0.00	0	0	0	0.00	−111	−95	−79	−0.09
Middle Eastern and North Africa	1	1	1	0.00	−1	−1	−1	−0.14	−420	−361	−302	−0.08
Sub Saharan Africa	−24	−20	−16	−0.10	−43	−38	−33	−0.07	−55	−47	−39	−0.09
Oceania countries	37	45	53	0.09	14	17	20	0.09	−17	−15	−13	−0.07

Table 19 continued

Region	Confidence interval and coefficient of variation							
	Air transport				Total			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	219	262	305	0.08	1,686	2,061	2,436	0.09
European Union	40	48	56	0.08	−2,342	−2,018	−1,694	−0.08
Brazil	−32	−27	−22	−0.09	451	560	669	0.10
Canada	14	16	18	0.06	675	814	953	0.09
Japan	8	8	8	0.00	140	168	197	0.08
China and Hong Kong	−240	−204	−168	−0.09	44,549	53,081	61,613	0.08
India	5	5	5	0.00	−99	−87	−75	−0.07
Central and Caribbean Americas	0	0	0	0.00	62	77	92	0.10
South and Other Americas	6	6	6	0.00	882	1,074	1,266	0.09
East Asia	3	4	5	0.17	−118	−101	−84	−0.08
Malaysia and Indonesia	782	936	1,090	0.08	12,311	14,738	17,165	0.08
Rest of South East Asia	71	85	99	0.08	470	565	660	0.08
Rest of South Asia	6	8	10	0.14	77	88	99	0.06
Russia	0	0	0	0.00	845	1,015	1,185	0.08
Other East Europe	−1	−1	−1	0.00	−399	−345	−291	−0.08
Rest of European Countries	0	0	0	0.00	−106	−92	−78	−0.08
Middle Eastern and North Africa	27	31	35	0.06	−135	−116	−97	−0.08
Sub Saharan Africa	2	2	2	0.00	−1,696	−1,437	−1,178	−0.09
Oceania countries	−19	−16	−13	−0.10	463	557	651	0.08

Table 20 EUPADDYRICE—change in world paddy rice, transport and total emissions (MTCO2e)

Region	Confidence interval and coefficient of variation											
	Paddy rice				Other transport				Water transport			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	−153	−87	−21	−0.38	−1,097	−611	−125	−0.40	−317	−176	−35	−0.40
European Union	1,837	9,443	17,049	0.40	−1,063	−583	−103	−0.41	−1,350	−761	−172	−0.39
Brazil	−65	−36	−7	−0.40	1	15	29	0.45	−38	−21	−4	−0.41
Canada	0	0	0	0.00	−80	−45	−10	−0.39	−14	−8	−2	−0.38
Japan	−185	−95	−5	−0.47	0	0	0	0.00	−135	−75	−15	−0.40
China and Hong Kong	−22,404	−12,456	−2,508	−0.40	21	102	183	0.40	−128	−73	−18	−0.38
India	−86	−39	8	−0.61	−164	−93	−22	−0.38	−79	−44	−9	−0.39
Central and Caribbean Americas	−323	−179	−35	−0.40	1	7	13	0.42	−13	−7	−1	−0.43
South and Other Americas	−213	−126	−39	−0.34	−102	−58	−14	−0.38	−32	−18	−4	−0.39
East Asia	−719	−401	−83	−0.40	−325	−182	−39	−0.39	−257	−145	−33	−0.39
Malaysia and Indonesia	−6,146	−3,348	−550	−0.42	8	46	84	0.41	−112	−64	−16	−0.38
Rest of South East Asia	−53,851	−30,477	−7,103	−0.38	−157	−87	−17	−0.41	−87	−49	−11	−0.39
Rest of South Asia	−1,004	−581	−158	−0.36	−24	−14	−4	−0.36	−11	−6	−1	−0.40
Russia	−303	−160	−17	−0.45	−366	−204	−42	−0.40	−83	−47	−11	−0.38
Other East Europe	−14	−8	−2	−0.38	−756	−423	−90	−0.39	−35	−19	−3	−0.42
Rest of European Countries	0	0	0	0.00	−30	−17	−4	−0.38	−68	−38	−8	−0.39
Middle Eastern and North Africa	−9	−4	1	−0.60	0	0	0	0.00	−228	−129	−30	−0.38
Sub Saharan Africa	−6,295	−3,064	167	−0.53	−35	7	49	3.00	−25	−15	−5	−0.33
Oceania countries	−208	−119	−30	−0.37	−48	−27	−6	−0.39	−9	−5	−1	−0.40

Table 20 continued

Region	Confidence interval and coefficient of variation							
	Air transport				Total			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	50	237	424	0.39	−3,006	−1,671	−336	−0.40
European Union	−291	−160	−29	−0.41	2,736	13,920	25,104	0.40
Brazil	1	2	3	0.33	−5	−3	−1	−0.38
Canada	3	10	17	0.33	−317	−177	−37	−0.40
Japan	4	12	20	0.33	−409	−227	−45	−0.40
China and Hong Kong	5	25	45	0.41	−23,250	−12,934	−2,618	−0.40
India	−6	−3	0	−0.50	−1,721	−1,017	−313	−0.35
Central and Caribbean Americas	−8	−4	0	−0.50	−427	−236	−45	−0.40
South and Other Americas	2	9	16	0.40	−568	−323	−78	−0.38
East Asia	−8	−4	0	−0.50	−1,134	−635	−136	−0.39
Malaysia and Indonesia	1	2	3	0.33	−5,610	−3,058	−506	−0.42
Rest of South East Asia	6	27	48	0.39	−47,977	−27,148	−6,319	−0.38
Rest of South Asia	3	12	21	0.36	−1,422	−822	−222	−0.37
Russia	−14	−8	−2	−0.38	−618	−339	−60	−0.41
Other East Europe	0	0	0	0.00	16	107	198	0.42
Rest of European Countries	−10	−6	−2	−0.33	−42	−24	−6	−0.38
Middle Eastern and North Africa	11	63	115	0.41	114	678	1,242	0.42
Sub Saharan Africa	−3	10	23	0.67	−5,303	−2,564	175	−0.53
Oceania countries	8	33	58	0.38	−79	−45	−11	−0.38

Table 21 CHNPADDYRICE—change in world paddy rice, transport and total emissions (MTCO2e)

Region	Confidence interval and coefficient of variation											
	Paddy rice				Other transport				Water transport			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	−2,675	−1,596	−517	−0.34	−863	−618	−373	−0.20	−630	−389	−148	−0.31
European Union	−1,555	−927	−299	−0.34	−949	−662	−375	−0.22	−5,413	−3,395	−1,377	−0.30
Brazil	−80	−51	−22	−0.29	−2	−1	0	−0.45	−176	−110	−44	−0.30
Canada	−1	−1	−1	0.00	−70	−61	−52	−0.08	−66	−41	−16	−0.31
Japan	−440	−214	12	−0.53	12	29	46	0.29	−551	−344	−137	−0.30
China and Hong Kong	55,229	185,492	315,755	0.35	−2,716	−1,124	468	−0.71	−1,962	−1,190	−418	−0.32
India	−3,391	−2,287	−1,183	−0.24	−74	−67	−60	−0.05	−153	−102	−51	−0.25
Central and Caribbean Americas	−186	−102	−18	−0.41	7	11	15	0.18	−63	−39	−15	−0.31
South and Other Americas	−925	−581	−237	−0.30	−91	−66	−41	−0.19	−155	−97	−39	−0.30
East Asia	−360	−224	−88	−0.30	−331	−223	−115	−0.24	−1,068	−671	−274	−0.30
Malaysia and Indonesia	−8,944	−4,362	220	−0.53	−19	50	119	0.69	−498	−313	−128	−0.30
Rest of South East Asia	−360,024	−222,763	−85,502	−0.31	−8	−5	−2	−0.33	−351	−222	−93	−0.29
Rest of South Asia	−4,432	−2,857	−1,282	−0.28	−41	−34	−27	−0.10	−38	−25	−12	−0.26
Russia	−616	−309	−2	−0.50	−150	−104	−58	−0.22	−324	−203	−82	−0.30
Other East Europe	−49	−29	−9	−0.34	−329	−202	−75	−0.32	−145	−91	−37	−0.30
Rest of European Countries	0	0	0	0.00	−13	−11	−9	−0.10	−262	−164	−66	−0.30
Middle Eastern and North Africa	−393	−222	−51	−0.39	−84	4	92	11.00	−1,028	−647	−266	−0.29
Sub Saharan Africa	−24,669	−11,354	1,961	−0.59	−14	129	272	0.55	−100	−68	−36	−0.23
Oceania countries	−5,053	−3,092	−1,131	−0.32	−460	−287	−114	−0.30	−24	−15	−6	−0.29

Table 21 continued

Region	Confidence interval and coefficient of variation							
	Air transport				Total			
	Lower	Mean	Upper	Co. Var.	Lower	Mean	Upper	Co. Var.
United States	−126	59	244	1.57	−6,765	−4,220	−1,675	−0.30
European Union	−38	−15	8	−0.78	−13,170	−8,354	−3,538	−0.29
Brazil	−5	−1	3	−2.00	−206	−55	96	−1.37
Canada	2	8	14	0.40	−774	−502	−230	−0.27
Japan	−6	−4	−2	−0.25	−481	−367	−253	−0.16
China and Hong Kong	−545	−264	17	−0.53	96,012	208,247	320,482	0.27
India	−9	−3	3	−1.00	−5,831	−4,121	−2,411	−0.21
Central and Caribbean Americas	0	0	0	0.00	−598	−382	−166	−0.28
South and Other Americas	6	10	14	0.18	−1,360	−827	−294	−0.32
East Asia	−49	−35	−21	−0.20	−1,815	−1,197	−579	−0.26
Malaysia and Indonesia	−15	−13	−11	−0.08	−7,785	−3,831	123	−0.52
Rest of South East Asia	34	110	186	0.35	−320,346	−198,213	−76,080	−0.31
Rest of South Asia	13	30	47	0.28	−6,434	−4,161	−1,888	−0.27
Russia	−10	−5	0	−0.50	87	93	99	0.03
Other East Europe	1	3	5	0.33	−17	44	105	0.69
Rest of European Countries	0	0	0	0.00	−302	−190	−78	−0.29
Middle Eastern and North Africa	5	32	59	0.41	−482	−315	−148	−0.27
Sub Saharan Africa	−5	39	83	0.56	−19,573	−8,760	2,053	−0.62
Oceania countries	74	238	402	0.35	−146	−99	−52	−0.24

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