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Student Research Report

AMS Nest Supply Chain Audit

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AMS NEST

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Contents

EXECUTIVE SUMMARY

Climate change has never been more apparent: extreme heat, record-breaking snowfall, and major floods have been just some of the signs we have seen across British Columbia within the past year. Anthropogenic greenhouse gas (GHG) emissions, a third of which are generated by agricultural and food supply chain activities, are a major driver of these climate change symptoms (Crippa et al., 2021). Serving food to over 60,000 students each year, the AMS Nest and their food supply chain play an important role in UBC's contribution to GHG emissions in our community. This report is a step forward in the AMS's journey to sustainability as outlined in the AMS Sustainable Action Plan (ASAP). We study the effects of transportation and sourcing on the carbon emissions of the Nest's supply chain using multivariate regression models, and introduce short and long-term recommendations while considering the key operational constraint of food vendors' menus and consumer demand in order to mitigate the Nest's carbon footprint.

Our key findings from this study show that sourcing products from outside BC contributes significantly to transportation emissions and represents a key opportunity to reduce emissions: switching to local suppliers for just 20 products reduces transportation emissions by 56%. However, animal-based products regardless of source location had the greatest overall impact on carbon emissions, increasing total emissions by nearly 8 tonnes on average for each type of animal-based product ordered. Reducing the consumption of animal-based products has the potential to reduce the associated emissions by half according to emissions estimates of plant-based alternatives. Across our data set, the AMS purchased over 100 tonnes of food products that generated 303.5 tonnes of GHG emissions - equivalent to driving a car around the Earth 48 times! These results led us to recommend that the AMS switch to local suppliers within BC to reduce transportation emissions in the short term, and take steps towards reducing animal-based product

consumption in the long term. We recommend immediate action on investigating the feasibility of sourcing products within BC from new suppliers, requesting locally-sourced products from existing suppliers, and reducing consumption of non-local products (sourced outside of BC). In the longer term, we recommend incremental reductions in animal-based product consumption through policies such as restricting the number of cheese-heavy dishes food vendors can offer and introducing "vegan days" to raise students' awareness around sustainable food choices and the AMS's sustainable food procurement practices. Reducing animal consumption through incremental changes is likely to be more palatable for both vendors and students, who will face additional costs associated with the required changes to vendors' menus.

Although our results are methodologically robust, we faced several data limitations that limit our analysis. Data on product origins and transportation distances vary in how specific they are across products and require a series of assumptions that may cause us to underestimate the total emissions generated. Despite these limitations, this report serves to introduce current opportunities for carbon emission mitigation and act as the first step towards improving sustainability at the AMS Nest. In order to meet the sustainability goals outlined in ASAP and reduce the Nest's carbon footprint, we recommend switching to suppliers located in BC wherever possible to reduce transportation emissions in the short term, and incrementally reduce the consumption of animal-based products to reduce overall emissions in the long term.

ABSTRACT

The AMS Nest serves food for over 60,000 students each year, yet there are few studies that can be applied to estimate the Nest's carbon footprint and target policies towards emissions reduction. This paper uses two multivariate regression models to estimate the impact of international sourcing and travel distances on the GHG emissions generated by the Nest's food supply chain. Using a sample of 61 food products ordered by the AMS over 8 months (UBC's winter session), we find that 1) sourcing products from outside British Columbia contributes the most to transportation emissions, and 2) consuming animal-based products contributes the most to total emissions, increasing by 6.5 tonnes of GHGs per animal-based product type. Simulating an adjusted supply chain by switching product sources to viable foodservice sources within BC reduced transportation emissions by 56%. Based on our results, we recommend new procurement policies that source products within BC in the short-term and reduce consumption of animal-based products in the long-term in order to effectively mitigate carbon emissions generated by the Nest's supply chain.

1. INTRODUCTION

The production, transportation, and packaging of food are some of the leading causes of climate change: one third of anthropogenic greenhouse gas (GHG) emissions are produced by agriculture and food supply chain activities (Crippa et al., 2021). Reducing our collective carbon footprint is a critical step towards mitigating climate change, and in doing so securing our ability to support the health, well-being and survival of current and future generations (United Nations). The UBC Alma Mater Society (AMS) Nest plays an important role in sustainability at the local level on the University of British Columbia (UBC) campus: food service at the Nest serves over

60,000 students each year and is a significant contributor to anthropogenic GHG emissions in our community. In early 2020 the AMS introduced new goals to increase environmental, social and economic sustainability in the AMS Sustainability Action Plan (ASAP), in alignment with the United Nations 2030 Sustainable Development Goals (AMS, 2019). One of these goals is goal 1.15, "implementing carbon neutral operational practices" (AMS, 2019). Our paper works towards this goal by studying the following research questions: what are the effects of transportation on overall carbon emissions in the supply chain? How can carbon emissions be reduced by sourcing products domestically and locally? And how much emissions can we reduce in the short term without changing food vendors' menus?

In order to answer these research questions, we used two multivariate regression models to analyze the impact of product characteristics such as whether products were imported or animal-based, as well as the travel distances in different types of vehicles for each product type. Our main empirical challenges include the estimation of product origins and the travel distances derived from these estimates, many of which required key assumptions that will be covered in depth in Section 3. Despite these challenges and data limitations, we found robust results indicating a high impact on transportation emissions from products sourced outside of BC, as well as a substantial impact on overall emissions from animal-based products. These results led us to recommend a two-phase policy package that focuses on short-term mitigation of travel emissions by switching to product sources within BC and long-term mitigation of overall emissions by reducing the consumption of animal-based products at the AMS Nest.

The remainder of this paper is organized into the following sections. Section 2 provides a background on climate change and carbon emission estimation methodologies; in Section 3 we describe our data gathering methodologies and assumptions; and in Section 4 we describe and justify the two multivariate regression models used to analyze the data. Section 5 presents the results of our analysis; we then interpret these results in Section 6 and end with a discussion of policy recommendations and research limitations in Section 7 before concluding in Section 8.

2. BACKGROUND

Context

Climate change has been a growing concern for countries and international actors and is one of the largest challenges presently facing humankind. Studies on climate change have increased in response, with strong scientific consensus on the impact of greenhouse gasses, and especially the impact of carbon dioxide (CO_2) on rising global temperatures (United Nations). As GHG emissions are measured in kilograms of CO_2 equivalents - a number quantifying the global warming potential (GWP) of other gases such as nitric oxide into the equivalent CO_2 weight - in this paper, we will be using "GHG emissions" and "carbon emissions" interchangeably. One of the largest contributors of GHG emissions comes from the agricultural and food supply chain sector, responsible for 26% of global anthropogenic GHG emissions according to a 2018 study of farms, processors and retailers across the world (Poore and Nemecek). A more recent study updated this estimate to 34% of total GHG emissions, 4.8% of which comes from the transportation of food (Crippa et al., 2021). Such academic findings are reflected in growing consumer concern for environmental sustainability, and there has been a shift toward consumption practices that are more socially and environmentally sustainable (Migliore, 2021). These shifts include movements towards consuming plant-based alternatives with smaller carbon footprints compared to animal-based food products (van Vilet et al., 2020). Consequently, there have been attempts not only to determine the GHG emissions generated from various food production systems and consumption categories, but also to find new solutions to create a more sustainable food supply chain. Changes in consumer preferences and the pursuit of sustainable practices are equally present in the UBC community, the context of our research.

This paper is situated in a rich context of engagement with sustainability and carbon footprint reduction in the setting of post-secondary education institutions. UBC in particular has established policies to address growing student concern for climate change action, a change led by the UBC AMS, the student led governing body. While the AMS had established an ad-hoc Impacts Committee as early as 1999, more significant shifts toward sustainability have occurred in the last decade. With the establishment of the AMS Sustainability Projects Fund in 2011, the construction of the LEED Platinum sustainability certified "Nest" student union building in 2015, and the creation of an AMS Sustainable Action Plan (ASAP) in 2019, the University has seen a more aggressive shift toward the adoption of sustainable climate-forward policy actions. Goals in the AMS Sustainable Action Plan are intended to align with the U.N. Sustainable Development Goal #12: to ensure responsible consumption and production patterns. The AMS has consistently sought out ways to minimize carbon emissions in its operations, notably in its food supply chain for the Nest.

Related Literature

Prior to making alterations to a supply chain to reduce emissions, research must be conducted to identify products with a large impact on carbon emissions. One of the most popular methods for determining the carbon emission of a product is the life-cycle analysis (LCA), which quantifies "the environmental impact of a product through its life cycle encompassing extraction and processing of the raw materials, manufacturing, distribution, use, recycling, and final disposal"

(Ilgin & Gupta, 2010). LCAs amalgamate the carbon emissions of products between two points in a product's "life cycle", study scopes most often referred to as "cradle-to-gate" with the beginning of the production stage (e.g. sowing) and the point at which the product is sold defining the boundaries of the LCA (Verge et al, 2013). This systematic methodology has been standardized by the International Standards Organization (ISO), and has strict limitations governing their use to ensure the accuracy and reliability of the claims made from LCA studies (Brusseau, 2019). As a result, studies using the LCA methodology often restrict their research to a single product type from a specific region to ensure data availability and increased accuracy in their results. For example, we used two LCA studies by Winans et al. (2013) and Garcia et al. (2016) on unsweetened almond milk in California and sugar production in Mexico respectively to estimate production emissions for the respective products in our data set. However, the specificity of product type and region required in LCA studies sacrifices generalizability and broader applications. Despite this, LCAs represent one of the strongest methods of analyses currently available to estimate the emissions generated in a full lifecycle of a product, and are one of the primary tools used to support decision-making processes for sustainability purposes (Brusseau, 2019).

Within the lifecycle of products, research shows that transportation emission are not as impactful as production emissions, and that reducing transport emissions is not as impactful as other options such as reducing the consumption of products with high production emissions such as meat and cheese (Wakeland et al., 2011; Ritchie, 2020). However, we believe that focusing on reducing transport emissions presents realistic and tangible policy recommendations for the AMS that are more feasible than outright eliminating food products with high production emissions.

3. DATA

The initial data provided for this project was a snapshot of purchase orders covering 64 different food products, ordered by the AMS between September 2019 and April 2020. The dataset included supplier names, weight per case, number of cases ordered during the study period, and brand names. Immediate processing of this data included standardizing weight units into kilograms by converting other units of measurement (e.g. number of avocados per case) based on USDA data (2021) on average food product weights (e.g. an average avocado weighs 20 grams), and categorizing food products into the North American Product Classification System (NAPCS) categories (Statistics Canada, 2018). To supplement the raw data, the following data was gathered through secondary research: product origins, product emission factors, travel distances, and transportation emissions.

Estimating Product Origins and Emissions

Product origin information was gathered from the following sources:

1. Suppliers' and producers' product catalogs
2. Product package labels (catalog images or physical products)
3. Producers' websites and brochures

Many catalogs included general information on sourcing but were not especially precise. Product package labels were more helpful as they often included a "produced by", "packaged for", or "product of" section that contained a street address. Where package label images could not be found on product catalogues, we visited local grocery stores around the Nest to find the physical product on store shelves. Addresses were verified as acceptable origin locations if they were confirmed as production locations through observing publicly available Google Maps satellite images. Locations were easily identified as processing plants or distribution centers based on the size of the building, whether the address was in an industrial or agricultural area, and whether the address had many cargo trucks and loading bays available. Recovered addresses that were identified as corporate headquarters based on the visual appearance of the building (e.g. office buildings rather than warehouses) and the general location (i.e. in a business block rather than an industrial or warehouse block) were excluded, and alternative locations were identified.

Some products had more specific origin locations than others. For example, the origin of the "tofu" observation was traced down to a specific producers' street address, however the origin of "Assam breakfast tea" could only be traced as far as "Assam, India". Product origins outside North America were generalized to international ports based on a) proximity to approximate origin location, b) size of port in annual tonnage, and c) proximity to the Port of Vancouver. This is because many of these international products could not be traced beyond the country or province level (e.g. "Product of Vietnam"). In the case of "Assam breakfast tea", the largest and closest port to the Indian state of Assam is Paradip Port in Odisha, India. Although some travel within the origin country is excluded using this method, the bias on our results should be minimal as the majority of travel distance and emissions is captured in the distance international products have to travel to arrive in Vancouver.

Products that did not have origins that were easily identifiable through the above origin data gathering strategies required several assumptions based on other factors to arrive at an approximate origin location. Both chicken product observations in the data set fall into this category, and their origin data relied on the fact that 80% of BC's chicken products are produced in the Lower Mainland (Metro Vancouver, 2020). As the most recent chicken "Producer of the Year" was awarded to V.B. Kunze Farms Ltd. located in Abbotsford, BC (BC Broiler Hatching

Egg Commission, 2019) and their address could not be specified beyond the municipality level, the municipality of Abbotsford was used as a general proxy for chicken products. A similar assumption was made to determine the origin of coffee beans, as the producer Spirit Bear Coffee listed several continents in their bean sources for several different types of coffee roasts; Colombia in South America was chosen as Colombia was the top coffee exporter to Canada in 2021 (United Nations, 2022).

Even with the available data gathering methods, reasonable product origins could not be identified for three products which were subsequently dropped from the dataset: liquid hot chocolate, potato starch, and brie cheese. Origin information was not available on suppliers' product catalogs, physical products (both exact and substitute) could not be located in physical stores, and the producer of these products was not clear. Reasonable sourcing assumptions like those made for chicken products and coffee beans could not be made due to lack of evidence. The three products represent 4.69% of all observations, and represent 3.9% of cheese product observations, 4.5% of other food product observations, and 20% of intermediate food product observations respectively. As the carbon emission effects of their respective category types were already represented in the remaining data set, we do not expect that dropping these observations should cause any significant bias in the results.

Production emission factors (emission per kilogram of product) was sourced from peer-reviewed journal articles that incorporated a lifecycle analysis (LCA) methodology to calculate the amount of carbon emissions generated from "cradle-to-gate", or the steps of production between initial production up to leaving the origin location (e.g. the gate of a factory). As several products had multiple studies available, studies located in the same regions as the products in our dataset were selected. For example, LCA studies on Canadian dairy were chosen to provide a production emission factor for Canadian cheese products in our dataset. Products are assumed to be produced using standard methods and at a large enough scale to supply multiple distributors, so studies on alternative production methods and small-scale farms or factories were not selected.

Estimating Travel Distances and Emissions

Transportation emissions were estimated by first calculating the distance of each leg of the products' journeys to the Nest. Products begin at a producer, usually a farm or a plant in the case of a processed good, and are transported to Vancouver by ship or rail. Ship and rail cargo are first processed at the Port of Vancouver, the region's main hub for commercial cargo deliveries, before being transported by truck to distribution centers. Local products skip the Port of Vancouver and are usually transported by truck directly from producer to supplier or distributor. From suppliers' distribution centers, the products are transported to their final destination, the Nest. Ship travel distances were calculated using the SeaRoutes shipping API, which provides the shortest route between two ports while accounting for the curvature of the Earth and international shipping lanes. As routing includes navigation around land masses and uses key infrastructure like the Panama and Suez Canals where applicable, this method is the most accurate emulation of products' journeys to Canada. Rail travel distances within North America were calculated using a travel API called Rome2Rio, which provides travel distances between cities on major train lines. Passenger lines and cargo lines were assumed to share train tracks on major routes in order to emulate products' train journeys using this method. Finally, truck travel distances on roads were calculated using Google Maps. As Google Maps provides multiple route options based on traffic and road conditions, only the shortest road distances were chosen to avoid adding the effects of traffic and road conditions to the dataset.

In calculating travel distances, several key assumptions must be made due to restrictions on data availability around the travel and routing behavior of different shipping companies and their individual vehicle operators. We assume that 1) all travel distances are one-way trips with no additional deliveries or detours between origin and destination within each leg of the product journey; 2) vehicle operators choose the shortest routes between origin and destination; and 3) transportation routes are constant and do not change during the study period. These assumptions may cause a downward bias in our estimates: vehicle operators may not necessarily choose routes based solely on distance, but instead incorporate factors like personal preference and traffic conditions; seasonal weather conditions may also cause rerouting especially during Canada's winter months. Although these assumptions cannot be verified without additional data, we believe that our estimates of travel distance will still be effective for examining the overall relationships in our dataset and extracting meaningful policy recommendations.

Based on travel distances, a methodology adapted from Chao (2014) was used to calculate the transportation emission factor (emissions per kilogram-kilometer) for each products' unique journeys for each vehicle type that was involved in the product's transport. Vehicles' transportation emission factors, denoted ***e***, were estimated using the following formula:

$$e = \frac{E}{M \times D}$$

where ***M*** denotes the maximum load of the vehicle, ***D*** denotes the travel distance and ***E*** denotes total emissions generated during the trip, calculated by:

$$E = F \times L \times D$$

F denotes fuel emissions (kilograms of GHG emission per liter) and ***L*** denotes fuel mileage (in liters per kilometer). The derived emission factor ***e*** is then multiplied by the total weight of product ordered (denoted ***W***) and the total distance the product traveled to calculate the total transportation emission (denoted ***T***):

$$T = e \times D \times W$$

This methodology allows an accurate and unique estimation for each product's unique total weight ordered and total distance traveled, and addresses the issue of a product type making incremental trips as the AMS orders them multiple times during the study period. Vehicles will have different emission factors across product types, reflecting overall efficiency as travel distances change; however, only the relevant portion of total trip emissions are attributed to the product based on the weight of product ordered. Fuel emissions, fuel mileage, and maximum load information were obtained from Environment Canada (2021), Natural Resources Canada (2000), Statistics Canada (2022a and 2022b), and the American Railway Association (2020). We used an emission factor averaged across all container ship types and sizes from the International Maritime Organization (2020) to calculate total transportation emissions for ships.

Summary Statistics and Key Relationships

Several intriguing relationships were uncovered from the data, and in-depth analysis will be covered in Sections 5 and 6. Overall, the dataset included 101.1 tonnes of product ordered, which traveled a cumulative 343,049 kilometers and generated 303.5 tonnes of GHGs. The total emissions is equivalent to driving a 2018 Toyota Camry (Canada Energy Regulator, 2021) 1,913,035 kilometers, far enough to drive around the Earth nearly 48 times. Table 1 details the summary statistics for our key emission outcomes, production, transportation and total emissions, as well as for our key explanatory variables product weight (continuous) and four binary variables indicating whether products are imported, sourced outside of BC, animal-based products, processed products, or refrigerated products.

Table 1: Summary Statistics for Key Variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Production emission	61	4840.568	8930.145	7.7	49032
Transportation emission	61	129.192	260.058	.106	1330.215
Total emission	61	4969.76	9035.721	13.595	49443.922
Product weight	61	1657.332	2200.99	12	9033.72
imported	.	.	.	.	.
0	61	.41	.496	0	1
1	61	.59	.496	0	1
outBC	.	.	.	.	.
0	61	.197	.401	0	1
1	61	.803	.401	0	1
animal	.	.	.	.	.
0	61	.705	.46	0	1
1	61	.295	.46	0	1
processed	.	.	.	.	.
0	61	.41	.496	0	1
1	61	.59	.496	0	1
refrig	.	.	.	.	.
0	61	.574	.499	0	1
1	61	.426	.499	0	1

Figure 1 shows a breakdown of the total emissions generated by product type; meat products and dairy products together make up 54% of total emissions. In comparison, fresh produce makes up just 3%, and coffee and tea make up 6%. Other food products (18%) play a large role in emissions due to the additional inputs required to process raw ingredients into processed foods, and intermediate goods (17%) play a large role due to the large order volume of products such as flour and rice in this category.

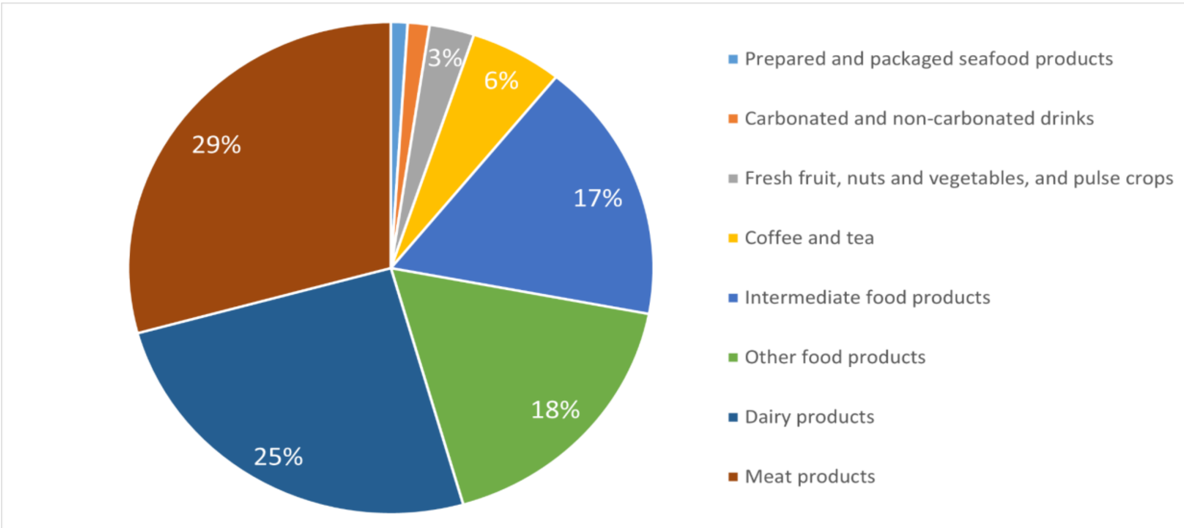

Fig 1. Total emissions by NAPCS product type

Focusing on emission factors, Figure 2 shows the top 10 products with the highest emissions per kilogram of product. Animal-based products such as sausages and cheese make up eight out of ten products on this list and indicate the high impact animal-based products have on overall GHG emissions. The average emission factor across animal-based products is 6.37kg of GHGs per kilogram of product, compared to an average 2.93 kilograms across all observations. The observation "Tea Oi-Ocha" comes in at #6 due to the additional processing required to prepare the beverage for bottling (Hu et al., 2018), and "Canola oil" comes in at #10 due to additional emissions associated with land-use, forest clearing, and processing (Poore and Nemecek, 2018).

Animal-based products having higher emission factors on average compared to the full sample has major implications when splitting the sample into "domestic" and "imported" categories. This can be seen in Figures 3a and 3b, which break down domestic and imported items into product categories. In Figure 3a, dairy products make up 44% of all domestic products, and meat products make up an additional 12%, meaning just over half (56%) of all domestic products are animal-based products.

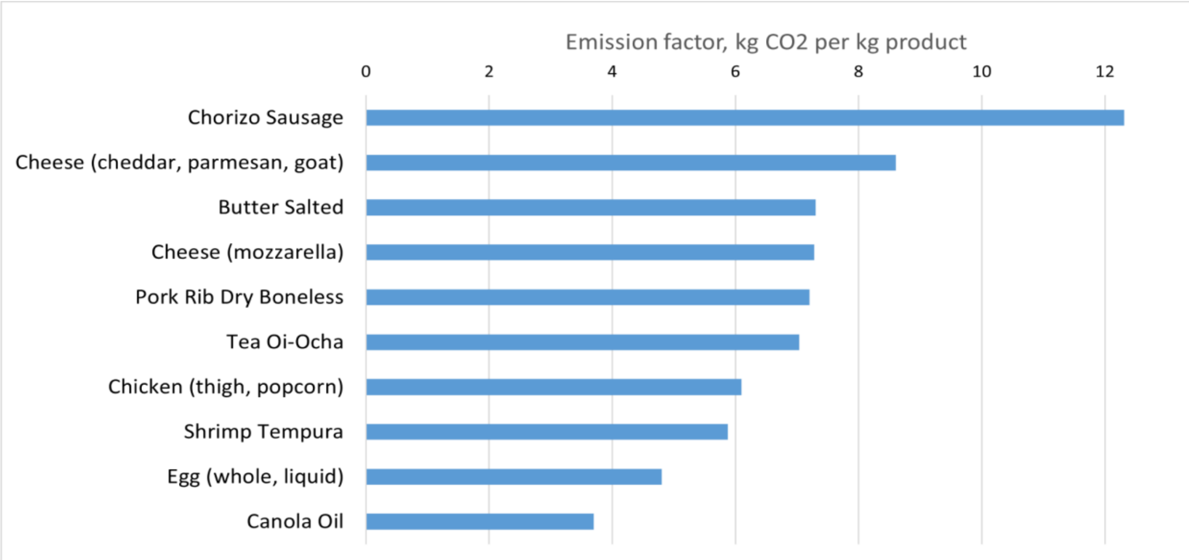

Fig 2. Top 10 highest emission factors by product type

Other food products, fresh produce, and coffee and tea make up much larger proportions of imported products as shown in Figure 3b. This difference is related to the availability of these products; many are not produced in Canada during the study period due to climate restrictions. Examples of these imported products include uncooked rice, leafy vegetables, and coffee beans.

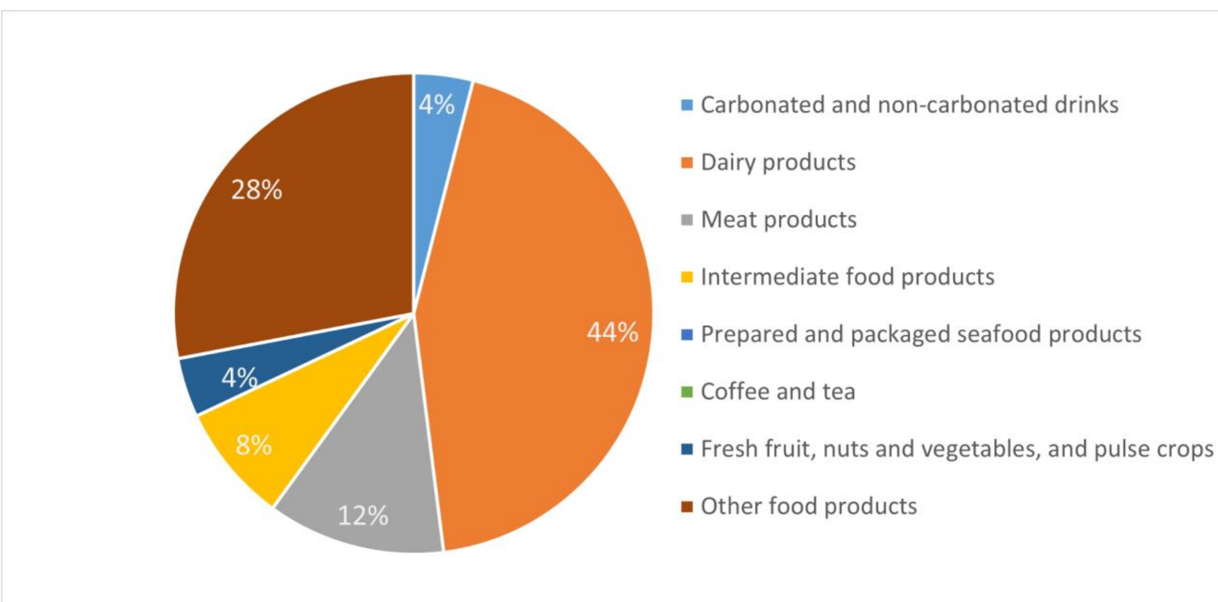

Fig. 3a: Domestic items by product type

The sourcing trends shown in Figure 3, as well as the differential impact on GHG emissions between animal and non-animal-based products shown in Figures 1 and 2, have large impacts on total emissions when dividing the sample into the imported and domestic sub-samples. As seen in Figure 4a, the majority of total emissions (78%) is generated by domestic products.

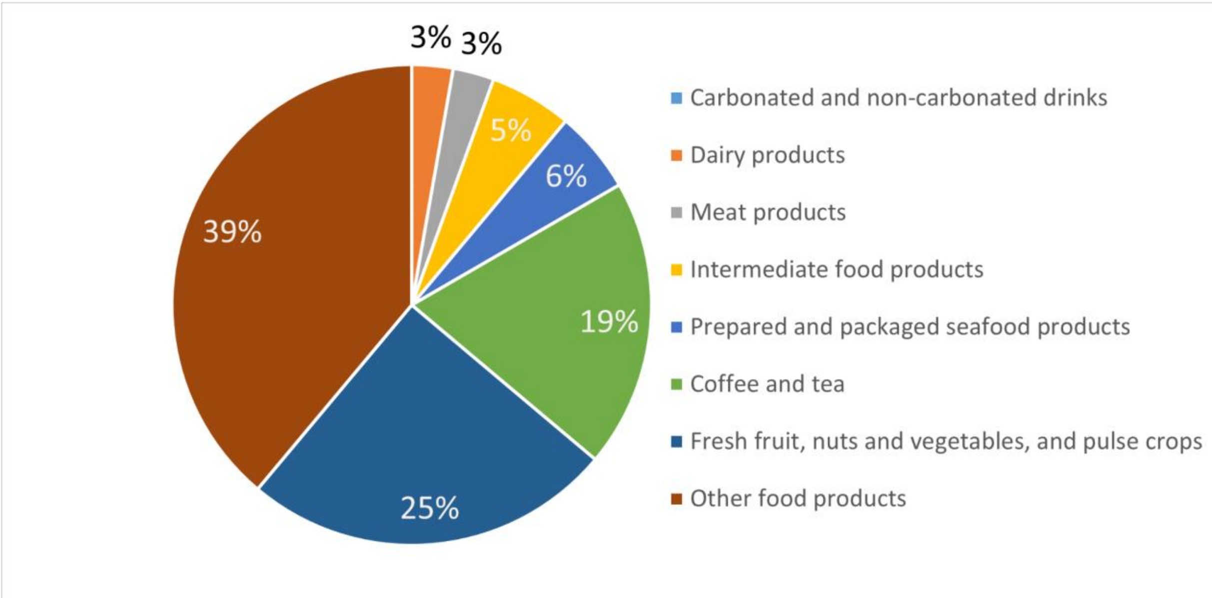

Fig. 3b: Imported items by product type

Animal-based products with high emission factors make up over half of the domestic product sub-sample, resulting in the domination of domestic products in total emissions.

The sourcing trends shown in Figure 3, as well as the differential impact on GHG emissions between animal and non-animal-based products shown in Figures 1 and 2, have large impacts on total emissions when dividing the sample into the imported and domestic sub-samples. As seen in Figure 4a, the majority of total emissions (78%) is generated by domestic products. Animal-based products with high emission factors make up over half of the domestic product sub-sample, resulting in the domination of domestic products in total emissions.

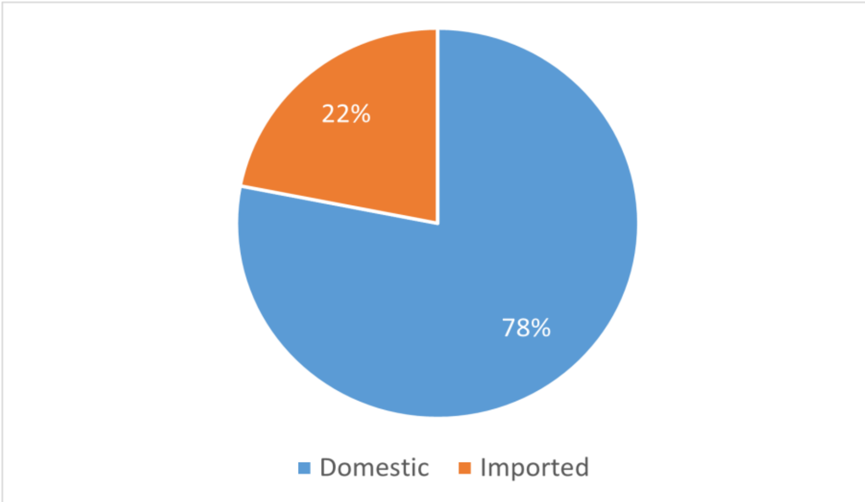

Fig. 4a: Total Emissions by Domestic and Imported Products

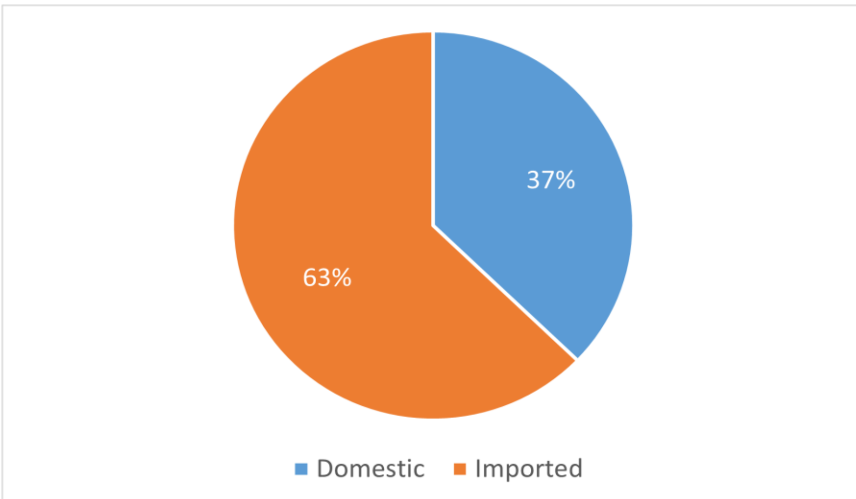

Fig. 4b: Transportation Emissions by Domestic and Imported Products

Focusing on just transportation emissions in Figure 4b, just under two-thirds (63%) of transportation emissions are generated by imported products while the remaining 37% are generated by domestic products. Imported products accounting for more transportation emissions is an intuitive result as imported items generally travel longer distances to arrive at their Canadian destination compared to domestic products.

As illustrated in Figure 5, imported products travel an average of 7,905 kilometers before arriving at the Nest, while domestic products travel an average of 2,337 kilometers. Figure 5 also breaks down the average travel distance by vehicle type, each of which reflect different domestic and international food trade trends. Air cargo was not estimated in this paper, as 0.16% of all global food trade is transported by plane (Our World in Data, 2018). Imports from outside North America were instead assumed to be transported by ship, the most popular method of transport responsible for 59% of global food-kilometers (Our World in Data, 2018), represented by the yellow portion of the bar showing that imported products travel an average of 6,065km by ship before arriving at the Nest.

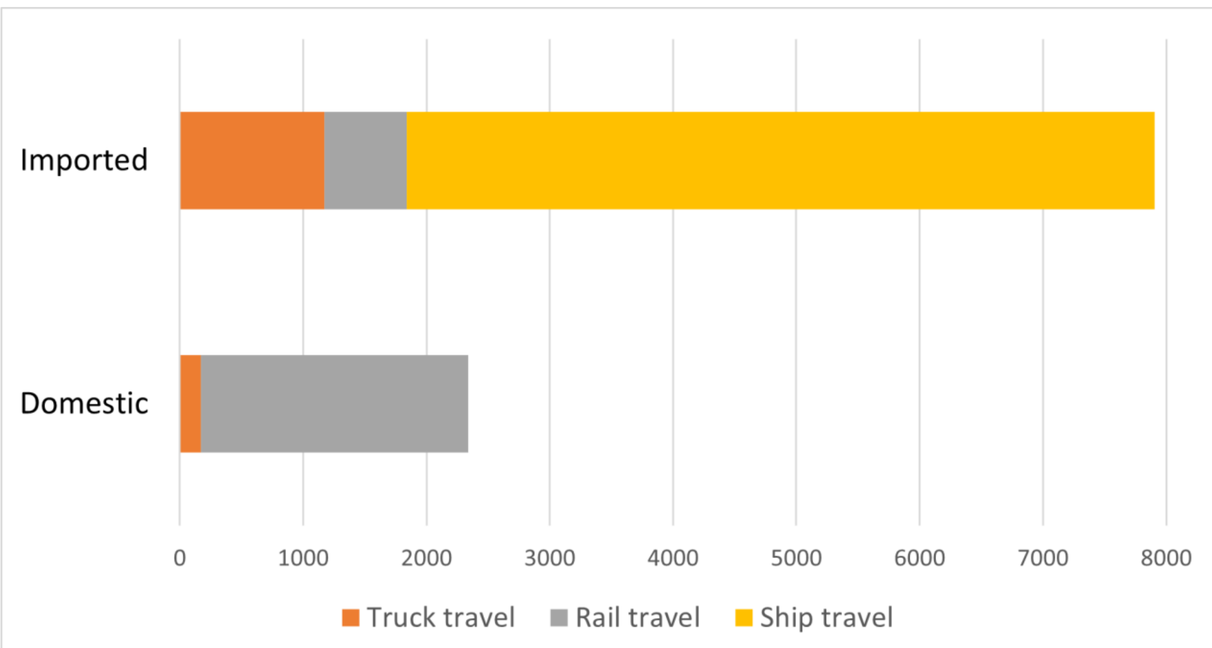

Fig. 5: Travel Distance by Vehicle Type for Imported and Domestic Products

Imported products travel further by truck than domestic products, traveling an average of 1,173km and 667km respectively; this reflects the lack of South-to-North rail infrastructure between the US and Canada causing the majority of US imports to be transported to Canada via truck (Kissinger et al., 2012). Finally, imported products travel an average of 667km by rail while domestic products travel an average of 2,167km, reflecting the substantial effort required to transport products in our data set sourced in Ontario and Quebec.

4. MODEL

For the purpose of this study, we chose to utilize two multivariate regression models to answer our research questions. Multivariate regression models allow us to identify the change in the dependent variable that is associated with the change in multiple independent variables. Model A is used to determine the impact of importing food products on total emissions while Model B is used to determine which transportation method contributes the most to carbon emissions. Both models use the same set of controls — AnimalBased and TotalKG. AnimalBased is a dummy variable that indicates whether or not a product is animal-based, and TotalKG is a continuous variable that signifies the total weight of product ordered in kilograms. These controls were selected because both are expected to have a positive impact on carbon emissions: animal-based products generally have higher emission factors, and total emissions intuitively increase with the total weight of product ordered. Controlling for these product properties allows us to isolate the true effect of the variables of interest on total emissions.

When building Model A, we first need to define the term ‘imported’. We determined that the term ‘imported’ can be interpreted in two different ways: imported from outside of Canada or imported from outside of British Columbia (BC). To decide which interpretation to use, we first note that the total emissions generated are comprised of production emissions and transportation emissions. Production emissions are the emissions generated during the production of a food product, whereas transportation emissions are the emissions generated during the transportation of said product from the point of production to the AMS Nest. Considering this composition of total emissions, we then compared our data in Table 2, which splits the data into two categories by source: ‘Within Region’ and ‘Outside Region’. It then identifies two regions: Canada and BC. Finally, it differentiates between production emissions and transportation emissions in Panels A and B respectively. Column 3 of this table allows us to observe whether or not the difference between mean emissions inside and outside of the specified region is statistically significant. As indicated in the first row of the table, the mean production emissions from products produced inside Canada are greater than those produced outside of Canada, and the difference is significant. Mean production emissions for products produced within BC are also greater than products produced outside of BC, but the difference is not statistically significant. One significant explanation for the discrepancy in emissions between products made in Canada and outside Canada are that domestic (within Canada) products are mostly animal-based products which have a high impact on carbon emissions regardless of where they are produced.

In the second row of Panel B, we find that the difference between the mean transportation emissions from products made inside BC and outside of BC is statistically significant, and transportation emissions for products coming from outside BC are significantly higher. This finding is intuitive as mean travel in the “outside region” sub-sample includes inter-provincial transportation, compared to the “outside region” sub-sample in the “Canada” group which only captures international transportation between other countries and Canada. We can deduce that the significant difference in mean overall emissions between products sourced inside and outside of BC can be largely attributed to transportation emissions for two reasons: 1) the Nest sources products that are transported across Canada from Ontario and Quebec, and 2) the majority of animal-based products are sourced outside of BC and causes the difference in production emissions between inside BC and outside of BC to be statistically insignificant.

Table 2: Differences in Mean Emissions of Imported and Outside-BC Products

	(1)	(2)	(3)
VARIABLES	Within region	Outside region	Difference
Panel A: Production emission			
Canada	9,316.62	1,702.39	7,614.24***
	(2,463.03)	(2,918.90)	
BC	5,383.09	4,685.80	697.28
	(2,126.68)	(1,335.00)	
Panel B: Travel emission			
Canada	117.28	137.47	-20.19
	(45.40)	(47.27)	
BC	5.87	159.39	-153.52**
	(1.80)	(40.35)	
Panel C: Total emissions			
Canada	9,433.90	1,839.85	7,594.05***
	(12,455.77)	(3,085.50)	
BC	5,388.96	4,845.20	543.77
	(2,128.09)	(1,353.21)	
Observations	61	61	61

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As a result of the above analysis, we decided to choose an independent variable for Model A that distinguishes between products sourced inside and outside of BC to determine the impact of importing food products on total emissions. Model A is specified as follows:

$$\boldsymbol{T_i = \beta_0 + \beta_1 OutBC_i + \beta_2 Controls_i + u_i}$$

The variable T_i signifies carbon emissions for product type i for the three classes of carbon emission outcomes we have identified: production emissions, transportation emissions, and total emissions. β_1 represents the change in total emissions if the product is sourced from outside of BC, and β_2 represents the change in total emissions based on the control variables, AnimalBased and TotalKG. The final term u_i is an error term that captures the effect of other factors not included in this model. This model allows us to identify the effect of importing products from outside of BC on carbon emissions and answer our second research question: the impact of sourcing products domestically and locally. The added controls allow us to observe the isolated effect of the OutBC variable, and also enables us to identify key factors of different products as targets for carbon footprint reduction policies. As will be discussed further in Section 5, the results of Model A show that products sourced outside of BC are associated with a significant increase in total carbon emissions, qualifying our decision to target products sourced from outside of BC as an area for potential emissions mitigation.

Model B is used to determine which transportation method contributes the most to carbon emissions and answer our first research question: the impact of transportation on overall carbon emissions. Model B is specified as follows:

$$\boldsymbol{T_i = \beta_0 + \beta_1 TruckKm_i + \beta_2 ShipKm_i + \beta_3 RailKm_i + \beta_4 Controls_i + u_i}$$

Like Model A, T_i represents our three emissions outcomes of interest. β_1, β_2, and β_3 represent the change in total emissions per kilometer of travel via truck, ship and rail respectively. Specifying travel distance for each vehicle instead of using one variable for the total travel distance allows us to compare the impact of different transportation methods on GHG emissions, and allows for differences between the fuel efficiencies (and therefore emissions generated per kilometer) of each vehicle type. β_4 is the change in total emissions based on the controls, which are the same AnimalBased and TotalKG variables from Model A, and u_i is the error term. As will be discussed further in the results section, Model B revealed that trucks were the most significant contributor to carbon emissions.

5. RESULTS

Table 3 presents the results from our preliminary version of Model A, regressing carbon emissions on the Imported, AnimalBased and TotalKG variables. The results show that both product weight and animal-based products correlate positively and significantly with emissions. The effect of product weight is intuitive, as more product volume ordered (measured in kilograms) increases total emissions - total emissions increase by 2.81kg of GHGs on average per kilogram of product ordered. The result on animal-based products is also aligned with our initial research, as animal-based products generally have higher production emissions compared to non-animal-based products. On average, animal-based products are associated with an average increase of 6.5 tonnes of GHG emissions for each type of animal-based product consumed. The variable of interest in Table 3 is the Imported variable, which has estimates that are positive in value and significant with regards to transportation emissions but are negative and statistically insignificant on both production and total emissions. From these results alone we might conclude that importing products generates more travel emissions and recommend that the AMS only source products domestically; however, while a positive relationship between imported products and transportation

Table 3: Emissions of Imported Products

VARIABLES	(1) Production	(2) Travel	(3) Total
Imported	-2,020	111**	-1,910
	(1,815)	(41.8)	(1,798)
Animal	6,450***	1.56	6,451***
	(1,921)	(44.2)	(1,904)
Product weight	2.70***	0.11***	2.81***
	(0.34)	(0.0078)	(0.34)
Observations	61	61	61
R-squared	0.625	0.766	0.641

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

emissions is expected, the negative point estimate for total emissions is not as this implies lower overall carbon emissions from imported products. As stated earlier in Section 4, the majority of animal-based products are produced and sourced domestically in Canada, causing domestic products to have higher production and total emission and thereby offsetting the effect of imported items.

Table 4: Emissions of Outside-BC Products

VARIABLES	(1) Production	(2) Travel	(3) Total
Outside BC	1,299	142***	1,441
	(1,865)	(41.1)	(1,843)
Animal	7,927***	-38.1	7,889***
	(1,626)	(35.8)	(1,607)
Product weight	2.80***	0.10***	2.90***
	(0.33)	(0.0073)	(0.33)
Observations	61	61	61
R-squared	0.621	0.783	0.638

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

To investigate the negative point estimate on imported products, we used our finalized Model A which divides our sample between products that are produced inside and outside BC. The results are shown in Table 4 above. The relationships between the controls and total emissions are consistent with the results from Table 3 as expected. The difference is in the first row, where the estimates on products sourced outside BC are positive across all three emissions outcomes. Although this implies that all products sourced outside BC generate more emissions compared to products sourced inside BC, we note that the coefficient for total emissions is not statistically significant. Only the estimate on Outside BC for transportation emissions is significant - compared to the estimate on Imported in Table 3, the point estimate is greater and statistically significant at the 1% level, showing the effects of inter-provincial travel captured in our modified specification for Model A. From these results we can conclude that the impact of sourcing food products from outside BC generates more GHGs, and that the AMS has a potential opportunity to reduce emissions by sourcing products from within BC instead. However, Model A also clearly indicates that animal-based products are a significant driver of overall carbon emissions and represent a key policy target for reducing carbon emissions.

The results of Model B are shown in Table 5 below - continuous variables indicating the in kilometers travelled by ship, rail and truck were used, along with the two control variables as in Model A. Starting with ship distance, although the point estimate is statistically significant under Column 2, the values in themselves across all three emission outcomes are small and close to zero – meaning that minimizing ship travel distance would not result in a large decrease in transportation emissions. The point estimates on rail distance are equally small for transportation emissions, and are positive but not significant for production and total emissions. These results likely reflect the high-emission animal-based products travelling via rail from Quebec and Ontario

Table 5: Emissions by Travel Distance

VARIABLES	(1) Production	(2) Travel	(3) Total
Ship distance	-0.027	0.0074**	-0.020
	(0.13)	(0.0029)	(0.13)
Rail distance	0.26	0.0085	0.27
	(0.36)	(0.0077)	(0.35)
Truck distance	-0.068	0.033**	-0.035
	(0.61)	(0.013)	(0.61)
Product weight	2.78***	0.10***	2.88***
	(0.34)	(0.0073)	(0.34)
Animal	7,213***	-30.7	7,182***
	(1,790)	(38.5)	(1,772)
Observations	61	61	61
R-squared	0.621	0.793	0.638

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

to BC, and the fact that the production emissions for these products far outweighs the impact of travel. The most notable results from this table are the point estimates for truck travel distance, which show that trucks are associated with a statistically significant effect on transportation emissions and are also the least efficient mode of transport: each kilometer transported by truck is associated with a 0.033kg increase in emissions, more than four times the impact of ships. Although the point estimates are small, we note that the average travel distance by truck and ship are 762km and 3580km respectively; this means that on average, products generate approximately 25kg of GHGs during truck transport and 26.5kg of GHGs during ship transport. From these results, we can conclude that reducing these average travel distances by switching to product sources closer to the Nest will be effective for reducing transportation emissions.

Table 6: Robustness Checks

VARIABLES	(1) Production	(2) Travel	(3) Total	(4) Production	(5) Travel	(6) Total	(7) Production	(8) Travel	(9) Total
Outside BC	1,332	142***	1,473	1,269	144***	1,413	1,554	150**	1,704
	(1,884)	(41.5)	(1,863)	(1,911)	(42.0)	(1,889)	(2,458)	(58.4)	(2,427)
Animal	8,042***	-39.8	8,002***	8,175***	-45.2	8,129***	9,212***	-57.6	9,154***
	(1,695)	(37.3)	(1,675)	(1,765)	(38.8)	(1,745)	(2,430)	(57.7)	(2,398)
Product weight	2.78***	0.10***	2.88***	2.76***	0.10***	2.86***	2.53***	0.10***	2.63***
	(0.34)	(0.0074)	(0.33)	(0.35)	(0.0077)	(0.35)	(0.37)	(0.0088)	(0.36)
Processed	-414	6.21	-407	-337	3.12	-334	-106	11.9	-94.5
	(1,551)	(34.2)	(1,533)	(1,584)	(34.8)	(1,566)	(1,696)	(40.3)	(1,674)
Refrigerated				-493	20.0	-473	-457	16.9	-440
				(1,641)	(36.1)	(1,622)	(1,923)	(45.7)	(1,899)
Observations	61	61	61	61	61	61	49	49	49
R-squared	0.621	0.783	0.638	0.622	0.784	0.639	0.619	0.787	0.638
Dairy products							No	No	No

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

To ensure that our results from Model A are valid and accurate, we also performed a series of robustness checks. The first of these are shown in Table 6: Columns 1-3 show the effect of adding the "Processed" binary variable which indicates whether products are processed or not; Columns 4-6 show the effect of adding the "Refrigerated" binary variable indicating whether products require refrigeration; and Columns 7-9 show the effect of running Models A and B with our additional controls on a sample that excludes all dairy products. Processed and refrigerated foods may impact emissions due to the additional inputs required to produce or control temperatures; however, as we see in Table 6, neither the point estimates, signs, or statistical significances change substantially compared to Table 4. Dairy products in our data set are mostly produced in Quebec and are somewhat overrepresented in our sample, but excluding them from the analysis does not appear to have a substantial effect compared to Columns 1-3 and suggests that the impact of dairy products did not drive our results or skew the data.

Table 7: Log emissions of Outside-BC products

VARIABLES	(1) Log(production)	(2) Log(travel)	(3) Log(total)
Outside BC	-0.11	2.92***	-0.012
	(0.47)	(0.38)	(0.45)
Animal	1.76***	0.20	1.69***
	(0.43)	(0.35)	(0.41)
Product weight	0.00063***	0.00058***	0.00062***
	(0.000085)	(0.000069)	(0.000081)
Observations	61	61	61
R-squared	0.592	0.705	0.602

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In a separate robustness check, we log-transformed the outcome variables to check whether the OLS assumption of homoscedasticity is valid as both Models A and B employ linear OLS regression techniques; the results from Table 7 indicate that our results from Table 4 are robust, showing the same directions of relationships between variables as well as the same statistical significance of particular point estimates.

6. DISCUSSION

The results of our analysis point to several opportunities for reducing the carbon footprint of the Nest's food supply chain. Products sourced outside of BC have a significant impact on transportation emissions and provide an immediate opportunity for emissions mitigation by switching to sources within BC wherever possible. However, transportation emissions make up only a small part of overall carbon emissions, and the substantial portion of total carbon emissions associated with animal-based products represent a key long-term policy target for reducing emissions from the production of the food products consumed at the Nest.

Based on the results of our analysis on product sourcing location, we investigated just how much transportation emissions we could reduce if we were to only source food products within BC by simulating an adjusted food supply chain based on our initial data. Of the 47 products sourced outside of BC, we were able to identify local alternatives for 20 of these products. Alternative local products were deemed to be suitable substitutes if a) the alternative product was identical, and b) the producers' scale was large enough to support major foodservice demand that included the Nest. For example, artisan cheddar produced by a small-scale boutique farmer in BC would not be a suitable local alternative for cheddar cheese, while a popular cheddar produced by a large dairy farm like Birchwood Dairy Farm (Abbotsford, BC) may be more appropriate. The simulated supply chain reduced transportation emissions by 4.4 tonnes of GHGs - approximately 56% of total transportation emissions. As switching suppliers is a relatively accessible policy change compared to changing food vendors' menus, we focus on these results in our discussion of policy recommendations below. A full list of the 20 alternative local sources is included in Appendix B: Local Alternatives for Outside BC Sources.

Although the prospect of reducing transportation emissions by over half is exciting, we acknowledge that this solution is limited in the degree of impact on overall GHG emissions. Ultimately, reducing the amount of animal-based products consumed at the Nest will be the key to significantly reducing overall emissions of the food supply chain. Animal-based products generate an average of 6.5 kilograms of emissions per kilogram of product; however, plant-based meat alternatives such as the Beyond and Impossible Burgers have been found to generate an average of 3.2 kilograms of emissions (Heller and Keoleian, 2018), potentially reducing production emissions by half. However, immediate policy change imposing restrictions on the use and consumption of animal-based products at the Nest may also result in backlash as consumer demand is left unmet and students are unable to consume their preferred foods at the Nest. Immediate policy change may also result in excess food waste if the supply of vegan food alternatives fails to meet consumer demand from the student population. Therefore, we suggest a policy recommendation package that is split into two phases: short-term policies focused on sourcing local products, and a long-term plan to reduce the overall consumption of animal-based products at the Nest. The two-phase policy package is summarized in the table below:

Phase 1	**Phase 2**
Source products within BC	Reduce consumption of animal-based products
Reduce consumption of products without BC alternatives	Restrict the number of cheese-heavy dishes
Encourage suppliers to source locally	Raise awareness of sustainable food choices

Phase 1 begins with sourcing as many products as possible within BC in order to reduce transportation emissions. For products that are not available in BC due to climate restrictions or a lack of suitable suppliers, consumption should be reduced to limit the impact of transportation emissions generated by these products. Encouraging suppliers to source locally by requesting locally produced goods and expressing preference for local products may also help to increase the variety of products and suppliers that the Nest can choose from. As many local producers may also have capacity for foodservice supply, recommending local producers as new partners for local suppliers such as Snow Cap and FreshPoint may also be effective for enhancing the Nest's local sourcing options.

Phase 2 revolves around reducing the overall consumption of animal-based products, and in extension changing the type of items served on food vendors' menus at the AMS Nest. Phase 2 will be a more extensive, long-term process due to the logistics involved in changing menus. Food vendors will face additional costs associated with creating new recipes, training chefs, updating signage and potentially even acquiring new kitchen equipment. Reducing the consumption of animal-based products in increments will be helpful for spreading these costs over multiple periods while also allowing the AMS to monitor students' responses to these new policy changes. We recommend a two-part policy strategy to reduce consumption of animal-based products in the long term: consumption reduction policies and awareness campaigns. Incrementally reducing the consumption of animal-based products such as cheese and meat products through restrictions on the number of animal-based dishes on menus and offering vegan alternatives at lower price points will be helpful for reducing the actual consumption of animal-based products. Awareness campaigns focus on indirectly reducing animal-based food consumption by shifting consumer behaviour through branding and marketing to raise students' awareness about the amount of carbon emissions produced by the food we consume, as well as about the steps the AMS will be taking to mitigate the carbon emissions of the Nest's supply chain. One such example of a possible marketing campaign is a "vegan day" event that demonstrates the variety of dishes that can be made with only plant-based products, and invites students to try these dishes themselves by offering samples and coupons to the Nests' various food vendors.

Our research has provided some preliminary results and policy recommendations for reducing the Nest's carbon footprint; however, our study has several limitations that should be considered when implementing these policies. The first of these are the data limitations covered in Section 3. Several assumptions and generalizations were made for product origins that could not be traced to a specific address, which reduces the accuracy of our transportation emission estimates especially for products imported to Canada. Travel distances also rely on some key assumptions, and further studies on supplier and vehicle operator behaviour are needed to accurately estimate the effect of multi-destination supply routes that are not captured in our analysis. Although we have shown methodological robustness at the end of Section 5, we note that our sample only included 61 observations - further studies should be repeated with larger and more recent data sets to verify the results of our study, preferably with monthly data included to analyze seasonal trends.

We are also limited by the scope of our research, which only covers emissions generated between the production of food products and their arrival at the Nest. Possible areas of further research include a cost-benefit analysis of switching suppliers or substituting animal-based products for plant-based products, analyses of consumer demand and responses to changes in the food service available at the Nest, and analyses on food and packaging waste at the Nest. We encourage the AMS to continue partnering with students and the community and conduct further research in order to help us understand the impact of different products' full lifecycles.

7. **CONCLUSION**

As the world reaches a critical turning point for climate change, the AMS is uniquely positioned to influence the direction of sustainability practices and the carbon footprint of the UBC community. To better understand the impact of the Nest's food supply chain on local GHG emissions, our study focused on the impact of sourcing products outside of BC and the emissions associated with transporting the food products we consume at the Nest. We found that sourcing products from outside BC has a large impact on transportation emissions, and that transportation by truck contributes the most to transportation emissions. However, animal products have the greatest impact on the Nest's carbon footprint. These results are limited by the assumptions we made to process our data and estimate transportation emissions, but are still an important step forward to reducing carbon emissions and achieving the environmental sustainability goals outlined in ASAP.

Based on our results, we recommend a two-phase approach to reducing carbon emissions, focusing on switching to local sources in phase 1 to reduce transportation emissions, and focusing on reducing animal-based product consumption in phase 2 to reduce overall emissions. Although our paper has provided valuable results and insights into the environmental impact of the Nest's food supply chain, these recommendations are only the first steps towards ASAP goal 1.15: carbon neutral operations. We encourage the AMS to pursue further research into consumer demand, cost-benefit analysis, and food waste, in order to better understand the environmental impact of the Nest's food supply chain and identify new paths towards a sustainable future for students and the world alike.

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DATA APPENDIX

Appendix A: Raw Data

Please see the file <Supply Chain Info V_FINAL.xlsx> accompanying our final submission.

Appendix B: Local Alternatives for Outside BC Sources

Product Type	Current Source	Alternative Local Source
Pork rib (dry, boneless)	Select Ready (Edmonton, AB)	Johnston's (Chilliwack, BC)
Fries (7/16in)	McCain Foods Ltd. (Florenceville-Bristol, NB)	BCFresh (Delta, BC)
Cucumbers (long English)	FreshPoint (Mexico)	Windset Farms (Delta, BC)
Spinach	FreshPoint (Arizona)	Iron Gates Natural Farm & Pottery (Ashcroft, BC)
Tomato	FreshPoint (Florida)	Windset Farms (Delta, BC)
Salad mix	FreshPoint (Arizona)	Windset Farms (Delta, BC)
Red peppers	FreshPoint (Mexico)	Windset Farms (Delta, BC)
Onions	FreshPoint (Washington)	BCFresh (Delta, BC)
Lettuce (green leaf)	FreshPoint (Arizona)	East Ridge Farms (Maple Ridge, BC)
Cheese - shredded mozzarella	Saputo Inc. (Montreal, QC)	Natural Pastures Cheese Company (Courtenay, BC)
Butter (salted)	Saputo Inc. (Montreal, QC)	Howard Wong Farms (Abbotsford, BC)
Cheese - shredded blend	Saputo Inc. (Montreal, QC)	Natural Pastures Cheese Company (Courtenay, BC)
Cheese - shredded cheddar	Saputo Inc. (Montreal, QC)	Birchwood Dairy Farm (Abbotsford, BC)
Cheese - sliced cheddar	Saputo Inc. (Montreal, QC)	Birchwood Dairy Farm

		(Abbotsford, BC)
Cheese - goat, crumble	Woolwich Dairy (Orangeville, ON)	Goat’s Pride Dairy (Abbotsford, BC)
Cheese - sliced mozzarella	Saputo Inc. (Montreal, QC)	Tanto Latte Cheese (Salmon Arm, BC)
Chorizo sausage (crumble)	Burke Corp. (Nevada, Iowa)	Berryman Brothers Meat Ltd. (Victoria, BC)
Almond Milk	Almond Breeze (Sacramento, California)	Earth’s Own (Delta, BC)
Udon noodles (dry)	Sanukiya (San Francisco, California)	Win Ful Foods Inc. (Vancouver, BC)