

## THE FOOD MILES EFFECT OF THE KOREA-CHINA FREE TRADE AGREEMENT

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### **Keywords**

Food miles, CO<sub>2</sub> emission, Korea-China FTA, product life-cycle approach

### **Abstract**

This paper estimates food miles effects for Korea. The data set is constructed using 4-digit Harmonized System codes for 169 products and each product's trade flows with a total of 71 trading partners. The food miles level is estimated as 258 billion ton-km in 2010, which is equivalent to 5.4 million tons of carbon dioxide (CO<sub>2</sub>) emissions, or 1% of the total agricultural import value. Under the Korea-China FTA framework the trade expansion effect brings about a higher CO<sub>2</sub> emission level than the case of trade shifting effects. This finding suggests that trade expansion should put more weight in gauging the CO<sub>2</sub> emission effects of the FTA. Finally, analysis of Napa cabbage and turnip trades confirms the non-reversal of their food miles effects when they are estimated by a product life-cycle approach.

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## I. Introduction

The concept of “food miles” captures the distance that food travels from production sites until it arrives points of consumption (Paxton 1994). Since the 1990s, the term has been used as an indicator that gauges the potential environmental effect of food transportation. The environmental impact of food miles has been further conceptualized and explicitly linked to global warming in terms of “carbon footprint” and “carbon accounting” in the food sector (Amani and Schiefer 2011; Coley et al. 2009; Stechemesser and Guenther 2012).

Measured as kilometers traveled, food miles refer to an all-inclusive sum of the distance from farms to processors, from processors to warehouses, from warehouses to vendors, and from vendors to consumers. The longer the journey that foods must travel the greater the resulting environmental consequences (Ballingall and Winchester 2010). A growing body of literature on food miles has recently begun to assess carbon emissions from the use of fossil fuels for not only food distribution, but crop farming activities as well (ATE Technology 2005; Coley et al. 2011; Torrellas et al. 2012). For instance, Wong and Hallsworth (2012) found that the CO<sub>2</sub> emission for tomatoes grown in greenhouses was about 7 times larger than in open fields.

In addition, food miles concepts are finding increasing popularity as a measure of environmental sustainability (Pirog and Schuh 2003; Smith et al. 2005; Passel 2010). Country-specific case studies are addressing consumer interests in relation to food miles and discussing their cost implications (Pretty et al. 2005; Sirieix et al. 2008).

This paper’s motivation arose from an observation that despite its simplicity of calculation and usefulness to assess environmental consequences related to the food supply system, few studies have actually calculated food miles in the case of Korean imports (Ju et al. 2010).<sup>1</sup> Precise empirical estimation of a country’s (here Korea’s) food miles level helps to illuminate the environmental sustainability of its current trading system. Additionally, this study provides the first application of Korean food miles estimates to assess the potential environmental consequence of defined scenarios under the Korea-China Free

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<sup>1</sup> Nevertheless, Ju et al. (2007) appears to lack exact details or technical methodologies that estimates food miles.

Trade Agreement (FTA).

## II. Agricultural Trade and Geography

Although agriculture is diminishing in importance in the Korean economy, Korea's agricultural trade is rapidly and dynamically expanding in volume. Agricultural exports increased by 34 times while agricultural imports expanded by 70 times over the last 40 years (MIFAFF 2012). The relative sharp expansion of agricultural imports furthered agricultural trade deficits from 251 million dollars to 25,493 million dollars in a nominal term.

The notably increase in Korean agricultural imports suggests a deterioration of the national food self-sufficiency rate. When the staple crop, rice was excluded, the self-sufficiency rates are 0.5% for wheat, 1.0% for corn and 9.8% for soybeans in 2009, respectively (KREI 2010). The grain self-sufficiency rate of 28% in 2010 is the lowest level among the OECD countries (MIFAFF 2012). By importing 7.7 million tons of corn in 2011, Korea ranked as the third largest buyer from the world market. Korea ranked as the world's fourth largest importer of pork, having imported 600,000 tons that same year. The country is also a major importer of beef.

Table 1 summarizes world agricultural trade flows. Data importantly suggest that agricultural trade is still dominated by the developed countries. The proportion of low or middle income (LMI) countries accounted for 39% of world agricultural exports. This share is not large given the fact that the LMI countries have high reliance on the agricultural sectors. The Least Developed Countries' share is merely 1%, whose agriculture accounts for a quarter of the GDP on average. Chinese shares in world agricultural trade are 4.5% in export and 5.9% in import, respectively. The EU and the United States explain more than half of the total trade.

In recent data from the Ministry of Agriculture, China revealed that its agricultural trade recorded 156 billion dollars, securing the position of third largest agricultural trader of the world in 2011 (MAPRC 2012). Export was 61 billion dollars and import was 95 billion dollars, which generated a deficit of 34 billion dollars. The agricultural trade deficit is on a steady rise from 0.6 billion dollars in 2006. Major exports were fishery products, vegetables, livestock

products, fruits and beverages. While top importing products were fats, live-stock products, vegetable oils, fishery products and cotton in 2010 (Chung and Lee 2012). The top destinations of China's agricultural export included Japan, the U.S., Hong Kong, Korea and Indonesia. The U.S., Brazil, Argentina, Australia and Malaysia were the leading exporters to the Chinese market.

TABLE 1. World Agricultural Trade Flows in 2009-2010

Unit: Mill USD

Importer	Exporter								
	World	China	EU27	Japan	India	Korea	LDC	LMI	U.S.
World	785,460	35,636	307,079	3,332	14,676	3,168	7,048	305,773	117,854
China	46,447	-	3,191	271	906	369	393	18,286	17,458
EU27	300,065	4,802	224,197	224	2,003	73	1,820	72,250	9,545
India	7,145	520	315	6	-	10	511	5,585	815
Japan	38,960	6,005	4,165	-	412	900	80	12,964	12,245
Korea	13,909	2,214	1,328	321	212	-	28	5,243	5,330
LDC	21,515	1,000	3,721	21	1,314	86	1,079	15,916	1,687
LMI	267,348	12,687	45,128	692	7,254	1,153	3,680	144,499	61,216
US	67,779	3,238	11,862	502	1,030	339	211	35,494	-

Note: 1) Data for India, Korea, Least Developed Countries (LDC) and Low and Middle Income Countries (LMI) are on the based on 2009 data. Other countries/regions are based on 2010 data.

2) Agricultural products are defined by the WTO in terms of the Harmonized System (HS) codes.

Source: UN Comtrade data through WITS.

Table 2 shows that Korea's largest agricultural trading partner is the U.S. accounting for 8.42 billion dollars or 24% of Korean agricultural imports in 2011. China is the second with 4.11 billion dollars or a 12% share followed by the EU (2.87 billion dollars, or 8%) and Japan (920 million dollars, or 3%). For agricultural exports, China stands shoulder to shoulder with the traditional top importer, Japan. Nevertheless, agricultural trade deficits with China are on a steady rise from 1.3 billion dollars to 4.1 billion dollars over the period from 2000-2011 (MIFAFF 2012).

TABLE 2. The Main Agricultural Trade Partners of Korea

Unit: Billion USD

	Year	China		U.S.		EU27		Japan		World	
		EX	IM	EX	IM	EX	IM	EX	IM	EX	IM
Agricultural products	2010	1.75	3.35	0.77	6.70	0.56	2.11	2.03	0.88	9.35	26.61
Share (%)	2011	2.49	4.11	0.94	8.42	0.80	2.87	2.58	0.92	12.70	34.68
		(20)	(12)	(7)	(24)	(6)	(8)	(20)	(3)	(100)	(100)
Food	2010	0.65	2.83	0.45	5.27	0.18	1.60	1.65	0.52	4.99	19.18
	2011	1.02	3.40	0.50	6.60	0.18	2.29	2.02	0.47	6.17	25.37
	Fish	2010	0.21	1.04	0.11	0.11	0.13	0.07	0.76	1.57	3.09
		2011	0.43	1.17	0.13	0.14	0.09	0.09	0.83	1.98	3.83
	Other food	2010	0.44	1.79	0.34	5.16	0.06	1.53	0.89	3.42	16.09
		2011	0.59	2.22	0.37	6.45	0.08	2.20	1.18	4.18	21.54
	Raw material	2010	1.09	0.52	0.33	1.43	0.37	0.51	0.38	4.36	7.44
		2011	1.46	0.72	0.44	1.83	0.63	0.57	0.45	6.54	9.31

Note: “EX” and “IM” indicate export and import values, respectively.

Source: WTO (2012).

Processed foods including sugar, coffee, and ramen capture the lion’s share of the Chinese market (Eor 2012). On the contrary, major importing products from China consist of grains and raw materials for food processing such as rice, starch, kimchee and garlic.<sup>2</sup>

Once the on-going Korea-China FTA negotiations are completed, a huge change in trade landscapes is expected.<sup>3</sup> Particularly, substantial increases in access to Korean markets of vegetables and specialty crops are envisioned in the short run. When sanitary and phytosanitary issues are resolved over the long term, a massive surge in Chinese exports to Korea is anticipated (Jeon et al. 2011; Lee and Lim 2013).

On account of the Korea-China FTA, this paper incorporates potential changes in trade flows in terms of “trade expansion” and “trade shifting” effects. The trade expansion effect refers to a situation where bilateral trade flows increase from a surge in China-sourced imports that will likely displace domestic Korean farm production. On the other hand, the trade shifting effect

<sup>2</sup> KITA (<http://www.kita.org>) provides product-specific trade data.

<sup>3</sup> Korea and China embarked on the FTA negotiations in May, 2012. The two countries have completed the 8<sup>th</sup> round of bilateral negotiations by the end of 2013.

postulates a potential change in import flows from other countries to China given unchanged domestic production levels. These changes in trade flows will be transmitted into the computation of food miles, which sheds some light on environmental consequences of the Korea-China FTA.

Additionally, product-specific cases of Napa cabbage and radish are studied and compared to weigh their potential trade-offs in environmental and economic comparative advantages. The environmental impact calculation is based on not only differences in transportation costs but also farm-level production systems.

### III. Calculation Methods and Data

The concept of food miles represents the distance that food travels from points of production to points of consumption. The volume of food should also be embedded in the calculation because carbon emissions depend on how much the food weighs. Equation (1) shows a standard formula for food miles.

$$FM = \sum_{i=1}^M \{Q_i \cdot D_i\} \quad (1)$$

Where FM is food miles expressed by ton·kilometer (t·km),  $Q_i$  is the imported quantity from the exporting country  $i$ ,  $D_i$  is a linear distance from the exporting country  $i$  and  $M$  refers to the number of exporting countries.

The bilateral distance is divided into two parts: internal and external distance. The internal distance measures the distances from the country's capital to the nearest port or vice versa while the external distance is based on the distance between the exporting country's port to the importing country's port. Overland transportation by trucks is assumed to have higher coefficients of carbon dioxide emissions than maritime transportation by container ships.

Equation (2) shows how to compute carbon emissions on the basis of food miles and the corresponding carbon coefficients for overland and maritime transportation.

$$CE = \sum_{k=1}^2 FM_k \cdot \delta_k \quad (2)$$

Where CE is the carbon emission level in kilograms, FM refers to food miles,  $\delta$  is the carbon coefficient and subscript k indicates the two transportation methods. The carbon coefficient for overland transportation by trucks,  $\delta_1$  is assumed to be 0.249kg per t·km, which is higher than the level for maritime transportation by container ships,  $\delta_2$ , 0.009kg per t·km.<sup>4</sup> These carbon emission coefficients were established in 2009 by the Korea Environmental Industry and Technology Institute (KEITI: [www.keiti.re.kr](http://www.keiti.re.kr)) as a way to implement the Environmental Product Declaration.

Food miles for internal distance,  $FM_1$ , is the product of internal distance and the volume of import, while food miles for external distance,  $FM_2$ , is obtained by multiplying the external distance by import quantity. All food imports are assumed to be by way of the Incheon sea port in Korea.<sup>5</sup>

The computation of food miles and carbon emissions is carried out on utilizing 2010 trade data. Classification and definition of agricultural products were based on the Harmonized Commodity Description and Coding System (HS). The Agreement on Agriculture under the World Trade Organization covers HS Chapters 1(live animal) to 24(tobacco), 33(essential oils), and 35(modified starches) less 14(vegetable materials). The total number of agricultural products under HS 4-digit classification amounts to 169, which is extracted from the Korea International Trade Association database([www.kita.org](http://www.kita.org)).<sup>6</sup>

Since there are a large numbers of exporting countries for each agricultural product, it is necessary to limit the numbers by setting a *de minimum* threshold. When a 90% threshold of the total import volume is applied in each tariff line, the number comes down to a total of 71 exporting countries. For example, Korea imported rice (HS code 1006) from eight countries in 2010 in-

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<sup>4</sup> A concrete estimation may need a further breakdown of transportation methods. For example, shipping by a bulk ship carries a lower carbon emission level at 0.008 kg per ton-km. Likewise, if trucks are replaced by diesel trains in overland transportation, the carbon coefficient is radically drop to 0.092 kg per ton-km. This paper does not explicitly consider these differences for analytical simplicity.

<sup>5</sup> Incheon is the second largest sea port in Korea and plays as a major trade outlet especially with China.

<sup>6</sup> The following HS 4-digit products were excluded from the list of agricultural products: 0101, 0106, 1301, 1505, 1506, 1518, 1520, 1521, 1522, 3302, 3303, 3304, 3305, 3306, 3307, 3503, 3504, 3505, 3506, and 3507 (US International Trade Commission: [www.usitc.gov](http://www.usitc.gov)).

cluding Australia, China, India, Israel, Italy, Pakistan, Thailand, and the U.S. When the 90% threshold was applied, the number came down to three: China, Thailand and the U.S. In the case of chilled beef (HS 0201), four exporting countries shrank to only two countries. Finally, distance data are from the CEPII ([www.cepii.fr](http://www.cepii.fr)) and Mayer and Zignago (2011).

#### IV. Food Miles and Carbon Emission Estimates

Table 3 shows the estimates for food miles and carbon emission levels in 2010. Given the total volume of food import as 28.5 million tons, food miles are estimated as 258.6 billion t·km, producing an equivalent of 5.4 million tons of carbon dioxide (CO<sub>2</sub>) emissions. The conversion of these estimates into a per capita basis yields 5,324 t·km of food miles and 112 kg of CO<sub>2</sub> emissions.

It seems reasonable to conjecture that the food miles of Korea are relatively higher than those of other countries. Ju et al. (2010) pointed out that food miles of Korea on a per capita basis in 2007 were even larger than those of Japan by a small margin. It also indicated that the United Kingdom and France had 52% and 24% of the food miles of Korea, respectively. An earlier study (Nakata 2003) claimed that Japan as one of the largest agricultural importers in the world had the highest food miles in 2001. About 7,093 t·km of Japan's food miles were larger than 6,637 t·km for Korea, 1,051 t·km for the U.S., 3,195 t·km for the U.K., 1,738 t·km for France, and 2,090 t·km for Germany.

At the HS 2-digit level, Korea's imports of grains (HS 10, 11 and 19) yield the highest food miles followed by animal feeds. Grains alone accounted for about 51% of the total food miles and 44% of the total CO<sub>2</sub> emissions. When summed over with animal feeds, the two figures rise to 68% and 66%, respectively. High food miles largely stem from the two main drivers: 1, a large volume of grains, animal feeds, and oilseed imports and 2, trade with distant exporting countries including the U.S. and Australia.



TABLE 3. Food Miles and CO<sub>2</sub> Emissions in 2010: A Per Capita Basis

Product description	HS chapter	Volume of import (kg)	Food miles (ton-km)	CO <sub>2</sub> emission (kg)
Livestock	01, 02, 04	15.67	169.61	2.91
Fishery products	03	20.29	77.85	2.80
Vegetables and fruits	07, 08, 20	42.71	166.80	4.89
Grains	10, 11, 19	264.67	2,716.21	48.56
Oilseeds	12	52.71	598.86	13.59
Sugar	17	48.48	352.46	6.92
Coffee, tea & cocoa	09, 18	3.64	32.08	0.73
Beverages	22	6.64	62.44	1.88
Animal feeds	23	105.94	910.24	25.56
Other agricultural products	13, 15, 16, 21, 24, 33, 35	26.05	237.03	3.68
Per Capita-wide Total		586.79	5,323.58	111.52
Country-wide Total		28.5 million tons	258.6 billion ton-km	5.4 million tons

Source: Authors' calculation.

The former can be explained by relatively low grain and food self-sufficiency rates or high dependence on imports of major commodities. As of 2010, Korea keeps a mere 27.6% of grain and 54.0% of food self-sufficiency rates (Park and Seung 2013). The latter can be highlighted by the fact that a large volume of agricultural imports is accompanied by long-distance transportation. Simple average physical distance from Korea's top ten agricultural exporters to the country is estimated at 9,309 km in 2012 (KREI 2013).<sup>7</sup> The calculated distance is far greater than the case for all trades, which suggests that measures need to be taken to mitigate the adverse environmental effects in the midst of ever increasing agricultural trades (KITA 2001).

Conversion of the 5.4 million tons of CO<sub>2</sub> emissions to a monetary term results in 134.3 billion won which accounts for 1% of total agricultural import value in 2010.<sup>8</sup>

<sup>7</sup> Physical distance between countries is obtained from "Distance Calculator" (<http://www.entfernungsrechner.net/en/>).

<sup>8</sup> Conversion into a monetary value was made by applying the EU emission allowance, 16.19 euros per ton CO<sub>2</sub> in 2010. An average exchange rate was 1,532 won per euro.

## V. The Food Miles Effects of the Korea-China FTA

The concept of food miles can be used to gauge the potential environmental effect of the proposed Korea-China FTA. A likely increase of trade volumes within the bloc generates two plausible and independent effects. The first is a trade expansion effect under which Chinese imports are substituting for and displace domestic Korean agricultural products. The consequence is that domestic production, which is not internationally competitive, will decrease much as import rises.

Table 4 shows assumptions of the trade expansion effects. The volume growth of import for major Chinese products owing to the FTA is assumed by 25%, 50% or 100% over the 2010 benchmark level (Han et al. 2011). The 50% rise in rice imports reflects the planned tariffication at the end of 2014.<sup>9</sup> The existing SPS protection measures (the WTO Agreement on the Application of Sanitary and Phytosanitary Measures) for fruits including grapes, apple, mandarin and pear are forecast to be cleared.

TABLE 4. Assumptions for the trade expansion effects

Volume growth of import over the 2010 benchmark	Products	HS 10-digit code
25%	Grapes	0806100000, 0806200000
	Red pepper	0709600000, 0709601000, 0709609000 0710807000, 0904201000, 0904202000
50%	Apple	0808100000, 0813300000
	Mandarin	0805201000, 0805209000
	Rice	1006100000, 1006201000, 1006202000 1006301000, 1006302000, 1006400000
	Garlic	0703200000, 0703201000, 0703209000 0710802000, 0712901000
100%	Onion	0703101000, 0710801000, 0712200000
	Pears	0808201000

Note: Volumes of import increase is largely based on Han et al. (2011).

<sup>9</sup> Rice import is currently subject to the minimum market access (MMA) regime in which any import over the predetermined quota is not allowed. Besides, Korea allocates country-specific quotas for rice MMA imports.

Table 5 provides assumptions for the trade shifting effects. A trade shifting effect due to the proposed FTA permits China to capture the total market share having enjoyed by existing exporting countries. When world exports to Korea for the selected agricultural products are taken as given, an underlying assumption is that China takes over all the markets. For example, the trade shifting effect is evident for onion import where a China-sourced product displaces onion sourced in the U.S. and India. As with the previous case, China is allowed to bring in their fruits after the removal of SPS measures.

TABLE 5. Assumptions for the trade shifting effects

Products	HS code	Existing exporting countries
Red pepper	0710807000	China, Vietnam, Indonesia
	0904201000, 0904202000	China, Japan, Mexico, India, Thailand, Israel, Sri Lanka, Italia, Malawi
Onion	0712200000	China, US, India
Rice	1006100000, 1006201000	China, US, Thailand, Pakistan, Australia, India
	1006202000, 1006301000	
	1006302000, 1006400000	
Apple	0808100000	Thailand
	0813300000	U.S.
Pears	0808201000	US, Canada, Thailand
Grapes	08061000000, 0806200000	Chile, US, Turkey
Mandarin	0805201000	China

Source: KITA ([www.kita.net](http://www.kita.net)).

Table 6 shows the calculated food miles arising from trade expansion and shifting effects. The trade expansion effects naturally turn out to raise food miles and thus CO<sub>2</sub> emissions. Overall, a food miles increase by 1.7% eliciting a 10.9% increase in CO<sub>2</sub> emissions. As free trade with China renders the Korean production of the specified domestic products less competitive, Korean imports of such Chinese products is likely to increase its import from China. Here again, expanded food miles mean a greater pressure on the environmental quality by emitting more CO<sub>2</sub> during transportation.

On the other hand, the trade shifting effects demonstrate a minimal

change in the estimate. It shows a slight reduction in food miles by 0.5% and thus CO<sub>2</sub> emissions by 0.02%. The relatively small change proves that China dominates Korean markets as a major supplier of most agricultural products. The amounts of agricultural trades shifted from existing exporters to China are modest and therefore have little environmental consequence.

TABLE 6. The Food Miles Effects of the Korea-China FTA

		2010 Benchmark	Expansion effect	Shifting effect
Food miles	Total (million t-km)	258,620	263,028	257,366
	Per capita (kg)	5,324	5,414	5,298
CO <sub>2</sub> emission	Total (million ton)	5.418	6.008	5.417
	Per capita (kg)	112	124	112

Source: Author's calculation.

The geography of a large country also factors in the calculation. For China, the overland transportation from the capital city, Beijing to the exporting port, *Da Lian*, is a lengthy haul, a factor that is consistent with the cases of other Asian exporting countries such as Vietnam, Indonesia, Pakistan, and Thailand. Truck transportation over long distances is generally associated with higher carbon exhaustion rates than maritime transportation.

In addition, the low gain in CO<sub>2</sub> emissions could arise from the limited trade volumes. For example, fruit imports are actually hypothetical, since they are not importable under the current SPS measures. When the removal of the SPS protection is set in for the analysis, the fruit inflows are posited to be large since expanded market access into Korean markets will arise.

The net environmental effect of the proposed Korea-China FTA from a food miles perspective will depend on the relative magnitude between the trade expansion and shifting effects. Albeit with a less significant change under the trade shifting effect, the interplay of the two effects will bear the FTA-induced environmental consequence. If the trade expansion effect dominates, there is a high chance of an increase in food miles and more CO<sub>2</sub> emissions. The alternate is expected when the trade shifting effect gains ground.

*Product life-cycle effects: An Illustration*<sup>10</sup>

The calculation method for the countrywide food miles effects faces a critical limitation by embodying only physical distance that the agricultural products are traveling across countries. As a matter of fact, CO<sub>2</sub> emissions also occur during the production process. A product life-cycle approach to estimate CO<sub>2</sub> emissions may consider amounts of input use such as fertilizers and pesticides, the extent of energy or electricity use, different soil types and other agricultural materials. In order to incorporate part of a product life-cycle approach, calculation of CO<sub>2</sub> emissions of two leading vegetables importing from China, Napa cabbage (HS 0704902000) and turnip (HS 0704901000), are posited and investigated.<sup>11</sup>

Korea imported 13,370 tons of Napa cabbage and 6,116 tons of turnip from China in 2010 (KITA: [www.kita.net](http://www.kita.net)). The import prices amounted to 432,311 won and 378,025 won per ton, respectively. A practical premise is that China only exports open field vegetables to Korea while Korea produces both open field and greenhouse vegetables. The average wholesale prices of open field Napa cabbage and turnip were 889,000 won and 709,000 won per ton in the same year (Korea Agro-Fisheries & Food Trade Corporation: [www.kamis.or.kr](http://www.kamis.or.kr)). In the case of greenhouse vegetables the average prices of Napa cabbage and turnip were 833,700 won and 765,889 won per ton, respectively (Seoul Agro-Fisheries & Food Corporation: [www.garak.co.kr](http://www.garak.co.kr)).<sup>12</sup> In comparison with the average import prices from China, prices of Korean vegetables are about two times higher.

Table 7 shows the comparison of CO<sub>2</sub> emissions for Napa cabbage and turnip.<sup>13</sup> The CO<sub>2</sub> emissions in the production stage account for the

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<sup>10</sup> Since no study has attempted to predict the FTA effects on Napa cabbage or turnip, this paper assumes continuation of existing trade situations to analyze their food miles effects.

<sup>11</sup> It is virtually impossible to consider all 169 HS 4-digit products due to the lack of data on production methods and costs.

<sup>12</sup> Data for prices of greenhouse Napa cabbage or turnip is not available. So, the bid prices of the Seoul-Garak wholesale market in May for Napa cabbage and in April for turnip are regarded as the prices for greenhouse vegetables. The two months are peak seasons for their harvests.

<sup>13</sup> The lack of data for greenhouse production in China prevents direct comparison

TABLE 7. CO<sub>2</sub> Emissions and Prices for Napa Cabbage and Turnip in 2010

Product	Type	Product life-cycle	CO <sub>2</sub> emission (kgCO <sub>2</sub> /ton)	Price equivalent (won/ton)
Napa cabbage in Korea	Open field	Production	301	7,476
		Transportation	44	1,097
		Wholesale price	-	889,000
		Total	-	897,573
	Greenhouse	Production	485	12,041
		Transportation	30	744
		Wholesale price	-	833,700
		Total	-	846,485
Turnip in Korea	Open field	Production	230	5,702
		Transportation	61	1,520
		Wholesale price	-	709,000
		Total	-	716,222
	Greenhouse	Production	244	6,054
		Transportation	51	1,278
		Wholesale price	-	765,889
		Total	-	773,221
Napa cabbage in China	Open field	Production	46	1,142
		Transportation	130	3,231
		Import price	-	432,311
		Total	-	436,684
	Greenhouse	Production	36	886
		Transportation	130	3,231
		Import price	-	378,025
		Total	-	382,142

Note: 1) CO<sub>2</sub> emissions are converted into prices by applying EU emissions allowance, 16.19 euros per ton CO<sub>2</sub> (the average price in 2010).

2) “Production” includes amounts of input use such as different types of fertilizers, energy and electricity, and agro-materials including vinyl and carbon steel (Kim and Yoon 2013; Lee et al. 2012).

3) “Transportation” counts distance from major production areas to Seoul for Korean vegetables and distance from Shandong Province to Seoul for Chinese vegetables.

Source: Authors' calculation.

with Korea's case. In fact, Korea is importing mostly open field Napa cabbage and turnip from China.

amounts of input use such as organic and inorganic fertilizers, energy and electricity, and other agro-materials including vinyl and carbon steel for greenhouse (Kim and Yoon 2013; Lee et al. 2012). Korea's CO<sub>2</sub> emissions in the production stage turn out to be far greater than those of China's. The CO<sub>2</sub> emission gaps between the two countries amounted to 255 kgCO<sub>2</sub> per ton for Napa cabbage and 194 kgCO<sub>2</sub> per ton for turnip.<sup>14</sup> Intensive farming in Korea is attributable to the large gap in CO<sub>2</sub> emissions. Greenhouse cultivation generates even greater disparity by using more energy and electricity. Comparison of CO<sub>2</sub> emissions measured by price equivalents highlights that Korea bears close to seven times higher prices.

The CO<sub>2</sub> emissions from transportation are contrary to the results from production. Since Chinese vegetables are assumed to ship from the Shandong Province to Korea, this overseas transportation must emit greater amounts of CO<sub>2</sub>. On the other hand, internal transportation for Korean vegetables refers to distance between Seoul and major production regions including Gyeonggi-do, Chungcheongbuk-do, Chungcheongnam-do, Jeollabuk-do, Jeollanam-do, Daegu and Gwangju. The transportation gaps for Napa cabbage and turnip between Korea and China are 86 kgCO<sub>2</sub> per ton and 69 kgCO<sub>2</sub> per ton, respectively. Conversion of these gaps into price equivalents indicates that China faces two and three times higher environmental burdens in Napa cabbage and turnip transportation, respectively.

Finally, average wholesale prices for Korea Napa cabbage and turnip are about two times higher than average import prices from China, respectively. This suggests China should have comparative advantage in trades with Korea.<sup>15</sup> The sum of all the price equivalents of food miles associated with production and transportation as well as market prices is 897,573 won per ton for Napa cabbage and 716,222 won per ton for turnip in Korea. The corresponding prices in China are 436,684 won per ton and 382,142 won per ton, respectively.

At *ceteris paribus*, these results imply that China is likely to maintain her comparative advantage in exporting these fresh products to Korea. When taking into consideration that existing tariffs of 27% on Napa cabbage and 30%

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<sup>14</sup> Details of calculation methods and data are available from authors.

<sup>15</sup> Cost advantage in trade is determined by not only prices but also product quality, traits, or origin. However, a fundamental assumption of this paper is that the two products are identical.

on turnip charged by the Korean government will be subject to reductions as the FTA between Korea and China progresses, the standpoint of China will be firmly established. Besides, it confirms that the extent of food miles effects from transportation is not enough to cancel out the effects originated from the production. Measures need to be taken to mitigate food miles effects of using more agricultural inputs and energy.

## VI. Conclusions

The conceptual popularity of food miles and its ramification on carbon emission levels largely rests on the concept's simplicity of computation and potential application. As a gauging tool for any environmental outcome, food miles could deliver on its promises. Especially, by being the first to extend and apply the concept in the case of the Korea-China FTA, this paper finds that the FTA will have notable consequences of CO<sub>2</sub> emissions. Considering only food miles effects based on distance, more imports from China generate more CO<sub>2</sub> emissions that elicit higher levels of fossil-fuel energy consumption.

Although the trade expansion and trade shifting effects are somewhat hypothetical in dealing with the SPS protection measures and the change in import flows before and after the FTA, they suggest the likelihood of expansion effects that dominate the trade shifting effects. The minimal influence on the CO<sub>2</sub> emissions of the trade shifting effects implies that having China-sourced products crowd-out domestic Korean products has a more profound impact than China's imports displacing Korean-bound exports of other countries. The relatively weak trade shifting effect could stem from the fact that China has come to grips with long distance overland transportation and limited improvement in the product-specific market access to Korea.

Nevertheless, it is more relevant and important to assess the food miles effects of a product life-cycle approach. An illustrative analysis of the cases of Napa cabbage and turnip points out that food miles effects inclusive of production process could be far greater than the distance effects. More specifically, CO<sub>2</sub> emissions during production in Korea are seven times higher than China in terms of their price equivalents. On the contrary, the gap of CO<sub>2</sub> emissions between the two countries during internal and overseas transportation tags only



up to three times. The profound consequences of production surpassing the distance effects suggest Chinese Napa cabbage and turnip maintain their competitive advantage even in terms of an environmental aspect. It also suggests prudent policy measures need to be taken for Korea to alleviate CO<sub>2</sub> emissions by enhancing efficiency in agricultural inputs and energy uses.

The product life-cycle approach is further praised by other researches. For example, Hallsworth and Wong (2012) demonstrated that Dutch-supplied tomatoes to the UK can incur more carbon emissions than the supply from Spain, a longer distance exporter. The determining factor is whether the tomatoes are grown in heated greenhouses or in open fields. A precise measurement of food miles should take into account the differences in production and processing methods. Saunders et al. (2006) also find that New Zealand's agricultural products are more energy efficient in producing and delivering to the UK markets than the UK is.

Being a double-edged sword for Korea, food miles effects of production and long-distance could be substantial under the proposed Korea-China FTA. However, what are required are pertinent policy measures and concerted efforts to alleviate accumulating environmental burdens by making more leeway. This may include more R&D investment, appropriate command and control, economic incentives and public awareness and support.

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