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Analysis of the impact of agricultural quality standards on the trade of fruit and vegetables

Results of the study: Impacts of OECD Fruit and Vegetables Scheme and UNECE Fresh Fruit and Vegetables Standards on International Trade in Fresh Produce

Submitted by the secretariat

Summary

Following discussions at the 2021 session of the Specialized Section on Standardization of Fresh Fruit and Vegetables, the Organisation for Economic Co-operation and Development (OECD) and ECE jointly initiated work on a study to assess the impact of agricultural quality standards on the trade of fruit and vegetables.

The following document contains the results of the analysis. It is presented for information purposes.

Impacts of OECD Fruit and Vegetables Scheme and UNECE Fresh Fruit and Vegetables Standards on International Trade in Fresh Produce*

Abstract

Although the international trade effects of food safety standards have been extensively studied across a variety of markets, less is known about the effects of harmonized food marketing standards. We analyze the trade effects of the Organisation for Economic Co-operation and Development (OECD) Fruit and Vegetables Scheme (FVS) and the United Nations Economic Commission for Europe (UNECE) Fruit and Vegetable Standards, integrated international systems established in the mid-twentieth century to define, implement, and harmonize marketing standards for fresh fruits and vegetables. Using annual BACI data for the 21-year period 1995-2015, we estimate a structural gravity equation using standard OLS and PPML methods with a wide array of control variables. Of the 39 categories of fresh fruit and vegetables considered, we find that publication of FVS brochures and implementation/revision of UNECE standards are associated with substantial increases in international trade across multiple product categories. Specifically, we find conclusive evidence that trade in various types of fresh fruits and vegetables is larger, in general, after publication or revision of FVS and UNECE standards. Importantly, our methodology controls for a number of other important variables and potentially confounding factors, including FVS membership, countries' GDP and population levels, economic integration agreements, OECD membership, any time-invariant properties that define trading country pairs (e.g., common cultures and shared histories), and any linearly-trending time effects. The effect sizes are comparable across individual products and do not appear to differ considerably based on organization (i.e., FVS or UNECE). A difference-in-differences (DID) analysis, which relies on other modeling assumptions and methods, complements the empirical gravity estimates by providing evidence of short-term trade effects on FVS and UNECE member countries.

Keywords: Marketing standards, standards harmonization, food marketing, OECD, UNECE, fresh fruit, fresh vegetables, structural gravity models, trade creation.

I. Introduction

Technological advances, such as the increased ability to detect fruit and vegetable ripening, and the advent of modern methods for preservation and storage, have played an important role in increasing international trade of fresh fruit and vegetables. Similarly, mechanized harvesting has also brought about greater production, thus contributing to increased trade, though large shares of fruits, vegetables, and tree nuts in OECD countries are still manually harvested (e.g., Calvin and Martin, 2010; Huffman, 2012). Despite the role of technological progress, integrated systems that define, interpret, and harmonize marketing standards—such as the United Nations Economic Commission for Europe (UNECE) standards for fresh fruit and vegetables, and the OECD Fruit and Vegetables Scheme (FVS)—have had positive influence on exports of member countries. As such, the objective of this study is to quantify the effects of standards and a common inspections system on international trade in fruit and vegetables.

Trade liberalization in recent decades has brought about substantially lower tariff rates and increased the salience of standards among policymakers (Fugazza and Maur, 2008;

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The terms country and economy as used in this report also refer, as appropriate, to territories or areas; the designations employed and the presentation of the material do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

UNCTAD, 2019). The trade effects of a standard partially depend on whether the standard is public or private, mandatory or voluntary, and serves product differentiation, risk management, or other purposes (Henson and Humphrey, 2010). In principle, standards can increase demand for the product as result of correcting an externality and/or reduce supply in the domestic and foreign markets due to increased compliance costs; if standards are protectionist, rents could accrue to domestic firms (Beghin et al., 2015).

The consequences of imposing new product standards, or harmonizing existing standards, vary according to affected markets. Early studies focused on technical compatibility and impacts to innovation and competition (e.g., David and Greenstein, 1990). Testing and certification procedures can be technical barriers to trade (TBT), though infrequently implemented by national governments as explicit protectionist measures, because they can raise firms' costs to meet the standards, relative to scenarios in which no standards (or weak standards) exist (Maskus et al., 2005).[1] By contrast, firms that face numerous—and potentially conflicting—national standards that differ by export market could experience significant cost savings under harmonized systems. In such cases, certain production and marketing processes need not be adapted to meet separate technical requirements for each market. In aggregate, changes in firms' costs as a result of imposing or harmonizing technical standards can substantially influence the direction and composition of a country's exports and imports.[2]

The effects of harmonization on export value can differ for trade between two participating countries, two non-participating countries, and a participating country and non-participating country. Theory suggests trade is likely to increase among participating countries but in some cases at the expense of non-participating countries, i.e., trade diversion. Trade among non-participating countries could increase or decrease mainly depending on impacts to prices and output. Impacts on trade may also vary based on whether the standards are part of mutual recognition agreements (MRAs) with restrictive rules of origin or have relatively shallow or deep coverage across products.

There is an extensive, earlier literature on the effects of standards on various types of trade. Using data from the United Kingdom of Great Britain and Northern Ireland (United Kingdom) and Germany for 1985-91, Swann et al. (1996) find that international voluntary standards boost British exports and imports, though domestic United Kingdom standards have a relatively stronger effect. Moenius (2004) builds on this by analyzing trade in over 400 industries among 12 OECD countries during 1980-95. He finds that harmonized bilateral standards are trade promoting and suggests this is partly due to reduced information costs to exporters, assuming standards convey costly information that would otherwise need to be acquired in their absence. In related work, Chen and Mattoo (2008), using data on 42 countries during 1986-2001, show that harmonization of international mandatory standards increases trade between participating countries but can reduce exports from excluded countries. They find MRAs to be relatively more trade promoting unless they contain restrictive rules of origin clauses. Additional work focusing on major exports of developing countries (agricultural commodities, textiles, and clothing) demonstrate that European Union (EU) standards which are harmonized to International Organization for Standardization (ISO) standards are less trade-restrictive than non-harmonized standards and are, in some cases, trade promoting (Czubala et al., 2009; Shepherd and Wilson, 2013).

A parallel set of studies has attempted to determine the impacts of international standards harmonization on the extensive margin (i.e., new firms entering harmonized markets) and the intensive margin (i.e., existing firms adjusting export quantities to harmonized markets). Baller (2007) finds negligible effects on participating countries, with excluded OECD countries benefiting and excluded developing countries not benefiting from harmonization.

1 A comprehensive review of the literature on trade barriers and product standards is beyond the scope of this study. For an overview and framework for analyzing TBTs in agriculture, see Roberts et al. (1999). Baldwin (2000) models liberalization of TBTs, arguing that liberalization results in a two-tiered trading system in which mutual recognition of rules and tests ultimately excludes developing countries. Swann (2010) is a thorough review of the empirical literature on the trade effects of international standards.

2 It is possible for standards harmonization to raise exporting firms' costs if the harmonization process entails a switch from voluntary to mandatory standards in firms' export markets.

She also finds that harmonization has relatively larger effects on the probability that new firms will export, as does Shepherd (2007) in situations where complying with the standards is not too costly for firms. Using trade data directly linked to United States of America (United States) firms, Reyes (2011) shows that harmonization of EU product standards boosts United States exports to the EU. This is the result of more Unites States firms entering the EU market (mainly from among the set of highly productive firms exporting to developing markets), even though the volume of trade decreases from firms previously exporting to the EU prior to harmonization.

Within agricultural economics, there is a growing body of empirical studies concerning international standardization and agricultural trade. Much past and ongoing work focuses on the effects of sanitary and phytosanitary measures on trade of agricultural commodities (e.g., Disdier et al., 2008; Peterson and Orden, 2008; Schlueter et al., 2009)—of major significance because of widespread implications for food safety and human health. Additional work has examined trade and country-of-origin labeling (Hallren and Opanasets, 2018), voluntary sustainability standards (Elamin and de Cordoba, 2020), and harmonization of other food regulations (de Frahan and Vancauteren, 2006). By contrast, this report analyzes the trade effects of unique standards harmonization systems—under the umbrella of two major intergovernmental organizations—on fresh fruit and vegetables, with important implications for consumer demand and farmers' income.

II. Background on Harmonized Fresh Fruit and Vegetables Standards

In this section, I first overview the OECD system, their members, and the set of standards. I then provide analogous background material for the relevant UNECE standards.

A. The OECD Fruit and Vegetables Scheme (FVS)

The Scheme for the Application of International Standards for Fruit and Vegetables (FVS) was established in 1962 to define, implement, and harmonize marketing standards for fresh fruits and vegetables. Since this time, the FVS has published numerous explanatory brochures on standards for specific fruits, vegetables, and tree nuts or groupings (e.g., citrus fruit). In addition to defining inspection procedures that are mutually recognized by member countries, the FVS also sponsors training courses and organizes peer reviews so as to help members improve the quality of their inspection systems. Membership has grown from 15 countries in 1962 to 26 countries in 2021, with current representation in North and South America, Europe, Africa, and Oceania (Table 1). By defining and harmonizing certain marketing criteria, FVS is designed to boost trade through a process that provides quality assurances, with common procedures and regulations (OECD, 2018).

Since the early 1990s, the FVS has published 51 high-quality brochures of fresh fruits, vegetables, and tree nuts, with several being published in 2021 (Table 2). The brochures contain explanatory notes and illustrations to facilitate uniform implementation of the product's standard across all member countries. The brochures describe and demonstrate quality parameters, typically accompanied by high-resolution photographs, thus serving as an important tool for inspection authorities, traders, professional bodies, and other groups interested in international trade of fresh produce.

As of the early 1990s, 28 brochures have been published on fruit or groups of fruit (with some fruits having multiple publications) and 19 brochures have been published on vegetables or groups of vegetables, in addition to brochures on cultivated mushrooms, figs, and hazelnuts. In this period, five brochures were published in the 1990s, 17 brochures were published during 2000-09, 19 brochures were published during 2010-19, and 10 brochures have been published during 2020-21. Three categories of products have had three brochures—avocados, beans, and mangoes—and 13 have had two brochures published (Table 2).

Beyond publication of brochures, the FVS also organizes and implements a number of additional activities that generate value to the broad international community of fruit and vegetable stakeholders. Regular training courses offer hands-on demonstrations of inspections, permitting knowledge-sharing between inspection staff and discussion of potential differences in interpretation of the standards. The 2018 meeting in Slovakia included participation from more than one dozen countries and covered topics related to produce safety and quality, climate change, food waste, and development of producers' organization—among other agenda items. Moreover, the OECD Meeting of Heads of National Inspection Services enables discussions between countries' inspection services on major problems, development and challenges in the sector, and quality inspection systems. In recent years, these meetings have occurred in Spain (2018), Italy (2016), and Poland (2014). Last, the Peer Review process is a rigorous examination and assessment of performance of inspection systems by experts from other countries, convened under the auspices of the OECD. The overall aim is to improve policymaking by ensuring countries are adopting best practices with regard to inspection and complying with established standards and principles. Results from the peer reviews are available on the FVS website: France (2016), Finland (2015), Spain (2013), and the Netherlands (2012) (OECD, 2018).

Table 1
List of Current or Former OECD Fruit and Vegetable Schemes Members

	Years		
Country	*Country Code*	*Joined*	*Withdrew*
Australia	AUS	1985	1997
Austria	AUT	1987	
Belgium	BEL	1962	
Brazil	BRA	2018	
Bulgaria	BGR	2003	
Canada	CAN	1962	1995
Czechia	CZE	1993	2000
Denmark	DNK	1962	1999
Finland	FIN	1995	
France	FRA	1962	
Germany	DEU	1962	
Greece	GRC	1962	
Hungary	HUN	1996	
Ireland	IRL	1978	
Israel	ISR	1963	
Italy	ITA	1962	
Kenya	KEN	2009	
Luxembourg	LUX	1962	
Morocco	MAR	2004	
Netherlands	NLD	1962	
New Zealand	NZL	1974	
Poland	POL	1994	

		Years	
Country	*Country Code*	*Joined*	*Withdrew*
Portugal	PRT	1962	2000
Romania	ROM	1971	
Serbia	SRB	2009	
Slovakia	SVK	1997	
South Africa	ZAF	1994	
Spain	ESP	1962	
Sweden	SWE	1997	
Switzerland	CHE	1962	
Türkiye	TUR	1962	
United Kingdom	GBR	1962	1999
United States	USA	1962	1998

Notes: The source is OECD.

Table 2
OECD Fruit and Vegetable Schemes Publications Since 1990

	Publication Years		
Brochure	*First*	*Second*	*Third*
Apples	2011	2021	-
Apricots	1994	2010	-
Asparagus	2000	2011	-
Avocados	1995	2004	2021
Beans	2006	2021	-
Broccoli	2000	2013	-
Carrots	2000	-	-
Cherries	2016	-	-
Chicory	1994	2021	-
Chinese Cabbage	2015	-	-
Citrus Fruit	2010	-	-
Cucumbers	2008	-	-
Cultivated mushrooms	2006	-	-
Figs	2015	-	-
Garlic	2017	-	-
Hazelnuts	2009	2011	-
Kiwifruit	1992	2008	-

	Publication Years		
Brochure	*First*	*Second*	*Third*
Leeks	2019	-	-
Lettuces	2002	2021	-
Mangoes	1993	2012	2021
Melons	2006	2014	-
Onions	2012	-	-
Peaches and nectarines	2010	-	-
Pears	2009	2021	-
Plums	2002	2021	-
Pomegranate	2014	-	-
Potatoes	2009	-	-
Root and tubercle vegetables	2020	-	-
Shallots	2014	-	-
Strawberries	2006	2021	-
Table grapes	2007	-	-
Tomatoes	2003	2019	-
Watermelons	2014	-	-

Notes: The source is OECD.

B. The UNECE Fresh Fruit and Vegetables Standards

The UNECE established the Working Party on Agricultural Quality Standards (WP.7) in 1947 to harmonize national standards into international standards and to develop a means for their enforcement. The stated goals are to facilitate fair trade, prevent TBTs, and increase transparency while also promoting sustainable marketing of quality produce and protecting consumer interests. As of 1954, the standards follow a common layout and establish uniform minimum quality requirements, definitions and classifications, product-specific tolerances, and other criteria related to sizing, presentation, and markings. Although all of the standards are voluntary, many have been incorporated into national or regional legislations (as requirements for import, export, or domestic sales), as well as commercial contracts (Annovazzi-Jakab, 2016; UNECE, 2015).

The standards are developed and revised in an inclusive process: all United Nations member countries are eligible to participate, have equal standing, and can request the development or revision of any standard, with decisions made on a consensual basis. Oftentimes delegates to the WP.7 are the relevant national food or agricultural authority, private sector representatives, and members of recognized non-governmental organizations (NGOs). Input into the development or revision of the standards comes from these delegations—representing both net exporters and net importers—and at all stages, including a trial phase and subsequent evaluation process. To avoid duplication of work, the WP.7 coordinates with other international bodies including the OECD, EU, the Codex Alimentarius Committee, and the WTO, among others (Annovazzi-Jakab, 2016; UNECE, 2015).

Although any United Nations member country can join the WP.7, and thus the impacts of the standards can be felt by UNECE and non-UNECE members alike, it should be noted that there are currently 56 UNECE member States (Table 3). While membership has been open to non-European countries (e.g., Canada, United States of America (United States)), the UNECE is comprised largely of European countries: all of the 27 current EU members are also part of the UNECE, as is the United Kingdom. There is also substantial overlap between the UNECE and the OECD FVS: roughly 38% of UNECE countries are current FVS members, and 85% of current FVS members are also a UNECE member State.

UNECE has over 100 standards for FFV, DDP, meat and seed potatoes. From those, UNECE has a set of 56 standards that cover fresh fruit and vegetables, 27 were adopted in the 1960s, 6 were adopted in the 1970s, 5 were adopted in the 1980s, 3 were adopted in the 1990s, 5 were adopted in the 2000s, and 9 were adopted in 2010 or later. Many of these have been revised at least once since the 1990s (Table 4), with the average number of revisions during this time being 2.7. For some products like avocados, melons, and table grapes, the standards have been revised frequently—in principle, to reflect changes in production, marketing, inspection, or regulatory environments (UNECE, 2015). The product distribution of the current set of standards is 42% fruit (including sweet chestnuts) and 58% vegetables (including ceps, chanterelles, cultivated mushrooms, and truffles).

Table 3
List of Current UNECE Member states

Country	*Country Code*	*Year Joined*
Albania	ALB	1955
Andorra	AND	1993
Armenia	ARM	1993
Austria	AUT	1955
Azerbaijan	AZE	1993
Belarus	BLR	1947
Belgium	BEL, BLX	1947
Bosnia and Herzegovina	BIH	1992
Bulgaria	BGR	1955
Canada	CAN	1973
Croatia	HRV	1992
Cyprus	CYP	1960
Czechia	CZE	1947
Denmark	DNK	1947
Estonia	EST	1991
Finland	FIN	1955
France	FRA	1947
Georgia	GEO	1993
Germany	DEU	1973
Greece	GRC	1947
Hungary	HUN	1955
Iceland	ISL	1947
Ireland	IRL	1955

Country	*Country Code*	*Year Joined*
Israel	ISR	1991
Italy	ITA	1955
Kazakhstan	KAZ	1994
Kyrgyzstan	KGZ	1993
Latvia	LVA	1991
Liechtenstein	LIE	1990
Lithuania	LTU	1991
Luxembourg	LUX, BLX	1947
Malta	MLT	1964
Monaco	MCO	1993
Montenegro	MNE	2006
Netherlands	NLD	1947
North Macedonia	MKD	1993
Norway	NOR	1947
Poland	POL	1947
Portugal	PRT	1955
Republic of Moldova	MDA	1992
Romania	ROU	1955
Russian Federation	RUS	1947
San Marino	SMR	1993
Serbia	SRB	2000
Slovakia	SVK	1947
Slovenia	SVN	1992
Spain	ESP	1955
Sweden	SWE	1947
Switzerland	CHE	1972
Tajikistan	TJK	1994
Türkiye	TUR	1947
Turkmenistan	TKM	1993
Ukraine	UKR	1947
United Kingdom	GBR	1947
United States	USA	1947
Uzbekistan	UZB	1993

Note: The source is UNECE.

Table 4
UNECE Fruit and Vegetable Standards Revisions Since 1990

	Publication/Revision Years							
Brochure	*First*	*Second*	*Third*	*Fourth*	*Fifth*	*Sixth*	*Seventh*	*Eighth*
Annonas	1994	2002	2003	2019				
Apples	2009	2012	2020					
Apricots	1992	2009	2014	2017	2021			
Artichokes	1996	2003	2010					
Asparagus	1996	1999	2010					
Aubergines	1993	2000	2016					
Avocados	1994	1998	2001	2002	2003	2009	2019	
Beans	1993	1998	2000	2001	2010			
Berry fruits	2010	2017	2019					
Broccoli	1994	1997	1998	1999	2010	2019		
Brussels sprouts	2010							
Carrots	1996	1998	2021					
Cauliflowers	1996	2000	2021					
Ceps	2007	2010						
Chanterelles	2009	2014						
Cherries	2007	2019						
Chicory	1992	2016						
Chili peppers	2013							
Chinese cabbage	1991	2021						
Citrus fruit	2010	2016						
Cucumbers	2008	2021						
Courgettes	2000	2003	2010					
Cultivated mushrooms	1996	2000	2004	2012				
Fennel	2000	2017						
Figs	2021							
Garlic	1996	1998	2016					
Headed cabbage	2000	2020						
Kiwifruit	2004	2008	2017					
Leafy vegetables	2010	2012						
Lambs lettuce	2015							
Leeks	1996	2002	2003	2016				

	Publication/Revision Years							
Brochure	*First*	*Second*	*Third*	*Fourth*	*Fifth*	*Sixth*	*Seventh*	*Eighth*
Lettuce and endives	1999	2001	2009	2012				
Mangoes	1991	2012						
Melons	1992	1998	2000	2002	2003	2006	2012	
Onions	2001	2003	2019					
Peaches and nectarines	1994	2003	2004	2009	2010			
Pears	2010	2020						
Peas	1998	2000	2001	2010				
Persimmons	2020							
Pineapples	2003	2012						
Plums	1996	1998	1999	2002	2004	2020		
Pomegranates	2021							
Potatoes, early and ware	2006	2009	2011					
Quinces	2014							
Ribbed celery	1995	2010						
Rhubarb	1996	2017						
Roots and tubercles	2010	2019						
Shallots	2010	2013						
Strawberries	1992	2002	2003	2021				
Sweet chestnuts	2016							
Sweet peppers	1996	2000	2001	2009	2020			
Table grapes	1997	1999	2000	2001	2002	2003	2007	2020
Tomatoes	1997	2000	2009	2017				
Truffles	2006	2016						
Watermelons	1996	1998	2004	2021				

Notes: Multiple UNECE documents are the sources.

Similar to the FVS, the UNECE publishes a limited number of high-quality, explanatory brochures of benefit to farmers, traders, inspectors, and others in helping to facilitate uniform implementation of the standards across countries. However, they are not duplicative of the FVS brochures; the UNECE currently offers brochures on chili peppers, persimmons, pineapples, and sweet peppers. Apart from regular meetings of the WP.7, the UNECE has sponsored capacity-building workshops in Central Asia, Russian Federation, Thailand, Mexico, Italy, and elsewhere in recent years (UNECE, 2022). Taken together, the UNECE standardization system is expected to boost sustainability, food security, and market access across the global supply chain of fresh fruits and vegetables while lowering food loss and waste (Annovazzi-Jakab, 2016).

III. International Trade in Fresh Fruit and Vegetables

This section details construction of the bilateral trade data on fresh fruit and vegetables, in addition to supplementary data on FVS membership, UNECE countries, and other information needed for the analysis. We then provide summary statistics on trade and a brief discussion of descriptive trends.

A. Data Construction

Many studies in the empirical trade literature rely on bilateral trade data from the United Nations Commodity Trade Statistics Database (COMTRADE), the largest repository of international trade data. The database is comprised of country-to-country information on annual trade in commodities/services reported by national governments to the United Nations Statistics Division for years 1962-2018. The United Nations converts annual data on the value of exports and imports from national currencies to US dollars with exchange rates either supplied by reporting countries or derived from monthly market rates and volume of trade data (United Nations Trade Statistics, 2016). Import values are reported CIF (cost, insurance, and freight), while export values are reported FOB (free on board), which typically account for differences in values by 10-20% (World Bank, 2010).

Such differences in valuations between importer-reported and exporter-reported data, known as the "mirror problem", can be challenging to resolve in trade analyses. The BACI (Base Pour L'Analyse du Commerce International) data, developed by the Paris-based CEPII organization, largely resolves this issue. This database provides information on more than 5,000 products across 200 countries based on COMTRADE data. BACI is provided under the HS classification system at the 6-digit product level. The harmonization system used to produce the BACI data proceeds in two steps. First, CIF costs are estimated using an equation similar to the main equation in this report and then removed from the reported import values, so that all import data are expressed FOB. Second, the FOB-FOB mirror data are averaged using a procedure that down-weights reporters that are estimated to be unreliable (Gaulier and Zignago, 2010). The end result is a large dataset of bilateral trades having valuations that are harmonized (expressed in nominal US dollars), reliable, and internally consistent. The main downside of BACI is that the data are only available since 1995.

Although the BACI data are available for 200 countries, multi-country regions (e.g., United States Miscellaneous Pacific Islands) and largely uninhabited areas (e.g., Antarctica) are not included in the BACI data. To simplify the analysis, several other smaller countries, semi-autonomous areas, and other regions are dropped.[3] However, available data for this latter group are quite sparse, so virtually none of the analysis would change if these data were to be included. Table A1 in Appendix A contains a list of the set of 196 final countries that are included in the analysis.

Regardless of whether COMTRADE or BACI data are used, the underlying structure of international trade classifications is such that trade valuations do not align perfectly with all types of fruits and vegetables of interest to the FVS and/or UNECE. To ensure the largest possible sample from BACI, we use information at the 6-digit product level from the first revision of the HS trade classification system (Table 5). In many instances, individual product data align exactly with the product covered in a single brochure or standard: fresh apples, fresh apricots, fresh cherries, fresh peaches and nectarines, fresh strawberries, and so on. In other instances, the data aggregate across fresh or dried products (e.g., hazelnuts, figs,

[3] Although the BACI dataset does not contain information on many of the following areas, any included data for these regions/countries are dropped: American Samoa, British Indian Ocean Territory, British Virgin Islands, Bouvet Island, Cayman Islands, Christmas Island, Cocos Islands, Cook Islands, Equatorial Guinea, Falkland Islands, Faeroe Islands, French Southern Territories, Gibraltar, Guam, Heard Island and McDonald Islands, Holy See, Democratic People's Republic of Korea, Nauru, Curaçao, Sint Maarten, Bonaire, Niue, Norfolk Island, Northern Mariana Islands, Marshall Islands, Pitcairn, Saint Barthelemy, Saint Helena, Saint Pierre and Miquelon, Solomon Islands, South African Customs Union, South Sudan, State of Palestine, Tokelau, Turks and Caicos Islands, United States Minor Outlying Islands, Wallis and Futuna Islands, and Western Sahara.

avocados), fresh or chilled (nearly all vegetables), and shelled or unshelled (e.g., beans)—with no way of removing the value of trade that does not correspond exactly with that covered in the brochure or standard. In many other instances, the 6-digit code aggregates across products, including: guavas, mangoes, and mangosteens; melons and watermelons; pears and quinces; plums and sloes; onions and shallots; leeks and other alliaceous vegetables; cauliflower and broccoli; various berries; various citrus fruits, and so on—again with no way of removing the value of trade for the product that does not correspond exactly with what the brochure covers.

All feasible attempts have been made to match trade product codes as closely as possible to the relevant FVS brochure/standard and UNECE standard (Table 5). Since the trade data are merged with data on international economic integration agreements (detailed below), and the latter are only available through 2017, the analysis is performed on 22 years of data (1996-2017). This means that, although the organizations have created standards for, published brochures on, or revised standards for products in various years, the relevant year(s) may only enter our dataset once. For example, the OECD has published two brochures on apricots: one in year 1994 and the other in year 2010. Since 1994 predates the beginning year of the dataset (1996), any effect of the apricot brochures can only be attributed to impacts from the later publication. Note that since brochures (and standards) may take some time to have full impact, we measure a one-year lagged effect. Thus, our analysis assumes that the FVS apricots brochure would have an effect in year 2011 (one year after its publication date). Unfortunately, there are several products with FVS brochure publication years that are not captured at all in the analysis. This occurs for figs (single brochure, year 2015), cherries (singe brochure, year 2016), garlic (single brochure, year 2017), leeks (single brochure, year 2019), and chicory (two brochures, years 1994 and 2021). Although brochures for mangoes and onions were published in 2012, since the analysis is concerned with a one-year lag effect, these brochures are assumed to have impact in 2013, and thus their effects cannot be captured. Similarly, the effect of UNECE's standards cannot be estimated for the following products: Chinese cabbage (1991, 2021), figs (2021), persimmons (2020), or pomegranates (2021).

Table 5
Brochures, Standards, and Fruits and Vegetables in Analysis Sample (1996-2017)

HS0 Code	*Description*	*OECD Brochure(s)*	*UNECE Standard(s)*
080221	Nuts, edible; hazelnuts or filberts (corylus spp.), fresh or dried, in shell	Hazelnuts	--
080222	Nuts, edible; hazelnuts or filberts (corylus spp.), fresh or dried, shelled	Hazelnuts	--
080240	Nuts, edible; chestnuts (castanea spp.), fresh or dried, whether or not shelled or peeled	--	Sweet chestnuts
080420	Fruit, edible; figs, fresh or dried	Figs	Figs
080430	Fruit, edible; pineapples, fresh or dried	--	Pineapples
080440	Fruit, edible; avocados, fresh or dried	Avocados	Avocados
080450	Fruit, edible; guavas, mangoes and mangosteens, fresh or dried	Mangoes	Mangoes
080610	Fruit, edible; grapes, fresh	Table grapes	Table grapes
080710	Fruit, edible; melons (including watermelons), fresh	Melons, Watermelons	Melons, Watermelons
080810	Fruit, edible; apples, fresh	Apples	Apples
080820	Fruit, edible; pears and quinces, fresh	Pears	Pears, Quince
080910	Fruit, edible; apricots, fresh	Apricots	Apricots
080920	Fruit, edible; cherries, fresh	Cherries	Cherries

HS0 Code	*Description*	*OECD Brochure(s)*	*UNECE Standard(s)*
080930	Fruit, edible; peaches including nectarines, fresh	Peaches and nectarines	Peaches and nectarines
080940	Fruit, edible; plums and sloes, fresh	Plums	Plums
081010	Fruit, edible; strawberries, fresh	Strawberries	Strawberries
081020	Fruit, edible; raspberries, blackberries, mulberries and loganberries, fresh	--	Berry fruits
081030	Fruit, edible; black, white or red currants and gooseberries, fresh	--	Berry fruits
081040	Fruit, edible; cranberries, bilberries and other fruits of the genus vaccinium, fresh	--	Berry fruits
080510	Fruit, edible; oranges, fresh or dried	Citrus fruit	Citrus fruit
080520	Fruit, edible; mandarins (including tangerines and satsumas), clementines, wilkings and similar citrus hybrids, fresh or dried	Citrus fruit	Citrus fruit
080530	Fruit, edible; lemons (citrus limon, citrus limonum), limes (citrus aurantifolia)	Citrus fruit	Citrus fruit
080540	Fruit, edible; grapefruit, fresh or dried	Citrus fruit	Citrus fruit
080590	Fruit, edible; citrus fruit n.e.s. in heading no. 0805, fresh or dried	Citrus fruit	Citrus fruit
070190	Vegetables; potatoes (other than seed), fresh or chilled	Potatoes, early and ware	Potatoes, early and ware
070200	Vegetables; tomatoes, fresh or chilled	Tomatoes	Tomatoes
070310	Vegetables, alliaceous; onions and shallots, fresh or chilled	Onions, Shallots	Onions, Shallots
070320	Vegetables, alliaceous; garlic, fresh or chilled	Garlic	Garlic
070390	Vegetables, alliaceous; leeks and other kinds n.e.s. in heading no. 0703, fresh or chilled	Leeks	Leeks
070410	Vegetables, brassica; cauliflowers and headed broccoli, fresh or chilled	Broccoli	Broccoli, Cauliflower
070420	Vegetables, brassica; brussel sprouts, fresh or chilled	--	Brussels sprouts
070511	Vegetables; cabbage (head) lettuce (lactuca sativa), fresh or chilled	--	Headed cabbage
070519	Vegetables; lettuce (lactuca sativa), (other than cabbage lettuce), fresh or chilled	Lettuces	Lettuce and endives
070521	Vegetables; witloff chicory (cichorium intybus var. foliosum), fresh or chilled	Chicory	Chicory
070610	Vegetables, root; carrots and turnips, fresh or chilled	Carrots	Carrots
070690	Vegetables, root; salad beetroot, salsify, celeric, radishes and similar edible roots, fresh or chilled	Roots and tubercles	Roots and tubercles
070700	Vegetables; cucumbers and gherkins, fresh or chilled	--	Cucumbers
070810	Vegetables, leguminous; peas (pisum sativum), shelled or unshelled, fresh or chilled	--	Peas

HS0 Code	*Description*	*OECD Brochure(s)*	*UNECE Standard(s)*
070820	Vegetables, leguminous; beans (vigna spp., phaseolus spp.), shelled or unshelled, fresh or chilled	Beans	Beans
070910	Vegetables; globe artichokes, fresh or chilled	--	Artichokes
070920	Vegetables; asparagus, fresh or chilled	Asparagus	Asparagus
070930	Vegetables; aubergines, (egg plants), fresh or chilled	--	Aubergines
070940	Vegetables; celery (other than celeriac), fresh or chilled	--	Ribbed celery
070951	Vegetables; mushrooms, fresh or chilled	Cultiv. mushrooms	Cultiv. mushrooms
070952	Vegetables; truffles, fresh or chilled	--	Truffles
070490	Vegetables, brassica; edible, n.e.s. in heading no. 0704, fresh or chilled	--	Leafy vegetables
070970	Vegetables; spinach, New Zealand spinach and orache spinach (garden spinach), fresh or chilled	--	Leafy vegetables

Notes: The underlying data from BACI are available for 1995-2020 (Gualier and Zignago, 2010). However, since the economic information agreements data (e.g., Baier et al., 2014) are only available through 2018, the sample used for the analysis ends in 2018.

Moreover, the analysis does not include data on several categories of fruits and vegetables for which there are an FVS and/or UNECE standard—either because the United Nations does not collect disaggregated trade data for these products, or such data are not available at the 6-digit level and thus not covered by BACI. These products are: annonas, ceps, chanterelles, chili peppers, Chinese cabbage, courgettes, fennel, Lambs lettuce, persimmons, pomegranates, rhubarb, and sweet peppers. Nevertheless, the analysis covers the vast majority of products for which there are brochures and standards (Tables 2, 4, and 5).

Data from several other sources are necessary for the analysis. First, we record whether one or both trading partners in a given year are OECD FVS members and/or UNECE countries (see Tables 1 and 3). Second, we incorporate annual, bilateral information on six types of economic integration agreements (EIAs) (one-way or two-way preferential trade arrangements, free trade area, customs union, common market, or economic union) from the NSF-Kellogg Database on Economic Information Agreements (e.g., Baier et al., 2014). Following Dai et al. (2014), we also use these data to construct measures of whether the importing (exporting) country has at least one other EIA in place with another country that is not the exporting (importing) partner. Third, we use annual data on countries' gross domestic product (GDP) from the World Development Indicators to control for economic size effects (World Bank, 2020). Similarly, these data are used to categorize whether the country belongs to the Global North or South (e.g., McFadden, 2021).[4] Fourth, annual data on each country's population are included and taken from CEPII (Mayer and Zignago, 2011). Last, we record whether both trading partners in a given year are members of the OECD—not the more narrowly defined OECD FVS (OECD, 2021).[5]

B. Descriptive Statistics and Trends

Figure 1 depicts growth in the 39 product categories across the 196 countries used for this analysis in the full set of years for which the BACI data are available, 1995-2020. In the

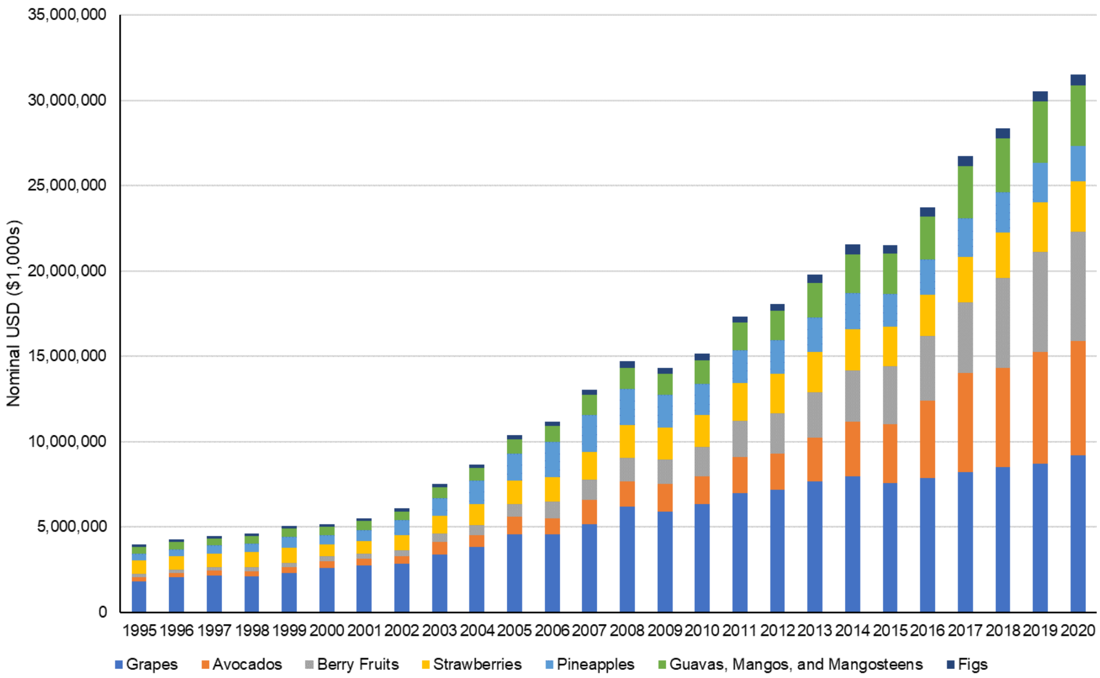
[4] For purposes of this report, the Global North in year *t* is defined to be the set of countries deemed to be high income in year *t* according to the World Bank's country income classifications. Likewise, the Global South in year *t* is the set of middle- and low-income countries in year *t*.

[5] The analysis does not change if this variable instead indicates whether only one of the trading partners was an OECD member.

market for fresh berries and other fruit (grapes, avocados, berry fruits, strawberries, pineapples, guavas, mangoes, mangosteens, and figs), the value of total exports has increased from $4.0 billion in 1995 to $31.5 billion in 2020, with year-on-year increases in nearly all time periods (Figure 1a). Although all categories have experienced growth in exports, the largest growth over the 26-year period has occurred for grapes and berry fruits, while the slowest growth has been for strawberries and figs. Markets for fresh or chilled pomes, stone fruit, and other fruits have experienced similar trade growth, though the trend was mainly flat early during 1995-2002 (Figure 1b). Overall, exports have increased from $10 billion in 1995 to $33.5 billion in 2020, with cherries and citrus fruit experiencing the largest growth and apricots, peaches, and nectarines experiencing the smallest growth.

Figure 1a

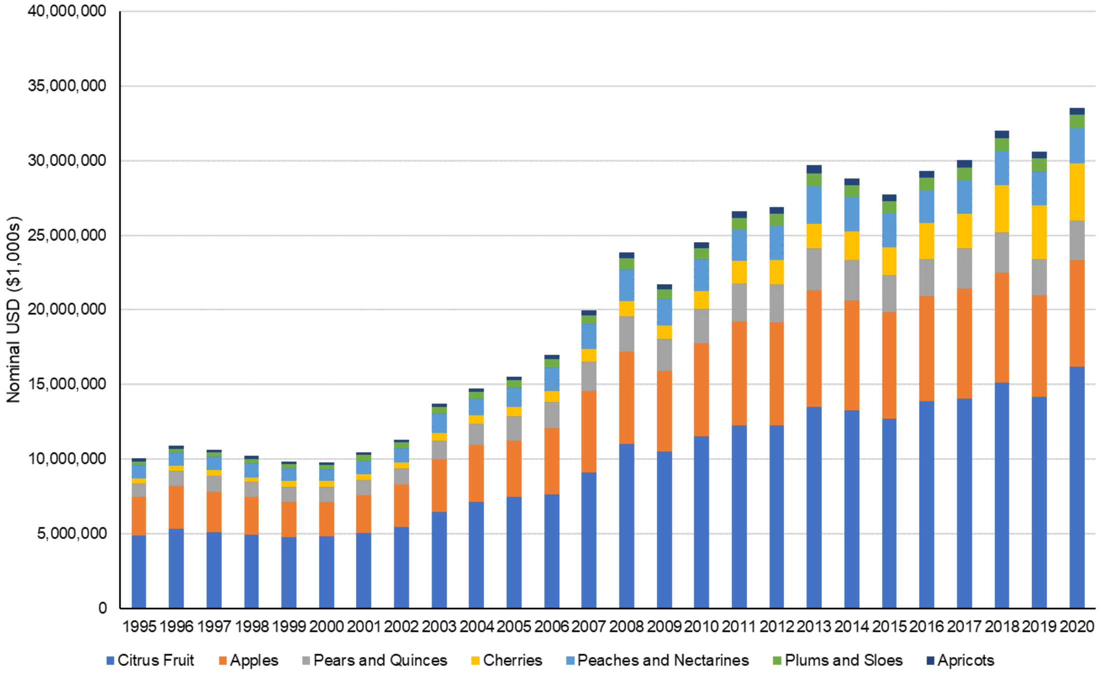
Exports of Fresh Berries and Other Fruit



Notes: Data, available since 1995, are from BACI (Gaulier and Zignago, 2010) and denominated in nominal US dollars (thousands).

Figure 1b

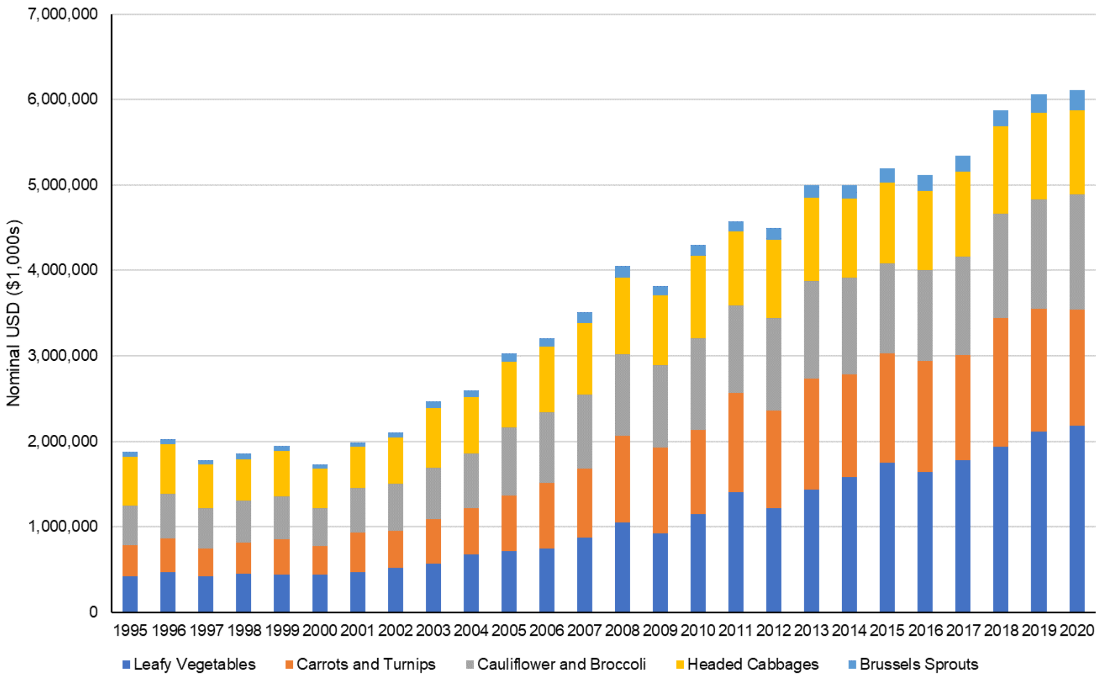
Exports of Fresh Pomes, Stone Fruit, and Other Fruit



Notes: Data, available since 1995, are from BACI (Gaulier and Zignago, 2010) and denominated in nominal US dollars (thousands).

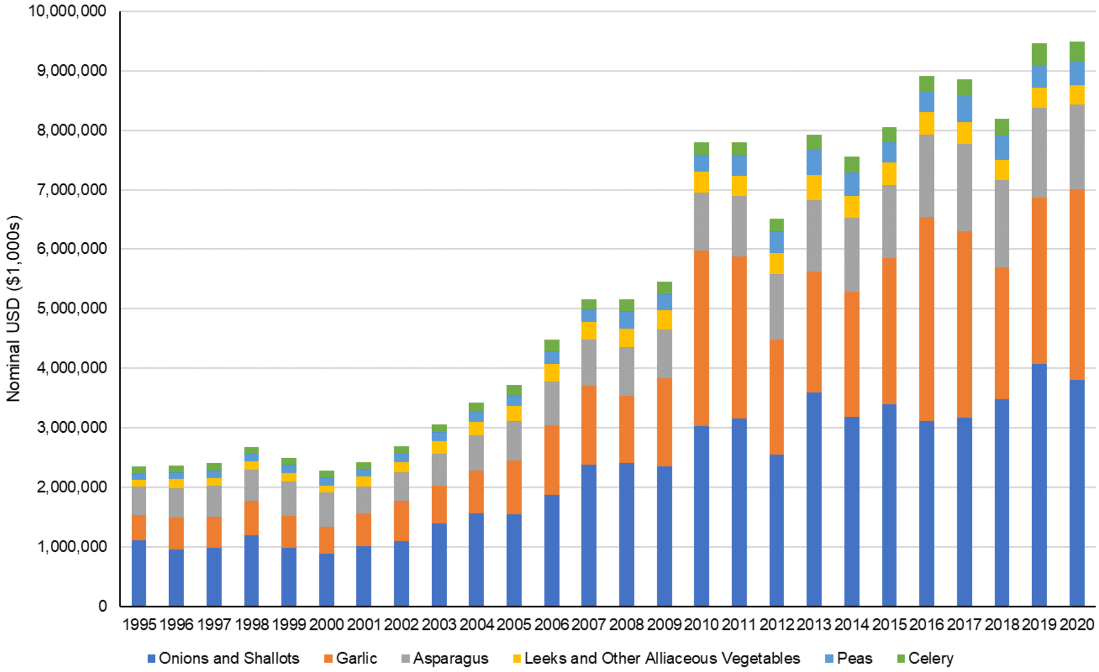
Figure 1c

Exports of Brassicas and Leafy Vegetables



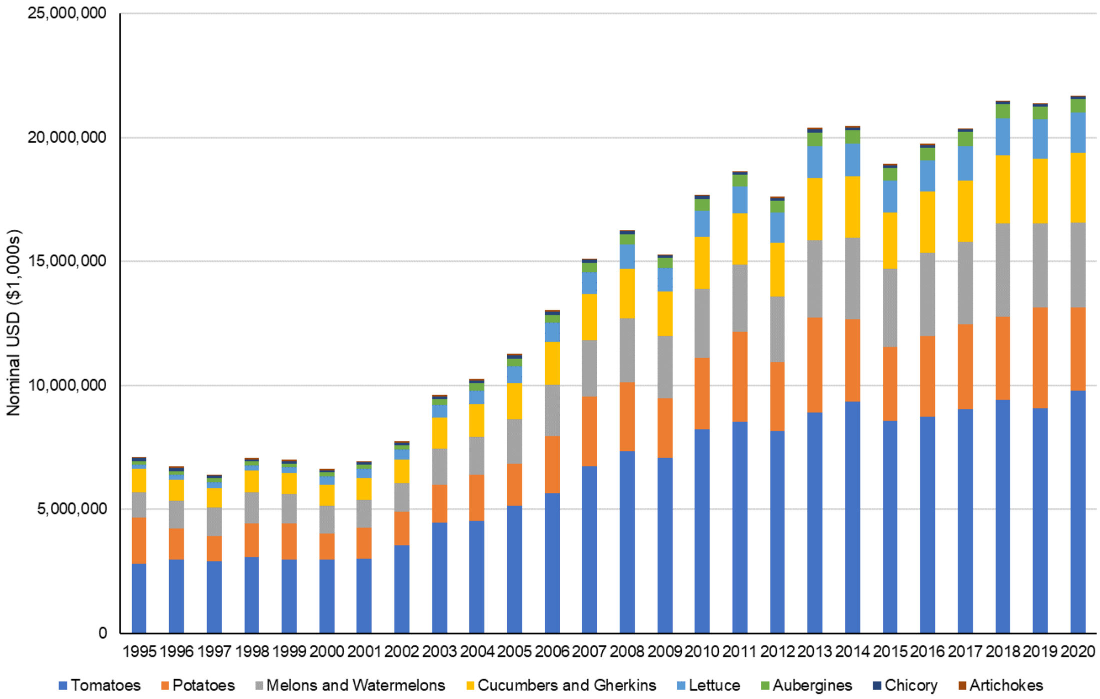
Notes: Data, available since 1995, are from BACI (Gaulier and Zignago, 2010) and denominated in nominal US dollars (thousands).

Figure 1d
Exports of Alliaceous Vegetables and Green Vegetables



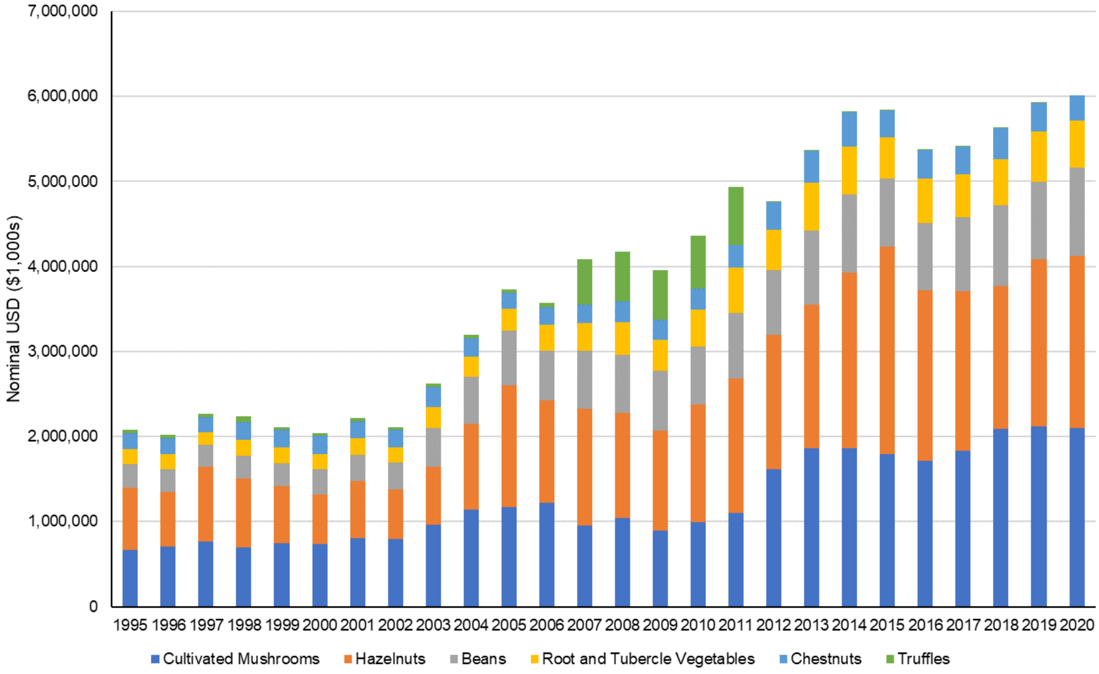
Notes: Data, available since 1995, are from BACI (Gaulier and Zignago, 2010) and denominated in nominal US dollars (thousands).

Figure 1e
Exports of Cucurbits, Nightshade Vegetables, and Aster Vegetables



Notes: Data, available since 1995, are from BACI (Gaulier and Zignago, 2010) and denominated in nominal US dollars (thousands).

Figure 1f
Exports of Nuts, Fungi, and Other Vegetables



Notes: Data, available since 1995, are from BACI (Gaulier and Zignago, 2010) and denominated in nominal US dollars (thousands).

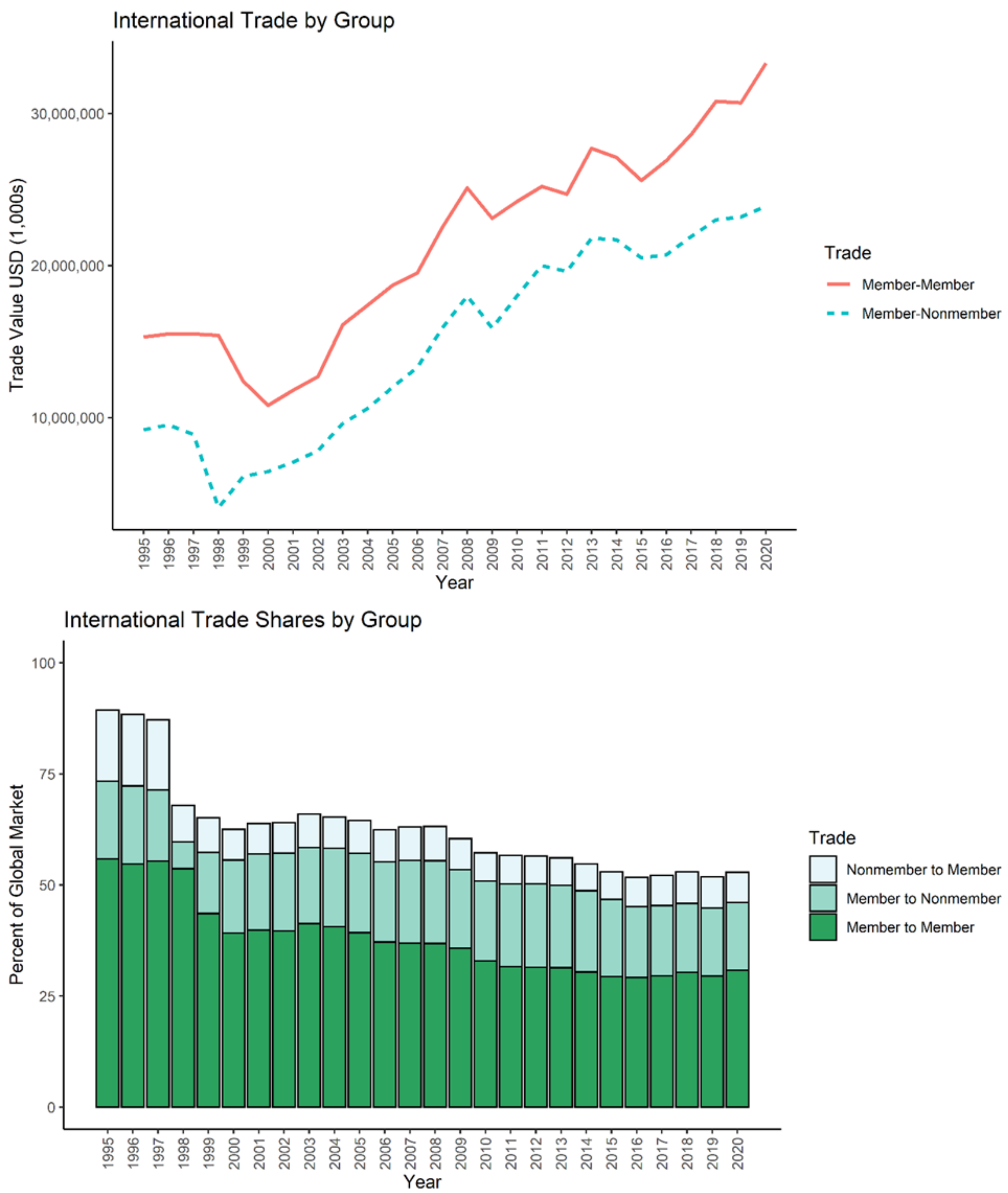
The global market for fresh or chilled vegetables has experienced comparable dynamics, though total value has been somewhat lower than that of fresh fruit. The market for brassicas and leafy vegetables (figure 1c), as well as alliaceous vegetables (onions, shallots, garlic, leeks, and others) and other green vegetables (asparagus, peas, and celery) (figure 1d) was flat during 1995-2000 but then experienced substantial growth since 2001. Among these two groups, the largest increases have been experienced in onions and shallots, garlic, peas, leafy vegetables, and Brussels sprouts, while headed cabbages have grown more modestly. Similarly, the market for cucurbits (including melons and watermelons), nightshade and aster vegetables, fungi, nuts, and other vegetables experienced little growth during 1995-2002 but then grew substantially after (Figures 1e and 1f). Global growth has occurred at similar pace across many of these products, though lettuce and aubergines have had larger growth over time. Chicory has remained relatively flat, while artichokes and truffles have experienced wide swings in global export volumes.

International trade between two FVS members and between an FVS member and nonmember has been somewhat variable, though a strong upward trend emerged in 2000 (Figure 2, top panel). The dip in member-member trade and member-nonmember trade in the late 1990s is likely the result of Australia, Canada, Denmark, the United Kingdom, and the United States withdrawing in various years during this time period (1995-1999). Nonetheless, member-member trade in the 39 product categories was valued at over $33 billion in 2020, with the value of member-nonmember trade being $23.9 billion. As a share of the global market in 2020, member-member trade accounted for 30.8%, members' exports to non-members were 15.3%, and nonmembers' exports to members were 6.8% (Figure 2, bottom panel).

Because of the overlap between FVS members and UNECE countries, in addition to the fact that many of these countries are exposed to similar sets of global economic fluctuations, the trends for UNECE countries are comparable (Figure 3). As with the set of FVS members, trade between two UNECE countries was initially flat before opening to significant growth post 2000 (top panel). Trade between UNECE and non-UNECE countries was sluggish during 1995-2002 but then increased significantly during 2002-2008 and in subsequent periods. As of 2020, trade between UNECE countries was $49.5 billion, while trade between UNECE countries and other countries was $34.6 billion. By shares of the 2020 global market in the 39 product categories, UNECE-UNECE trade was 45.7%, UNECE country exports to non-UNECE countries was 5.0%, and non-UNECE country exports to UNECE countries was 27% (bottom panel).

These stylized facts are qualitatively mirrored in decompositions of trade levels and trade shares by Global North-South status (Appendix B, Figure B1). Since the early 2000s, there has been pronounced growth in both North-North and North-South trade. In 2018, the most recent year for which data are available by development status, trade between two high-income countries was valued at nearly $48 billion, while trade between a country in the North and country in the South summed to $37.8 billion. South-South trade, also of relevance to the FVS and UNECE, similarly increased during this time, though at a slower rate. Exports from the North have accounted for 54-69% of annual trade by value, while exports from the South have comprised lower shares of annual trade values, 31-46% (Figure B1, bottom panel).

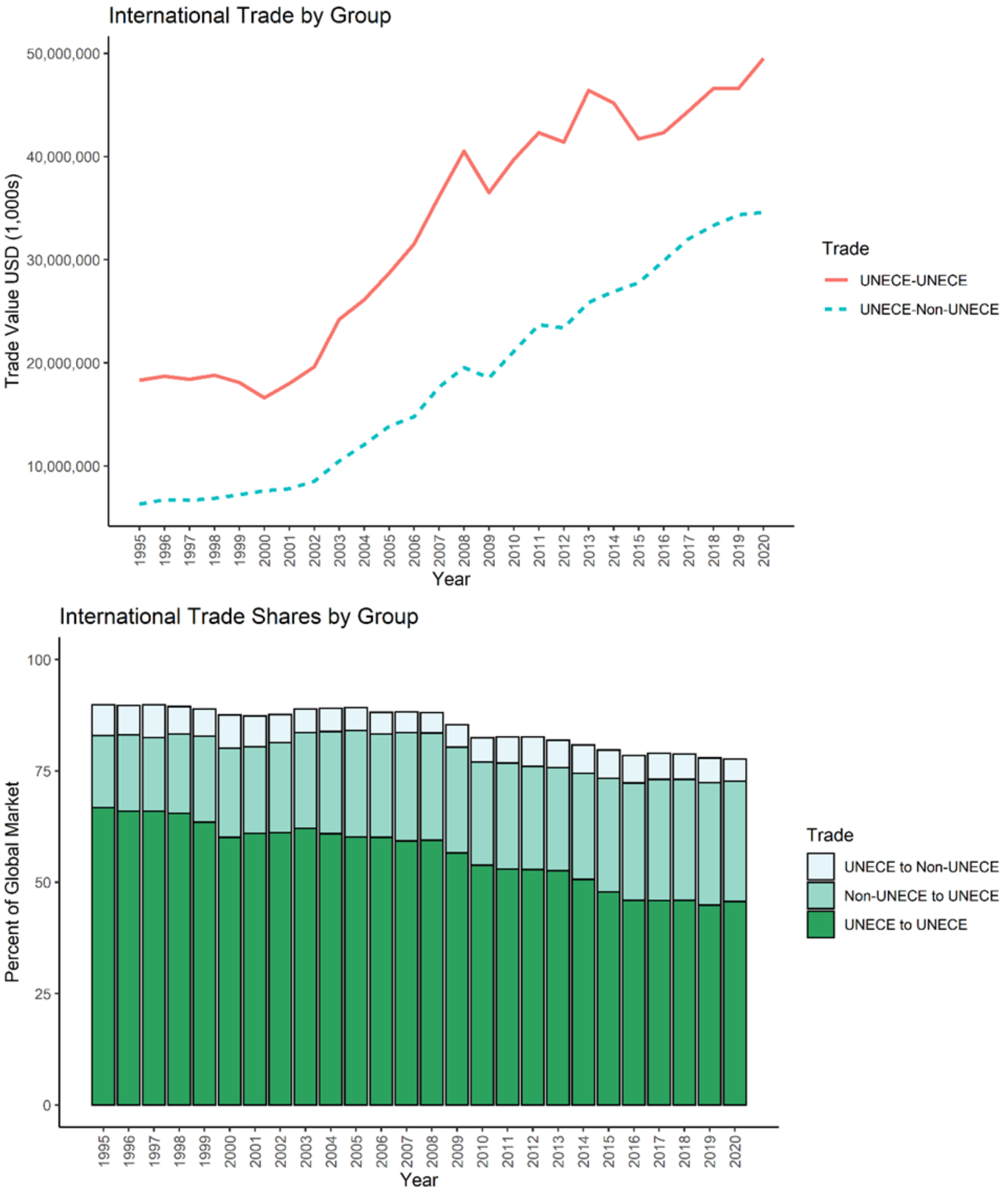
Figure 2
International Trade by OECD FVS Scheme Membership Status



Notes: Data, available since 1995, are from BACI (Gaulier and Zignago, 2010) and denominated in nominal US dollars (thousands). The data are the sum of all trade values corresponding to the HS codes appearing in Table 5.

Since the underlying trade data have been harmonized and reported FOB, these data may not match export values published by national governments in official reports.

Figure 3
International Trade by UNECE Country Status



Notes: Data, available since 1995, are from BACI (Gaulier and Zignago, 2010) and denominated in nominal US dollars (thousands). The data are the sum of all trade values corresponding to the HS codes appearing in Table 5. Since the underlying trade data have been harmonized and reported FOB, these data may not match export values published by national governments in official reports.

Over the 26-year period, the eight largest exporters of fresh fruit and vegetables have been the United States, Spain, Netherlands, Mexico, Italy, France, China, and Chile (Figure 4, top panel). In 2020, Spain was the largest exporter, representing 13.1% of total exports in the 39 product categories, though Mexico and China also had large shares (10.6% and 9.0%, respectively). Many of these same countries have been among the world's largest importers in recent years—particularly the United States, France, Netherlands, and Italy (Figure 4, bottom panel). In 2020, the largest importer was the United States (15.6% of the market), followed by Germany (10.4%) and Netherlands (5.8%). Country concentration has been roughly similar between the sets of exporters and importers. Over the 26-year period, these top exporters have accounted for 58-68% of global exports, while the top importers have accounted for 53-65% of global imports. Importantly, five of the top eight exporters are current or former FVS members, while seven of the top eight importers are current or former members. Five of these exporters are also current UNECE countries, and all eight of the top importers are current UNECE countries.

Table 6 provides the medians of annual fresh fruit and vegetable exports for UNECE countries and current or former FVS members in small increments across the 26-year period.[6] The general trend has been positive, and several countries have experienced growth in exports across all intervals: Australia, Austria, Azerbaijan, Bosnia and Herzegovina, Brazil, Bulgaria, Canada, Denmark, Germany, Latvia, Portugal, Serbia, South Africa, Spain, Sweden, Switzerland, Türkiye, and the United States. A few other countries have experienced large increases over time, though with a slight downturn between the 2010-14 and 2015-20 periods (e.g., Czechia, France, Georgia, Ireland, Kenya, Poland). Annual exports have increased in all but five countries, with some countries—Andorra, Portugal, and most Eastern European nations—experiencing very pronounced growth. The median growth rate across the countries, measured between the beginning increment and ending increment, has been 244%—more than a three-fold increase.[7]

IV. Empirical Analysis of Fruit and Vegetable Trade

This section describes the underlying economic theory supporting the main empirical analysis—the gravity model of international trade—and presents the main equations. We then discuss estimation of the model, followed by presentation of a complementary difference-in-differences (DID) analysis.

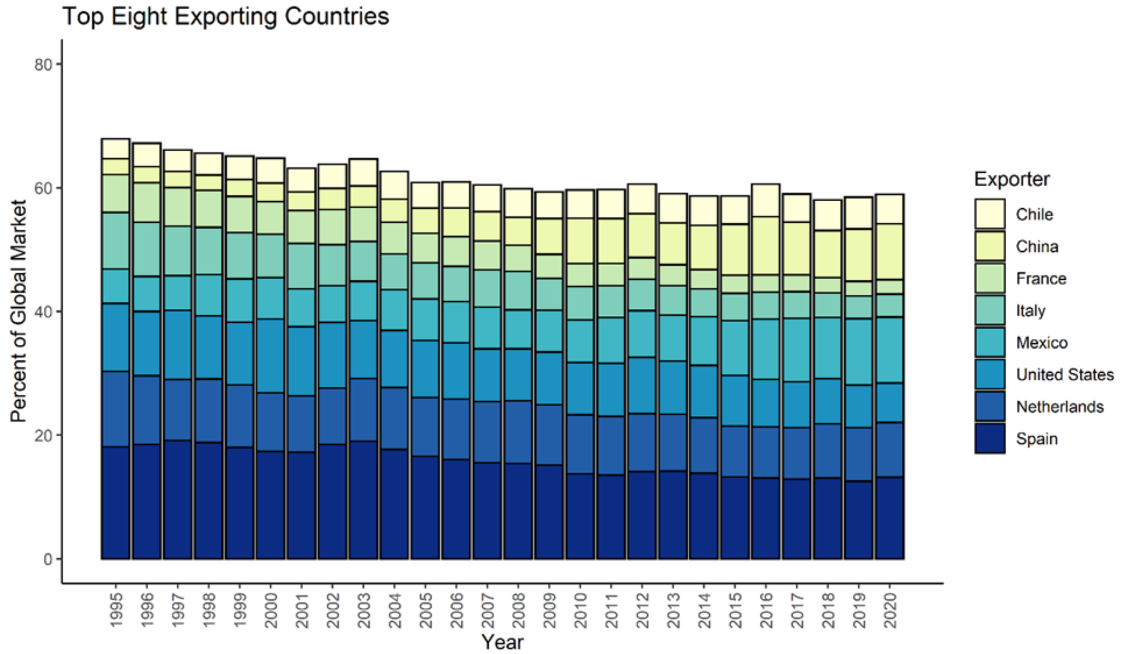
A. Gravity Model of Bilateral Trade

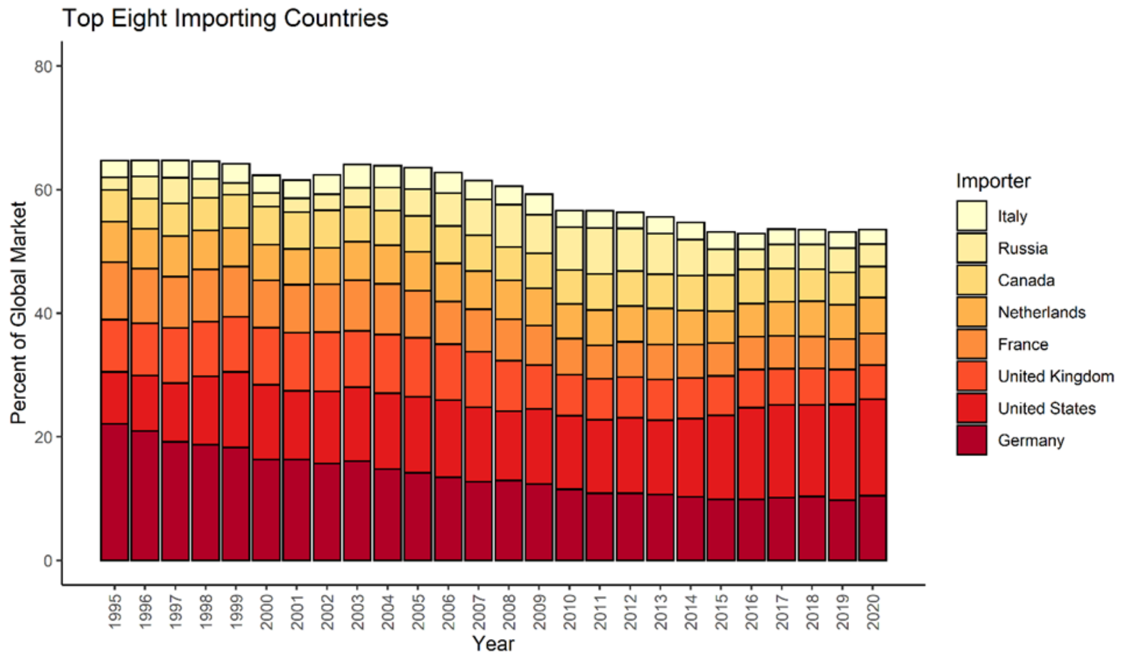
Decades of development and application of the gravity model have rendered this framework among the most successful empirical models in economics. It derives from an analogy to Newton's law of gravitation: a "mass" of goods supplied at origin *i* is attracted to a "mass" of demand for those goods at destination *j*, but this trade linkage is diminished by the physical distance between *i* and *j* (Anderson, 2011). Starting with Tinbergen (1962), the model had been widely used to explain trade flows between countries, despite the lack of rigorous economic foundations to rationalize its use. More recent theoretical advances (Eaton and Kortum, 2002; Anderson and van Wincoop, 2003) have shown that the main equations of the gravity model logically follow from minimal assumptions about the economic behavior of consumers and firms.

[6] Medians of annual sums across the five-to-six-year periods, rather than means, are calculated to reduce the effects of very small or very large trade values. Data are presented in intervals, rather than annual increments, to smooth very short-term trends.

[7] This is calculated as the median of the growth rate between the endpoints, 1995-99 and 2015-20. For some countries, the beginning point occurs after 1995-99. The median is taken, rather than the average, to reduce the effects of very small and very large percentage changes.

Figure 4
Top Eight Exporting and Importing Countries' Shares of Global Market





Notes: Data, available since 1995, are from BACI (Gaulier and Zignago, 2010) and denominated in nominal US dollars (thousands). The data are the sum of all trade values corresponding to the HS codes appearing in Table 5. Since the underlying trade data have been harmonized and reported FOB, these data may not match export values published by national governments in official reports.

Table 6
Median Annual Fresh Fruit and Vegetable Export Values, UNECE Countries and Current or Former Members of OECD FVS

	Years				
Country	*1995-99*	*2000-04*	*2005-09*	*2010-14*	*2015-20*
Albania	1,561	438	966	14,979	65,154
Andorra	2	86	370	115	27
Armenia	588	306	4,041	24,245	51,402
Australia	356,613	375,187	426,776	556,187	1,026,223
Austria	89,995	98,180	202,452	262,654	269,094
Azerbaijan	14,265	23,654	136,210	161,971	427,845
Belarus	16,417	26,171	53,596	156,510	299,556
Belgium[a]	--	1,350,982	1,973,661	1,670,405	1,593,027
Belgium-Luxembourg[a]	1,231,701	--	--	--	--
Bosnia and Herzegovina	1,931	4,151	12,764	26,038	38,687
Brazil	119,794	219,604	554,323	630,344	742,023
Bulgaria	15,430	13,516	43,233	57,588	85,869
Canada	300,860	552,252	879,374	1,147,536	1,505,214
Croatia	7,019	4,944	19,744	36,129	55,256
Cyprus	83,128	77,801	105,499	111,926	92,043
Czechia	17,540	22,354	131,635	178,321	151,330
Denmark	25,613	32,869	84,089	127,314	169,471
Estonia	2,846	2,574	7,061	9,639	8,730
Finland	12,772	6,689	9,792	13,806	11,652
France	1,723,749	1,827,697	2,509,018	2,800,932	2,576,325
Georgia	10,725	15,531	72,673	144,814	122,044
Germany	378,120	501,618	1,135,306	1,320,138	1,414,288
Greece	442,287	411,444	584,235	831,565	784,746
Hungary	104,479	94,673	138,146	168,057	158,321
Iceland	700	390	589	783	479
Ireland	123,725	143,438	185,100	212,776	192,149
Israel	404,474	338,896	563,429	643,053	573,700
Italy	2,229,781	2,163,859	3,299,519	4,030,398	3,999,439
Kazakhstan	28,851	24,959	107,855	11,383	98,505
Kenya	52,397	64,483	116,103	234,587	200,874
Kyrgyzstan	18,878	3,766	65,115	76,441	22,426
Latvia	2,585	3,010	16,133	49,695	56,621
Lithuania	20,724	24,743	324,008	710,405	225,649
Luxembourg[a]	--	4,149	28,516	13,240	18,572
Malta	3,358	2,638	3,347	6,268	2,832
Montenegro[b]	--	--	7,041	6,125	2,908
Morocco	509,030	492,580	992,445	1,380,390	2,345,212
Netherlands	2,940,719	2,906,714	6,009,705	7,601,198	8,074,617
New Zealand	342,587	313,180	436,530	632,843	776,290
Norway	2,771	2,492	3,835	4,418	2,943
Poland	167,155	226,864	918,960	1,381,444	1,247,363
Portugal	59,020	110,595	261,022	474,576	885,012

	Years				
Country	*1995-99*	*2000-04*	*2005-09*	*2010-14*	*2015-20*
Republic of Moldova	21,274	11,441	41,267	107,307	143,048
North Macedonia	28,619	17,141	53,896	107,508	105,784
Romania	34,147	27,774	48,673	73,666	81,751
Russian Federation	17,402	28,422	61,543	39,902	100,375
San Marino[c]	--	19	7	43	7
Serbia[d]	--	--	73,627	155,264	255,152
Slovakia	24,317	18,326	67,869	67,429	67,063
Slovenia	9,252	7,925	32,462	40,064	62,833
South Africa[e]	--	994,123	1,713,374	2,351,190	3,103,550
Spain	5,231,442	5,925,212	9,444,150	11,000,000	12,500,000
Sweden	14,417	21,827	60,082	69,633	70,987
Switzerland	5,691	6,075	9,588	12,898	15,170
Tajikistan	8,945	7,217	24,188	23,234	11,461
Türkiye	1,006,991	1,026,833	2,350,087	3,319,585	3,388,167
Turkmenistan	1,243	1,035	3,209	3,145	10,827
Ukraine	10,865	9,944	62,345	87,339	69,757
United Kingdom	171,671	171,298	277,247	329,547	327,147
United States	2,943,499	3,406,957	5,215,284	7,140,054	7,141,374
Uzbekistan	73,060	70,539	234,577	329,559	500,705

Notes: Data are reported in nominal US dollars (thousands). The data include all six-digit HS codes for the fruits, vegetables, nuts, and fungi listed in Table 3. Since the underlying trade data have been harmonized and reported FOB, these data may not match export values published by national governments in official reports. The United Nations does not collect data on these products for Liechtenstein or Monaco independently of Switzerland and France, respectively.

[a] Data for Belgium and Luxembourg were reported jointly as Belgium-Luxembourg until 1999. Separate data are available for each country starting in 1999.

[b] Data for Montenegro begin in 2008.

[c] Export data from San Marino were either not reported or were recorded as zeroes prior to 2000.

[d] Data for Serbia begin in 2008.

[e] Export data from South Africa were either not reported or were recorded as zeroes prior to 2000.

A verbal description of the model is as follows (Appendix C contains several of the key equations that lead to the gravity model).[8] Consumer preferences for goods are assumed to be identical across countries. A consumer in country j derives economic wellbeing from goods produced in country i, c_{ij}, with a "demand shifter" constant, α_i. In the eyes of the consumer, one country's goods can substitute for another country's goods, albeit imperfectly, according to a fixed constant, σ. Consumers maximize their wellbeing but are constrained by their budget. In particular, expenditure by consumers in country j, E_j, must equal the price of the good from country i, p_{ij}, multiplied by the number of units consumed, c_{ij}, summed over all countries. Importantly, the price of country i's good consumed in country j includes a markup that represents bilateral trade costs, t_{ij}. The solution to the consumer's maximization problem yields an equation for optimal trade flows of goods from exporter i to importer j, X_{ij}, and an equation representing an index of consumer goods prices, P_j.

International markets in traded goods are assumed to clear, i.e., there are no shortages or surpluses of goods. This implies that, at delivered prices, the value of output in country i, Y_i, equals the total spending on goods from country I summed over all countries, including itself. The value of global output, Y, is just the sum of output value in all countries.

[8] See Anderson (2011) or Yotov et al. (2016) for more details and a complete derivation of the model.

The economic optimization yields three equations that define the gravity model:

$$X_{ij} = \frac{Y_i E_j}{Y}\left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \tag{1}$$

$$\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} \frac{E_j}{Y} \tag{2}$$

$$P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i}\right)^{1-\sigma} \frac{Y_i}{Y} \tag{3}$$

Equation (1) is the theoretical gravity equation describing bilateral trade flows, consisting of a size term, $\frac{Y_i E_j}{Y}$, and a trade cost term, $\left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma}$. The size term has three implications: 1) larger producers will export greater quantities to all markets, 2) high-income destination markets will import greater quantities from all markets, and 3) trade between two countries will be larger the more both partners are similar in size (Yotov et al., 2016).

The trade cost term captures the effects of trade costs, i.e., realized trade for any two countries tends to be lower than levels that are theoretically possible in the absence of trade frictions (e.g., tariffs, quotas, technical restrictions). The direct bilateral trade costs, t_{ij}, have traditionally been approximated by distance between countries, tariff levels, or presence of trade agreements. Our approach assumes that these bilateral trade costs are lower for those countries who join the FVS. The term Π_i is the outward multilateral resistance (OMR) and represents exporter *i*'s ease of market access. Likewise, P_j is the inward multilateral resistance (IMR) and represents importer *j*'s ease of market access (Anderson, 2011; Yotov et al., 2016). Although the multilateral resistance terms are theoretical constructs and cannot be directly observed in trade data, it can nevertheless be important to control for them in empirical analysis to avoid bias in the estimated trade effects (Anderson and van Wincoop, 2003). Equations (2) and (3) show the dependence of these multilateral resistance terms on expenditures, output value, and trade costs.

B. Estimating the Effects of FVS Membership and Brochure Publication on Fresh Fruit and Vegetables Trade

It is straightforward to estimate equation (1) directly from bilateral trade data with two modifications: 1) log-linearization of the equation, and (2) addition of a zero-mean, normally-distributed error term, $\varepsilon_{ij,t}$, on the right side to account for non-systematic noise in the recorded trade data. Bilateral exports from *i* to *j* in year *t* can be analyzed using the following equation:

$$\ln X_{ij,t} = \ln E_{j,t} + \ln Y_{i,t} - \ln Y_t + \left(1-\sigma\right)\ln t_{ij,t} - \left(1-\sigma\right)\ln P_{j,t} - \left(1-\sigma\right)\ln \Pi_{i,t} + \varepsilon_{ij,t}. \tag{4}$$

Although this equation underpins much of the empirical trade literature, there are some pitfalls. First, since $\Pi_{i,t}$ and $P_{j,t}$ are unobservable, they tend to be proxied by other variables, which can be ad hoc and may give a range of results based on the chosen proxy variables. Second, the left side of equation (4) is undefined in all instances in which both countries do not trade in a given year, i.e., situations in which there are zero trade flows. Most past studies that estimate the log-linearized equation using least-squares (OLS) regression have simply dropped the zeroes from the data prior to estimation, but this could introduce bias into the estimates if the zero trade flows systematically vary with the explanatory variables. Zero flows can be problematic in international fruit and vegetables markets since it is not always possible or otherwise economically viable to transport fresh produce over long distances. Third, $\varepsilon_{ij,t}$ is assumed to have constant variance, though this is rarely true for trade data, an issue termed heteroskedasticity.

Despite these potential pitfalls, we rely on OLS regressions to analyze the trade data because interest centers on the effects of brochure publication. One method that is now frequently used to overcome the pitfalls described above is Poisson pseudo-maximum likelihood (PPML) estimation, usually with a very large number of exporter-by-year and importer-by-year fixed effects to control for the outward and inward multilateral resistances. Although theoretically desirable, we cannot use high-dimensional fixed effects because the large number of time-varying fixed effects are collinear with certain brochure publication years. Thus, we rely on a more traditional gravity model that makes use of importer and exporter GDP and population variables, in addition to time-invariant country pair fixed effects, EIA indicators, OECD indicators, and a linear time trend.

In the spirit of Sun and Reed (2010), and as partially motivated by a standard difference-in-differences framework, we apply OLS to the log-linearized model of bilateral fruit and vegetable trade to analyze the effects of individual OECD FVS brochure publications. Importantly, because we are able to directly control for whether one or both trading partners are OECD FVS members, this potentially mitigates a kind of "selection" bias resulting from estimation on non-zero trade flows. On the other hand, because any United Nations member country can benefit from the UNECE standards, it is not possible to directly control for membership, and thus we would be more concerned about potential biases resulting from estimates based on only non-zero trades. Therefore, to accommodate the many instances of zero trade, we use PPML estimation to analyze the effects of UNECE standard revision on fresh fruit and vegetable trade.

So as to limit the possibility of "effects contamination," for each regression, we restrict each sample to include only one brochure publication (OECD FVS) or standard revision (UNECE). For example, the FVS has recently published two brochures on melons: one in 2006 and another in 2014. For this regression, we thus drop data for years after 2013; years 1995-2005 are considered the "pre-publication" period, while years 2006-2013 are the "post-publication" period—on which interest centers. Similarly, the UNECE has revised its asparagus standard recently in three years: 1996, 1999, and 2010. For this regression, we drop data prior to 2000; the pre-revision period is thus considered 2000-2009, while the post-revision period is 2010-2015. In some sense, our methodology can be viewed as drawing from a difference-in-differences approach.

The two main equations of interest are:

$$ln(X_{ij,t}) = \beta_0 + \beta_1 \text{BrochurePeriod}_t + \beta_2 \text{Both}_{ij,t} + \beta_3 \text{Single}_{ij,t} + \boldsymbol{\psi}\mathbf{C_{ij,t}} + \gamma_{ij} + \zeta_t + \varepsilon_{ij,t} \quad (5)$$

$$X_{ij,t} = exp\left[\beta_0 + \beta_1 \text{StandardRevision}_t + \boldsymbol{\psi}\mathbf{C_{ij,t}} + \gamma_{ij} + \zeta_t\right] + \varepsilon_{ij,t} \quad (6)$$

In this specification, BrochurePeriod_t is an indicator variable equal to one if the brochure has been published by year *t* and zero otherwise (for the OECD FVS brochures), while $\text{StandardRevision}_t$ is an indicator variable equal to one if the UNECE standard has been revised (or first published) by year *t* and zero otherwise. Moreover, $\text{Both}_{ij,t}$ is an indicator variable equal to one if *i* and *j* are FVS members in year *t* and zero otherwise; $\text{Single}_{ij,t}$ is an indicator variable equal to one if either *i* or *j* are FVS members in year *t* (but not both) and zero otherwise; γ_{ij} is a set of time-invariant country-pair fixed effects; ζ_t is a linear time trend term; and $\varepsilon_{ij,t}$ is the error term. The linear time trend controls for the gradually increasing nature of global fruit and vegetable trade that has occurred over the sample period.

The vector $\mathbf{C_{ij,t}}$ is a set of control variables that includes the importer's and exporter's annual GDP (separate variables), the importer's and exporter's population levels (separate variables), an indicator variable equal to one if *i* and *j* belong to the OECD and zero otherwise; and a set of indicator variables for the type of EIA between *i* and *j* in year *t*, as well as separate indicator variables for whether *i* had an EIA with any country not equal to *j* in year *t* and whether *j* had an EIA with any country not equal to *i* in year *t*.

Equation (5) is estimated separately for 25 OECD FVS fruit and vegetable brochures for which there are corresponding trade data. Equation (6) is estimated separately for 37 UNECE standard revisions or first publications for which there are corresponding data. It must again be noted, as is clear from Table 5, that there is imperfect alignment between the brochure or standard and the trade data. For each estimation, the specific value of the BrochurePeriod_t or $\text{StandardRevision}_t$ variables are changed so that they align with the product and publication or revision of relevance.

C. Supplementary Difference-in-Differences (DID) Analysis

In addition to estimation of the structural gravity model, we also perform a complementary difference-in-differences (DID) analysis to shed more light on trade and the timing of membership. Callaway and Sant'Anna (2021) have developed methods that generalize the canonical DID estimator with two time periods and two groups to multiple groups having various treatment starting points, though this latter aspect of multiple groups and starting points is unimportant for our analysis. We define a "treatment" as the specific year of FVS brochure publication or UNECE standards implementation/revision for a set of FVS or UNECE countries that remain fixed across the sample period.[9] Countries that joined or exited the FVS or UNECE during 1995-2020 must be considered as "non-treated" so as to not violate the staggered treatment adoption assumption (i.e., once a "unit" participates in the "treatment," it remains "treated"). Countries that have never been FVS or UNECE members are also considered to be "non-treated" in all years. As with the gravity approach, we restrict the set of years so that only one FVS brochure publication or UNECE standard revision are included in each regression. This allows us to identify the average treatment effect on the treated (ATT) based on variation in the timing of the brochure or standard and differences in trade values between members and nonmembers. See appendix section D for details of the methodology and the assumptions needed for identification.

V. Empirical Results

We first overview and discuss the results for the OECD FVS brochure publications and then present the results for the UNECE standard revisions. For convenience, the columns of the tables correspond to products arranged in alphabetical order.

A. OECD FVS Brochure Publication

Regardless of the type of product, the regression results are consistent with the hypothesis that publication of FVS brochures has had considerable positive effects on trade in fresh fruit and vegetables (Table 7). Of the 25 brochures investigated, fully 14 indicated large and statistically significant effects on trade. In particular, in the years following publication, trade is statistically significantly larger for fruits and vegetables related to these brochures: apples (by 22%), apricots (22%), beans (25%), citrus fruits (27%), cucumbers (22%), figs (18%), grapes (9%), mangoes (29%), melons (24%), onions (23%), pears (25%), potatoes (42%), shallots (18%), and watermelons (34%). Note that all effects are with respect to the pre-brochure period. Thus, for example, the interpretation of column (1) is that, after controlling for a wide variety of economic factors deemed to affect fresh produce trade, we find that trade in apples is 22% larger in the post-brochure period (2011-15) relative to 1995-2015.

Table 7
FVS Brochure Effects on International Trade in Fresh Fruit and Vegetables

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
Brochure	*Apples*	*Apricots*	*Asparagus*	*Avocados*	*Beans*	*Broccoli*	*Carrots*
Post brochure period	0.216***	0.222***	0.101	-0.453***	0.248***	-0.527***	-0.599***
	(0.043)	(0.061)	(0.064)	(0.078)	(0.063)	(0.073)	(0.068)
N	38,692	16,169	13,517	18,812	24,429	15,044	22,510
R^2	0.68	0.66	0.71	0.70	0.64	0.71	0.67
FVS Membership	Y	Y	Y	Y	Y	Y	Y

[9] By restricting the two sets of "treated" countries to a small set of FVS and UNECE countries that had fixed membership during 1995-2020, we do not confound a brochure year effect with a "joining" or "withdrawal" effect.

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
Brochure	*Apples*	*Apricots*	*Asparagus*	*Avocados*	*Beans*	*Broccoli*	*Carrots*
Importer GDP, Exporter GDP	Y	Y	Y	Y	Y	Y	Y
Importer Population, Exporter Population	Y	Y	Y	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y	Y	Y	Y
Economic Integration Agreements	Y	Y	Y	Y	Y	Y	Y
OECD Membership	Y	Y	Y	Y	Y	Y	Y
Linear Trend	Y	Y	Y	Y	Y	Y	Y
Sample period	1995-2015	1995-2015	2001-2015	1996-2015	1995-2015	1995-2012	1995-2015
Post-brochure period	2011-2015	2010-2015	2011-2015	2004-2015	2006-2015	2000-2012	2000-2015
Percent of sample post-brochure	0.29	0.36	0.37	0.73	0.58	0.83	0.86
Interval of data	Annual	Annual	Annual	Annual	Annual	Annual	Annual
Reporting partner	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized

Note: The dependent variable is the logarithm of the value of trade to country *i* from country *j* in nominal US dollars (1,000s). Country pair fixed effects are symmetric, i.e., $\mu_{ij} = \mu_{ji}$ (Anderson and Yotov, 2016). Robust standard errors, clustered at the country-pair level, are in parentheses. Significance is denoted as *** p<0.01, ** p<0.05, * p<0.1.

Table 7 (continued)
FVS Brochure Effects on International Trade in Fresh Fruit and Vegetables

	(8)	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*
Brochure	*Citrus Fruits*	*Cucumbers*	*Figs*	*Grapes (Table)*	*Hazelnuts*	*Lettuces*	*Mangoes*
Post brochure period	0.269***	0.220***	0.181***	0.093**	-0.129	-0.175**	0.288***
	(0.039)	(0.063)	(0.064)	(0.048)	(0.088)	(0.079)	(0.043)
N	54,955	20,850	21,812	34,572	6,098	16,085	34,905
R^2	0.64	0.68	0.68	0.68	0.76	0.68	0.67
FVS Membership	Y	Y	Y	Y	Y	Y	Y
Importer GDP, Exporter GDP	Y	Y	Y	Y	Y	Y	Y
Importer Population, Exporter Population	Y	Y	Y	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y	Y	Y	Y
Economic Integration Agreements	Y	Y	Y	Y	Y	Y	Y
OECD Membership	Y	Y	Y	Y	Y	Y	Y
Linear Trend	Y	Y	Y	Y	Y	Y	Y
Sample period	1995-2015	1995-2015	1995-2015	1995-2015	2010-2015	1995-2015	1995-2015
Post-brochure period	2010-2015	2008-2015	2015	2007-2015	2011-2015	2002-2015	2012-2015

Brochure	*(8)* *Citrus Fruits*	*(9)* *Cucumbers*	*(10)* *Figs*	*(11)* *Grapes (Table)*	*(12)* *Hazelnuts*	*(13)* *Lettuces*	*(14)* *Mangoes*
Percent of sample post-brochure	0.35	0.46	0.07	0.52	0.85	0.79	0.25
Interval of data	Annual	Annual	Annual	Annual	Annual	Annual	Annual
Reporting partner	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized

Note: The dependent variable is the logarithm of the value of trade to country *i* from country *j* in nominal US dollars (1,000s). Country pair fixed effects are symmetric, i.e., $\mu_{ij} = \mu_{ji}$ (Anderson and Yotov, 2016). Robust standard errors, clustered at the country-pair level, are in parentheses. Significance is denoted as *** p<0.01, ** p<0.05, * p<0.1.

Table 7 (continued)
FVS Brochure Effects on International Trade in Fresh Fruit and Vegetables

Brochure	*(15)* *Melons*	*(16)* *Mushrooms (Cultivated)*	*(17)* *Onions*	*(18)* *Peaches and Nectarines*	*(19)* *Pears*	*(20)* *Plums*	*(21)* *Potatoes*
Post brochure period	0.241***	-0.353***	0.227***	0.064	0.254***	-0.210***	0.424***
	(0.053)	(0.067)	(0.045)	(0.056)	(0.045)	(0.059)	(0.053)
N	27,863	22,522	35,156	22,535	28,454	23,026	30,614
R^2	0.67	0.63	0.63	0.68	0.70	0.67	0.63
FVS Membership	Y	Y	Y	Y	Y	Y	Y
Importer GDP, Exporter GDP	Y	Y	Y	Y	Y	Y	Y
Importer Population, Exporter Population	Y	Y	Y	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y	Y	Y	Y
Economic Integration Agreements	Y	Y	Y	Y	Y	Y	Y
OECD Membership	Y	Y	Y	Y	Y	Y	Y
Linear Trend	Y	Y	Y	Y	Y	Y	Y
Sample period	1995-2013	1995-2015	1995-2015	1995-2015	1995-2015	1995-2015	1995-2015
Post-brochure period	2006-2013	2006-2015	2012-2015	2010-2015	2009-2015	2002-2015	2009-2015
Percent of sample post-brochure	0.49	0.56	0.23	0.35	0.40	0.77	0.40
Interval of data	Annual	Annual	Annual	Annual	Annual	Annual	Annual
Reporting partner	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized

Note: The dependent variable is the logarithm of the value of trade to country *i* from country *j* in nominal US dollars (1,000s). Country pair fixed effects are symmetric, i.e., $\mu_{ij} = \mu_{ji}$ (Anderson and Yotov, 2016). Robust standard errors, clustered at the country-pair level, are in parentheses. Significance is denoted as *** p<0.01, ** p<0.05, * p<0.1.

Table 7 (continued)
FVS Brochure Effects on International Trade in Fresh Fruit and Vegetables

	(22)	*(23)*	*(24)*	*(25)*
Brochure	*Shallots*	*Strawberries*	*Tomatoes*	*Watermelons*
Post brochure period	0.177***	0.077	-0.330***	0.338***
	(0.047)	(0.070)	(0.063)	(0.049)
N	35,156	19,558	28,927	31,670
R^2	0.63	0.67	0.66	0.67
FVS Membership	Y	Y	Y	Y
Importer GDP, Exporter GDP	Y	Y	Y	Y
Importer Population, Exporter Population	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y
Economic Integration Agreements	Y	Y	Y	Y
OECD Membership	Y	Y	Y	Y
Linear Trend	Y	Y	Y	Y
Sample period	1995-2015	1995-2015	1995-2015	1995-2015
Post-brochure period	2014-2015	2006-2015	2003-2015	2014-2015
Percent of sample post-brochure	0.12	0.58	0.71	0.12
Interval of data	Annual	Annual	Annual	Annual
Reporting partner	Harmonized	Harmonized	Harmonized	Harmonized

Note: The dependent variable is the logarithm of the value of trade to country *i* from country *j* in nominal US dollars (1,000s). Country pair fixed effects are symmetric, i.e., $\mu_{ij} = \mu_{ji}$ (Anderson and Yotov, 2016). Robust standard errors, clustered at the country-pair level, are in parentheses. Significance is denoted as *** p<0.01, ** p<0.05, * p<0.1.

There are four brochures for which trade is not significantly higher in the post-brochure period: asparagus, hazelnuts, peaches and nectarines, and strawberries. However, the coefficients are large and positive for asparagus (10%), peaches and nectarines (6%), and strawberries (8%). It is difficult to pinpoint the exact cause(s) of the insignificance, though it is worth noting that the samples underlying these regressions are small, with 13,517, 6,098, 22,535, and 19,558 observations, respectively. It is likely that the small sample sizes are resulting in large and imprecisely estimated standard errors. Moreover, it should be reiterated that the hazelnuts regression makes use of data that aggregate both shelled and in-shell hazelnuts (Table 5).

At first glance, it is puzzling that there are a small number of regressions for which there are negative, statistically significant coefficients. This is the case for avocados, broccoli, carrots, lettuces, cultivated mushrooms, plums, and tomatoes. It is likely the main reason for this is the mismatch between the products covered by the brochures and the trade data. Specifically, the trade data combines broccoli with cauliflower, carrots with turnips, and plums with sloes. Moreover, the trade data for mushrooms are without specific regard to cultivation. One possible explanation for the counterintuitive sign for lettuces includes the fact that the FVS brochure specifically covers curled-leaf endives and Batavian endives, while the data only includes trade in produce from the *lactuca sativa* family, excluding headed cabbages. Possible explanations for the avocado and tomato regressions include the well-known existence of historical trade barriers and altered trade patterns between major producers and consumers (i.e., Mexico and the United States in the case of avocados) and the complexity of production, regional trade, and wide availability of varieties (e.g., tomatoes).

Although of less major importance, we also find that trade is generally larger if both partners are FVS members. The effect of dual membership (i.e., both partners being FVS members) ranges from effectively zero to highs in excess of 100% (results not shown in Table 7). For many of these same regressions, the effect of single-country FVS membership is also positive, large, and statistically significant. Effect sizes range from zero to well over 50%. In some instances, the effect of single-country membership is insignificant or negative, likely reflecting the fact that many FVS members are trading with nonmember countries that either produce relatively less (i.e., their exports are relatively low) or consume relatively less (i.e., their import demand is relatively low).

The DID estimates, detailed here as 95% confidence intervals, supplement and broadly confirm the results from the gravity analysis (Table 8). Of the 28 products examined, we find that trade was significantly larger upon or after brochure publication (up to a total of three post-brochure years), on average, for 12 products.[10] Positive brochure year effects are found for apples, apricots, citrus fruits, grapes, lettuces, melons, peaches, plums, strawberries, and tomatoes. Negative brochure year effects were found for onions and pears. For these two products, additional analysis beyond the scope of this report is needed, though we note that the United Nations trade data combines onions with shallots and pears with quinces, so there is an imperfect match between the trade data and brochure product coverage. See Figure D1 for the usual "event study" time plots of the ATTs across years.

Table 8
Average Treatment Effects of FVS Brochure Years on Selected FVS Countries

Brochure	*Brochure Year Analyzed*	*95% Confidence Interval*
Apples	2011	[58.90, 191.40]*
Apricots	2010	[0.40, 15.01]*
Asparagus	2011	[-3.72, 12.02]
Avocados	2004	[-16.86, 33.34]
Beans	2006	[-6.66, 10.44]
Broccoli	2013	[-0.14, 25.36]
Carrots	2000	[-12.76, 2.85]
Cherries	2016	[-79.59, 32.28]
Citrus Fruit	2010	[39.91, 170.84]*
Cucumbers	2008	[-4.70, 30.03]
Figs	2015	[-5.26, 4.03]
Garlic	2017	[-24.27, 21.70]
Grapes (Table)	2007	[42.97, 184.89]*
Hazelnuts	2009	[-20.60, 20.60]
Leeks	2019	[-1.56, 10.18]
Lettuces	2002	[2.96, 26.44]*
Mangoes	2012	[-21.34, 15.20]
Melons	2006	[3.68, 48.68]*
Mushrooms (Cultivated)	2006	[-30.60, 13.35]
Onions	2012	[-50.51, -5.28]*
Peaches and Nectarines	2010	[7.43, 76.55]*
Pears	2009	[-40.85, -5.51]*
Plums	2002	[5.64, 14.91]*
Potatoes	2009	[-28.71, 28.11]
Shallots	2014	[-38.97, 6.38]
Strawberries	2006	[2.26, 37.72]*
Tomatoes	2003	[19.89, 178.22]*
Watermelon	2014	[-30.45, 4.26]

[10] It is possible to estimate ATTs for a larger set of products than in the gravity analysis because the DID approach only controls for distance between countries, which is time-invariant. The additional products are cherries, garlic, and leeks.

Note: The 95% confidence interval is the 95% simultaneous confidence band for the point estimate of the overall average treatment effect on the treated (ATT) as defined by Callaway and Sant'Anna (2021). The bands are reported in units of UDS ($1,000s). The ATT is conditional on population-weighted distance between the two trading countries. The "treated" group is a set of 16 countries that have been OECD FVS members during the entire sample period, 1995-2020, with the exception of Belgium and Luxembourg since these countries reported combined trade data to the United Nations until 1999. The set of "treated" countries are Austria, Finland, France, Germany, Greece, Ireland, Israel, Italy, Netherlands, New Zealand, Poland, Romania, South Africa, Spain, Switzerland, and Türkiye. The "treatment" (i.e., brochure publication) is assumed to start for these 16 countries in the year indicated in the second column; trade between at least one FVS member prior to these years, as well as all countries not in the set of 16, are considered to be "not treated." The estimation method is doubly robust and all dynamic effects are estimated annually up to three years before and after onset of the treatment, where possible. Sample sizes generally differ across each regression to ensure that only one brochure year has been included in the set of estimation years. Significance: * indicates the 95% confidence interval does not cover zero.

B. UNECE Standards and Standard Revisions

Evidence on the effects of the UNECE standards and standard revisions is comparable to that of the OECD FVS brochures (Table 9). Of the 37 standards and/or standard revisions examined, there are positive, statistically significant effects on trade in artichokes (35%), asparagus (27%), broccoli (11%), carrots (14%), ribbed celery (25%), citrus fruits (16%), lettuce and endives (8%), mangoes (22%), cultivated mushrooms (82%), roots and tubercles (29%), shallots (16%), tomatoes (12%), and truffles (1,418%).[11] The very large effect size for truffles reflects the ten-fold growth in global exports of truffles that occurred between 2006 and 2007—a high level of trade that was sustained through 2011 before a ten-fold decrease in exports between 2011 and 2012.

As expected, international trade for several of the product categories are not statistically significantly larger post implementation/revision of the UNECE standard relative to the pre implementation/revision period. This is the case for apples, apricots, aubergines, avocados, beans, berry fruits, Brussels sprouts, headed cabbages, cauliflower, cherries, garlic, table grapes, leeks, melons, onions, peas, pears, pineapples, potatoes (early and ware), quinces, and watermelons. This is mainly due to the much larger sample sizes and inclusion of zero trade flows, which, as described above, should be included given that "membership" (or other types of potential selection effects) cannot be directly controlled for in each regression. Another explanation can be that some changes/revisions are quite small, so a revision per se may not have a dramatic effect on trade per se (e.g. a new standard might have more impact than a revision).

Nonetheless, for these products, it is important to reiterate the mismatch between product coverage of the UNECE standard and the actual trade data. This is of particular relevance for the measure of berry fruit trade (which combines five distinct 6-digit HS codes), cauliflower trade (which also includes broccoli), table grapes (which aggregates across all types of grapes), melons (which also includes watermelons), onions (which also includes shallots), pears (which includes quinces), potatoes (which includes all potatoes other than seed), quinces (which includes pears), and watermelons (which includes melons).

As with the OECD FVS regressions, there are a small number of product categories for which trade is lower in the post-revision period prior to the pre-revision period. Products with a statistically significant, negative coefficient are cucumbers, leafy vegetables, and plums. A relatively small sample may be one underlying reason contributing to this negative outcome for leafy vegetables (24,080 observations). Somewhat more mechanically, however, the leafy vegetables trade data are comprised of various spinaches and other brassicas, whereas the UNECE standard applies to spinach, as well as watercress, rocket, turnip greens, broccoli

[11] Owing to the nonlinear nature of equation (6), to correctly interpret the percentage impact of the post-revision period, one must apply this transformation, $(exp(x) - 1) \times 100$, where x is the coefficient. For example, trade in artichokes is 35% higher during 2010-15 relative to 2004-15 as $(exp(0.30) - 1) \times 100 \approx 34.99$.

rabe, and chard. Mismatches are also inherent in the cucumber data (which incudes gherkins) and plums (which includes sloes).

Table 9
UNECE Standards and Revisions Effects on International Trade in Fresh Fruit and Vegetables

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
Standard	*Apples*	*Apricots*	*Artichokes*	*Asparagus*	*Aubergines*	*Avocados*	*Beans*
Post revision period	0.012	0.008	0.300***	0.239*	-0.004	-0.057	-0.026
	(0.032)	(0.081)	(0.065)	(0.139)	(0.079)	(0.082)	(0.063)
N	41,332	19,386	31,042	75,366	110,512	65,005	97,932
Pseudo R^2	0.82	0.84	0.81	0.94	0.87	0.93	0.93
Importer GDP, Exporter GDP	Y	Y	Y	Y	Y	Y	Y
Importer Population, Exporter Population	Y	Y	Y	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y	Y	Y	Y
Economic Integration Agreements	Y	Y	Y	Y	Y	Y	Y
OECD Membership	Y	Y	Y	Y	Y	Y	Y
Linear Trend	Y	Y	Y	Y	Y	Y	Y
Sample period	2010-2015	2010-2015	2004-2015	2000-2015	1995-2015	2004-2015	2002-2015
Post-revision period	2012-2015	2014-2015	2010-2015	2010-2015	2000-2015	2009-2015	2010-2015
Percent of sample post-revision	0.67	0.33	0.50	0.37	0.77	0.58	0.43
Interval of data	Annual	Annual	Annual	Annual	Annual	Annual	Annual
Reporting partner	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized

Note: The dependent variable is the value of trade to country *i* from country *j* in nominal US dollars (1,000s). Country pair fixed effects are symmetric, i.e., $\mu_{ij} = \mu_{ji}$ (Anderson and Yotov, 2016). Robust standard errors, clustered at the country-pair level, are in parentheses. Significance is denoted as *** p<0.01, ** p<0.05, * p<0.1.

Table 9 (continued)
UNECE Standards and Revisions Effects on International Trade in Fresh Fruit and Vegetables

	(8)	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*
Standard	*Berry Fruits*	*Broccoli*	*Brussels Sprouts*	*Cabbages (headed)*	*Carrots*	*Cauliflower*	*Celery (ribbed)*
Post revision period	0.073	0.101*	-0.131	-0.106	0.128*	-0.096	0.220**
	(0.080)	(0.060)	(0.135)	(0.071)	(0.067)	(0.077)	(0.097)
N	135,442	84,486	64,542	96,304	117,266	102,024	82,010
Pseudo R^2	0.93	0.89	0.88	0.88	0.88	0.89	0.89
Importer GDP, Exporter GDP	Y	Y	Y	Y	Y	Y	Y
Importer Population, Exporter Population	Y	Y	Y	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y	Y	Y	Y
Economic Integration Agreements	Y	Y	Y	Y	Y	Y	Y

Standard	*(8)* Berry Fruits	*(9)* Broccoli	*(10)* Brussels Sprouts	*(11)* Cabbages (headed)	*(12)* Carrots	*(13)* Cauliflower	*(14)* Celery (ribbed)
OECD Membership	Y	Y	Y	Y	Y	Y	Y
Linear Trend	Y	Y	Y	Y	Y	Y	Y
Sample period	1995-2015	2000-2015	1995-2015	1995-2015	1997-2015	1997-2015	1996-2015
Post-revision period	2010-2015	2010-2015	2010-2015	2000-2015	1998-2015	2000-2015	2010-2015
Percent of sample post-revision	0.29	0.37	0.29	0.77	0.95	0.85	0.30
Interval of data	Annual	Annual	Annual	Annual	Annual	Annual	Annual
Reporting partner	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized

Note: The dependent variable is the value of trade to country *i* from country *j* in nominal US dollars (1,000s). Country pair fixed effects are symmetric, i.e., $\mu_{ij} = \mu_{ji}$ (Anderson and Yotov, 2016). Robust standard errors, clustered at the country-pair level, are in parentheses. Significance is denoted as *** p<0.01, ** p<0.05, * p<0.1.

Table 9 (continued)

UNECE Standards and Revisions Effects on International Trade in Fresh Fruit and Vegetables

Standard	*(15)* Cherries	*(16)* Citrus Fruits	*(17)* Cucumbers	*(18)* Garlic	*(19)* Grapes (table)	*(20)* Leafy Vegetables	*(21)* Leeks
Post revision period	-0.243	0.149***	-0.118*	0.055	-0.106	-0.133**	0.129
	(0.169)	(0.045)	(0.064)	(0.093)	(0.067)	(0.065)	(0.139)
N	104,432	251,978	125,066	149,916	93,530	24,080	14,498
Pseudo R^2	0.84	0.85	0.91	0.89	0.85	0.92	0.85
Importer GDP, Exporter GDP	Y	Y	Y	Y	Y	Y	Y
Importer Population, Exporter Population	Y	Y	Y	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y	Y	Y	Y
Economic Integration Agreements	Y	Y	Y	Y	Y	Y	Y
OECD Membership	Y	Y	Y	Y	Y	Y	Y
Linear Trend	Y	Y	Y	Y	Y	Y	Y
Sample period	1995-2015	1995-2015	1995-2015	1995-2015	2004-2015	2011-2015	1997-2002
Post-revision period	2007-2015	2010-2015	2008-2015	1998-2015	2007-2015	2012-2015	2002
Percent of sample post-revision	0.43	0.29	0.38	0.86	0.75	0.80	0.17
Interval of data	Annual	Annual	Annual	Annual	Annual	Annual	Annual
Reporting partner	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized

Note: The dependent variable is the value of trade to country *i* from country *j* in nominal US dollars (1,000s). Country pair fixed effects are symmetric, i.e., $\mu_{ij} = \mu_{ji}$ (Anderson and Yotov, 2016). Robust standard errors, clustered at the country-pair level, are in parentheses. Significance is denoted as *** p<0.01, ** p<0.05, * p<0.1.

Table 9 (continued)

UNECE Standards and Revisions Effects on International Trade in Fresh Fruit and Vegetables

	(22)	*(23)*	*(24)*	*(25)*	*(26)*	*(27)*	*(28)*
Standard	*Lettuce and Endives*	*Mangoes*	*Melons*	*Mushrooms (cultivated)*	*Onions*	*Peas*	*Pears*
Post revision period	0.080**	0.195*	-0.064	0.600***	0.078	0.118	-0.035
	(0.034)	(0.105)	(0.045)	(0.143)	(0.073)	(0.097)	(0.052)
N	22,262	182,668	57,826	61,808	110,912	76,880	151,400
Pseudo R^2	0.92	0.90	0.92	0.90	0.85	0.85	0.82
Importer GDP, Exporter GDP	Y	Y	Y	Y	Y	Y	Y
Importer Population, Exporter Population	Y	Y	Y	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y	Y	Y	Y
Economic Integration Agreements	Y	Y	Y	Y	Y	Y	Y
OECD Membership	Y	Y	Y	Y	Y	Y	Y
Linear Trend	Y	Y	Y	Y	Y	Y	Y
Sample period	2010-2015	1995-2015	2007-2015	2005-2015	2002-2015	2002-2015	1995-2015
Post-revision period	2012-2015	2012-2015	2012-2015	2012-2015	2003-2015	2010-2015	2010-2015
Percent of sample post-revision	0.67	0.19	0.44	0.36	0.93	0.43	0.29
Interval of data	Annual	Annual	Annual	Annual	Annual	Annual	Annual
Reporting partner	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized

Note: The dependent variable is the value of trade to country *i* from country *j* in nominal US dollars (1,000s). Country pair fixed effects are symmetric, i.e., $\mu_{ij} = \mu_{ji}$ (Anderson and Yotov, 2016). Robust standard errors, clustered at the country-pair level, are in parentheses. Significance is denoted as *** p<0.01, ** p<0.05, * p<0.1.

Table 9 (continued)

UNECE Standards and Revisions Effects on International Trade in Fresh Fruit and Vegetables

	(29)	*(30)*	*(31)*	*(32)*	*(33)*	*(34)*	*(35)*
Standard	*Pineapples*	*Plums*	*Potatoes (early and ware)*	*Quinces*	*Roots and Tubercles*	*Shallots*	*Tomatoes*
Post revision period	0.047	-0.398***	0.025	-0.002	0.257***	0.148***	0.116***
	(0.056)	(0.108)	(0.044)	(0.053)	(0.068)	(0.033)	(0.042)
N	86,532	71,828	33,888	151,400	132,610	29,230	110,356
Pseudo R^2	0.92	0.81	0.85	0.82	0.87	0.85	0.91
Importer GDP, Exporter GDP	Y	Y	Y	Y	Y	Y	Y
Importer Population, Exporter Population	Y	Y	Y	Y	Y	Y	Y
Country Pair FE	Y	Y	Y	Y	Y	Y	Y
Economic Integration Agreements	Y	Y	Y	Y	Y	Y	Y
OECD Membership	Y	Y	Y	Y	Y	Y	Y
Linear Trend	Y	Y	Y	Y	Y	Y	Y

Standard	*(29)* Pineapples	*(30)* Plums	*(31)* Potatoes (early and ware)	*(32)* Quinces	*(33)* Roots and Tubercles	*(34)* Shallots	*(35)* Tomatoes
Sample period	2004-2015	2003-2015	2010-2015	1995-2015	1995-2015	2011-2015	2001-2015
Post-revision period	2012-2015	2004-2015	2011-2015	2014-2015	2010-2015	2013-2015	2009-2015
Percent of sample post-revision	0.33	0.92	0.83	0.10	0.29	0.60	0.46
Interval of data	Annual	Annual	Annual	Annual	Annual	Annual	Annual
Reporting partner	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized	Harmonized

Note: The dependent variable is the value of trade to country *i* from country *j* in nominal US dollars (1,000s). Country pair fixed effects are symmetric, i.e., $\mu_{ij} = \mu_{ji}$ (Anderson and Yotov, 2016). Robust standard errors, clustered at the country-pair level, are in parentheses. Significance is denoted as *** p<0.01, ** p<0.05, * p<0.1.

Table 9 (continued)
UNECE Standards and Revisions Effects on International Trade in Fresh Fruit and Vegetables

Standard	*(36)* Truffles	*(37)* Watermelons
Post revision period	2.7201***	-0.084
	(0.398)	(0.106)
N	78,834	133,926
Pseudo R^2	0.80	0.91
Importer GDP, Exporter GDP	Y	Y
Importer Population, Exporter Population	Y	Y
Country Pair FE	Y	Y
Economic Integration Agreements	Y	Y
OECD Membership	Y	Y
Linear Trend	Y	Y
Sample period	1995-2015	1999-2015
Post-revision period	2006-2015	2004-2015
Percent of sample post-revision	0.48	0.71
Interval of data	Annual	Annual
Reporting partner	Harmonized	Harmonized

Note: The dependent variable is the value of trade to country *i* from country *j* in nominal US dollars (1,000s). Country pair fixed effects are symmetric, i.e., $\mu_{ij} = \mu_{ji}$ (Anderson and Yotov, 2016). Robust standard errors, clustered at the country-pair level, are in parentheses. Significance is denoted as *** p<0.01, ** p<0.05, * p<0.1.

The DID analysis suggests several positive years effects from implementation or revision of the UNECE standards (Table 10). A total of 41 products were analyzed, of which 11 had statistically significant estimates.[12] Positive effects on trade were found for artichokes, berry fruits, celery, grapes, lettuce and endives, plums, strawberries, tomatoes, and watermelon, with negative effects on apricots and peaches and nectarines. A smaller set of products with significant impacts is found for the DID analysis relative to the gravity analysis, we hypothesize, because of the difference in underlying assumptions between the methods. For identification, the DID analysis must consider non-UNECE countries to have never been "treated" (i.e., receive an impact from the standard or standard revision). In practice, this assumption is likely to be violated since all United Nations member countries—not just

[12] Analogous to the DID analysis for the FVS brochures, we are able to estimate effects for a larger set of products than in the gravity analysis because of the use of only one control variable (distance between the trading countries). The four additional products relative to the gravity analysis include chestnuts, chicory, peaches and nectarines, and strawberries.

UNECE members—may benefit from the harmonized standards. Follow-up research is needed to examine alternative identification strategies. See Figure D2 for the standard "event study" time plots of the ATTs across the relevant years.

VI. Summary and Conclusions

The analysis suggests that, of the 39 categories of fresh fruit and vegetables considered, publication of OECD FVS brochures and implementation/revision of UNECE standards are associated with substantial increases in international trade across multiple product categories. Based on regression analysis of individual products, we find conclusive evidence that trade in various types of fresh fruits and vegetables is larger, in general, in the post-publication and/or post-revision period. Our methodology controls directly for FVS membership, countries' GDP and population levels, economic integration agreements, OECD membership, any time-invariant properties that define trade pairs (e.g., common cultures and shared histories), and any linearly-trending time effects. The effect sizes are comparable across individual products and do not appear to differ considerably based on organization (i.e., FVS or UNECE). There is also evidence suggesting that, among the first set of regressions, trade is generally larger when both trading partners are FVS members. A separate DID analysis finds evidence of positive effects on trade for a small number of years, on average, for certain FVS and UNECE member countries.

Owing mainly data limitations, we do not find that trade in fresh produce is always larger in the years following brochure publication and/or standards revision. Although it is likely this is the result of small samples and/or United Nations trade data that are not collected in such a way as to fully match the product(s) covered by the standards, there are other possible explanations. Broadly, international trade in perishable products such as fruit and vegetables involves highly sophisticated logistics and advanced storage technologies, and such trade is also subject to a number of external economic factors. Though we have made attempts to control for these relevant factors, additional control variables could be incorporated into the analysis.

Table 10
Average Treatment Effects of UNECE Standards and Revision Years on Select UNECE Countries

Brochure	*Brochure Year Analyzed*	*95% Confidence Interval*
Apples	2012	[-34.98, 26.35]
Apricots	2014	[-10.81, -0.96]*
Artichokes	2010	[0.71, 3.28]*
Asparagus	2010	[-3.60, 29.75]
Aubergines	2016	[-1.73, 5.48]
Avocados	2009	[-10.15, 42.22]
Beans	2010	[-5.19, 8.40]
Berry Fruits	2010	[17.21, 73.15]*
Broccoli	2010	[-6.45, 8.57]
Brussels Sprouts	2010	[-0.82, 4.80]
Cabbages (Headed)	2000	[-2.64, 2.92]
Carrots	1998	[-0.12, 6.71]
Cauliflower	2000	[-3.26, 2.87]
Celery (Ribbed)	2010	[0.73, 4.11]*
Cherries	2007	[-1.08, 13.46]
Chicory	2016	[-0.69, 0.36]
Citrus Fruit	2016	[-12.10, 68.19]
Cucumbers	2008	[-25.53, 12.78]

Brochure	*Brochure Year Analyzed*	*95% Confidence Interval*
Garlic	2016	[-30.78, 2.52]
Grapes (Table)	2007	[18.14, 79.43]*
Leafy Vegetables	2012	[-20.03, 15.98]
Leeks	2016	[-4.98, 9.78]
Lettuce and Endives	2012	[1.89, 12.56]*
Mangoes	2012	[-26.61, 17.58]
Melons	2012	[-15.20, 17.45]
Mushrooms (Cultivated)	2012	[-1.25, 28.14]
Onions	2019	[-12.01, 72.12]
Peaches and Nectarines	2009	[-41.30, -12.08]*
Pears	2010	[-7.17, 16.12]
Peas	2010	[-1.21, 4.24]
Pineapples	2012	[-18.75, 14.25]
Plums	2004	[1.44, 7.49]*
Potatoes (Early and Ware)	2011	[-7.19, 38.48]
Quinces	2014	[-39.86, 1.70]
Roots and Tubercles	2019	[-1.80, 4.04]
Shallots	2013	[-24.78, 22.16]
Strawberries	2002	[11.59, 34.45]*
Sweet Chestnuts	2016	[-2.80, 4.26]
Tomatoes	2017	[13.67, 95.22]*
Truffles	2016	[-0.01, 0.02]
Watermelon	2004	[5.23, 41.12]*

Note: The 95% confidence interval is the 95% simultaneous confidence band for the point estimate of the overall average treatment effect on the treated (ATT) as defined by Callaway and Sant'Anna (2021). The bands are reported in units of UDS ($1,000s). The ATT is conditional on population-weighted distance between the two trading countries. The "treated" group is the set of 52 UNECE countries with complete data, with the exception of Belgium and Luxembourg since these countries reported combined trade data to the United Nations until 1999. The "treated" countries are Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Canada, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Monaco, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Malta, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, San Marino, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Türkiye, Turkmenistan, Ukraine, United Kingdom, United States, and Uzbekistan. The "treatment" (i.e., brochure publication) is assumed to start for these countries in the year indicated in the second column; trade between at least one UNECE member prior to these years, as well as all countries not in the set of 52 countries above, are considered to be "not treated." The estimation method is doubly robust and all dynamic effects are estimated annually up to three years before and after onset of the treatment, where possible. Sample sizes generally differ across each regression to ensure that only one brochure year has been included in the set of estimation years. Significance: * indicates the 95% confidence interval does not cover zero.

There are three caveats to the analysis and findings. First, we are unable to estimate a structural gravity model that accounts for inward and outward multilateral resistances through use of importer-by-year and exporter-by-year fixed effects. This is because estimation of brochure/standard year effects must be undertaken in order to produce a through economic evaluation, which precludes use of time-varying, directional fixed effects. Although we control for numerous time-varying, country-specific factors that are likely to influence fresh produce trade (i.e., population levels, GDP, EIAs, FVS membership, OECD membership), it is possible that the estimated effects could be biased if one or more of these variables are highly correlated with a time-varying, omitted variable that is an important driver of fruit and vegetable trade. Second, the post-publication/post-revision effects cannot be entirely attributed to brochure/standard publication or revision; rather, they absorb the effect of anything that occurred in the relevant ex post period. It would be possible to redefine these variables to reflect FVS- or UNECE-specific year effects, though this redefinition would still not permit causal identification within the current framework. Third, the bilateral trade data in fresh fruit and vegetable markets are sparse, and it is unclear if the many instances of zero trade between countries are true zeroes or, instead, censored observations. Thus, it is currently unclear if the zero trade observations should be replaced with positive, imputed values—and if so, which observations and imputation methodology would need to be chosen.

The latter consideration presents opportunities for future work. Inclusion of imputed trade values could result in more realistic estimates, though it would be highly difficult to assess the accuracy of the imputed data. Regardless of any data imputation, use of regression specifications that allow for importer-by-year and exporter-by-year fixed effects, could result in more accurate estimates. However, the current data are insufficient to permit these types of models because of the degree of collinearity across the time-varying variables. Resolution of this challenge, however, would allow for estimation of country-specific membership effects on exports and prices through use of a general equilibrium, counterfactual analysis.

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Appendix A

List of economies included in the analysis

Table A1
Countries Included in the Analysis

Afghanistan	Denmark	Lebanon	Rwanda
Albania	Djibouti	Lesotho	Saint Kitts and Nevis
Algeria	Dominica	Liberia	Saint Lucia
Andorra	Dominican Republic	Libya	Saint Vincent and the Grenadines
Angola	Dutch Antilles	Lithuania	Samoa
Anguilla	Ecuador	Luxembourg	Sao Tome and Principe
Antigua and Barbuda	Egypt	Macao, China	Saudi Arabia
Argentina	El Salvador	Madagascar	Senegal
Armenia	Estonia	Malawi	Serbia
Australia	Eswatini	Malaysia	Serbia and Montenegro[a]
Austria	Ethiopia	Maldives	Seychelles
Azerbaijan	Fiji	Mali	Sierra Leone
Bahamas	Finland	Malta	Singapore
Bahrain	France	Mauritania	Slovakia
Bangladesh	French Polynesia	Mauritius	Slovenia
Barbados	Gabon	Mayotte	Somalia
Belarus	Gambia	Mexico	South Africa
Belgium	Georgia	Micronesia (Federated States of)	South Sudan
Belgium-Luxembourg	Germany	Mongolia	Spain
Belize	Ghana	Montenegro	Sri Lanka
Benin	Greece	Montserrat	Sudan
Bermuda	Greenland	Morocco	Suriname
Bhutan	Grenada	Mozambique	Sweden
Bolivia (Plurinational State of)	Guatemala	Myanmar	Switzerland
Bosnia and Herzegovina	Guinea	Namibia	Syrian Arab Republic
Botswana	Guinea-Bissau	Nepal	Tajikistan

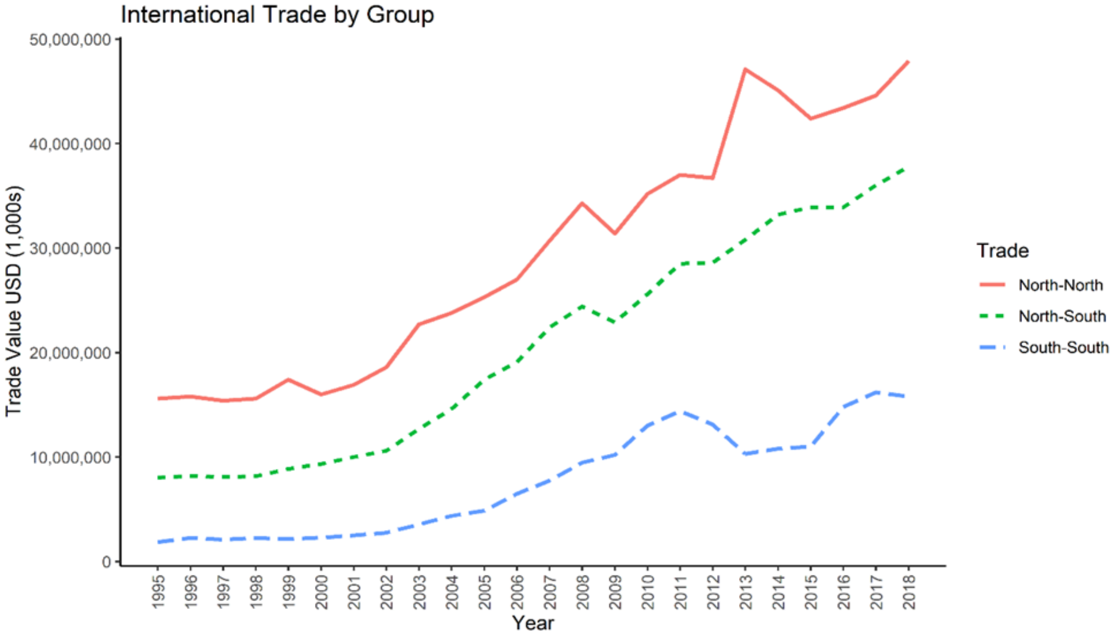
Brazil	Guyana	Netherlands	Thailand
Brunei Darussalam	Haiti	New Caledonia	Timor-Leste
Bulgaria	Honduras	New Zealand	Togo
Burkina Faso	Hong Kong, China	Nicaragua	Tonga
Burundi	Hungary	Niger	Trinidad and Tobago
Cabo Verde	Iceland	Nigeria	Tunisia
Cambodia	India	North Macedonia	Türkiye
Cameroon	Indonesia	Norway	Turkmenistan
Canada	Iran (Islamic Republic of)	Oman	Tuvalu
Central African Republic	Iraq	Pakistan	Uganda
Chad	Ireland	Palau	Ukraine
Chile	Israel	Panama	United Arab Emirates
China	Italy	Papua New Guinea	United Kingdom
Colombia	Jamaica	Paraguay	United Republic of Tanzania
Comoros	Japan	Peru	Uruguay
Congo	Jordan	Philippines	United States
Costa Rica	Kazakhstan	Poland	Uzbekistan
Côte d'Ivoire	Kenya	Portugal	Vanuatu
Croatia	Kiribati	Qatar	Venezuela (Bolivarian Republic of)
Cuba	Kuwait	Republic of Korea	Viet Nam
Cyprus	Kyrgyzstan	Republic of Moldova	Yemen
Czechia	Lao People's Democratic Republic	Romania	Zambia
Democratic Republic of the Congo	Latvia	Russian Federation	Zimbabwe

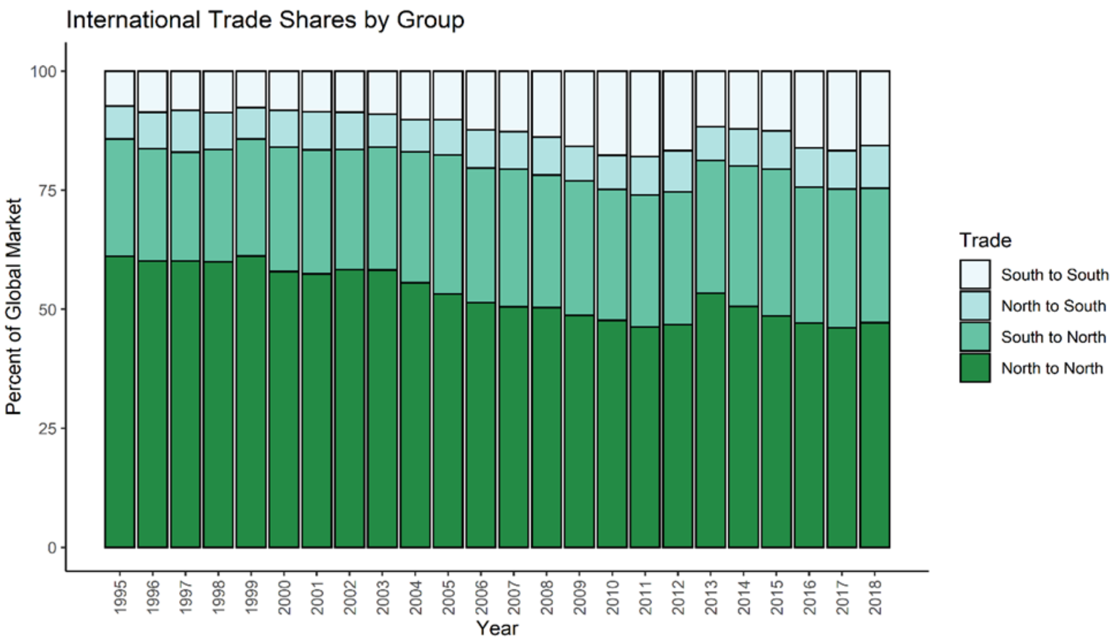
[a] Data refer to Serbia and Montenegro during the period 1992-2006.

Appendix B

The Global North and South: Descriptive Statistics

Figure B1
International Trade by OECD FVS Scheme Membership Status





Note: Trade data are from BACI (Gaulier and Zignago, 2010) and denominated in nominal US dollars (thousands). See notes for Figure 2 regarding the specific fresh fruit and vegetable categories that are included in the analysis. The North-South classifications are based on the World Bank's annual country income classifications. In any given year, countries the World Bank considers to be high income are classified as "North." Countries the World Bank considers to be upper middle income, lower middle income, or low income are classified as "South."

Appendix C

Details of the Structural Gravity Model

This section provides some of the model details and equations underlying the structural gravity system of equations (1)-(3), following closely the development presented in Anderson et al. (2011) and Yotov et al. (2016).

Consumers are assumed to have homothetic and identical preferences across countries, with a utility function that has a constant elasticity of substitution (CES) form. Countries are assumed to produce one type of good, so there are as many "varieties" as there are countries. A consumer in country j derives utility from consuming goods from i countries in the following way:

$$U(c_{ij}) = \left[\sum_i \alpha_i^{\frac{1-\sigma}{\sigma}} c_{ij}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma-1}{\sigma}}$$

Note that $\sigma > 1$ is the elasticity of substitution across goods from different countries, α_i is a preference parameter (i.e., demand shifter), and c_{ij} indicates consumption of good from country i in country j. Consumers maximize their utility function above subject to the budget constraint

$$\sum_i p_{ij} c_{ij} = E_j$$

where E_j is total spending in country j and p_{ij} is the price of the good from country i shipped to country j. This constraint embodies the fact that total spending on goods in country j must equal the number of units consumed (c_{ij}) multiplied by their consumer price (p_{ij}), summed over all possible types of goods.

Consumer prices are assumed to be equal to manufacturers' prices (i.e., factory-gate prices) in the exporting country, marked up by trade costs between the two trading countries: $p_{ij} = p_i t_{ij}$, where $t_{ij} \geq 1$.

The solution to the consumer's utility maximization problem above leads to a solution for spending on goods from country i to country j:

$$X_{ij} = \left(\frac{\alpha_i p_i t_{ij}}{P_j}\right)^{1-\sigma} E_j$$

where X_{ij} are nominal trade flows from i to j, and P_j is a CES-type consumer price index:

$$P_j = \left\{\sum_i \left(\alpha_i p_i t_{ij}\right)^{1-\sigma}\right\}^{\frac{1}{1-\sigma}}$$

To close the model, a market clearing condition is required. This condition states that the value of output in country i (Y_i) is just equal to the total spending on this country's "variety" in all countries (including itself). This means that $Y_i = \sum_j X_{ij}$, so that market clearing gives:

$$Y_i = \left(\frac{\alpha_i p_i t_{ij}}{P_j}\right)^{1-\sigma} E_j$$

Define $Y = \sum_i Y_i$, divide both sides of the above market-clearing by Y, and re-arrange to get:

$$\left(\alpha_i p_i\right)^{1-\sigma} = \frac{Y_i / Y}{\sum_j \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} \frac{E_j}{Y}}$$

We can define the term in the denominator as $\Pi_i^{1-\sigma}$, implying that $(\alpha_i p_i)^{1-\sigma} = \frac{Y_i / Y}{\Pi_i^{1-\sigma}}$.

Substitute this last expression into the equations above for trade flows, X_{ij} , and the consumer price index, P_j. These two expressions (re-arranged), combined with the definition of the (transformed) outward multilateral resistance, $\Pi_i^{1-\sigma}$, leads to the three-equation structural gravity system:

$$X_{ij} = \frac{Y_i E_j}{Y}\left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma}$$

$$\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} \frac{E_j}{Y}$$

$$P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i}\right)^{1-\sigma} \frac{Y_i}{Y}$$

Appendix D

Details of Difference-in-Differences (DID) Estimation

Callaway and Sant'Anna (2021) have developed methods for estimation of treatment effect parameters using difference-in-differences (DID) with multiple time periods, variation in treatment timing, and when the "parallel trends" assumption holds only after conditioning on observed covariates. In what follows, we provide an overview of the assumptions relevant for our application, in addition to more discussion and details of the estimated results. The presentation and discussion closely follow that of Callaway and Sant'Anna (2021).

The standard DID technique involves two time periods and two groups: both groups are untreated in the first time period, whereas only one group receives the treatment in the second time period. We use this approach for estimation. However, Callaway and Sant'Anna (2021) have shown that the canonical DiD estimator with two groups and two periods extends to greater dimensions. For group g in period t, the average treatment effected on the treated (ATT) is:

$$ATT(g,t) = E\left[Y_t(g) - Y_t(0) \mid G = g\right]$$

where $Y_t(g)$ is the potential outcome (i.e., value of tractor imports) in time period t if treated (i.e., join the codes) in period g, $Y_t(0)$ is the untreated potential outcome, and G is the time period of treatment. Generally, groups are defined by the time period when a unit becomes treated.

Main Assumptions

Let D_{it} be an indicator variable describing whether unit i has been treated by time t, i.e., $D_{it} = 1$. Assuming there are T time periods, the staggered treatment adoption assumption is:

$$D_{it} = 1 \Rightarrow D_{it+1} = 1 \text{ for } t = 1,\ldots,T.$$

That is, once a unit participates in the treatment, it remains treated. In our application, this assumption is not met with the inclusion of certain countries that have withdrawn from the FVS (e.g., the United States), and so they are considered to be non-treated.

Further, for all units in the sample, it is assumed that $(Y_1,\ldots Y_T, X, D_1,\ldots D_T)$ is independent and identically distributed, where X is a set of time-invariant covariates. This assumption implies that we have access to panel data (though not strictly necessary) and that all potential outcomes are random.

For our application, the control group, C, is the set of "never-treated" or "withdrawn" units (i.e., countries that were never FVS or UNECE members—or countries that subsequently withdrew from the FVS).

The parallel trends assumption based on never-treated units is thus:

$$E\left[Y_t(0) - Y_{t-1}(0) \mid G = g\right] = E\left[Y_t(0) - Y_{t-1}(0) \mid C = 1\right] \ \forall g = 2,\ldots T, t = 2,\ldots,T, t \geq g.$$

This states that, without treatment, average untreated potential outcomes for the group first treated at time g and for the "never treated" group would have been on parallel paths post treatment, $t \geq g$. Since there is a large group of "never treated" observations in the data, and since such observations are sufficiently similar to eventually treated observations, this assumption is preferred to an alternative parallel assumption based on use of a "not-yet-treated" control group.

This assumption can be made more plausible, and thus more likely to hold, by conditioning on pre-treatment, time-invariant covariates:

$$E\left[Y_t(0) - Y_{t-1}(0) \mid X, G = g\right] = E\left[Y_t(0) - Y_{t-1}(0) \mid X, C = 1\right] \ \forall g = 2,\ldots T, t = 2,\ldots,T, t \geq g.$$

Consistent with traditional empirical gravity model estimation, we condition on the logarithm of distance between countries (CEPII, Mayer and Zignago, 2011). This is because international tractor trade, absent countries' accession to the codes, would be expected to depend on distance between trading partners.

There are two other assumptions. First, the "limited treatment anticipation" assumption restricts anticipation of the treatment for all "eventually treated" groups, though this can be relaxed to incorporate situations in which the analyst has a good understanding of anticipatory behavior. The second assumption is an overlap condition that excludes "irregular identification"; a non-zero fraction of the population starts the treatment in g and that, for all g and t, the generalized propensity score is uniformly bounded away from one.

Discussion

Under the never-treated version of the parallel trends assumption, the group-time ATT is:

$$ATT(g,t) = E\left[Y_t - Y_{g-1} \mid G = g\right] = E\left[Y_t - Y_{g-1} \mid C = 1\right].$$

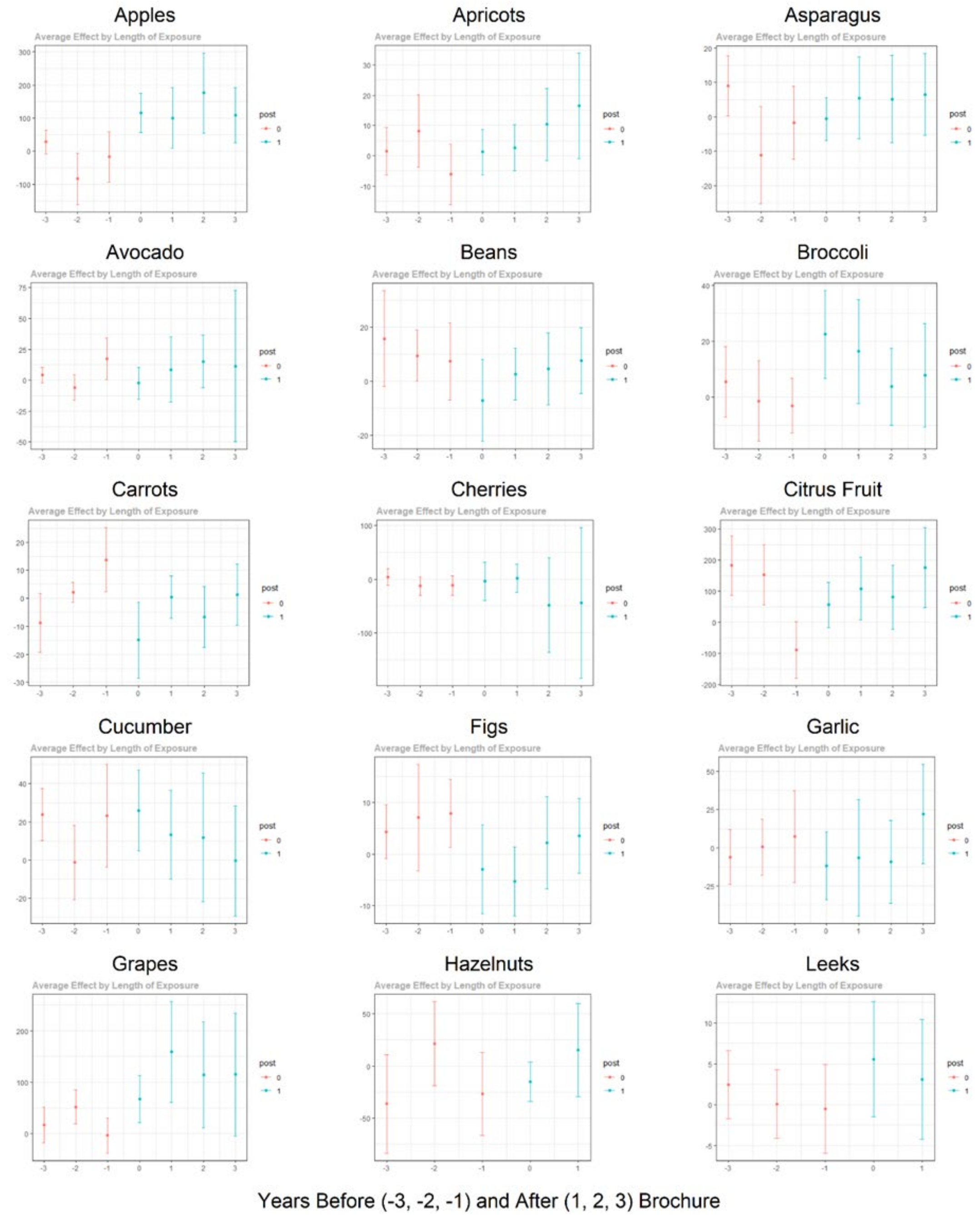
In our application, there are multiple estimated ATTs. Importantly, a country is considered treated if it is the importing country or exporting country. This is distinct from our main gravity analysis, in which there is some focus on the impacts of both partners being members.

In light of the many estimated ATTs, it is useful to consider ways of summarizing the results. To this end, we examine how the treatment effect varies by elapsed treatment time, which is the subject of event study analyses. The average effect of participating in the treatment for the group of observations that have had the treatment for exactly *e* time periods is:

$$\theta_D = \sum_{g=2}^{T} 1\{g + e \leq T\} ATT(g, g+e) P(G = g \mid G + e \leq T).$$

In this expression, $1\{g + e \leq T\}$ is the indicator function and $P(G = g \mid G + e \leq T)$ is a group-specific weight that allows for the calculation of the weighted average, Θ_D. It is this calculation that underlies estimate of the 95% confidence intervals in Tables 8 and 10.

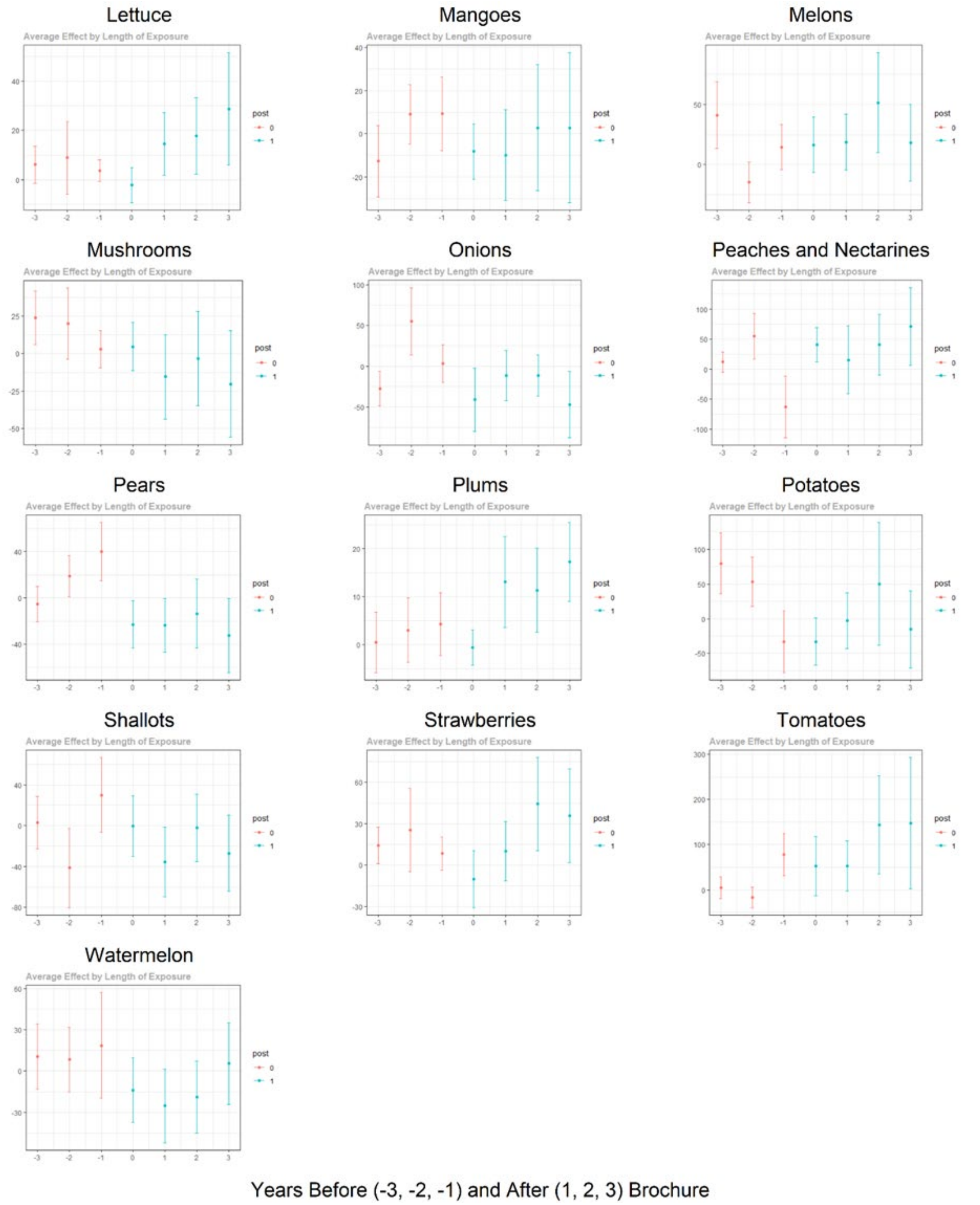
Figure D1
Dynamics of Overall ATTs for FVS Brochures



Notes: Table 8 presents group-time average treatment effects on the treated based on these underlying point estimates. The 95% intervals are simultaneous confidence bands that are robust to multiple hypothesis testing. Note that “post” = 0 in red indicates pre-treatment years, while “post” = 1 indicates post-treatment years.

Figure D1

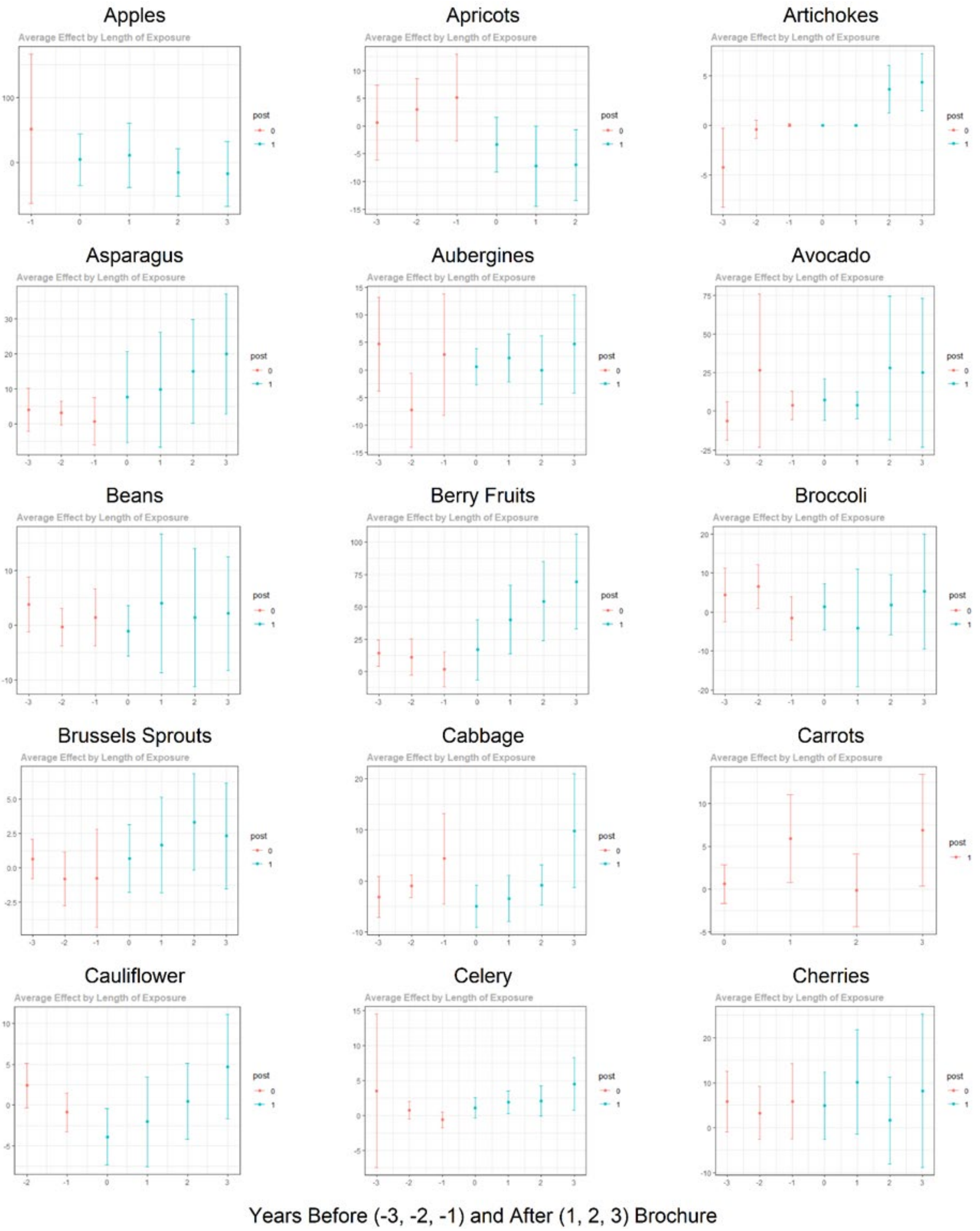
Continued. Dynamics of Overall ATTs for FVS Brochures



Notes: Table 8 presents group-time average treatment effects on the treated based on these underlying point estimates. The 95% intervals are simultaneous confidence bands that are robust to multiple hypothesis testing. Note that “post” = 0 in red indicates pre-treatment years, while “post” = 1 indicates post-treatment years.

Figure D2

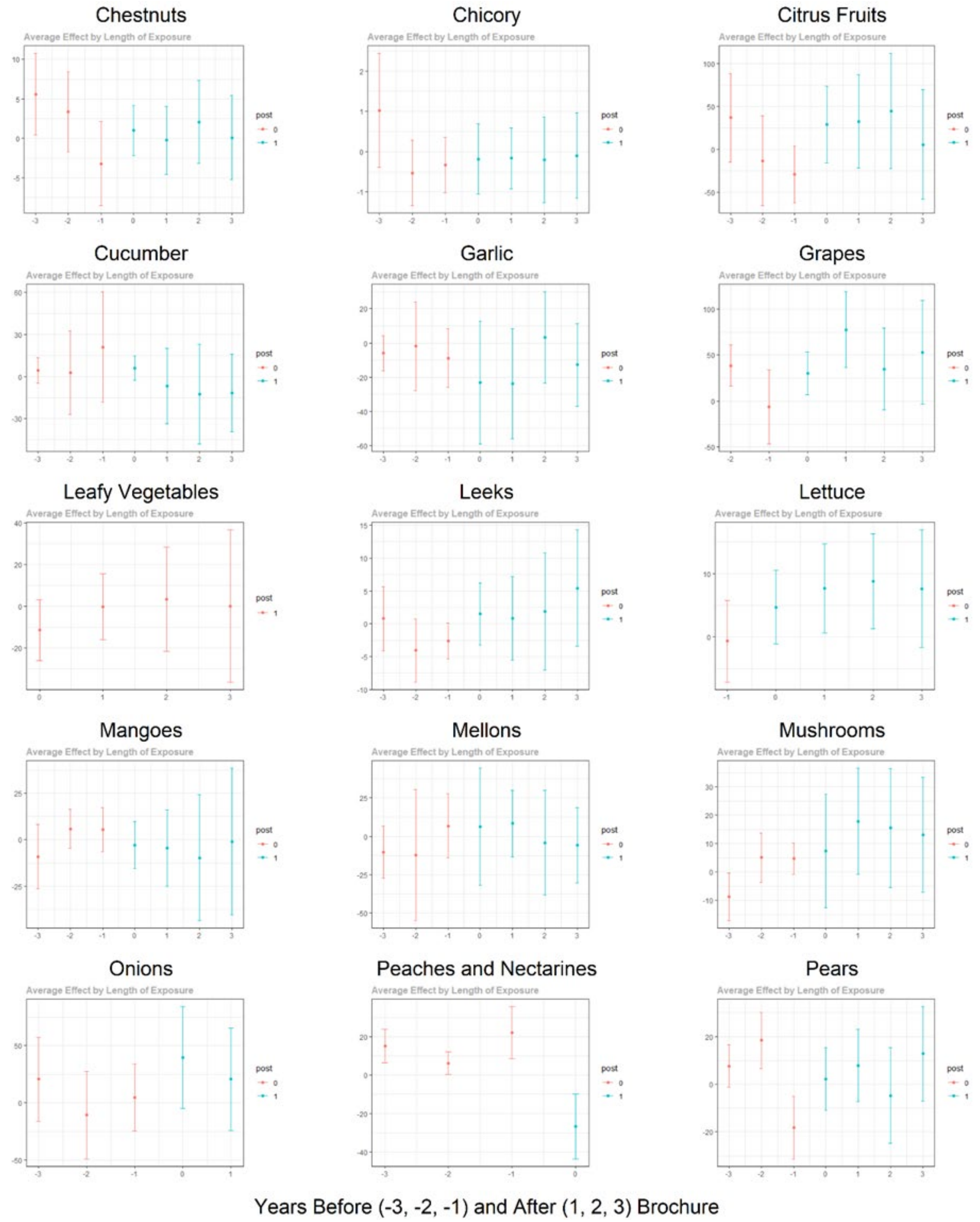
Dynamics of Overall ATTs for UNECE Standards and Revisions



Notes: Table 10 presents group-time average treatment effects on the treated based on these underlying point estimates. The 95% intervals are simultaneous confidence bands that are robust to multiple hypothesis testing. Note that "post" = 0 in red indicates pre-treatment years, while "post" = 1 indicates post-treatment years.

Figure D2 (continued)

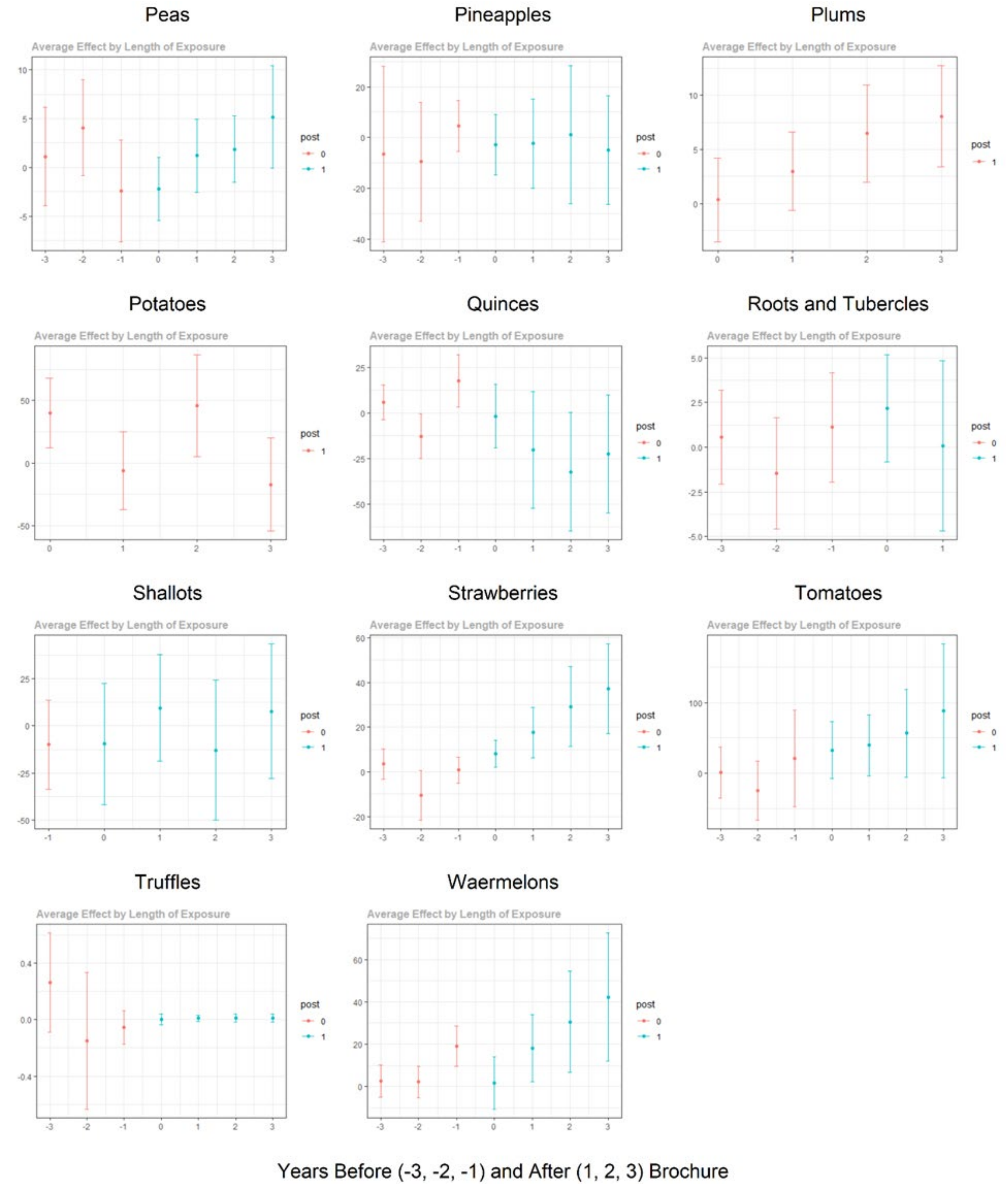
Dynamics of Overall ATTs for UNECE Standards and Revisions



Notes: Table 10 presents group-time average treatment effects on the treated based on these underlying point estimates. The 95% intervals are simultaneous confidence bands that are robust to multiple hypothesis testing. Note that "post" = 0 in red indicates pre-treatment years, while "post" = 1 indicates post-treatment years.

Figure D2 (continued)

Dynamics of Overall ATTs for UNECE Standards and Revisions



Notes: Table 10 presents group-time average treatment effects on the treated based on these underlying point estimates. The 95% intervals are simultaneous confidence bands that are robust to multiple hypothesis testing. Note that “post” = 0 in red indicates pre-treatment years, while “post” = 1 indicates post-treatment years.