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U.S. DEPARTMENT OF AGRICULTURE

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Methodology of the USDA, Economic Research Service's Agricultural Trade Multipliers

Steven Zahniser, Wendy Zeng, Fengxia Dong, Maros Ivanic, Megan Husby, Xuan Pham, and Douglas Meade

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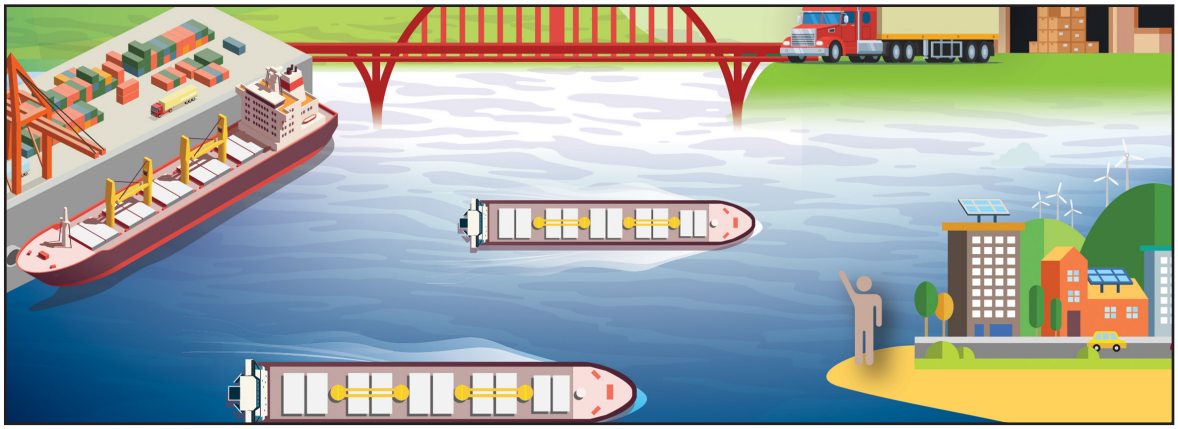

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Abstract

USDA's Economic Research Service (ERS) produces the Agricultural Trade Multipliers (ATMs)—a data product that provides annual estimates of the economic output and number of jobs supported by U.S. agricultural trade, with detail for 124 product groups. The ATMs are a resource for government agencies, academics, and other stakeholders to estimate the effect that U.S. agricultural trade has on the farm and nonfarm sectors of the U.S. economy and the contribution of U.S. agricultural exports to employment and economic output. In 2021, ERS researchers overhauled the computer programming used to estimate the multipliers to implement an approach that was more streamlined and automated while retaining the structure of the existing model. This bulletin outlines the methodology used in the new programming to access the data needed to estimate the ATMs and to utilize that information to calculate the estimates.

Keywords: Agricultural Trade Multipliers, ATM, exports, imports, agricultural trade, output, jobs, employment

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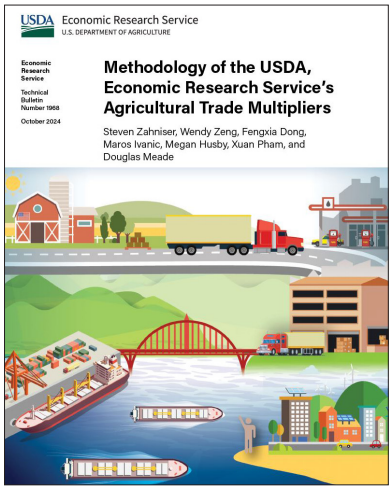


What is the Issue?

USDA, Economic Research Service (ERS) produces the Agricultural Trade Multipliers (ATMs)—a data product providing annual estimates of the economic output and number of jobs supported by U.S. agricultural trade. The ATMs are used by government agencies, academics, and other stakeholders to gauge the effect that U.S. agricultural trade has on the farm and nonfarm sectors of the U.S. economy and the contribution of U.S. agricultural exports to employment and output. In 2021, USDA, ERS created a new program to estimate the ATMs and revised its ATM methodology. Supply-use tables (made up of supply tables and use tables) are a key input for the new program. The supply tables detail the domestically produced goods and services and imports available for domestic use in the economy, while the use tables show how this supply is used across the U.S. economy in terms of intermediate inputs, final demand, and value added.

What Did the Study Find?

The ATMs rely on an empirical approach called "input-output analysis" that explores the quantity of inputs needed to obtain one unit of output. To quantify the economic activity and employment supported by U.S. agricultural exports, the new computer program used to estimate the ATMs draws upon multiple data sources. These include trade data from the U.S. Department of Commerce's Bureau of the Census, supply-use tables from the U.S. Department of Commerce's Bureau of Economic Analysis, farm sector cash receipts data from USDA, ERS, and employment data from the U.S. Department of Labor's Bureau of Labor Statistics and from USDA's Agricultural Resource Management Survey (ARMS). Together, these data are used to calculate the number of jobs and the total value of the economic activity supported by each dollar of U.S. agricultural exports. The employment and output estimates are calculated separately for 124 agricultural product groups, from soybeans to essential oils.

How Was the Study Conducted?

The USDA, ERS researchers who wrote the new computer program for calculating the ATMs also constructed an annotated version. The notes to the computer program were then used to write a description in nontechnical language of how the program works—including the main steps taken by the program to generate the ATMs, the data sources used in the ATM model, and how these data were utilized. The new program contains several features:

- It directly extracts most of the data from the publicly available Federal Government databases used in the ATM model;
- It is written in the R Language, an open source and free programming language for statistical computing and graphics that can run on a variety of operating systems and computing platforms; and
- The steps for generating the multipliers are all contained within a single R program.

These features were incorporated in the ATMs to lower the probability of human error, increase the calculating and processing speed, and provide a platform to conduct subsequent research using the multipliers that would allow for better replicability and transparency of the model.

Methodology of the USDA, Economic Research Service Agricultural Trade Multipliers

Introduction

The Agricultural Trade Multipliers (ATMs) are a data product published by USDA's Economic Research Service (ERS). The multipliers provide annual estimates of the output and employment effects of agricultural trade on the U.S. economy. For exports, the multipliers measure the dollars of domestic economic activity and the number of jobs supported per dollar of U.S. agricultural exports. In 2021, for example, the United States exported $177.3 billion in agricultural products. According to the ATM estimates for that year, each $1 billion of these exports supported 6,939 jobs, and each $1.00 of these exports supported $2.07 of economic activity throughout the U.S. economy (Zeng et al., 2023).[1] In addition, the multipliers offer an overview of the economic activity that would have occurred in the absence of U.S. agricultural imports. This information is presented for different major sectors of the economy (agriculture, food processing, other manufacturing, and services, trade, and transportation) and for trade in bulk and nonbulk agricultural products.

The ATMs also include detailed estimates of the value of output and number of jobs supported by U.S. exports in 124 agricultural product groups at either the producer's stage (the completion of production) or the port stage (the exportation of the product).[2] For instance, soybeans are one of the leading U.S. agricultural exports, with $27.5 billion in exports in 2021 (USDA, Foreign Agricultural Service, 2023). Using the producer-value multiplier, each $1 billion of these exports supported 5,599 jobs, and each $1.00 of the exports supported $1.44 of economic activity throughout the U.S. economy. Using the port value multiplier and the ATM default margin shares for soybeans at 84 percent for the producer, 15 percent for transportation, and 2 percent for wholesale and retail trade, each $1 billion of U.S. soybean exports in 2021 supported 6,702 jobs, and each $1.00 of these exports supported $1.72 of economic activity (USDA, ERS, 2022a).[3] Because the ATMs improve the public's understanding of the linkages between U.S. agricultural trade and the domestic farm and nonfarm economies, they are used by a broad set of public and private sector stakeholders.

The ATMs are rooted in work conducted by USDA, ERS researchers during the 1970s and 1980s (e.g., Schluter, 1972; Henry & Schluter, 1985; Schluter & Edmondson, 1989). During the 1980s and 1990s,

[1] The ATMs are currently calculated with biodiesel included as an agricultural product, given that soybean oil is the largest feedstock for U.S. biodiesel production, even though biodiesel is not classified by USDA as an agricultural product. The inclusion of biodiesel added about $718 million to U.S. agricultural exports in 2021 and brought the total value of U.S. agricultural exports to $177.3 billion. Without biodiesel, U.S. agricultural exports totaled $176.6 billion in 2021, according to the trade figures available when the ATMs for 2021 were estimated.

[2] In this technical bulletin, the word "port" is used in two different contexts. First, the ATM estimates of the jobs and economic activity supported by U.S. agricultural exports include port-level estimates that reflect the value of the product at the port where it departs the United States. Second, the international trade statistics used to estimate the ATMs contain details on the U.S. ports of entry where exports depart and imports arrive, but we do not use that level of detail in our analysis and rely instead on export and import statistics aggregated at the national level.

[3] Zeng and Dong (2022b) illustrate the economic activity supported by U.S. soybean exports using the ATMs for 2020. The default margin shares add to 101 rather than 100 due to rounding.

this research generated periodic papers, overviews of the ATMs (e.g., Schluter & Edmondson, 1994), and two- to three-page synopses (e.g., Edmondson, 1986, 1996) published in *Foreign Agricultural Trade of the United States (FATUS)*, a discontinued USDA hardcopy publication that reported U.S. agricultural trade statistics.[4] After the USDA, ERS website was created in the late 20th century, the ATMs eventually transitioned to become a USDA, ERS data product (USDA, ERS, 2022), featuring annual data overviews (e.g., Zeng et al., 2023; Zeng & Dong, 2022a; Zahniser & Meade, 2021; Zahniser et al., 2020; Persaud, 2019a, 2018, 2017) and methodological descriptions, complemented by summary publications and graphics (e.g., Zeng et al., 2022; Zeng & Dong, 2022b; Scott, 2020; Persaud, 2019b, 2017, 2015, 2014).

Underlying the current multipliers is an input-output (I/O) model based on the national benchmark table for 2012. This table is complemented with additional information for the calendar year examined (2021 for the ATMs released in March 2023), including agricultural trade values, farm sector cash receipts, sectoral employment data, and employment data for specific production specialties within agriculture. Together, this information is used to estimate the relationship between employment and output on the one hand and agricultural trade on the other.

In 2021, USDA, ERS researchers wrote a single computer program to replace the sequence of computer programs and manual data manipulations previously used to produce the ATMs. This new program contains several useful features:

- The program directly extracts most of the data from the publicly available Federal Government databases used in the ATM model;
- The program is written in the R Language, a free and open-source programming language for statistical computing and graphics that can be operated on a variety of operating systems and computing platforms; and
- The steps for generating the multipliers are all contained within a single R program.

These features were incorporated within the ATMs with the intent of lowering the probability of human error, increasing the speed at which the ATMs could be calculated, processed, and published, and providing a platform for conducting subsequent research using the multipliers that would allow for better replicability and transparency of the model.

This technical bulletin provides an overview of the new computer program, including the main steps taken to generate the ATMs, the data sources, and how these data were utilized.

Input-Output Models

Underlying USDA, ERS's ATM Model is an empirical approach pioneered by the late Wassily Leontief, who revolutionized economic analysis by introducing the concept of Input-Output (I/O) tables. I/O

[4] USDA, Economic Research Service (2023) uses trade statistics from the U.S. Department of Commerce, Bureau of the Census to produce the Foreign Agricultural Trade of the United States (FATUS) data product that presents summary tables for different aspects of U.S. agricultural trade by month, calendar year, and fiscal year. This USDA, ERS data product relies on the FATUS classification scheme, one of several product-classification methods used by USDA to analyze agricultural trade. In addition, U.S. agricultural trade statistics may be downloaded from the *Global Agricultural Trade System* (*GATS*), an online database compiled by USDA, Foreign Agricultural Service (2023) that also uses the trade data collected by the Census Bureau.

tables "indicate how much each industry requires of the production of each other industry in order to produce one dollar of its output" (Nasdaq, 2023). Leontief outlined the I/O approach around the 1930s (Nobel Prize, 2023) and constructed the first modern I/O tables for the U.S. economy, covering the years 1919, 1929, and 1939. Leontief's I/O model deviated from earlier models by providing "a practical extension of the classical theory of general interdependence" (Leontief, 1987, as cited by Kurz and Salvadori, 2006). This innovative framework allows us to view the entire economy as a single interconnected system and continues to influence economic analysis and policy decisions globally (Streitwieser, 2011).

Grounded in the I/O framework, the ATM Model shares several strengths with I/O models:

- The ATM Model is comprehensive, capturing the interrelationships between different sectors of the economy;
- The ATM Model generates quantifiable results—namely, the output and employment multipliers by agricultural product group—allowing for precise comparisons and assessments of the economic activity connected to agricultural exports; and
- Since assumptions and calculations in I/O models are transparent and well-documented, the estimates generated by the ATM Model are consistent, credible, and understandable.

However, the ATM Model also inherits some weaknesses from I/O models. For example, I/O models are often static, assuming fixed relationships between inputs and outputs, potentially limiting their ability to adequately reflect dynamic changes in technology, consumer behavior, and market conditions. I/O models may rely on assumptions about factors such as no input substitution, constant returns to scale,[5] and fixed proportion of inputs, which might not always align with reality and can affect the model's outcomes. Moreover, it is assumed that each industry produces its output using a distinct set of inputs, though in reality, the inputs required for the industry's products may vary substantially (Horowitz & Planting, 2009). In addition, I/O models often assume that each industry's production capacity is fixed, potentially overlooking production bottlenecks or adjustments in response to changes in demand or prices (Casler, 2004; Munroe & Biles, 2005).

Another important weakness is that I/O models typically contain no supply-side constraints, meaning that the model allows for additional economic activity to occur without any competition with other economic activities for inputs or resources (Australian Bureau of Statistics, 2015). However, in its presentation of its Agricultural Trade Multipliers, USDA, ERS is careful not to represent the ATMs as a measure of the changes to employment and output resulting from a counterfactual increase or decrease in agricultural exports. Instead, the ATMs are presented as a measure of the employment and economic activity supported by agricultural exports in a given calendar year.

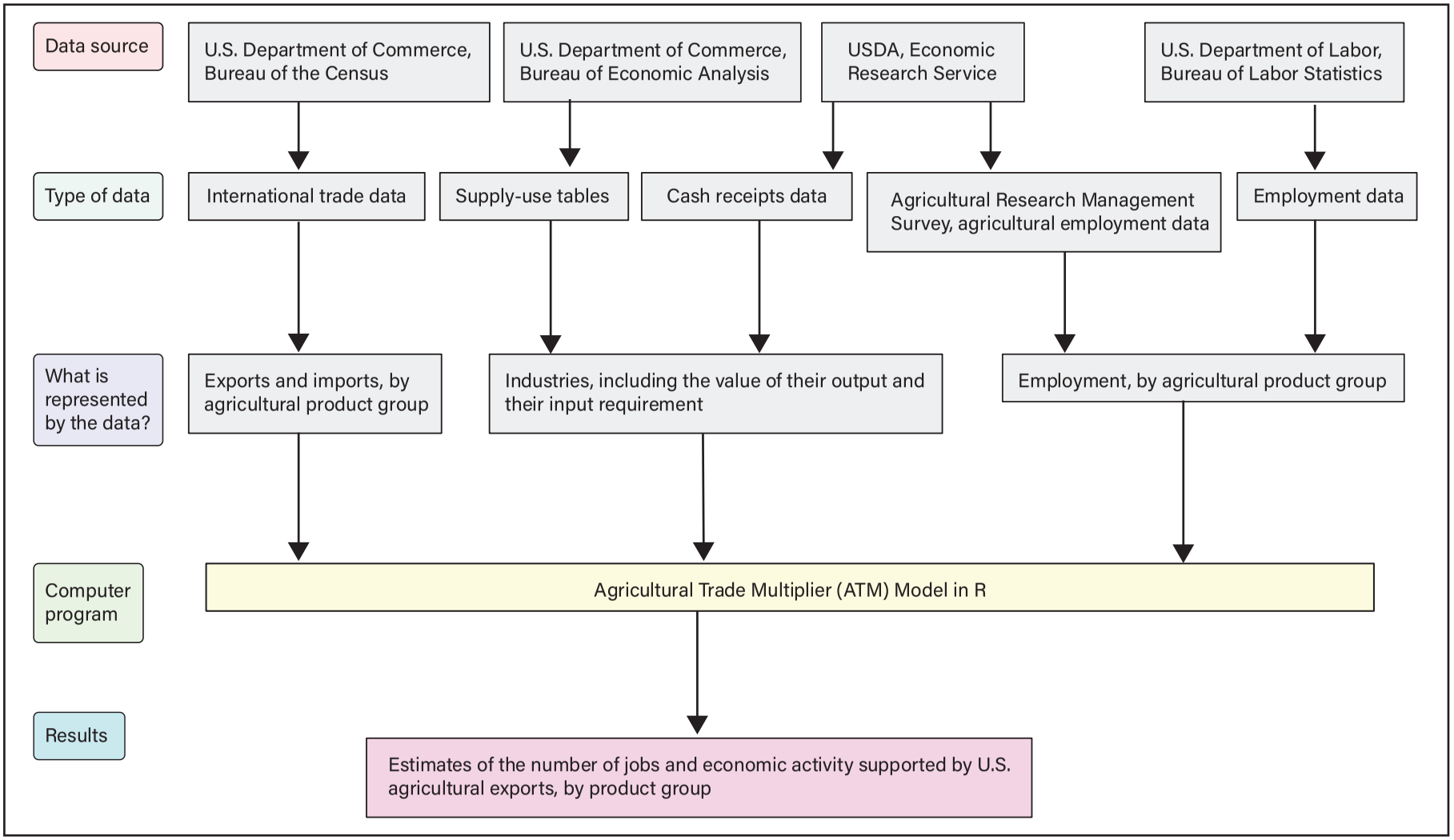
Finally, the simplification of focusing on a single calendar year ignores longer-term economic relationships that span one or more calendar years. Investments in physical and human capital and expenditures on research and development commonly affect the levels of future output. In addition, the marketing years for agricultural commodities do not neatly align with the calendar year. For instance, corn harvested in the autumn of one calendar year might be exported or fed to domestic livestock in the following calendar year.

[5] In a firm with constant returns to scale, a proportionate change in all inputs results in an increase in output by the same proportion. For instance, if a soybean farm has constant returns to scale, a doubling of all inputs (land, number of labor hours, number of seeds planted, quantity of fertilizer applied, etc.) will result in a doubling of the quantity of soybeans harvested.

Data Overview

USDA, ERS annually estimates the ATMs for the most recent calendar year for which U.S. international trade data are available. The open model of economic activity used to generate this data product measures the direct and indirect effects of agricultural trade; that is, the effects of sales and purchases between all goods and services sectors of the domestic economy, sales to final demand (e.g., consumption, investment, government, and net exports), and input purchases (land, labor, and capital). To make the ATMs, USDA, ERS utilizes several datasets published by the Federal Government, including U.S. trade data, farm sector cash receipts, employment and wages by industry, and supply-use tables (figure 1).

Figure 1
Data sources and how they are used to generate the Agricultural Trade Multipliers



Source: USDA, Economic Research Service.

Trade Data

The international trade data used in the ATMs come from the U.S. Department of Commerce's Bureau of the Census (Census Bureau) (U.S. Department of Commerce, Bureau of the Census, 2022c). These data consist of detailed statistics on goods and estimates of services shipped to and from approximately 240 U.S. trading partners through 400 U.S. ports located in 45 U.S. customs districts.[6] The Census Bureau publishes its national trade statistics monthly, along with year-to-date totals, from continuously compiled data based on "automated forms and reports filed initially with the U.S. Customs Service or, in some cases, directly with the Census Bureau, for virtually all shipments leaving (exports) or entering (imports) the United States" (U.S. Department of Commerce, Bureau of the Census, 2022a)—with the exception of exports to Canada, which are compiled from the Canadian Government's import data. The Census Bureau is the official source of monthly statistics on U.S. exports and imports.[7]

Input-Output Accounts

In addition to the trade data, the ATMs use the national I/O tables from the U.S. Department of Commerce's Bureau of Economic Analysis (BEA) in a supply-use framework, which conforms to international economic accounting standards (Young et al., 2015).[8] The supply table details the domestically produced goods and services and imports available for domestic use in the economy, with industries and imports appearing across columns and commodities across rows. Each cell of the supply table indicates how much of each commodity is produced domestically on average across industries and how much is imported. In addition, the supply table provides information on valuation adjustments, including trade margins, transportation cost, import duties, tax on products, and subsidies.

The use table shows the use of goods and services across the U.S. economy. It consists of three sections: intermediate inputs, final demand, and value added. As in the supply table, industries appear across columns and commodities across rows. Each cell in the intermediate inputs section indicates how much of a commodity is purchased by each industry as an intermediate input into the industry's production process. The final demand section includes expenditure-side components of Gross Domestic Product (GDP) such as personal consumption expenditures, private investment, exports of goods and services, and government consumption expenditures and gross investment. The value-added section contains information on returns to labor (compensation of employees), returns to capital (gross operating surplus), and returns to government (other taxes on production). The sum of both intermediate and final uses of each commodity valued at purchasers' prices in the use table is equal to the total supply at purchasers' price in the supply table.

BEA publishes its most detailed benchmark I/O tables approximately every 5 years, with the data describing the U.S. economy as it existed about 4 to 6 years earlier. The most recent set of benchmark tables was released in November 2018 and covers the year 2012 (U.S. Department of Commerce,

[6] U.S. Department of Commerce, Bureau of the Census (2022a) provides information about the scope and coverage of the Census Bureau's foreign trade program and its statistics.

[7] The Census Bureau's *USA Trade Online* (U.S. Department of Commerce, Bureau of the Census, 2023) is an online database providing access to current and cumulative data for U.S. exports and imports.

[8] Horowitz and Planting (2009) provide a thorough explanation of the concepts and methods of the I/O tables.

Bureau of Economic Analysis, 2018). Benchmark tables are fully integrated with the annual industry and national income and product accounts, resulting in a detailed view of the U.S. economy. BEA also produces annual I/O tables, but these have less detail than the benchmark tables. The annual tables divide the economy into 73 commodities and industries, compared with 405 in the benchmark table. The ATMs use the most recent benchmark supply-use table and the annual table for the calendar year examined to produce an estimated supply-use table with 405 commodities; this process is described in further detail below.

The new ATM program (first estimated for calendar year 2020) contains one methodological change regarding the input-output data and their definition: the new program uses a supply-use framework (as mentioned above), while the ATM estimates for calendar years before 2020 relied on a make-use approach. The make-use tables—which, like the supply-use tables, come from BEA—specify by industry the production and consumption of commodities. However, the make-use tables for recent calendar years were not available when the new ATM program was being developed, which led to the decision to rely on the supply-use tables instead. At the time of this technical bulletin, however, both the supply-use tables and the make-use tables were available from BEA for 15- and 71-industry disaggregations of the U.S. economy through calendar year 2022 (U.S. Department of Commerce, Bureau of Economic Analysis, 2024).

Switching to the supply-use framework enables the ATM model to incorporate the total domestic supply of goods and services from domestic and foreign producers and how this supply is used across the U.S. economy as an alternative to the make-use table methodology. The supply-use tables now used in the ATMs provide data before the redefinitions, while the previously used make-use tables contain data after redefinitions. Data before redefinitions represent the industries' outputs as reported to BEA, while data provided after redefinitions represent the industries' outputs where the output value of the secondary commodities, defined as goods or services produced by an industry other than the primary product of that industry, has been attributed to the industry that produces those commodities as primary commodities. Because of differences in the definition of industries, the data before and after redefinitions are not directly comparable. Even though the commodity totals match, the industry sizes are different.

Farm Sector Cash Receipts

The ATM model also incorporates farm sector cash receipts data from the USDA, ERS Farm Income and Wealth Statistics (USDA, ERS, 2023). These data augment the industry and commodity outputs in the supply-use tables by providing additional detail on agricultural sectors. For example, oilseed farming in the BEA data is disaggregated into soybeans and other oilseeds based on the estimates of the ratios of their cash receipts to the sum of their cash receipts. In addition, when a sector is split this way, elements of the supply and use table are allocated in a way that is internally and mutually consistent. This is accomplished by ensuring that the total use is equal to the total supply of the commodity. Farm sector cash receipts draw upon data from published and unpublished sources from USDA's National Agricultural Statistics Service (NASS), the annual Agricultural Resource Management Survey (ARMS) Phase III (also produced by NASS),[9] and Commodity Credit Corporation (CCC) loan data from USDA's Farm Service Agency.

[9] More information on the ARMS survey can be found at USDA, ERS, Agricultural Resource Management Survey Team (*2022*).

USDA, ERS farm sector cash receipts capture 94 percent of the total value of State cash receipts at the individual commodity level. Each crop's national cash receipts estimate is the sum of the States' annual estimates. Farm sector cash receipts data are released three times a year.[10]

Employment Data

The labor requirements for the model are drawn from the ARMS and from national industry and employment data in the Employment Projections (EP) produced by the U.S. Department of Labor's Bureau of Labor Statistics (BLS). These data are used to estimate the number of jobs associated with agricultural and nonagricultural activities in the U.S. economy. Many agricultural jobs do not conform to a conventional work schedule of 8 hours per workday, 5 workdays per week. In crop production, for instance, the quantity of labor required varies greatly across the agricultural cycle (i.e., soil preparation, planting, pest and weed control, watering, and harvesting). Moreover, this quantity can vary greatly by crop, with fruit and vegetables tending to be more labor intensive. In addition, many farms obtain labor from a diverse set of sources, including the principal and secondary operators, spouses, other family members, hired labor, and contract labor. The number of hours worked per day by these individuals can vary greatly from one person to the next, with some working just a few hours a day and others more than 40 hours each week. Also, some working hours of family members are unpaid. For example, many children in farm families have chores that contribute to the farm's operation, and the owners and operators of family farms routinely supply their own labor to their farms and are compensated in the form of farm income rather than a wage or salary.

Given the varied quantities and sources of labor employed in U.S. agriculture, the ATM model relies on data measuring hours of employment rather than numbers of workers to describe agricultural employment accurately. Specifically, the ARMS data provide detailed information on the number of labor hours employed by the farm from all sources, facilitating the exploration of the complexities associated with agricultural employment and offering greater detail about employment in different specialties of agricultural production. As ARMS data account for all paid and unpaid hours instead of the count of workers, employment figures derived from ARMS are notably larger than estimates provided by BLS and BEA. For 2021, the number of labor hours in crop and livestock production counted by the EP data corresponded to about 1.9 million full-time equivalent (FTE) workers, while the number tallied by the ARMS corresponded to about 3.0 million FTEs.[11] Both ARMS and EP data are released annually.

Assembly and Arrangement of Trade Data

The ATMs rely upon the definition of agricultural products used by the World Trade Organization (WTO). Agricultural products are those listed in Chapters 1–24 of the Harmonized Commodity Description and Coding System (HS), minus fish and fish products, plus a handful of products in other chapters, such as cotton, essential oils, and hides and skins. USDA adopted the WTO's definition of agricultural products as its standard definition to report agricultural trade at the start of calendar year 2021 (USDA, Foreign Agricultural Service, 2021). In addition, the ATMs cover biodiesel given the use

[10] USDA, ERS (2022b) offers more documentation on USDA, ERS's farm sector cash receipts data.

[11] According to BEA, "Full-time equivalent (FTE) employees equal the number of employees on full-time schedules plus the number of employees on part-time schedules converted to a full-time basis" (U.S. Department of Commerce, Bureau of Economic Analysis, 2007). The ATMs rely on the conversion ratio of 2,080 hours (52 weeks times 40 hours per week) per 1 FTE.

of soybean oil and other agricultural products as feedstocks for U.S. biodiesel production. This inclusion is made even though biodiesel is not classified by the WTO or USDA as an agricultural product for the purpose of measuring international trade.[12]

The ATM computer program directly obtains annual U.S. international trade data from the Census Bureau for agricultural products (and biodiesel) at the HS-10 level (i.e., where products are identified using 10-digit HS codes) by trade partner. Because the ATMs are not specific to any trade partner and are calculated annually, the program aggregates these partner-specific data to annual world totals (exports and imports) for each HS-10 product. As a quality check, the program verifies that the totals in the downloaded data match the official totals published by the Census Bureau. If the totals did not match, USDA, ERS researchers would explore the problem, beginning with the computer program and the downloaded data, and determine and implement the solution.

Unlike the trade data, which are provided at the HS-10 level, the ATMs are generated for a set of 124 agricultural product groups, ranging from soybeans to essential oils (table 1). Each of these product groups is defined by a certain set of HS-10 codes. For instance, the ATM product group "soybeans" encompasses the HS-10 codes 1201100000, 1201900005, and 1201900095 for exports and 120110000, 1201900005, 1201900010, and 1201900090 for imports (table 2). In general, the product groups follow the logic of existing USDA classification schemes for agricultural trade, such as the Foreign Agricultural Trade of the United States (FATUS) and Bulk, Intermediate, and Consumer-Oriented (BICO) classification schemes.

Table 1
The 124 agricultural product groups used in USDA, Economic Research Service's Agricultural Trade Multipliers

Product group	USDA, ERS number	Product group	USDA, ERS number
Soybeans	1	Palm oil and its fractions, refined but not chemically modified	63
Other oilseeds	2	Other fats and oils refining and blending	64
Corn	3	Breakfast cereal	65
Rice	4	Chocolate or cocoa food preparations	66
Sorghum	5	Cocoa butter	67
Wheat	6	Cocoa paste or powder	68
Other grains	7	Confectionery not containing cocoa, including chewing gum	69
Asparagus, fresh or chilled	8	Sugar and molasses manufacturing	70
Cucumbers and gherkins, fresh or chilled	9	Other sugar and confectionery products	71
Fruits of the genus capsicum (peppers) or of the genus pimento	10	Frozen potatoes, prepared or preserved	72
Lettuce, fresh or chilled	11	Other frozen food	73
Melons	12	Fruit juices	74
Pulses	13	Soups and broths and preparations therefore	75
Tomatoes, fresh or chilled	14	Other fruit and vegetable canning, pickling, and drying	76
Other vegetables	15	Fluid milk and butter	77
Avocados, fresh or dried	16	Cheese	78
Bananas and plantains	17	Nonfat dry milk	79
Fresh apples	18	Whey and modified whey, whether or not concentrated	80

Continued ►

[12] See Gómez et al. (2021) for a more detailed explanation of the Harmonized System.

◄Continued

Table 1

The 124 agricultural product groups used in USDA, Economic Research Service's Agricultural Trade Multipliers

Product group	USDA, ERS number	Product group	USDA, ERS number
Fresh oranges	19	Other dry, condensed, and evaporated dairy products	81
Fresh grapes	20	Ice cream and frozen desserts	82
Lemons and limes, fresh or dried	21	Bovine hides	83
Pineapples, fresh or dried	22	Bovine meat	84
Fresh blueberries	23	Bovine offal	85
Fresh raspberries	24	Swine meat	86
Fresh strawberries	25	Swine offal	87
Fresh cherries	26	Other animal slaughtering, rendering, and processing	88
Other berries	27	Chicken cuts and edible offal	89
Other fruit	28	Other poultry processing	90
Cocoa beans	29	Bread and bakery products	91
Coffee, not roasted, not decaf-feinated	30	Cookies, crackers, and pasta	92
Almonds, fresh or dried, in shell	31	Almonds, fresh or dried, shelled	93
Pistachios, fresh or dried, in shell	32	Walnuts, fresh or dried, shelled	94
Walnuts, fresh or dried, in shell	33	Cashew nuts, fresh or dried, shelled	95
Other tree nuts, fresh or dried, in shell	34	Other snack food	96
Fresh cut roses	35	Coffee, roasted, not decaffeinated	97
Other nursery and floriculture production	36	Other coffee and tea	98
Tobacco	37	Flavoring syrup and concentrate	99
Cotton	38	Sauces and preparations therefore, NESOI, and mixed condiments and mixed seasonings	100
Sugarcane and sugar beets	39	Other seasoning and dressing	101
Hay and other forage crops	40	All other food	102
All other crops	41	Soft drinks and ice	103
Cattle	42	Breweries	104
Poultry and egg production	43	Sparkling wine	105
Animal production, except cattle and poultry and eggs	44	Spirits distilled from grape wine or grape marc	106
Live horses, other than thoroughbreds	45	Wine of fresh grapes, containers of 2L or less	107
Forest nurseries, forest products, and timber	46	Other wineries	108
Fishing	47	Liqueurs and cordials	109
Dog and cat food	48	Tequila	110
Other animal food	49	Vodka	111
Flour milling and malt	50	Whiskies	112
Mixes and doughs	51	Other distilleries	113
Rice milling	52	Cigars, cheroots, cigarillos and cigarettes of tobacco substitutes	114
Corn gluten feed, meal, or other starch residues	53	Other tobacco products	115
High fructose corn syrup	54	Fiber, yarn, and thread mills	116
Distiller's dried grains	55	Textile and fabric finishing mills	117
Other wet corn milling	56	All other textile product mills	118
Rapeseed meal	57	Biodiesels	119
Rapeseed oil	58	Fuel ethanol	120
Soybean meal	59	All other basic organic chemicals	121
Crude soybean oil	60	Medicinal and botanical manufacturing	122
Olive oil and its fractions, virgin, not chemically modified	61	Adhesives	123
Other oilseed processing	62	Essential oils	124

NESOI = Not otherwise specified or indicated. ERS = Economic Research Service.

Source: USDA, Economic Research Service.

Table 2

Comparison of product group definitions for soybeans in the Bulk, Intermediate, and Consumer-Oriented and Foreign Agricultural Trade of the United States classification schemes and in the Agricultural Trade Multipliers

Exports				
		Included in soybean group?		
HS Code	Value in 2021	ATM	BICO	FATUS
	U.S. dollars (millions)			
1201100000 (soybean seeds of a kind used for sowing)	80	Yes	No	No
1201900005 (soybeans used as oilstock)	231	Yes	Yes	Yes
1201900095 (soybeans NESOI)	27,187	Yes	Yes	Yes
Imports				
		Included in soybean group?		
HS Code	Value in 2021	ATM	BICO	FATUS
	U.S. dollars (millions)			
1201100000 (soybean seeds of a kind used for sowing)	46	Yes	n.a.	No
1201900005 (soybean seeds of a kind used as oilstock)	28	Yes	n.a.	Yes
1201900010 (soybeans, certified organic, except seeds of a kind used for sowing or used as oilstock)	183	Yes	n.a.	Yes
1201900090 (soybeans, other than certified organic, NESOI)	157	Yes	n.a.	Yes

ATM = Agricultural Trade Multiplier. BICO = Bulk, Intermediate, and Consumer-Oriented. FATUS = Foreign Agricultural Trade of the United States. HS = Harmonized Commodity Description and Coding System. n.a. = not applicable. NESOI = Not elsewhere specified or indicated.

Note: The BICO classification scheme defines a product group for oilseed imports but not for soybean imports.

Source: USDA, Economic Research Service using product group definitions and trade data from USDA, Foreign Agricultural Service (2023) and product group definitions in USDA, Economic Research Service Agricultural Trade Multipliers.

An exploration of the histories of the BICO and FATUS classification schemes is beyond the scope of this technical bulletin but suffice it to say that both schemes reflect an effort to define product groups that make sense to direct participants in the agricultural sector (e.g., farmers, ranchers, food processors, input suppliers), analysts of that sector, and lay readers. For soybeans, the BICO and FATUS product groups for exports are defined identically, while the BICO classification scheme defines a product group for oilseed imports but not soybean imports (table 2). The sole difference between the ATM product groups for soybeans and the BICO and FATUS product groups for soybeans is that the ATM product group for soybeans includes soybean seeds of a kind used for sowing, while the corresponding BICO and FATUS product groups do not. Rather, FATUS includes soybean seeds in a different product group labelled "Seeds, Field/Garden". This difference reflects the fact that while all soybeans are the output of the economic activity of soybean farming, inputs such as soybean seeds of a kind used for sowing can be categorized differently within product group definitions.

The product groups in the ATM model were defined as part of a cooperative research project between USDA, ERS and the Interindustry Economic Research Fund (IERF), Inc. (formerly at the University

of Maryland), with the aim that the ATMs would provide more product-specific estimates of the economic effects of agricultural exports. The ATM product groups are intended to showcase well-defined sets of products with at least $100 million of annual exports or imports (or both).[13] Products with less than $100 million of either annual exports or annual imports tended to be aggregated with other products. The 124 groups were first used in the ATMs for calendar year 2019 (released in May 2021). Before that, the ATMs were presented using a set of 66 agricultural product groups.

The ATM computer program aggregates the U.S. export and import values at the world level and then maps them to the 124 agricultural product groups described above. The product groups are further classified into bulk and nonbulk categories following the structure of USDA's BICO classification scheme. The ATM's bulk category is the same as BICO's bulk category, while the ATM's nonbulk category consists of BICO's intermediate and consumer-oriented product categories. The computer program first generates the mapping for exports and then the mapping for imports. Occasionally, the Census Bureau makes changes to the HS codes, which necessitates USDA, ERS to review and update the concordance between the HS codes and the ATM product groups annually. In addition, the Census Bureau often updates its trade data, but USDA, ERS does not recalculate the ATMs when such updates are made.

Accessing and Updating the Supply-Use Tables

The ATM computer program directly retrieves the latest 405-commodity, benchmark supply-use tables from BEA. As mentioned, the 405-commodity benchmark tables are published about every 5 years and provide information on the U.S. economy as it existed about 4–6 years earlier. For the ATMs estimated for calendar year 2021, the most recently published set of benchmark tables was used; these represented the U.S. economy as of 2012. To update these tables with more recent data, the program uses the less-detailed, 71-commodity supply-use tables that BEA publishes annually. The 71-commodity supply-use tables used in the ATMs for calendar year 2021 are for that same year. To make the update, the program uses the mapping provided by BEA between the 71 and 405 commodities and then scales the blocks of cells in the 405-commodity benchmark tables to match the corresponding cell in the 71-commodity annual tables. With this scaling, the totals in the 405-commodity tables match the totals in the 71-commodity tables.[14]

Using Cash Receipts Data to Provide Detail for Additional Agricultural Sectors

To provide a finer level of detail for agricultural product groups, the ATM computer program further disaggregates the 405 industries and 405 commodities in the updated supply-use tables into specific agricultural sectors. This results in a fresh set of tables containing 20 additional industries. The disag-

[13] To explore U.S. agricultural trade data within the framework of these classification systems, consult the definitions of product groups in the reference section, as well as the data themselves, in USDA's *Global Agricultural Trade System* database (USDA, Foreign Agricultural Service, 2023).

[14] In place of this simple scaling, one could utilize BEA's data on gross output by industry and the Census Bureau's data on exports and imports to update the 405-commodity supply-use tables. The ATM program currently foregoes this approach, although further detailing of the model along these lines is possible.

gregation is performed using cash receipts data from the USDA, ERS Farm Income and Wealth Statistics data product and splits the following original sectors:

- The oilseed farming industry in BEA's supply-use table is split into two sectors: soybeans and other oilseeds;
- Grain farming is split into five sectors: corn, rice, sorghum, wheat, and other grain farming;
- Vegetable and melon farming is split into four sectors: lettuce, pulses, tomatoes, and other vegetable and melon farming;
- Fruit and tree nut farming is split into two sectors: fruit farming and tree nut farming;
- Other crop farming is split into five sectors: tobacco, cotton, sugarcane and sugarbeet farming, hay and forage, and all other crop farming;
- Animal (except poultry) slaughtering, rendering, and processing is split into six sectors: bovine hides, bovine meat, bovine offal, swine meat, swine offal, and other animal slaughtering, rendering, and processing; and
- Other basic organic chemicals is split into three sectors: biodiesel, fuel ethanol, and all other basic organic chemicals.

The 20 additional sectors correspond to the 20 ATM product groups that match the commodity groups in USDA, ERS cash receipts data, and the purpose of creating these new sectors is to make possible the calculation of the multiplier estimates for each of these product groups. Output values from the cash receipts data are used to calculate the share of output and employment in each original sector that is assigned to the corresponding new sectors. Missing values are substituted with either projections from historical data or estimates suggested by USDA, ERS analysts. Finally, the original values from the original sectors mentioned above are split among the new additional sectors according to their respective assigned shares. A similar approach is taken with the use table to allocate the values of final demand and intermediate demand to the newly created sectors split from the original sector.

Due to the scaling of each new sector in proportion to its share of the original sector's output and employment, the input requirements per unit of output of each new sector are identical to the requirements of the corresponding original sector. As a result, the multiplier's estimates within each set of new sectors are identical. For example, the employment multipliers for soybeans and for other oilseeds—each split from the original sector of oilseed farming—are the same, and the output multipliers for these two new sectors are also equivalent. In addition, the intermediate and final demands for each new sector's output are proportionate to the sector's share of the original sector's output. This is not true, of course. As an example, the demand for tobacco across sectors of the economy is very different from the demand for sugarcane. Thus, further work on the ATM model that better distinguishes each new sector from other new sectors split from the same original sector would improve the model's representation of the economy.[15]

[15] See Meade (2021) for possible alternative approaches.

Calculating the Expanded Domestic and Total Requirements Tables

Following the coding of agricultural production and trade data, the ATM computer program calculates expanded versions of the domestic requirements table and total requirements table. Using BEA's terminology, the domestic requirements table "show[s] the amount of domestic intermediate inputs required, both directly and indirectly, in order for industries to supply goods and services to final demand" (Medeiros & Howells, 2017). The domestic requirement table contrasts with the total requirements table, which includes both domestically produced and imported inputs.[16] The ATM's versions of these two tables differ from BEA's versions in that the former are "expanded" to include specific agricultural sectors disaggregated from certain sectors in BEA's version, as previously described. The domestic requirements table, represented in matrix form, allows the program to obtain the port multiplier for each commodity by summing across columns. Later, the program will calculate the domestic requirements table for producers (named with the suffix "prod") and the employment version of the domestic requirements table (named with the prefix "e").

The first step is to calculate the components tables of the total requirements table. In matrix form, these tables may be expressed by the equations below, followed by the description of their variables:

$$\boldsymbol{B} = \boldsymbol{U}\hat{\boldsymbol{g}}^{-1} \qquad (1)$$

$$\boldsymbol{D} = \boldsymbol{V}\hat{\boldsymbol{q}}^{-1} \qquad (2)$$

$\boldsymbol{U}$, a commodity-by-industry matrix, is the intermediate block of the use table in which each column gives the amount of commodity used by a given industry in its production processes;[17]

$\boldsymbol{g}$ is the column vector of industry outputs, with the "hat" or caret above the letter signifying that the vector has been diagonalized;

$\boldsymbol{V}$, an industry-by-commodity matrix, is the transpose of the supply table where each column gives the amount of a given commodity produced by each industry;[18]

$\boldsymbol{q}$ is the column vector of commodity outputs, again with the hat meaning that it is diagonalized;

$\boldsymbol{D}$ is an industry-by-commodity matrix (also known as the market share matrix or transformation matrix); and

$\boldsymbol{B}$ is a direct input coefficients matrix where entries in each column show the amount of a commodity used by an industry per dollar of that industry's output.

[16] Extensive trade creates complexity around separating total requirements into domestic requirements and imported requirements due to the use of different techniques to create inputs (Reimer, 2006).

[17] See U.S. Department of Commerce, Bureau of Economic Analysis (2012) for explanation and in-depth discussion of the use table and its usefulness.

[18] See U.S. Department of Commerce, Bureau of Economic Analysis (2023) for a fuller definition of the make table.

Next, the ATM's computer program calculates the total requirements table, expressed in matrix form by the following equation:

$$g = \boldsymbol{D}(\boldsymbol{I} - \boldsymbol{BD})^{-1}e \qquad (3)$$

where $\boldsymbol{I}$ represents the identity matrix and e is a column vector of the total final demand purchases of each commodity from the use table.

As was mentioned earlier, values in the total requirements table for a given vector of exports are greater or equal than corresponding values in the domestic requirements table since some requirements are imported from other countries. Therefore, the total requirements matrix may be separated into domestic requirements and imported requirements. Thus, the domestic requirements table and imported requirements table include, respectively, labor employed within the United States to make domestically produced goods and labor employed abroad to produce the imported requirements used to make those same domestically produced goods. To make this separation, the program first calculates the import share *s*:

$$s = m/dd \qquad (4)$$

where *m* denotes imports and *dd* denotes domestic demand (also referred to as apparent consumption).

The program pre-multiplies the matrix $\boldsymbol{BD}$ by the diagonal matrix $\hat{\boldsymbol{s}}$ (formed by diagonalizing the matrix $\boldsymbol{s}$) to obtain the domestic requirements matrix. Our final matrix equation for domestic requirements is:

$$g_{dom} = \boldsymbol{D}(\boldsymbol{I} - \hat{\boldsymbol{s}}\boldsymbol{BD})^{-1}e \qquad (5)$$

The set of commodities used by BEA is different from both the ATM's agricultural product groups and the HS product groups. To calculate trade multipliers corresponding to the ATM's 124 agricultural product groups, the computer program uses a mapping between BEA's commodities and the ATM's product groups.

Incorporation of BLS and ARMS Employment Data

The employment data in the ATM Model come from two sources: BLS's industry and employment databases and USDA's Agricultural Resource Management Survey (ARMS). BLS publishes information on the total output produced and total hours worked in 194 industries. In the ATM program's calculations, total hours worked in each industry are converted to full-time equivalent (FTE) employees by dividing the number of hours by 2,080. Employment-to-output ratios are constructed by dividing the number of FTEs by industry output for each industry. These ratios are then mapped from industries in the BLS data to the 124 product groups in ERS's Agricultural Trade Multipliers.

As BLS does not provide detailed employment information for agricultural sectors, we turn to the ARMS for additional employment data. The ARMS collects a variety of information on the production practices, resource use, and economic well-being of farms and ranches in the United States, including the farm's production specialty (the product from which the farm obtains most of its value of production) and the number of working hours (both paid and unpaid) provided by operators, family members, contractors, and hired labor. Again, the total number of hours is divided by 2,080 to convert to FTEs.

The production specialties cover 18 categories of crop and livestock products, as shown in the first column of table 3.

Table 3
Mapping of production specialties in the Agricultural Resource Management Survey to product groups in the Agricultural Trade Multipliers

	Production specialty identified by ARMS		ATM product groups
1	Wheat	1	Wheat
2	Corn	2	Corn
3	Soybeans	3	Soybeans
4	Grain sorghum	5	Grain sorghum
5	Rice	6	Rice
6	General cash grains	7	Other grains
7	Tobacco	8	Tobacco
8	Cotton	9	Cotton
9	Peanuts	4	Other oilseed crops
10	Other field crops	10	Sugar
		11	Hay and forage
		12	All other crops
11	Fruit and tree nuts	13	Fruits
		14	Tree nuts
12	Vegetables	15	Lettuce
		16	Pulses
		17	Tomatoes
		18	Other vegetables and melons
13	Nursery and greenhouse	19	Greenhouse, nursery, and floriculture production
14	Cattle	20	Cattle ranching and dairy farming
15	Dairy		
16	Poultry	21	Poultry and egg production
17	Hogs	22	Animal production, except cattle and poultry and eggs
18	All other livestock		

ARMS = Agricultural Resource Management Survey. ATM= Agricultural Trade Multipliers.

Source: USDA, Economic Research Service.

The general approach is to allocate the number of FTEs in each ARMS production specialty to one or more product groups. To match ARMS production specialties with product groups, the computer program makes several disaggregations (table 3):

- Employment in the ARMS production specialty "Other field crops" is separated into three product groups: sugar, hay and forage, and all other crops;
- Employment in the production specialty fruit and tree nuts is separated into two product groups: fruit, and tree nuts; and
- Employment in the production specialty vegetables is separated into four product groups: lettuce, pulses, tomatoes, and other vegetables and melons.

These disaggregations rely on the assumption that the product groups corresponding to particular production specialties have the same FTE-to-output ratio.

The program also makes several aggregations of ARMS production specialties to match production specialties to product groups (table 3):

- Employment in the cattle production and dairy production specialties is combined and allocated to the product group "Cattle ranching and dairy farming;" and
- Employment in the hog production and "All other livestock" production specialties is combined and allocated to the product group "Animal production, except cattle and poultry."

Finally, the program makes an aggregation and disaggregation in which two ARMS production specialties are combined and then matched to four product groups (table 3). Specifically, employment in the production specialties "Peanuts" and "All other crops" is combined and then allocated across four product groups: all other oilseed crops, sugar, hay and forage, and all other crops. As a result of these divisions and combinations, the ATMs incorporate ARMS employment data for 22 agricultural industries, which are used in place of aggregated employment information from BLS.

Calculating Margins and Value-Added Tables

The ATM computer program calculates the trade and transportation margins needed to evaluate the requirements tables at the producer level, before the output is traded and transported, and at the port level, once all domestic trade and transportation costs have been included. The two margins can be obtained directly from the supply table provided by the BEA, but the ATM program instead uses the values calculated in the ATM's disaggregated supply table, which contains the additional agricultural sectors. A percentage of the margins over total product supply is calculated by dividing each margin by the total product supply column in the disaggregated supply table. This calculation generates the ATM margins table.

The requirements tables indicate the value of inputs associated with a dollar of each output. Multiplying the export values of a given product by the value of the requirements needed to make one dollar of that product enables an estimation of the output supported by those exports. The program performs this estimation not only for the entire set of agricultural product groups but also for the broader categories of bulk and nonbulk agricultural products. As mentioned earlier, the definition of bulk and nonbulk follows that of the BICO classification scheme, with nonbulk including both intermediate and consumer-oriented products. The program further separates the output supported by agricultural trade into the broad industry groups of farming, food processing, other manufacturing, and services.

The program also estimates the economic activity that would have been supported by U.S. agricultural imports if those imports been produced in the United States rather than abroad. To account for the importation of products that the United States does not produce in large quantities, the model distinguishes between noncompetitive and competitive agricultural imports. Specifically, the program incorporates the assumption that certain agricultural products—primarily those grown or manufactured in tropical areas—are noncompetitive with U.S. production and do not substitute for domestic production. This assumption rests on the basic observation that the United States lacks the extensive tropical

climatic zones needed to produce these items in large quantities for commercial purposes. The imported product groups categorized as noncompetitive are bananas, plantains, pineapples, cocoa beans, coffee, palm oil, and tequila. All other imported agricultural products are treated as being potentially competitive with U.S. production.

Next, the ATM computer program calculates the value-added shares by industry. First, the program takes the value-added shares reported in the disaggregated supply table based on the use table from BEA under the value-added (producer value) row. This row is then diagonalized (with all the non-zero elements placed along the diagonal from upper left to lower right) and multiplied by the previously calculated domestic requirement table to obtain value-added shares by industry. Next, using the domestic requirement table, the program calculates the employment requirement matrix at both producer and port values. To calculate the employment requirement matrix at port values, the domestic requirement tables in matrix form are multiplied by the diagonalized form of the FTEs, also calculated previously. To calculate the employment requirement matrix at producer values, the trade and transportation margins are subtracted from the values in the domestic requirement table and again multiplied by the diagonalized form of the FTEs. Finally, the program calculates the tables for the aggregate economy for different industries (product groups) by summing the value-added shares calculated previously. From these tables, the program calculates the economic activity supported by agricultural trade, in addition to the value of exports.

Generation of Final Tables Containing ATM Estimates

The ATM computer program generates two output tables that are ultimately posted on the USDA, ERS website. The first is a summary table published on the website's landing page for the Agricultural Trade Multipliers Data Product (USDA, ERS, 2024). This table aggregates the economic activity and jobs supported by U.S. agricultural trade into broad industry categories.

The second table is the main input for the interactive, online ATM calculator on the USDA, ERS website (see USDA, ERS, 2022a). This calculator enables users to select a basket of exports from the list of 124 agricultural product groups, using either the predefined estimates or new estimates based on trade margins specified by the user. The second table contains the core output of the ATM model: the output and jobs multipliers for each agricultural product group. The table, along with the updated trade and transportation margins, is uploaded into the calculator application on the USDA, ERS website (see appendix for a description of the ATM online calculator and how to use it). From start to finish, it takes the ATM program about an hour to access and assemble the data, calculate the multipliers, and generate the output tables.

Conclusion

The USDA, ERS Agricultural Trade Multipliers (ATMs) provide annual estimates of the employment and economic output supported by U.S. agricultural trade. Underlying the ATM Model is a computer program written by USDA, ERS researchers that directly accesses the Federal Government databases containing the information needed to calculate the multipliers. The program draws upon data on international trade, input-output accounts, farm cash receipts, employment, and other aspects of the U.S. economy. In turn, these data are used to estimate the number of jobs and economic output supported

by U.S. agricultural exports—with detail for 124 agricultural product groups—as well as the supported economic activity and employment.

The multipliers provide annual estimates of the output and employment effects of agricultural trade on the U.S. economy. For exports, the multipliers measure the dollars of economic activity and number of jobs supported per dollar of U.S. agricultural exports. In addition, the multipliers offer a general overview of the economic activity generated by these exports and of the economic activity that would have occurred in the absence of U.S. agricultural imports. This information is presented for different sectors of the economy (agriculture, food processing, other manufacturing, and services, trade, and transportation) and for trade in bulk and nonbulk agricultural products. The ATMs also include detailed estimates of the value of output and the number of jobs supported by U.S. exports in 124 agricultural product groups at either the producer's stage (the completion of production) or the port stage (the exporting of the product).

The elegance of the computer program used to generate the ATMs—a single program that is written in the R Language and directly accesses the publicly available Federal Government databases containing the information needed to calculate the multipliers—is that it offers the prospect of lowering the probability of human error and increasing the speed at which the ATMs are calculated. Since the R Language is a free software for implementing statistical techniques, the new ATM program may also serve as a platform for subsequent USDA, ERS research using the Agricultural Trade Multipliers. Possible areas for future research include State-level assessments of the economic activity supported by agricultural trade, multiplier analysis of U.S. agricultural trade with specific trade partners, and more complete analysis of domestic economic activity in the United States supported by agricultural imports.

References

Australian Bureau of Statistics. (2015, June 24). *Input Output Multipliers*.

Casler, S. (2004). Input-output analysis. In C. Cleveland (Ed.), *Encyclopedia of Energy*, Vol. 3 (459-474). Elsevier.

Edmondson, W. (2008). *U.S. Agricultural Trade Boosts Overall Economy* (Report No. FA-124). U.S. Department of Agriculture, Economic Research Service.

Edmondson, W. (1996, September/October). Trade boosts the economy. In *Foreign Agricultural Trade of the United States*. U.S. Department of Agriculture, Economic Research Service.

Edmondson, W. (1986, September/October). U.S. trade benefits economy. In *Foreign Agricultural Trade of the United States*. U.S. Department of Agriculture, Economic Research Service.

Gómez, M., Puerto, S., Zahniser, S., & Li, J. (2021). *U.S. agricultural exports to Colombia: Rising sales in response to trade liberalization and changing consumer trends*. U.S. Department of Agriculture, Economic Research Service.

Henry, M., & Schluter, G. (1985). Measuring backward and forward linkages in the U.S. food and fiber system, *Agricultural Economics Research*, 37(4), 33-39.

Horowitz, K. & Planting, M. (2009). *Concepts and methods of the input-output accounts*. Updated version. U.S. Department of Commerce, Bureau of Economic Analysis.

Kurz, H., & Salvadori, N. (2006). Input-output analysis from a wider perspective: A comparison of the early works of Leontief and Sraffa, *Economic Systems Research*, 18(4), 373-390.

Leontief, W. (1987). Input-output analysis. In J. Eatwell, M. Milgate, and P. Newman (Eds.), *The New Palgrave. A Dictionary of Economics*, Vol. 2 (860-864). Palgrave Macmillan.

Meade, D. (2021). *Agricultural trade multiplier analysis for 2019*. Inforum.

Medeiros, G., &. Howells III, T. (2017, March). Introducing domestic requirements tables for 1997–2015, *Survey of Current Business*, 1-6.

Miyazawa, K. (1976). *Input-output analysis and the structure of -income distribution*. Springer-Verlag.

Munroe, D., & Biles, J. (2005). Regional Science. In K. Kempf-Leonard (Ed.), *Encyclopedia of Social Measurement*, Vol. 3 (325-335). Elsevier.

Nasdaq. (2018). *Glossary: Input-Output Tables*.

Nobel Prize Outreach AB. (2023, December 11). *The prize in economic sciences in memory of Alfred Nobel to the father of input-output analysis* [Press release]. Originally published October 18, 1973.

Persaud, S. (2019a). *Effects of trade on the U.S. economy: 2017 Data Overview*. U.S. Department of Agriculture, Economic Research Service.

Persaud, S. (2019b, June 3). "U.S. agricultural exports supported 1.2 million full-time jobs in 2017," *Amber Waves (Finding: International Markets & U.S. Trade)*, U.S. Department of Agriculture, Economic Research Service.

Persaud, S. (2018). *Agricultural trade multipliers: Effects of trade on the U.S. economy – 2016*. U.S. Department of Agriculture, Economic Research Service.

Persaud, S. (2017, January 30). *Agricultural trade multipliers: Effects of trade on the U.S. economy – 2015*. U.S. Department of Agriculture, Economic Research Service.

Persaud, S. (2015, May 4). "Calculating the jobs associated with U.S. agricultural exports," *Amber Waves (Statistic: U.S. Agricultural Trade)*, U.S. Department of Agriculture, Economic Research Service.

Persaud, S. (2014, February 3). *Figure 1: Number of civilian jobs generated by U.S. agricultural exports*. U.S. Department of Agriculture, Economic Research Service.

Reimer, J. (2006). Global production sharing and trade in the services of factors, *Journal of International Economics*, 68(2), 384-408.

Schluter, G. (1972). Linkages between agriculture and the U.S. national income and product accounts, *Journal of the Northeastern Agricultural Economic Council*, 1, 83-93.

Schluter, G., & Edmondson, W. (1994). *USDA's agricultural trade multipliers: A primer* (Agriculture Information Bulletin No. 697). U.S. Department of Agriculture, Economic Research Service.

Schluter, G., & Edmondson, W. (1989). *Exporting processed instead of raw agricultural products* (Staff Report No. AGES 89-58). U.S. Department of Agriculture, Economic Research Service.

Scott, S. (2020, October 20). *World statistics day: Agricultural trade multipliers showcase the many ways agricultural exports affect U.S. economy*. U.S. Department of Agriculture, Economic Research Service.

Streitwieser, M. (2011). *Measuring the nation's economy: An industry perspective: A primer on BEA's industry accounts*. U.S. Department of Commerce, Bureau of Economic Analysis.

U.S. Department of Agriculture, Economic Research Service. (2023, August 31). *Farm income and wealth statistics: Annual cash receipts by commodity* [Data set].

U.S. Department of Agriculture, Economic Research Service. (2024, May 15). *Agricultural trade multipliers*.

U.S. Department of Agriculture, Economic Research Service. (2022a, February 24). *Agricultural trade multipliers calculator* [Data set].

U.S. Department of Agriculture, Economic Research Service. (2022b, September 1). *Farm income and wealth statistics* [Data set].

U.S. Department of Agriculture, Economic Research Service, Agricultural Resource Management Survey (ARMS) Team. (2022, September 30). *ARMS farm financial and crop production practices*.

U.S. Department of Agriculture, Foreign Agricultural Service. (2023, April 14). *Global agricultural trade system* [Data set].

U.S. Department of Agriculture, Foreign Agricultural Service. (2021, January). *Updated 'Agricultural products' definition for trade reporting*.

U.S. Department of Commerce, Bureau of Economic Analysis. (2024, February 1). *Input-output data* [Data set].

U.S. Department of Commerce, Bureau of Economic Analysis. (2023, February 23). *Glossary*.

U.S. Department of Commerce, Bureau of Economic Analysis. (2018, November 30). *Comprehensive update of industry accounts now available*.

U.S. Department of Commerce, Bureau of Economic Analysis. (2012, November 9). The use table: An essential tool that looks deep inside the U.S. economy. *The BEA Wire: BEA's Official Blog*.

U.S. Department of Commerce, Bureau of Economic Analysis. (2007, April 2). *What are full-time equivalent employees?*

U.S. Department of Commerce, Bureau of the Census. (2023, November 21). *USA trade online* [Data set].

U.S. Department of Commerce, Bureau of the Census. (2022a). *About the international trade statistics: Guide to the U.S. foreign trade statistical program*.

U.S. Department of Commerce, Bureau of the Census. (2022b, September 12). *North American industry classification system*.

U.S. Department of Commerce, Bureau of the Census. (2022c, September 13). *U.S. international trade data*.

Young, J., Howells III, T., Strassner, E., & Wasshausen, D. (2015, September). Supply-use tables for the United States, *Journal of Current Business*, 1-8.

Zahniser, S., & Meade, D. (2021). *Agricultural trade multipliers: 2019 data overview*. U.S. Department of Agriculture, Economic Research Service.

Zahniser, S., Meade, D. & Christensen, C. (2020). *Agricultural trade multipliers: 2018 data overview*. U.S. Department of Agriculture, Economic Research Service.

Zeng, W., & Dong, F. (2022a, February 28). *Agricultural trade multipliers: 2020 data overview*.

Zeng, W., & Dong, F. (2022b, February 24). 2020 U.S. agricultural trade multiplier for soybeans, *Amber Waves*, U.S. Department of Agriculture, Economic Research Service.

Zeng, W., Dong F., & Husby, M. (2023, March 14). *Agricultural trade multipliers: 2021 data overview*. U.S. Department of Agriculture, Economic Research Service.

Zeng, W., Zahniser, S., Ivanic, M., Dong, F., Husby, M. & Pham, X. (2022, February 24). U.S. agricultural exports in 2020 supported 1,133,200 jobs and generated $154.3 billion in additional economic activity. In Kenner, B., Jiang, H, & Russell, D. (coordinators), *Outlook for U.S. Agricultural Trade* (Report No. AES-119) (22-27). U.S. Department of Agriculture, Economic Research Service and Foreign Agricultural Service.

Glossary

Bulk Agricultural Commodities

Bulk agricultural commodities are unprocessed agricultural commodities that are traded in large volumes and have low unit values, such as grains, oilseeds, cotton, and raw (unprocessed) tobacco. Contrasting categories of agricultural products are high-value processed products, semi-processed products, and fresh horticultural products. Bulk commodities are often treated as if they are homogeneous in nature before processing, even though there can be important distinctions across types of a specific bulk commodity—for instance, between yellow corn and white corn. Bulk commodities in the ATMs generally correspond to the bulk category in the Bulk-Intermediate-Consumer-Oriented (BICO) product classification method used by USDA.

Closed Model

Also known as Partially Closed Model; see that entry.

Direct Effects

Within the context of the ATMs, direct effects are the economic impacts of U.S. international trade of a specific product or product category on the sector that makes that product or product category (e.g., the farm sector or the food processing industry). See also Open Model.

Domestic Requirements Table

Domestic requirements tables "show the amount of domestic intermediate inputs required, both directly and indirectly, in order for industries to supply goods and services to final demand" (Medeiros & Howells, 2017).

Impacts

The effects of a given economic activity (e.g., exporting) measured in terms of jobs, income, output, or some other variable.

Indirect Effects

Within the context of the ATMs, indirect effects are the economic impacts of U.S. international trade of a specific product or product category on economic sectors or industries other than the one that makes that product or product category. See also Open Model.

Induced Effects

Induced effects are the economic impacts resulting from a new activity that will draw upon previously unused resources or output. For example, jobs added by producers to make possible additional exports increase household income, industrial activity, and gross domestic product (GDP). This additional income generates more spending, which in turn necessitates more production. See also Partially Closed Model.

Input-Output (I/O) Accounts

I/O accounts are benchmark tables published by the U.S Department of Commerce's Bureau of Economic Analysis that show the production of goods and services by different sectors of the economy, as well as the transaction flows of goods and services between different producing sectors and to different components of final use. These tables are used by economists to conduct I/O analysis and are the basis of the USDA, ERS Agricultural Trade Multipliers.

Input-Output (I/O) Analysis

I/O analysis uses the information in the accounting tables for a particular benchmark year to provide a snapshot of the interrelationships among the sectors of an economy. I/O analysis can be used to quantify the entire impact of a given economic activity (e.g., exporting) on a given geographic area, such as the United States.

Labor Productivity

Labor productivity is customarily measured as the ratio between the value of output and the labor time used to produce that output. As a measure of economic efficiency, labor productivity shows how effectively labor time is used to generate output. In general, productivity is measured by comparing the value or quantity of goods and services produced with the value or quantity of inputs used in production.

Margins

The U.S. Department of Commerce's Bureau of Economic Analysis (BEA) defines margin or margin costs as the "value of the trade services provided in delivering commodities from producers' establishments to purchasers, where the purchaser pays for the services," which reflects the value of transportation and wholesale and retail trade services (U.S. Department of Commerce, Bureau of Economic Analysis, 2018c). In an input/output (I/O) framework, margins are expressed as a percentage of the export value at the port level. For the USDA, ERS Agricultural Trade Multipliers data product, which uses the BEA Supply and Use tables, margins are national averages of the costs associated with shipping, handling, and distributing commodities for all uses. The multiplicative economic effect of exporting commodities or products can be measured more accurately by applying the correct margins to employment and/or output at the appropriate levels in the supply chain (i.e., producer, transportation, and wholesale and retail trade), which are still currently available from the BEA benchmark IO make and use tables.

Multiplier

An output multiplier is a summation of the economic output supported by one dollar of demand for a particular product from a particular industry, while an employment multiplier is a summation of the amount of employment supported by one dollar of such demand. In the USDA, ERS Agricultural Trade Multipliers data product, the demand is for agricultural exports, the output multiplier is measured in terms of economic output per dollar of agricultural exports, and the employment multiplier is measured in terms of the number of jobs per dollar of agricultural exports. The multipliers in this data product correspond to specific groups of agricultural products, the use of an open or partially closed input/output (I/O) model, and the stage of the export process (i.e., producer or port).

Nonbulk Agricultural Products

Nonbulk agricultural products are all agricultural products other than bulk commodities. Nonbulk agricultural products typically have higher unit values than bulk agricultural commodities and often require special handling (for instance, refrigeration in the case of meat or packaging to prevent damage during shipping in the case of fresh produce). Many nonbulk agricultural products are processed, which adds substantial value beyond the farm level. Processed foods are edible foodstuffs that have been transformed from their original post-harvest states into either semi-processed products (e.g., flour and meal) or final products (e.g., bread and breakfast cereal).

Open Model

An open model measures the direct and indirect effects of an economic activity (exports, for instance); that is, the impacts of sales and purchases between all goods and services sectors of the economy; sales to final demand (consumption, investment, government, and net exports); and purchases of land, labor, and capital services. Open model multipliers are best suited to describing what has already happened in an economy or the interrelatedness of sectors in a base period.

Output

Output is the value of the goods and/or services produced by a firm, industry, or country. See the definitions used by the U.S Department of Commerce, Bureau of Economic Analysis (2023) for gross domestic product and gross output.

Partially Closed Model

A partially closed model—sometimes called a Miyazawa model (see Miyazawa, 1976)—measures the direct, indirect, and induced effects of an economic activity (exports, in the case of the USDA, ERS Agricultural Trade Multipliers); that is, the impacts of sales and purchases between all goods and services sectors of the economy; sales to final demand (investment, government, and net exports); purchases of land, labor, and capital services; and the income that is generated by industry to households and the consumption demanded by households because of that income. It is appropriate to use partially closed I/O models only when estimating impacts associated with new economic activity that utilizes unused resources or production.

The model is "partially closed" because household income and personal consumption expenditures are endogenous (i.e., inside the modeling system), while some economic activities, such as investment, government purchases, and net exports, remain exogenous (i.e., outside the modeling system). By contrast, in an open model, which measures only direct and indirect economic activities, all final demands (including consumption) are exogenous. In a fully closed model, all final demands (including net exports) are endogenous.

Port-Value Multiplier

Port-value multipliers include the economic activity (jobs or value) supported by both the production of the farm or manufacturing sector's output and the shipping, handling, storage, and trading activities associated with moving that output from the producer or manufacturer to the port. The portions of the multiplier that apply to the producer (i.e., the economic activity supported by the production conducted

by the farm, food processor, or other manufacturer) are calculated. The jobs or value related to wholesale and retail trade is added to this, as well as the jobs or value associated with shipping the product from the farm or manufacturer to the port. When combined, these pieces constitute the port-value multiplier.

Price Index

A price index is an average of several prices that are representative of the product group for which an adjustment is being made for changing prices. The weight given to each representative product is fixed at the level for a given base year.

Producer-Value Multiplier

A producer-value multiplier includes just the activity embodied in the product as it leaves the farm gate or manufacturer's door. This type of multiplier is appropriate for understanding the economic impact of exports at the finished product stage of production, but it does not account for the shipping and handling charges that are added at the port to the value of an export.

Supply-Use Table

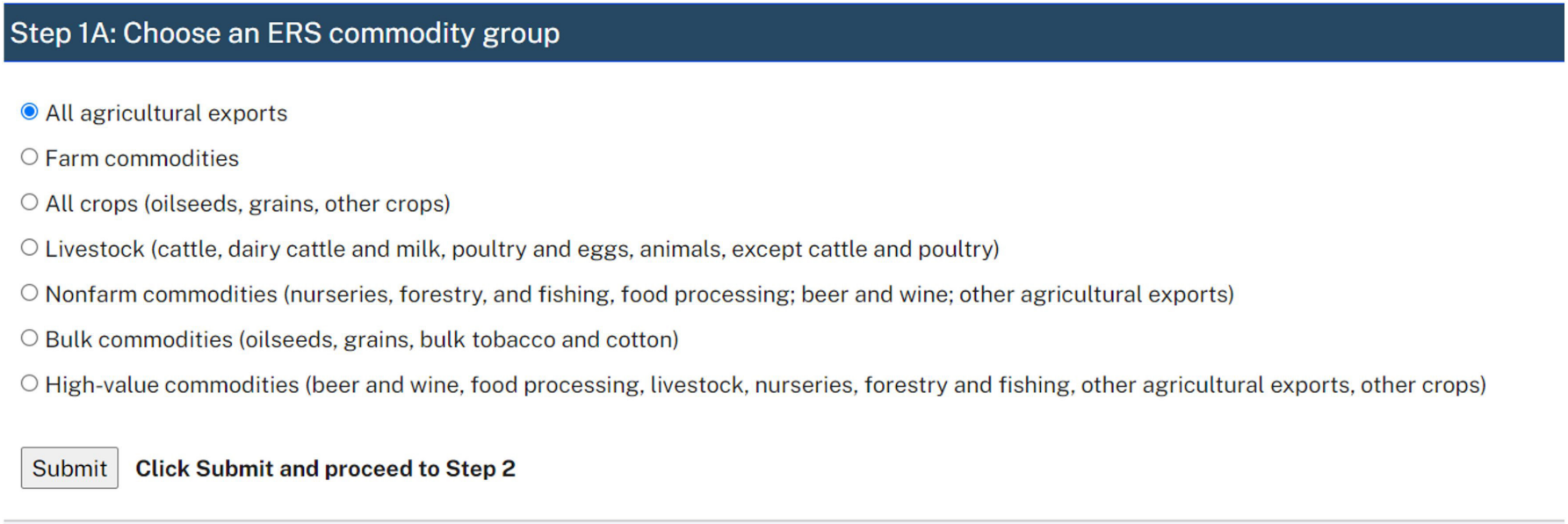
See Input-Output Accounts.

Total Requirements Table

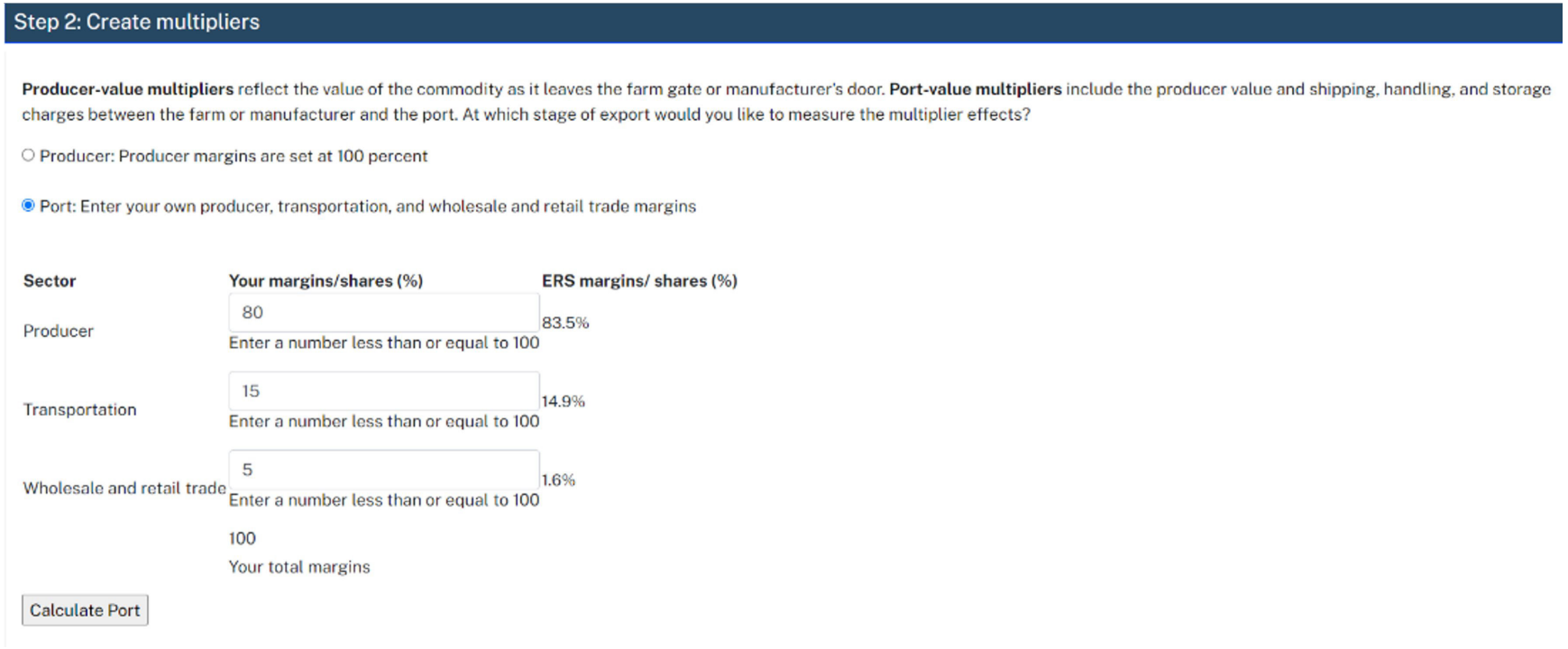
The total requirements table indicates the amount of intermediate inputs required, regardless of whether those inputs are imported or produced domestically, in order for industries to supply goods and services to final demand.

Appendix

The ATM online calculator can be accessed through the Data Products tab on the front page of the USDA, Economic Research Service website. In Step 1A, users have the option to explore the ATM for all agricultural exports or to narrow their focus to specific commodity subgroups, such as crops, livestock, nonfarm commodities, bulk commodities, and high-value commodities. Additionally, users can delve into ATMs for individual commodities (i.e., product groups) listed under commodity categories in Step 1B.



Moving to Step 2, users can select between producer value multipliers or port value multipliers. The margins for producer value multiplier are preset at 100 percent. For port value multipliers, USDA, ERS margins/shares are provided for producer, transportation, and wholesale and retail trade sectors, respectively. However, the calculator also allows users to input their own margins/shares, with the requirement that the sum of these user-defined values equals 100.



In Step 3, the calculator displays the ATM results based on the margins/shares set by either the user or USDA, ERS.