The Importance of Highways to U.S. Agriculture

APPENDIX A

Economic Significance of Surface Transportation to U.S. Agriculture

Read the full report:
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List of Abbreviations

Abbreviation	Term
ATRI	American Transportation Research Institute
CFS	Commodity Flow Survey
BTS	Bureau of Transportation Statistics
ERS	Economic Research Service
FAF	Freight Analysis Framework
FHWA	Federal Highway Administration
GDP	gross domestic product
IRI	International Roughness Indicator
NHS	National Highway System
SCTG	Standard Classification of Transported Goods
USDA	U.S. Department of Agriculture
U.S. DOT	U.S. Department of Transportation
VMT	vehicle miles traveled

Executive Summary

This report covers the findings of a research project carried out by the Volpe Center on behalf of the U.S. Department of Agriculture (USDA) Agricultural Marketing Service. The focus of this research effort was to determine the economic impacts of surface transportation on the U.S. agricultural sector, which is an important contributor to the U.S. economy.

The majority of all freight in the United States is shipped via truck, and the majority of truck movements occur on the National Highway System (NHS). The NHS is a federally designated system of roadways that are considered to be important to the U.S. economy, defense, and mobility—the purpose of the NHS is to identify high-priority roadways, and to encourage States to spend Federal money on NHS roads. Although congestion is concentrated on a small percentage of NHS roads, the NHS accounts for most congestion in the United States. Both congestion and the condition of the roads are growing concerns. Deteriorating roads impose higher costs of freight transportation in the form of vehicle operating costs, while congestion imposes costs through delays and additional requirements for labor and fuel. These cost increases affect ultimate prices for goods, reducing the competitiveness of the U.S. highway system in comparison to other countries.

Transportation costs help shape the overall economy and have even more profound effects on agriculture. A large segment of the transportation market is supported by the need to move agricultural goods, and in fact, the largest single user of freight services is agriculture. Agriculture does not make up a majority of freight movements, but no other single sector uses freight services more than agriculture does (USDA, 2010). According to data from the Commodity Flow Survey (CFS), in 2017, around a third (by ton-miles) of all goods shipped across all modes in the United States were agricultural products. By value, agricultural products were 17 percent of all freight (CFS, 2017).

Truck movements are particularly important for agriculture, especially for shorter, domestic shipments. They are also essential to international trade and have direct implications on international competitiveness. Export-bound agricultural products travel more often by rail or barge, but a truck is essential to getting the product off the farm and to a railroad or an inland waterway. Trucking competes with and complements other modes of service, such as rail and barge shipping. Thus, trucking competition moderates freight rates. A highly competitive trucking industry benefits agriculture by keeping costs down and expanding markets domestically and abroad. When combined, these phenomena enhance competition, lowering freight rates for shippers.

Although limited research is available on how improvements in surface transportation infrastructure would affect the U.S. agricultural sector, two studies on this topic were found. Both studies indicated positive results for agriculture, with Tong et al. (2013) finding that a 1-percent increase in the investment and maintenance of roads in a State increases agricultural output within the same State by between 0.02 and 0.03 percent. Additionally, Onofri and Fulginiti (2008) found that investments in public infrastructure gave, on average, a rate of return of 1 percent in real terms.

This report also looks at the international competitiveness of the United States agricultural exports and the role that U.S. transportation plays in keeping agricultural commodities competitive. Generally, transportation costs have been one of the key ways that the United States remains competitive against other countries—particularly, Brazil and Argentina. Although labor and land may be cheaper elsewhere, the United States has had, historically, the most efficient transportation networks. However, in the past several years, Brazil—the United States' strongest competitor for soybeans—has made vast improvements to its infrastructure and overtaken the United States in soybean exports. This development shows how the efficiency of surface transportation systems can affect global marketplaces.

As this report shows, the impacts of infrastructure improvements on the agriculture sector are vast, encompassing agricultural productivity, transportation costs, food prices, and international competitiveness. All of these areas are instrumental in analyzing where the greatest return on investment could be for agricultural freight projects. This report informs the chief task of this project: addressing the roles of various levels of government, including an assessment of the impacts of different investment levels and needs for future research.

1. Introduction

This report covers the findings of a research project carried out by the U.S. Department of Transportation (U.S. DOT) Volpe Center on behalf of the U.S. Department of Agriculture (USDA) Agricultural Marketing Service. The research aimed to determine the economic impacts of surface transportation on American agriculture. These included trucking's impacts on economic output,[1] domestic food prices, and the international competitiveness of U.S. agriculture. This research effort also involved projecting agricultural production 25 years into the future to understand how changes in the agricultural industry may affect surface transportation.

The agricultural sector of the United States plays an important role in the overall economy. Agriculture is approximately 5.5 percent of the U.S. gross domestic product (GDP), contributing over $1 trillion in 2017 (Economic Research Service (ERS), 2018), as can be seen in Figure 1. Although this could be viewed as a relatively small component of national GDP, 5.5 percent is still significant in a multi-trillion dollar economy. Of this, around $132.8 billion was from the output of America's farms (ERS, 2018), and agricultural exports account for around 10 to 11 percent of all U.S. exports (Cooke, Melton, and Ramos, 2017). Additionally, agriculture and related industries accounted for 11 percent of U.S. employment in 2017, equivalent to 21.6 million jobs, and around 2.6 million of these jobs were from direct on-farm employment (ERS, 2018). Furthermore, the products from the agriculture sector are essential to the overall economy, providing consumers with fresh, high-quality food that allows them to be healthy and productive in other sectors.

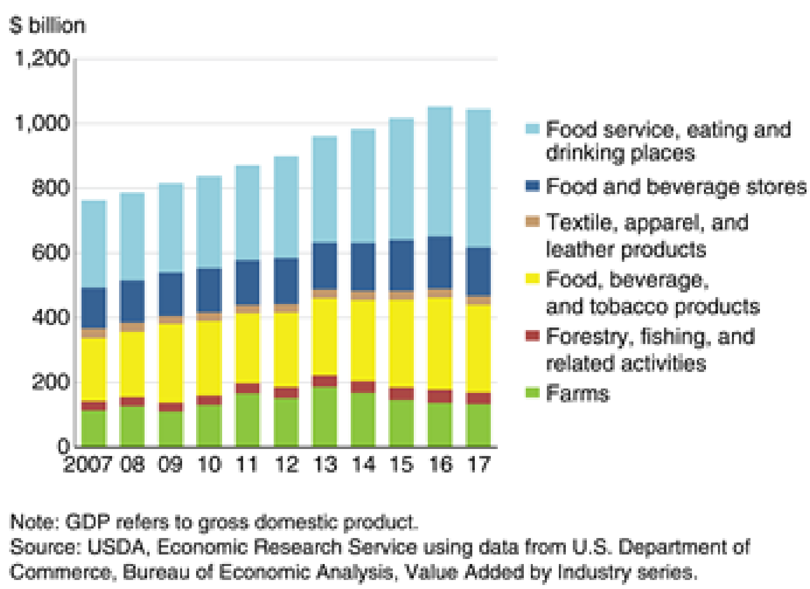

Figure 1. Value Added to GDP by Agriculture and Related Industries, 2007-2017

[1] Measured by Gross Domestic Output (GDP) – https://www.bea.gov/resources/learning-center/what-to-know-gdp

This report begins by discussing freight transportation generally in Section 2, providing background information on commodity movements across modes and infrastructure conditions. Section 2 also provides some background knowledge on agricultural freight specifically. Section 3 provides a discussion on the economic relationship of freight trucking to agriculture and the U.S. economy. It discusses economic impacts, linkage impacts, food prices, and the international competitiveness of U.S. agriculture in the context of surface transportation. Section 4 presents the results of the Volpe Center's 25-year commodity projections, which are based on USDA's 10-year projections. Section 5 concludes the report with a summary of key findings.

2. Freight Transportation

In the United States, freight movements, facilitated by a variety of networks (road, air, rail, and waterways), have steadily increased and are projected to continue to grow. Nearly 18.1 billion tons of goods worth about $19.2 trillion moved on the Nation's transportation network in 2015, based on the current Freight Analysis Framework 4 (FAF4) estimates (Bureau of Transportation Statistics (BTS), 2017). Every day, 49 million tons of goods valued at more than $53 billion are shipped throughout the country on all transportation modes. Figure 2 below shows U.S. DOT projections for the future value of goods shipped in the United States. The high estimate shows the value of shipped goods doubling by about 2040, and even the low estimate shows a large increase.

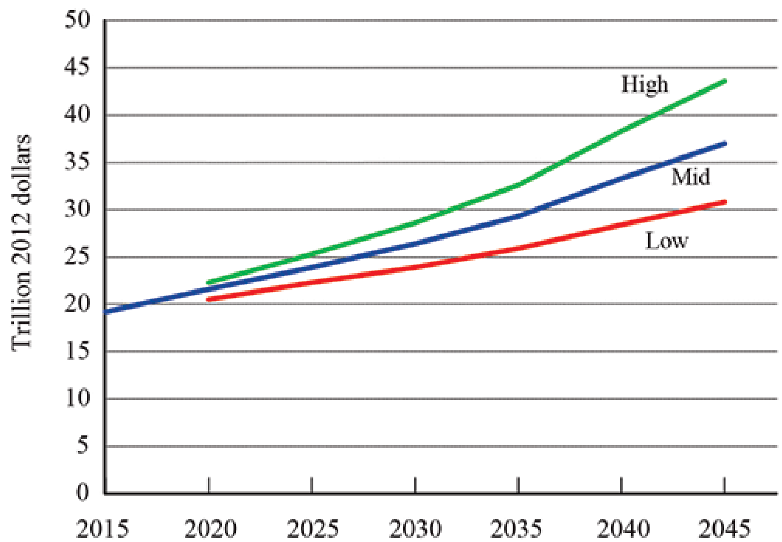

Figure 2. Value of Goods Shipped in the United States 2015-2045
Source: U.S. DOT, BTS and
Federal Highway Administration (FHWA), FAF, version 4.1, 2016.

All combined, goods moved by the modes of rail, pipelines, air, and river (barge) and ocean vessels total approximately half the dollar value of what trucks move. Mode shares by value are shown in Figure 3. Considering a different measurement, such as total tons moved, would provide a slightly different breakdown, but trucks always move the overwhelming majority of goods.

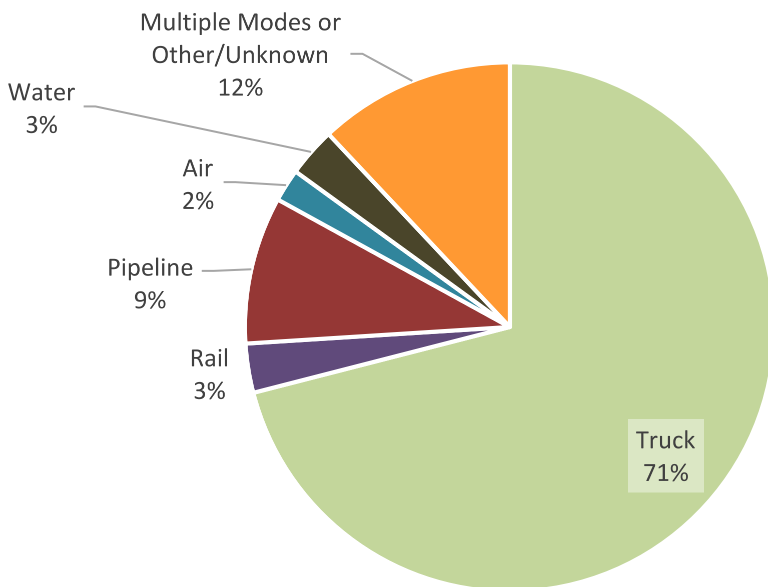

Figure 3. **Value of Shipments by Transportation Mode in 2018, as Defined by BTS**

Trucks move on a variety of road networks throughout the country, but one set of roadways that is vital to truck movement is the National Highway System (NHS). The NHS consists of roadways that are integral to the U.S. economy, defense, and mobility. It includes subsystems of roadways such as the Interstate System, other principal arterials, and intermodal connectors (FHWA, 2017). One of the NHS's advantages is it encourages States to focus on high-priority roads, and to focus Federal-aid funds on these roads, although Federal-aid dollars still can be used for other roads (Slater, 1996).

The NHS accounts for only around 5 percent of the country's roads (by center-line mileage), according to 2018 data from the Federal Highway Administration (FHWA); however, it accounted for 54.6 percent of all vehicle miles traveled (VMT) (FHWA, 2019a). For freight truck traffic specifically, the NHS accounted for around 311 million vehicle-miles per day of this traffic in 2015, with projections estimating that it could be as much as 488 million vehicle-miles per day in 2045 (BTS, 2019b). Understanding the NHS provides insight into truck movements, simply because the NHS's high volumes of traffic.

Intermodal connectors are also key components of the freight transportation network (see Table 1). They provide access between major intermodal facilities, such as ports and truck/pipeline terminals, and the NHS. Although freight intermodal connectors account for less than 1 percent of total NHS mileage (1,604 miles in 2016), they are vital for truck movement. Texas has the highest number of freight intermodal connectors (104), followed by Ohio (64).

Table 1. Freight Intermodal Connectors on the National Highway System by State: 2018

State	Port terminal	Truck/rail facility	Airport	Truck/pipeline terminal
Total	**322**	**276**	**271**	**72**
Alabama	5	4	4	1
Alaska	8	0	7	0
Arizona	0	2	5	0
Arkansas	3	7	3	3
California	16	15	14	3
Colorado	0	5	6	4
Connecticut	3	0	1	0
Delaware	1	0	1	0
District of Columbia	0	0	0	0
Florida	14	12	25	0
Georgia	5	13	4	7
Hawaii	10	0	5	0
Idaho	1	0	2	1
Illinois	9	43	4	0
Indiana	8	2	5	0
Iowa	6	1	3	3
Kansas	0	4	1	2
Kentucky	4	7	3	3
Louisiana	8	5	8	0
Maine	3	4	5	0
Maryland	8	3	1	3
Massachusetts	5	10	12	0
Michigan	15	8	11	0
Minnesota	1	1	3	0
Mississippi	22	2	3	0
Missouri	4	8	4	0
Montana	0	0	1	0
Nebraska	0	2	1	1
Nevada	0	0	2	0
New Hampshire	1	0	4	0
New Jersey	5	5	2	0
New Mexico	0	0	1	0
New York	8	16	17	0
North Carolina	2	4	9	5
North Dakota	0	0	2	0
Ohio	23	29	8	4
Oklahoma	4	1	2	1
Oregon	15	5	6	1
Pennsylvania	8	8	5	4
Puerto Rico	5	0	4	0
Rhode Island	2	0	1	0
South Carolina	4	2	4	0
South Dakota	0	2	3	0

Tennessee	5	8	4	2
Texas	43	20	23	18
Utah	0	3	2	6
Vermont	0	2	2	0
Virginia	6	3	7	0
Washington	11	6	14	0

SOURCE: U.S. DOT, FHWA, Office of Planning, Environment, and Realty, Intermodal Connectors, available at https://www.bts.gov/freight-intermodal-connectors-national-highway-system-state 2018.

The condition of roads will naturally deteriorate over time without maintenance or intervention because of general wear and tear. This implies that investment must match or exceed the rate of deterioration to keep roads in good condition. FHWA reports the International Roughness Index (IRI) for U.S. highways as a measure of highway condition. The IRI measures the smoothness of pavement, and a rating of greater than 170 inches per mile is generally considered to be “poor” (BTS, 2018).

As seen in Table 2, collector roads are in the worst condition, both in rural and urban settings. Almost half of all urban collectors have a high IRI, indicating that they are in a poor condition. Rural interstates have the best condition, with only around 2% having poor condition over the last few years. Rural minor arterials have had an increased share of mileage in poor condition, while urban minor arterials had a decrease. Poor road conditions contribute to higher freight costs, as rough pavement raises costs for vehicle maintenance. Internal estimates from U.S. DOT’S Highway Economic Requirements System suggest that going from an IRI of 95 to an IRI of 170 increases vehicle operating costs per mile by 13 percent for a combination truck traveling at 60 mph. Additionally, in extreme cases, poor conditions force vehicles to take alternative, longer routes to reach their destinations.

Table 2. Percent of U.S. Roadways in Poor Condition (IRI>170) by Functional System and Year (BTS, 2019a)

Road Type	2014	2015	2016	2017	2018
Rural Interstate	2.1%	1.8%	2.0%	2.0%	2.0%
Rural Other Principal Arterials	3.8%	4.4%	4.4%	4.1%	4.1%
Rural Minor Arterials	7.0%	7.9%	8.0%	8.1%	8.1%
Rural Collectors	20.2%	21.5%	22.0%	22.1%	20.4%
Urban Interstates	5.2%	5.0%	5.2%	5.2%	5.2%
Urban Other Freeways and Expressways	8.3%	8.2%	8.5%	7.8%	7.4%
Urban Other Principal Arterials	26.1%	27.7%	26.8%	26.7%	26.7%
Urban Minor Arterials	35.6%	38.3%	36.1%	36.9%	34.5%
Urban Collectors	49.5%	52.2%	50.8%	49.7%	47.7%

Bridge conditions have improved over the last couple decades, with the number of deficient bridges declining by approximately 40 percent since 2000. However, 7.6 percent of all bridges are still categorized as structurally deficient by FHWA, and an additional 11.1 percent of all bridges have weight restrictions to reduce stress on the structures (ARTBA, 2019). Further investment in U.S. infrastructure will likely be needed to help improve the state of surface transportation, which will benefit multiple industries and individuals, as well as the agricultural sector.

Although there is less data on local, rural roads, these roads are also often in poor condition (Cohen, 2020). Agricultural commodities may travel primarily on routes on the NHS and other large highway systems, but local roads are crucial to the beginning of every journey. Simply put, goods have to make it off of the farm even to reach a highway, rail head, or inland waterway. In these rural areas, transportation needs may often be underfunded, particularly because no State or Federal assistance can be used to help with smaller, local roads (Cohen, 2020).

Additionally, farm equipment often has to traverse these rural roads as the farmers take care of their crops or livestock, making the roads vital to every stage of the farming process, even before goods are ready to be shipped off of the farm. Heavy trucks and farm equipment wear down roads faster than a light-duty vehicle would. Some estimates indicate a legally loaded semi-trailer truck produces as much as 10,000 times the road damage of a car (Cohen, 2020). Because of limited funding and the high rate of road deterioration, the condition of rural, local roads is a key issue for rural communities and farmers.

In addition to the condition of the infrastructure, congestion on the roads is also a growing concern. Congestion imposes higher costs of freight transportation in the form of additional labor, fuel, and other vehicle-related costs. Congestion also has an opportunity cost in terms of time—more congestion means more hours lost. Lost hours can translate into other types of costs, such as higher inventory costs, for businesses. These cost increases affect ultimate prices for goods, reducing the competitiveness of the U.S. highway system compared to other countries. A congestion measurement from Texas A&M Transportation Institute's *2019 Urban Mobility Report* put the congestion cost for trucks at approximately $20 billion in 2017 (Schrank, Eisele, and Lomax, 2019). The report also stated that the truck share of congestion costs is higher than the truck share of traffic (Schrank, Eisele, and Lomax, 2019). The American Transportation Research Institute's (ATRI) estimate of congestion is significantly higher, at $74.5 billion in 2016 (Hooper, 2018).

FHWA data show that congestion is not equally distributed across the country. For example, based on 2005 data, the top 10 highway-interchange bottlenecks cause an average of 1.5 million annual truck hours of delay each, compared to less than 250,000 annual hours of truck delay for other truck bottlenecks (FHWA, 2005). These bottlenecks were identified using FHWA's Highway Performance Monitoring System, and truck volumes were determined using FAF data. The calculation considers things such as volumes, highway capacity, and temporal distributions, and uses available data to extrapolate key variables of interest, such as speeds and delay (FHWA, 2005). ATRI also produces a list of the top 100 truck bottlenecks every year, serving as another source of congestion data (ATRI, no date). These areas of significant congestion occur where there are large concentrations of people and, therefore, high demand for commodities, and are also often home to a major port where goods are exported overseas.

Figure 4 shows the major truck routes on the NHS in 2011. As the map shows, many areas of the NHS regularly experience high volumes of truck traffic.

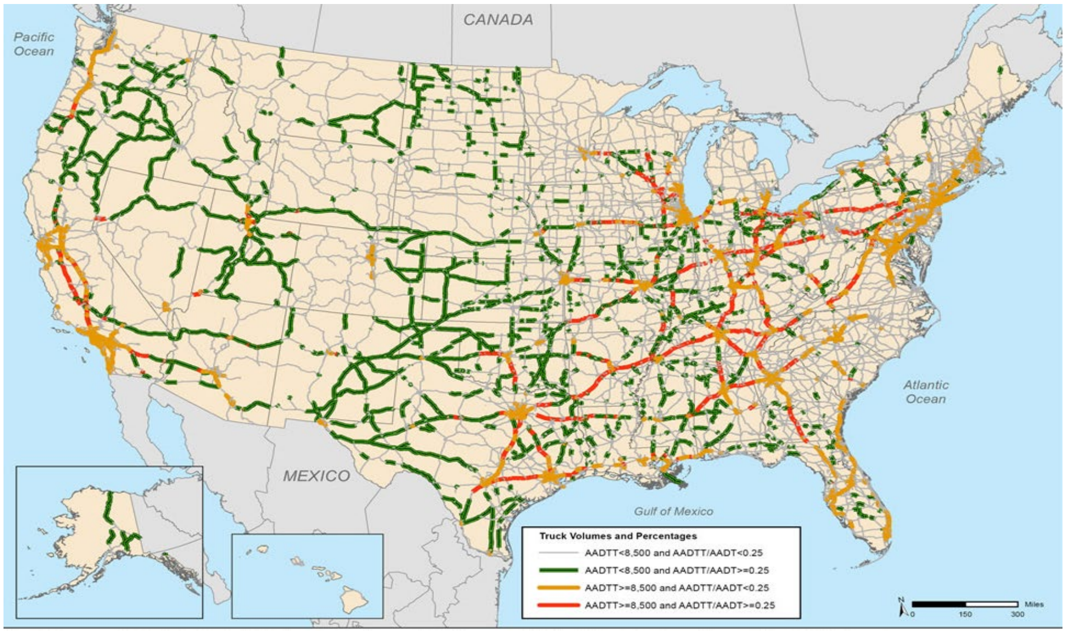

Figure 4. Major Truck Routes on the National Highway System in 2011

The map shows all freight movements, not limited to agricultural freight, and the highest truck volumes are concentrated in a number of corridors in the Northeast, Midwest, Texas, and California. These areas can experience even higher congestion levels during peak seasons and periods. Nonetheless, even areas with lower annual truck volumes could still potentially experience congestion during peak periods.

2.1 Agricultural Freight

Across sectors, agriculture is the largest user of freight services (USDA, 2010). The Commodity Flow Survey (CFS), conducted every 5 years, provides information on how much and where goods flow across the country. The 2017 CFS data indicate that agriculture represented just under 25 percent of all tons and about 33 percent of all ton-miles moved by the U.S. transportation system. Table 3 summarizes the volumes and value of agricultural commodity movements in 2017.

Table 3. Transportation Characteristics of Commodities, 2017

Commodity Group	Value ($ millions)	Tons (millions)	Ton-Miles (millions)	Average Miles Per Shipment
All Commodities	14,517,812	12,468.9	3,116,876	662
Agricultural Commodities	-	-	-	-
Animals and Fish (Live)	10,777	4.6	1,570	866
Cereal Grains (includes seed)	108,561	707.1	230,498	158
Other Agricultural Products	236,965	315.2	145,852	524
Animal Feed and Products	134,423	325.3	78,947	514
Meat, Poultry, Fish, Seafood	356,421	93.9	46,001	183
Milled Grain and Bakery Products	198,051	132.8	56,404	187
Other Prepared; Fats and Oils	606,280	530.2	203,307	373
Alcoholic Beverages	226,894	111.9	27,798	195
Tobacco Products	79,806	4.7	877	1,014
Fertilizers	57,886	172.5	40,112	102
Wood Products	220,916	322.8	88,755	350
Pulp, Paper	127,501	139.6	83,375	267
Paper or Paperboard Articles	148,420	80.9	26,305	577
Agricultural Products Sub-Total	2,512,901	2,941.5	1,029,801	-
% of All Commodities	17%	24%	33%	-

Source: U.S. DOT, BTS and U.S. Census Bureau, *Commodity Flow Survey*, 2017.

The CFS also shows shipments by commodity type and mode. Table 4 shows this data from 2017, breaking out the commodities by mode as a percent of all million tons shipped. These mode shares are across all shipments of the specific commodities, but the mode used can vary significantly between domestic and exported shipments. As a specific, older example, using data from USDA, 32 percent of all domestic wheat (in tons) was shipped via truck in 2011, while only 4 percent of exported wheat was shipped via truck (Denicoff, Prater, & Bahizi, 2014c). This difference was due to the use of barges, which moved only 1 percent of domestic shipments versus 29 percent of exported shipments. Rail use was relatively constant, at 67 percent for both domestic and exported wheat (Denicoff, Prater, & Bahizi, 2014c).

Table 4. Modal Transportation Characteristics of Agricultural Commodities by Volume, 2017

Commodity Group	Truck % of All Modes	Rail % of All Modes	Water % of All Modes	All Modes (Million Tons)
Animals and Fish (Live)	99.4%	0%	0%	4.6
Cereal Grains (includes seed)	55%	22.4%	16.9%	707.1
Other Agricultural Products	62.7%	11%	20.1%	315.2
Animal Feed and Products	85.7%	3.9%	1.5%	325.3
Meat, Poultry, Fish, Seafood	94.5%	0.3%	1.2%	93.9
Milled Grain and Bakery Products	82.8%	5.1%	0%	132.8
Other Prepared; Fats and Oils	86.4%	5.3%	0.9%	530.2
Alcoholic Beverages/ Denatured Alcohol	93.8%	0.8%	0.3%	111.9
Tobacco Products	94.1%	0%	0%	4.7
Fertilizers	76.5%	6.7%	6.5%	172.5
Wood Products	88.3%	4.1%	0%	322.8
Pulp, Paper	70.3%	8.6%	0%	139.6
Paper or Paperboard Articles	91%	1.4%	0.3%	80.9

Source: U.S. DOT, BTS, and U.S. Census Bureau, *Commodity Flow Survey*, 2017

The CFS also provides information on where trucks are traveling, as well as the types of commodities they carry. Figure 5 shows total U.S. freight movements on the U.S. interstate system, as well as agricultural freight as a subset of those movements. The thicker lines represent heavier freight traveling along that route. There is a high volume of freight movements, and particularly agricultural freight movements, in the Midwest region, as well as in the Northeast and in California. Gulf Coast States see somewhat lower levels of agricultural freight movements by truck, likely because much of that freight travels along the Mississippi River.

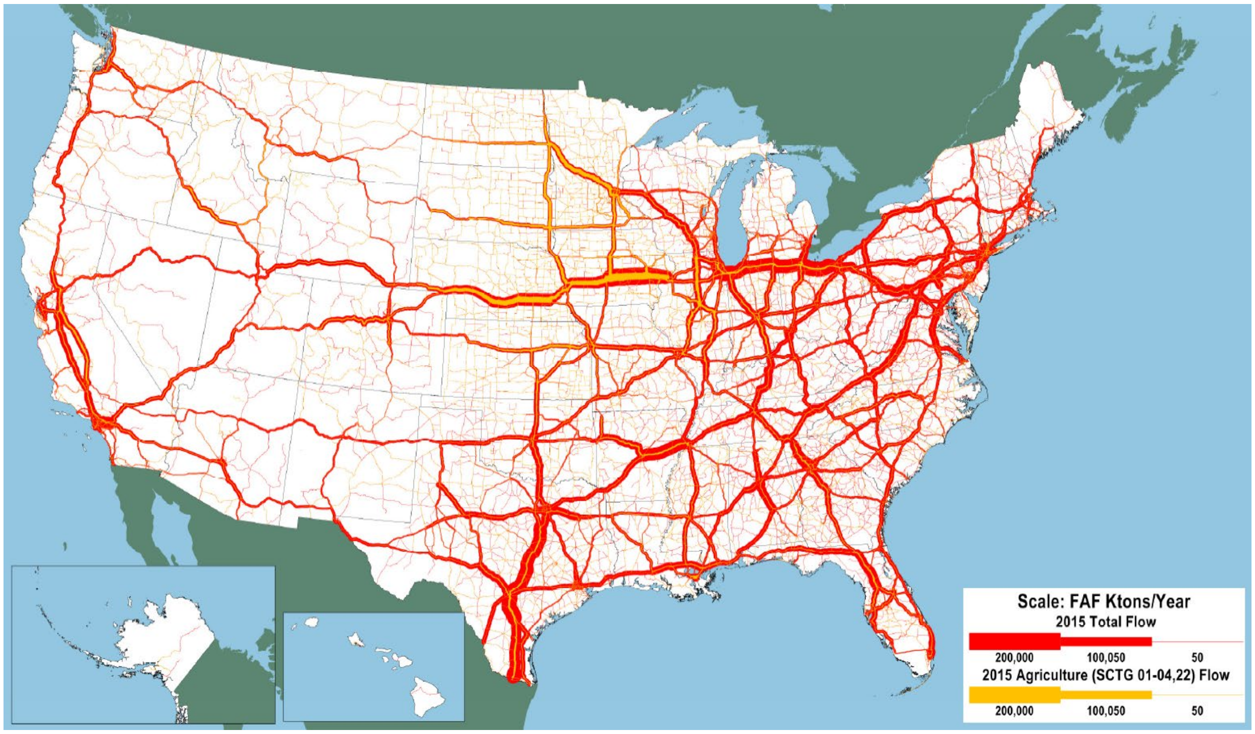

Figure 5. Agricultural and total freight moving on U.S. interstate system, 2015

Source: U.S. Department of Transportation, Bureau of Transportation Statistics and Federal Highway Administration, Freight Analysis Framework, version 4.3, 2018.

3. Economic Importance

This section discusses the economic importance of surface transportation both to the economy generally and to agriculture specifically. The section is further divided into four subsections: the first few sections cover the general macroeconomic impacts of the trucking industry, the importance of trucking to logistics and the agricultural supply chain, and the implications for food prices. The fourth and final subsection looks at surface transportation's role in maintaining international competitiveness in the agriculture sector, while also providing a case study using Brazil.

Transportation's importance to the U.S. economy is underscored by the fact that more than $1 out of every $10 produced in U.S. GDP is related to transportation activity. This includes all aspects of transportation, including the movement of goods and people, as well as the purchase of transportation-related products and services.

3.1 Macroeconomic Impacts

Transportation-related industries employ a large portion of the population—over 13.3 million people, or approximately 9 percent of the labor force, in 2017. Of that share, 1,748,140 were truck drivers for heavy trucks or tractor-trailers; 877,670 were truck drivers for light or delivery services; and another 570,300 were industrial truck and tractor operators.

Over 95 percent of trucking companies are small businesses with fewer than 20 trucks, and 84 percent have 6 or fewer trucks (OOIDA, 2020). Despite this prevalence of hundreds of thousands of small businesses, the 50 largest trucking companies represent 38 percent of the trucking industry (Cassidy, 2019). Most long-haul drivers are paid by the mile, by a flat fee, or portion of the gross revenue, not by the hour. The estimated average driver's pay is $0.60 per mile or $23.50 per hour (Murray and Glidewell, 2019). These truck drivers are vital to the U.S. economy as a whole, as well as to agriculture specifically.

Because of agriculture's reliance on trucking, the availability of drivers, especially during critical times such as planting and harvest, is key to farmers' profitability. Although the trucking industry has identified a driver shortage as a top industry issue (Miller, 2018; Truckload Carriers Association, no date), researchers in the field are skeptical that a labor shortage could persist, given that the barrier to entering the occupation is quite low. Increases in wages should easily incentivize new workers to enter the market (Burks and Monaco, 2016). Regardless, recruiting and retaining drivers in the long-haul trucking sector is an acknowledged problem, though it is largely outside the scope of this research effort. Nonetheless, it is worth remembering that infrastructure investment is not the only factor that could affect agricultural transportation.

Economic theory suggests multiple reasons infrastructure improvements could benefit the economy. Improved roads could reduce travel times, effectively reducing the cost of transportation and allowing producers to shift funds previously spent on transportation to other inputs, allowing them to increase their output. Lower costs for delivered products could also translate to lower costs and higher utility for consumers. Additionally, improved worker commute times could have a positive effective on the productivity of a worker, also benefiting production (Cohen, 2007).

Many studies attempt to quantify how infrastructure improvements could affect the U.S. economy, but they are generally not specific to agriculture. Most studies evaluating the output and productivity impact of transportation infrastructure in the agricultural sector have been outside the United States. (Antle, 1983; Craig et al., 1997; Felloni et al., 2001; Benin et al., 2009; Zhang and Fan, 2004). This review only found two studies—summarized in Table 5—that investigated the economic effects of infrastructure on U.S. agriculture.

Table 5. Studies Examining the Impact of Transportation Infrastructure

Study	Public Capital Measure	Outcome Measures	Findings
Onofri, A., and Fulginiti, L. E. (2008). Public inputs and dynamic producer behavior: endogenous growth in U.S. agriculture.	Public capital stocks are values of Federal, State, and local structures.	Output is an index of all crops and livestock products.	On average, investments in public infrastructure give a rate of return of 1%.
Tong, T., Yu, T. H. E., Cho, S. H., Jensen, K., and Ugarte, D. D. L. T. (2013). Evaluating the spatial spillover effects of transportation infrastructure on agricultural output across the United States	State road disbursements	Agricultural output data generated by physical quantities and market prices of crops and livestock.	A 1% increase in the investment and maintenance in roads in one State increases agricultural output within the same State by 0.02-0.03%.

Onofri and Fulginiti (2008) studied how investments in public transportation infrastructure affected the performance of U.S. agriculture. The authors tested two datasets, one from USDA covering 1948-1994 and one from an independent set of researchers covering 1926-1990. The authors used an endogenous growth model to test their various hypotheses. One finding was that an average dollar spent on public research and development stocks will reduce costs by 6.5 percent, indicating a rate of return of 190 percent, while the same investment in public infrastructure gave a rate of return of only 1 percent. However, the authors caution that there are modeling issues that they did not consider, and that their two datasets gave different results even though both datasets measured the U.S. agricultural sector (Onofri and Fulginiti, 2008). Given the uncertainty surrounding the study's results, caution should be used in interpreting the findings. Still, the findings are presented here because this study is one of the few that considers how investment affects U.S. agriculture.

Tong et al. (2013) looked at the direct effect and spatial spillover effect of transportation infrastructure on agricultural output. Their data covered 44 States from 1981 to 2004, and the authors used a spatial

Durbin panel data model for their analysis. Their analysis had several findings relevant for this report. First, the authors found that a 1-percent increase in road disbursement in a given State increases agricultural output in all other States by an average of 0.27 percent (Tong et al., 2013).

Additionally, Tong et al. (2013) further refined their finding based on the location of the State—border and coastal States had a much smaller spillover effect in their model than central States, due to simple geography. A State with only a few direct neighbors (potential examples could include Rhode Island, Florida, and Washington) had smaller spillover effects simply because there were fewer States nearby. However, Missouri has eight direct neighbors, and those States have 16 additional neighbors, which have 10 additional neighbors—spillover effects from Missouri would affect the majority of the continental U.S. In their model, a 1-percent increase in road disbursement in Missouri has a spillover effect in the range of 0.40 to 0.45 percent, while the same increase in Washington has a spillover effect only in the range of 0.10 to 0.15 percent (Tong et al., 2013). This finding indicates that road improvements in central States, which generally also are regions of major agricultural production, will have larger benefits on agriculture than road disbursement increases in other States (Tong et al., 2013).

3.2 Logistics and Supply Chain

Because of the nature of the agriculture supply chain, trucking is the sector's most-used mode of transportation. In a supply chain that stretches from the farm to the consumer, trucking provides the first miles, the last miles, and sometimes all the transportation miles. Trucks are generally more efficient than rail for trips under 500 miles (although this is only a rough estimate, and there are a variety of factors that affect the efficiency of trucks and rail), making trucks particularly crucial for short, domestic movements (Association of American Railroads, 2017; Zietlow et al., 2017). This is as true for agriculture as it is for other industries. Flexibility, timeliness, and efficient service are vital to shippers who handle perishable agricultural products. Figure 6 illustrates the intermodal agricultural supply chain for raw and processed products in the United States.

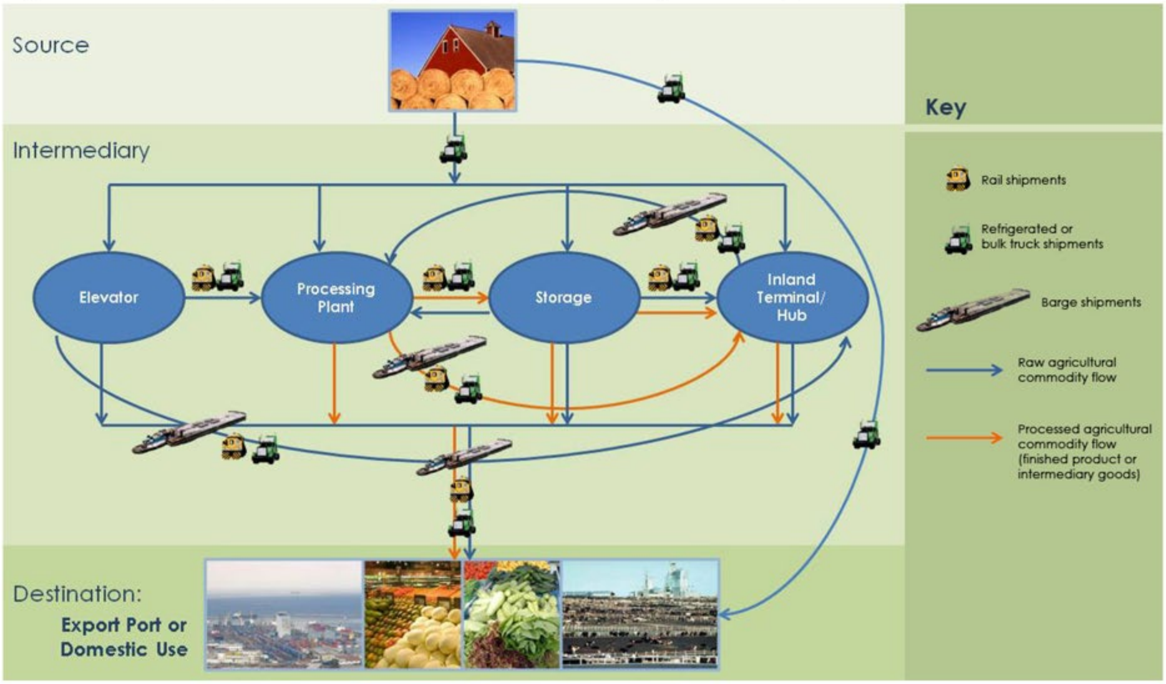

Figure 6. U.S. Agricultural Supply Chain

Courtesy of USDA, "U.S. Agricultural Supply Chain for Raw and Processed Products," p. 2, Study of Rural Transportation Issues, USDA, 2010

Thus, trucking provides a critical link for the national economy. It links farmers, ranchers, manufacturers, and service industries to packinghouses, grain elevators, ethanol plants, processors, feedlots, and rail, barge, and port terminals. The linkage with rail, barge, and port facilities is especially important because of the complementary and competitive relationship among modes of transport. Dependence on trucking has increased in rural areas over the past several years—particularly due to the lack of, decline of, or withdrawal of rail service, restrictions on access and routings to competing railroads, and rail rate increases (USDA, 2010).

Trucking competes with and complements other modes of service, such as air, rail, intermodal, and barge shipping. As a result, trucking competition moderates freight rates. Disruptions in barge traffic and sharp increases in barge rates divert cargo to trucks and rail (USDA, 2010). Diversions of business are particularly common in the winter, when parts of the Mississippi River close to make repairs and to avoid winter freezes (USDA, 2019). Combined, these phenomena enhance competition, thus lowering freight rates for shippers. A highly competitive trucking industry benefits agriculture by keeping costs down and expanding markets domestically and abroad. Despite wide variations, the average ratio of operating cost to operating revenue is a tight 95 percent in over-the-road long-haul truckloads, demonstrating that the sector is highly competitive, approaching what economists call atomistic or perfect competition.

To illustrate an example with a particular commodity, Figure 7 shows locations vital to the corn industry. Counties are highlighted by their level of corn production, showing where corn shipments are originating. Ethanol plants and the number of grain consuming animal units by state are also marked, indicating two major sets of domestic locations for corn. As the map shows, ethanol plants are densely concentrated in corn-producing areas, minimizing the distance that corn needs to travel to reach a plant. Similarly, States with high numbers of grain-consuming animal units also tend to produce, or be near other States that produce, a lot of corn, although this relationship is weaker than the one between ethanol plants and corn. Because ethanol plants and animals are generally close to corn farms, corn shipments usually travel by trucks to reach these domestic locations. However, if corn, or ethanol, is exported, those shipments will typically travel by rail or barge, since the port locations are relatively far from corn farms and ethanol plants.

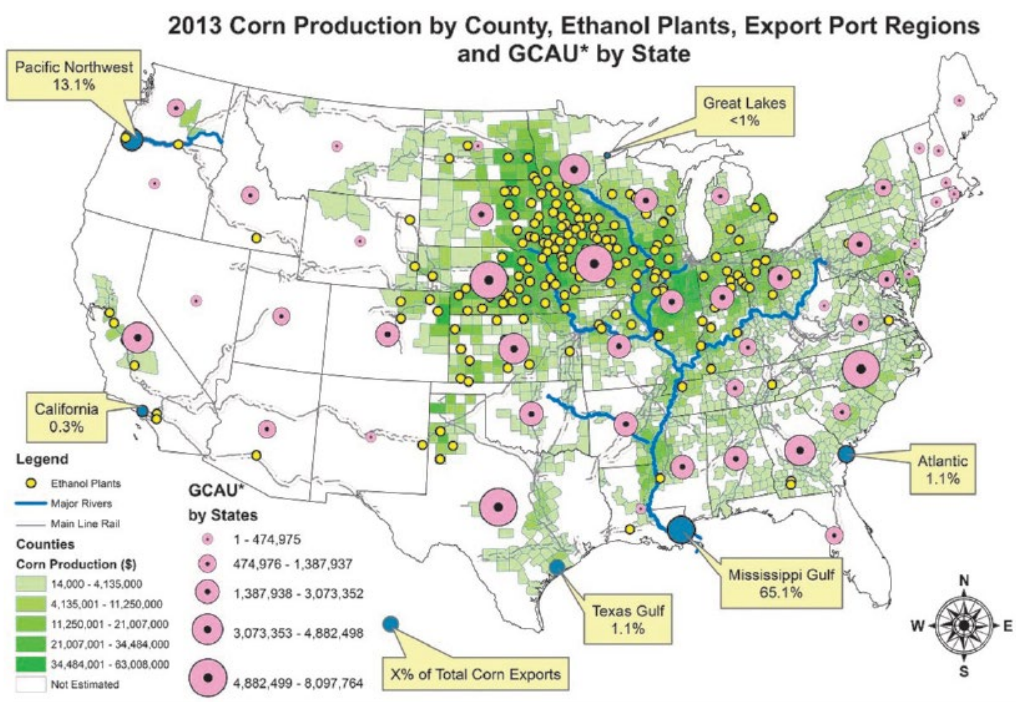

Figure 7. 2013 Corn Production by County, Ethanol Plants, Grain Consuming Animal Units by State, and Export Port Regions (Denicoff, Prater, & Bahizi, 2014a)

On the other end of the supply chain, large quantities of goods travel to West Coast and Gulf Coast ports. Figure 8 shows food commodity flows in the United States, but does not show details on the exact path being traveled. Instead, it pulls data from the FAF to show origin-destination pairs at the county level. A little less food travels around the East Coast—but still a sizeable amount. The area of the country with the most food flows is in the Midwest or Central U.S., particularly around the Mississippi River and locations with farmland.

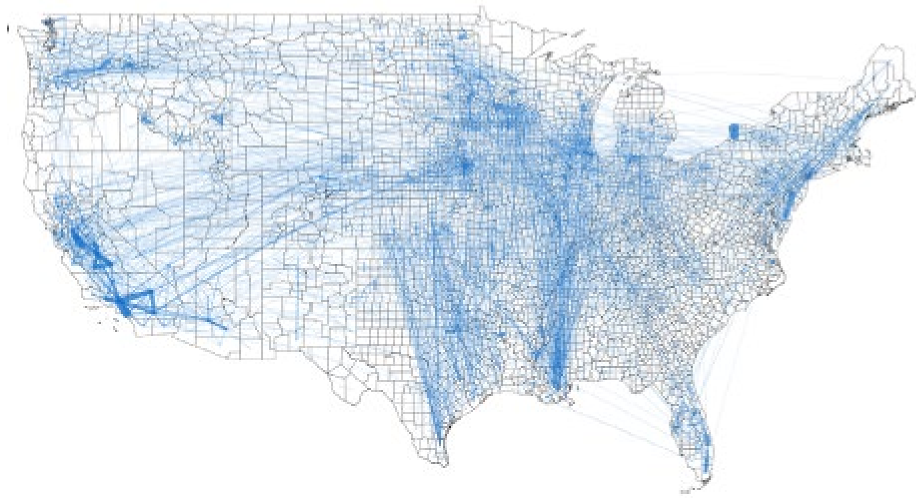

Figure 8**: Food Flows in the U.S. (Lin, Ruess, Marston, & Konar, 2019)**

3.3 Food Price Impacts

The USDA calculates a "food dollar" to provide an answer to the question "for what do our food dollars pay"? According to this data, the total transportation cost tends to make up around 3-4 percent of the food dollar (Canning, 2011). For exported goods, this ratio may be different, given the ocean journey, but for domestic goods, transportation is a small part of the total cost of food. That share has generally declined over the past several years, though the total dollar value has held roughly steady (Canning, 2011). Incorporating all aspects of preparing the food, from farm to fork, USDA's food dollar includes industries such as foodservices and retail trade that end up outweighing the transportation cost. Transportation's estimated share of the food dollar, in both cents per dollar and the total value in millions of dollars, can be seen in Figure 9.

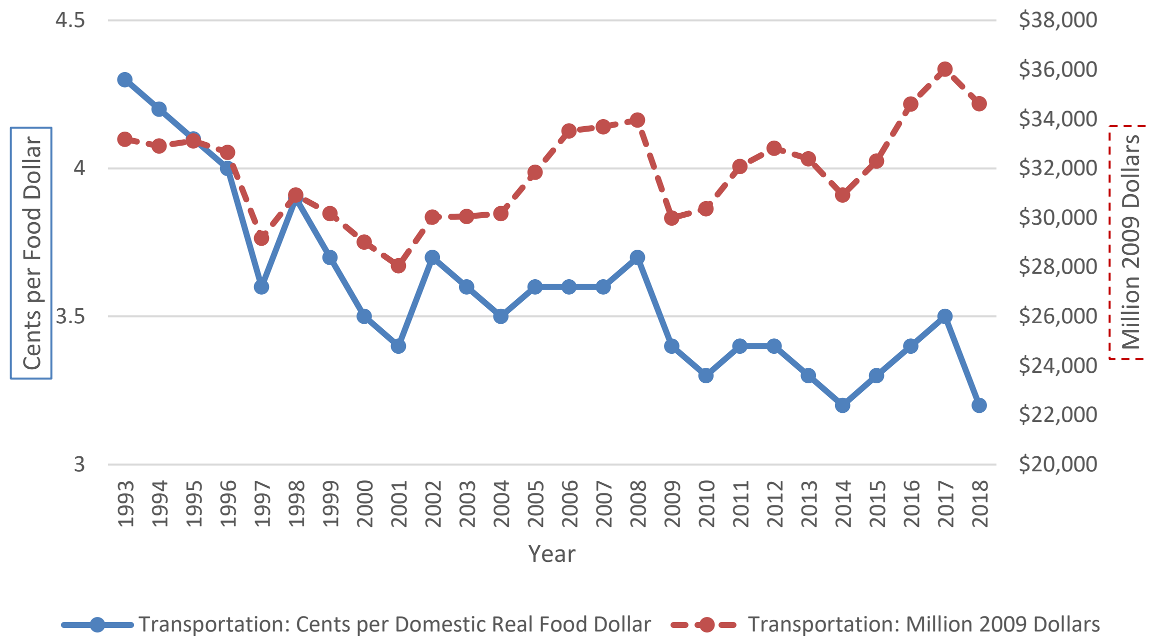

Figure 9. Transportation's Component of the Domestic Food Dollar (USDA, 2020a)

Although agricultural commodities also move on inland waterways and on rail, trucking is generally the most expensive of the three inland modes in terms of dollars per ton-mile and makes the most sense for the majority of shipments as it is both the quickest mode, and provides the connections for rail, barge, and ocean transportation. At only 3-4 cents per food dollar, transportation is not the largest component affecting domestic food costs. However, profit margins in agriculture tend to be very tight, and in 2013, USDA reported that almost 70% of all farms were in the "critical zone," meaning that their operating profit margin (the ratio of operating profit to gross cash farm income) was less than 10% (Hoppe, 2015). Small changes in costs, therefore, affect profit margins for farmers, particularly for small farms that have tighter margins than large farms (Hoppe, 2015).

For exported goods, the transportation cost share of food prices can be larger, as ocean freight rates and detention and demurrage charges due to port congestion become factors. Total transportation costs for soybeans from Minnesota to Japan have often been close to $100/metric ton, and costs increase if the goods go through the Gulf Coast instead of the Pacific Northwest, likely because of the longer ocean journey with expensive ocean freight rates (Denicoff, Prater, and Bahizi, 2014b). However, the truck share of that journey typically costs only around $10 to $15 per metric ton, with most of the inland cost coming from barge or rail freight rates. Figure 10 shows the percentage of the inland transportation cost that comes from the different modes for two routes of soybean exports.

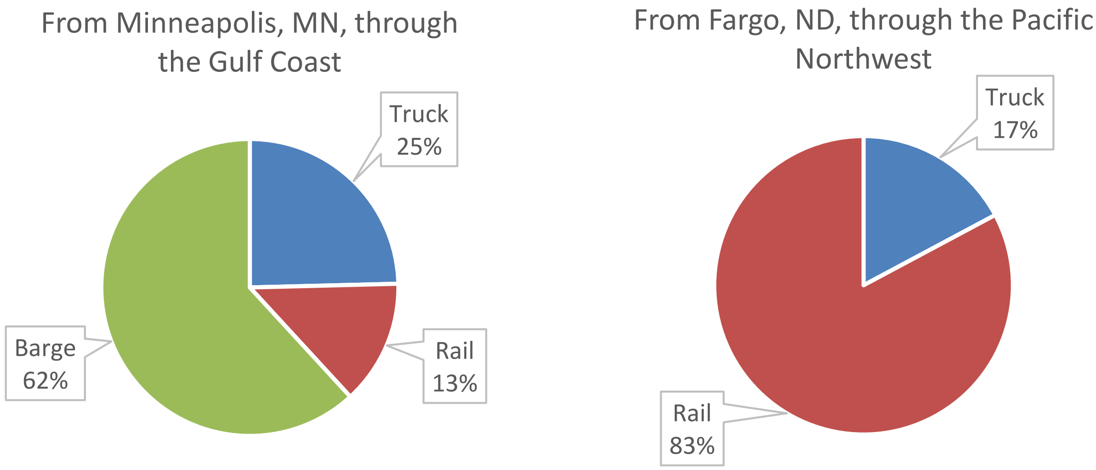

Figure 10. Modal Share of Inland Transportation Costs ($/mt) for Soybeans, Average from 2010 to 2018 (USDA, no date)

3.4 International Competitiveness

The efficiency of the transportation system also plays a key role in determining how competitive U.S. agricultural products are on a global scale. The United States faces strong competition from other countries for various commodities, and different countries have their own transportation costs and ways in which they attempt to increase their shares of the export market.

Adamopoulos (2011) used a general equilibrium framework to show how a large disparity in transportation infrastructure density translates to agricultural productivity differences across different countries. In other words, high transport costs distort allocation of resources not only across geographically dispersed production units within the agriculture sector but also across different sectors in the economy.

The efficiency and flexibility of trucking enables the United States to be competitive in the global marketplace for agricultural products. Disruptions in the multimodal supply chain—in rural and urban areas as well as at ports and inland terminals—affect agricultural markets and prices paid to farmers. The World Bank presents data on the cost to export by country. This cost index measures the total cost of importing or exporting a typical 20-foot ocean freight container in U.S. dollars. This cost covers all the fees associated with completing the procedures to export or import the goods, including documents, administrative fees for customs clearance and technical control, customs broker fees, terminal handling charges and inland transport. In Figure 11, the darker the shade of the country, the higher the value of its cost-to-export indicator is. The country with the highest value in the world (9,050) is Tajikistan, and the country with the lowest value in the world (410) is Timor-Leste.[2]

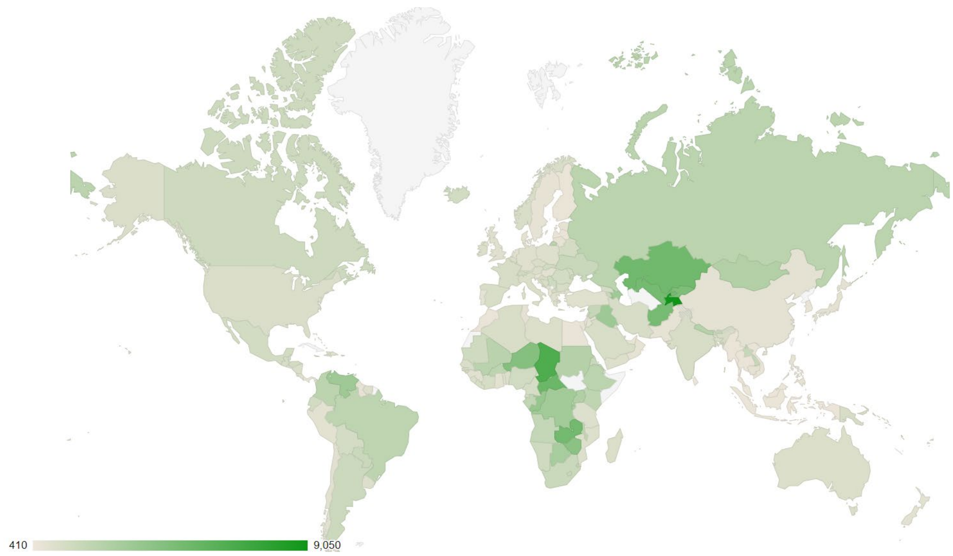

Figure 11. Cost-To-Export Indicator
(https://www.indexmundi.com/facts/indicators/IC.EXP.COST.CD)
Source: World Bank, Doing Business project (http://www.doingbusiness.org/).

Data from the World Bank were compared across key U.S. agricultural competitors. The cost-to-export indicator, as well as the main agricultural exports in which the country is competitive, appear in Table 6. The table does not include all agricultural commodities nor all countries that produce commodities, but rather presents the United States and its top competitors for select commodities, including soybeans, corn, sorghum, wheat, and cotton. As the table shows, while not the lowest, the United States does have a relatively low cost to export, particularly compared to Brazil and Argentina which are some of the United States' biggest competitors. Additionally, the cost-to-export indicator from the World Bank does not include refrigeration costs. Therefore, commodities that would require refrigeration (such as beef, pork, and chicken) are not included here.

[2] Definition: Cost measures the fees levied on a 20-foot container in U.S. dollars. All the fees associated with completing the procedures to export or import the goods are included. These include costs for documents, administrative fees for customs clearance and technical control, customs broker fees, terminal handling charges and inland transport. The cost measure does not include tariffs or trade taxes. Only official costs are recorded. Several assumptions are made for the business surveyed: that it has 60 or more employees; is located in the country's most populous city; and is a private, limited liability company. Also assumed is that the business does not operate within an export processing zone or an industrial estate with special export or import privileges; is domestically owned with no foreign ownership; and exports more than 10% of its sales. It is assumed that each traded product travels in a dry-cargo, 20-foot, full container load. Also assumed is that the product is not hazardous or include military items; does not require refrigeration or any other special environment; and does not require any special phytosanitary or environmental safety standards other than accepted international standards.

Table 6. Cost to Export and Key Agricultural Exports by Country

Country	Cost to Export Indicator	Top Agricultural Exports[1,2]
United States	1,224	Soybeans, *Corn*, *Sorghum*, Cotton, Wheat
Argentina	1,770	Soybeans, Corn, Sorghum
Australia	1,200	Sorghum, Wheat
Brazil	2,323	*Soybeans*, Corn
Canada	1,680	Soybeans, Wheat
China	823	*Cotton*
India	1,332	Cotton
Russia	2,401	*Wheat*

[1]These are the top agricultural exports from a country that are competitive with the U.S. in the world export market. A country's top agricultural export may not be listed in this table if it is only a small percent of the entire export market for that product.
[2]An *italicized* commodity means that the country is the largest exporter of that commodity.

3.4.1 Case Study: Brazil

Brazil is one of the biggest competitors for U.S. agriculture. The largest U.S. agricultural exports are soybeans and corn, both of which Brazil also produces in large quantities. The United States used to be the largest exporter of soybeans. However, Brazil overtook the United States in soybean exports in 2013 and has continued to be the largest exporter since then. Brazil has a lower cost of production than the United States because of lower costs for land and labor (Salin and Somwaru, 2018). Part of what allows the United States to remain competitive is transportation efficiency, but Brazil has been making strides in recent years in improving its road network to lower transportation costs, increasing their competitiveness in the export market.

At the end of 2019, Brazil finished a project to pave and improve BR-163, which connects Brazil's largest grain producing region to Miritubа, allowing products to reach northern ports in Brazil (Salin and Somwaru, 2018). This was only the most recent step in Brazil's efforts to improve its infrastructure to allow grains to make it to ports more quickly and more cheaply than in the past. These improvements to Brazil's infrastructure will result in less expensive and more competitive grain and soybeans to the end user. Plus, at the margin, Brazil's improvements will lead to more demand for Brazilian corn and soybeans, and less demand for U.S. corn and soybeans, all other things being equal.

Figure 12 and Figure 13 compare U.S. soybean transportation costs to Brazilian ones. U.S. costs have generally been lower historically, shipping either through the U.S. Gulf Coast or the Pacific Northwest. The Brazilian port of Santos has tracked closely with U.S. costs, and Paranaguá has had significantly higher costs than the United States (USDA, no date).[3] However, prices began to change around 2014. The costs of shipping through Paranaguá plummeted, due to decreased costs for trucking in Brazil. The

[3] U.S. Gulf costs are from Minneapolis, MN, through the Gulf Coast; the U.S. Pacific Northwest costs come from Fargo, ND; the Santos costs are from South Goiás, Brazil, through the port of Santos; and Paranaguá comes from North Mato Grosso, Brazil.

costs for Santos also dropped. They remain consistently below the costs of both the U.S. Gulf Coast and the Pacific Northwest through 2016 and 2017, and 2018 data is unavailable for the Santos route. The costs of shipping from Fargo, ND, through the Pacific Northwest remain relatively constant throughout the entire period analyzed in the graph (2010-2018), while the U.S. Gulf Coast route tends to have more variation because of rail and barge prices.

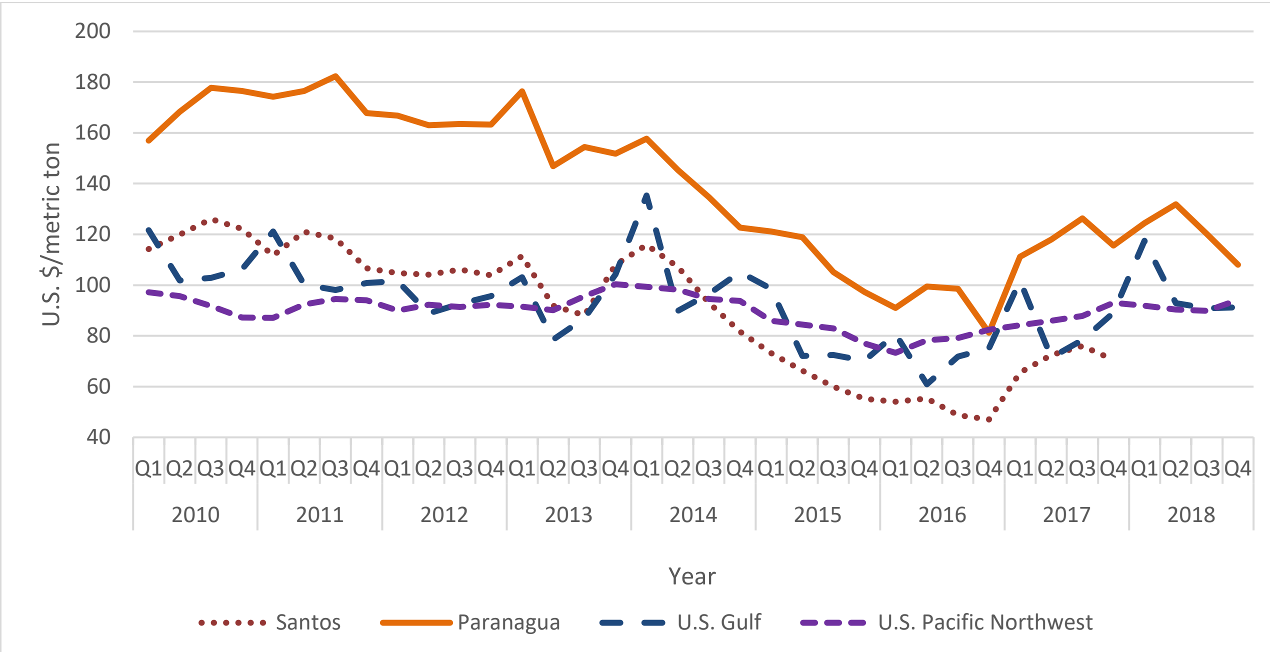

Figure 12. U.S. and Brazil Soybean Total Transportation Costs to Shanghai, China (USDA, no date)
U.S. Gulf*: From Minneapolis, MN, through the U.S. Gulf Coast;* ***U.S. Pacific Northwest****: From Fargo, ND, through the Pacific Northwest;* ***Santos****: From South Goiás, Brazil, data not available for 2018;* ***Paranaguá****: From North Mato Grosso, Brazil*

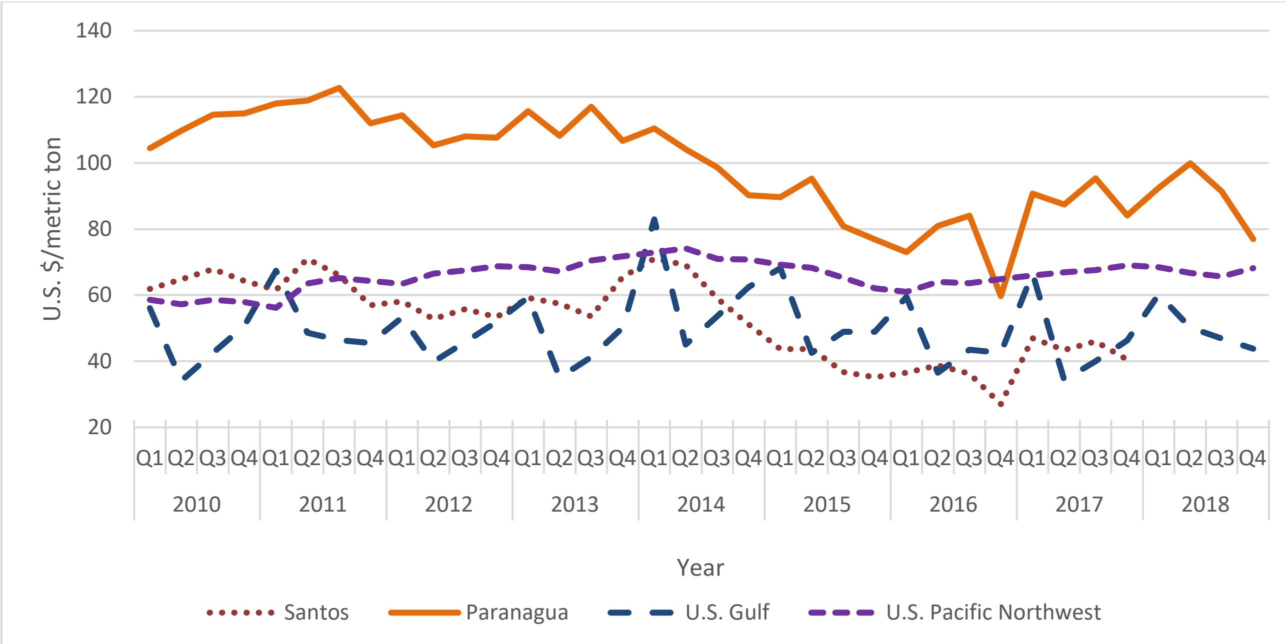

Figure 13. U.S. and Brazil Soybean Total Inland Transportation Costs to Shanghai, China (USDA, no date)
U.S. Gulf*: From Minneapolis, MN, through the U.S. Gulf Coast;* ***U.S. Pacific Northwest****: From Fargo, ND, through the Pacific Northwest;* ***Santos****: From South Goiás, Brazil, data not available for 2018;* ***Paranaguá****: From North Mato Grosso, Brazil*

Breaking out the inland transportation costs further shows that, for these routes, the U.S. truck cost is often around $10/metric ton, although it does vary, with the majority of the cost coming from the rail or barge portion of the journey (USDA, no date). Because the rail and barge components make up more of the overall cost for exported soybeans, it is possible that improvements to railroads and inland waterways could have a larger effect than improvements to roads on the U.S. cost to export. However, improvements to surface transportation are needed, as trucks provide the connections to railroads and waterways.

4. Agricultural Projections

Given the enormous role of agriculture in the economy, it is essential to use agricultural data to inform transportation planning. In particular, the future size of the agricultural industry is relevant for understanding the importance of surface transportation. Industry growth will increase congestion and require investment to mitigate the impacts of increased truck traffic. Additionally, transportation projects often have a long timeframe from planning to implementation. Freight projections are, therefore, particularly important to help strategically plan transportation projects. To help understand the future of agriculture, this project created projections for key agricultural commodities 25 years into the future.

USDA has its own 10-year projections of several commodities, which USDA updates every year. At the time this report was produced, the most current USDA forecast was from February 2020 and covered the period to 2029 (USDA, 2020b). (Some early-release tables from the February 2021 forecasts are now available, but were not used in this analysis.) These 10-year projections were used as a basis to develop 25-year projections of the same commodities that USDA projected. The approach leverages the longrun supply-demand equilibriums that exist for agricultural products for purposes of developing a long-term outlook. This relationship can be observed in time series data, whereby in the long run, there is a stable and consistent relationship between the two series, even though the two series may drift away from each other in the short run (in time series analysis, this is called a co-integrating relationship).[4] This relationship can be used to guide the development of a projection extension and ensure it is consistent with the USDA projection and historical trends. The process also recognizes and maintains the relationships between the stock and flow concepts by establishing identities used to produce total supply and use projections.

The detailed results of the 25-year projections will be presented for soybeans, corn, wheat, beef, and pork, and a description of the methodology behind the projections can be found in Section 6 of this Appendix. This section will provide an overview of the expected future trends for a few commodities, and discuss how these trends may affect traffic, infrastructure needs, and international competitiveness. There is always uncertainty around any projection, and this is particularly true for projections that cover many years, such as these 25-year projections. Thus, these projections are intended to serve only as a rough estimate of trends.

[4] For a more detailed discussion of co-integration, see Co-Integration and Error Correction: Representation, Estimation and Testing, R. Engle and C. Granger, Econometrica, March 1987.

4.1 Specific Commodities

The projection work covered all commodities for which USDA has 10-year projections. However, certain commodities represent a small share of the overall industry, and while those commodities are still critical to the agricultural industry, they do represent a smaller share of freight movements and agricultural exports. Accordingly, this section will highlight some of the largest commodities by volume and value. For crops, these large commodities include soybeans, corn, and wheat, and for livestock products, they include beef and pork.

4.1.1 Soybeans

Although there have been some declines in soybean supply in previous years, soybean projections indicate that the market should recover and continue to grow in the next 25 years. The projections include the export market—soybean exports should continue to rise, although the growth rate is consistent with the overall growth rate of demand of around 1.2% per year. Figure 14 and Figure 15 show the soybean projections.

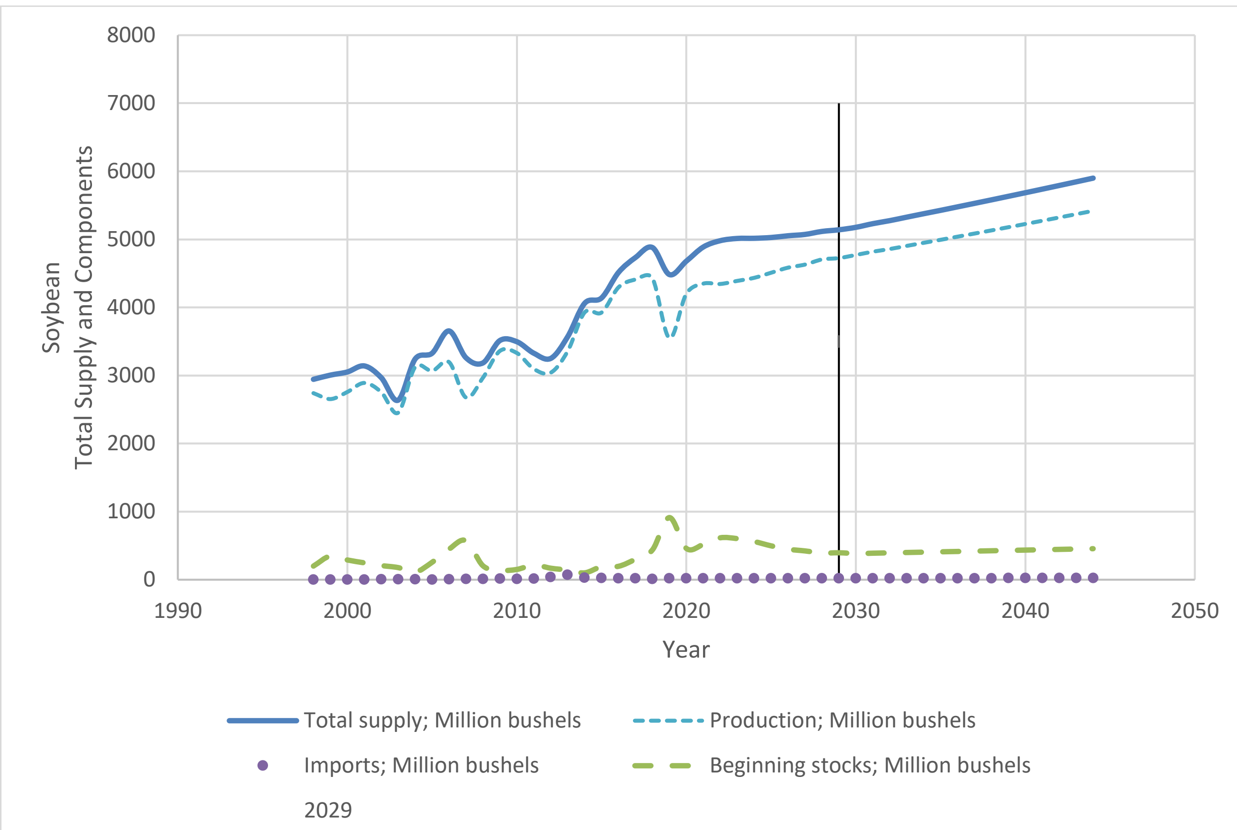

Figure 14. Soybean Total Supply and Components
Source: USDA 2020-2029 projection; Volpe projection extends from 2029.

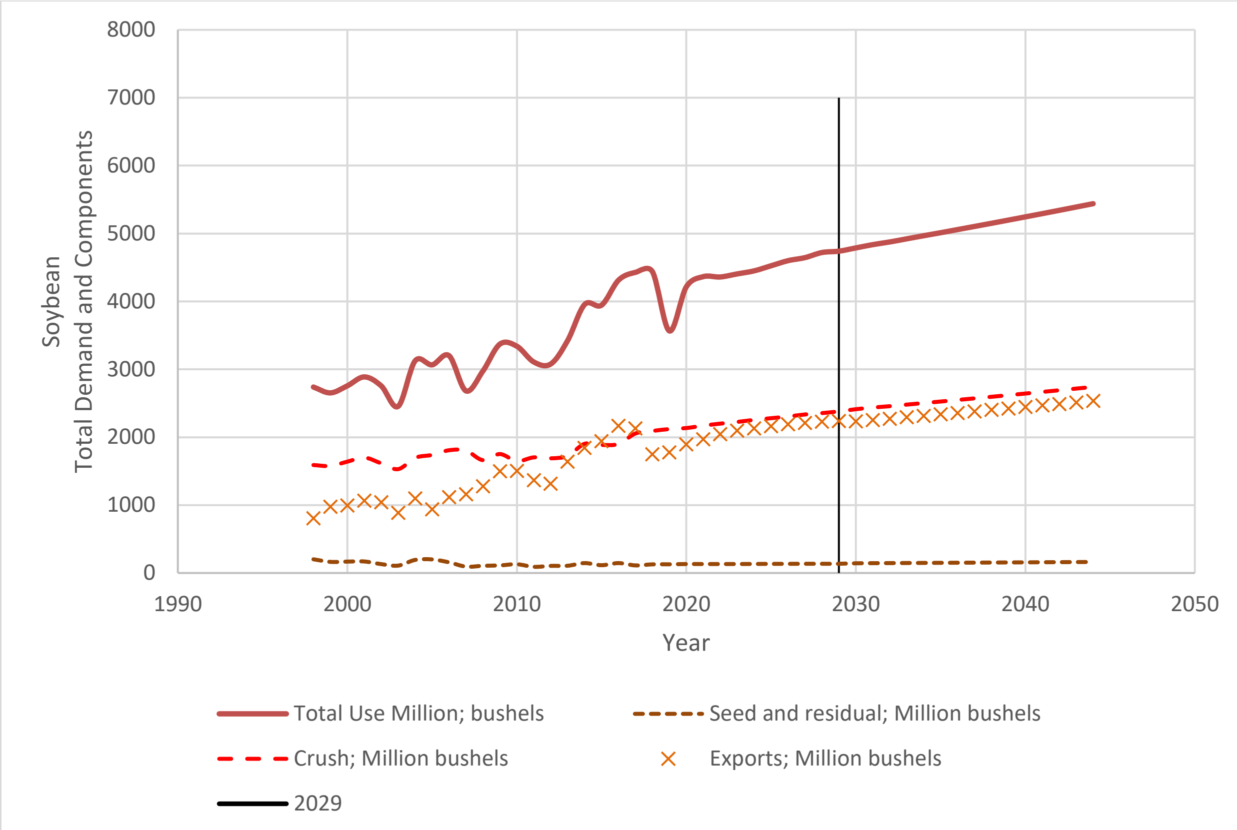

Figure 15. Soybean Total Demand and Components
Source: USDA 2020-2029 projection; Volpe projection extends from 2029.

4.1.2 Corn

Similar to the soybean market, the supply and demand for corn are both expected to continue to increase through the 25-year projection, at a rate similar to the soybean rate. Figure 16 and Figure 17 show the corn projections.

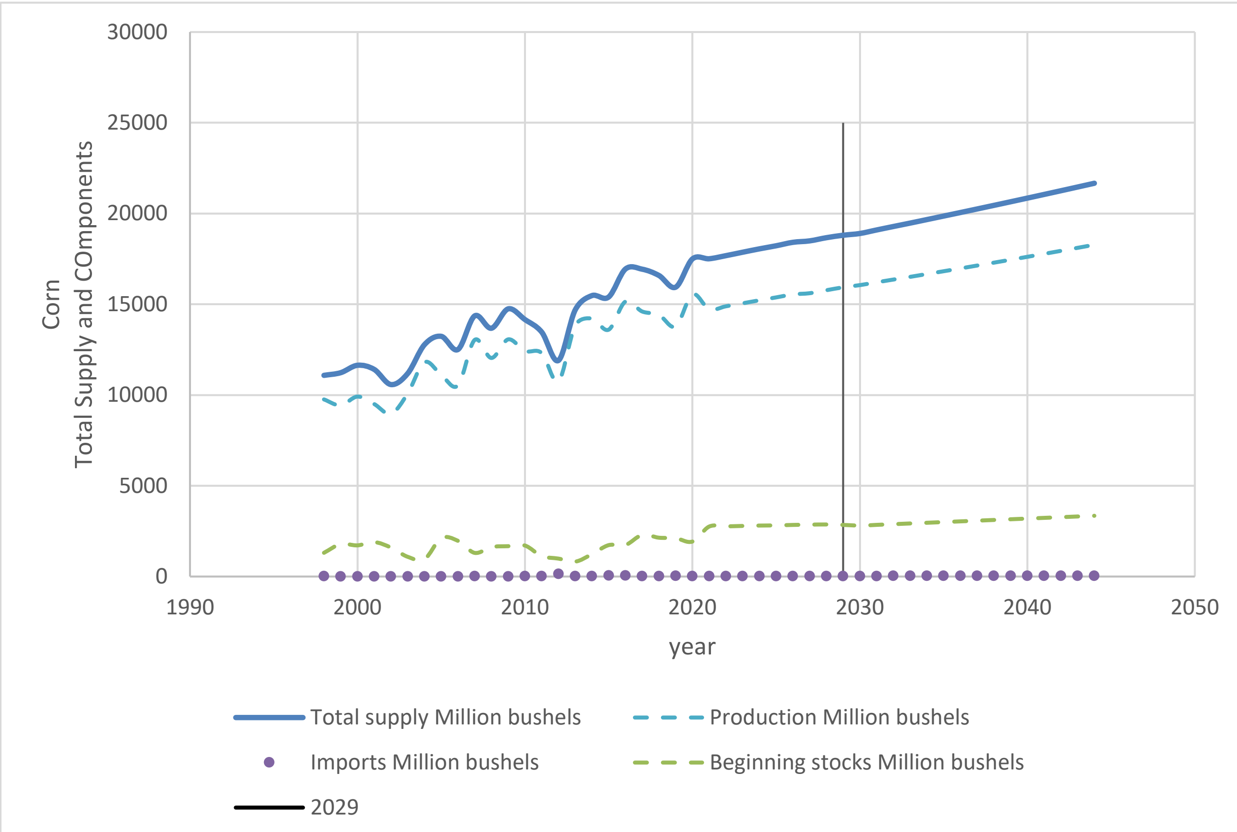

Figure 16. Corn Total Supply and Components
Source: USDA 2020-2029 projection; Volpe projection extends from 2029.

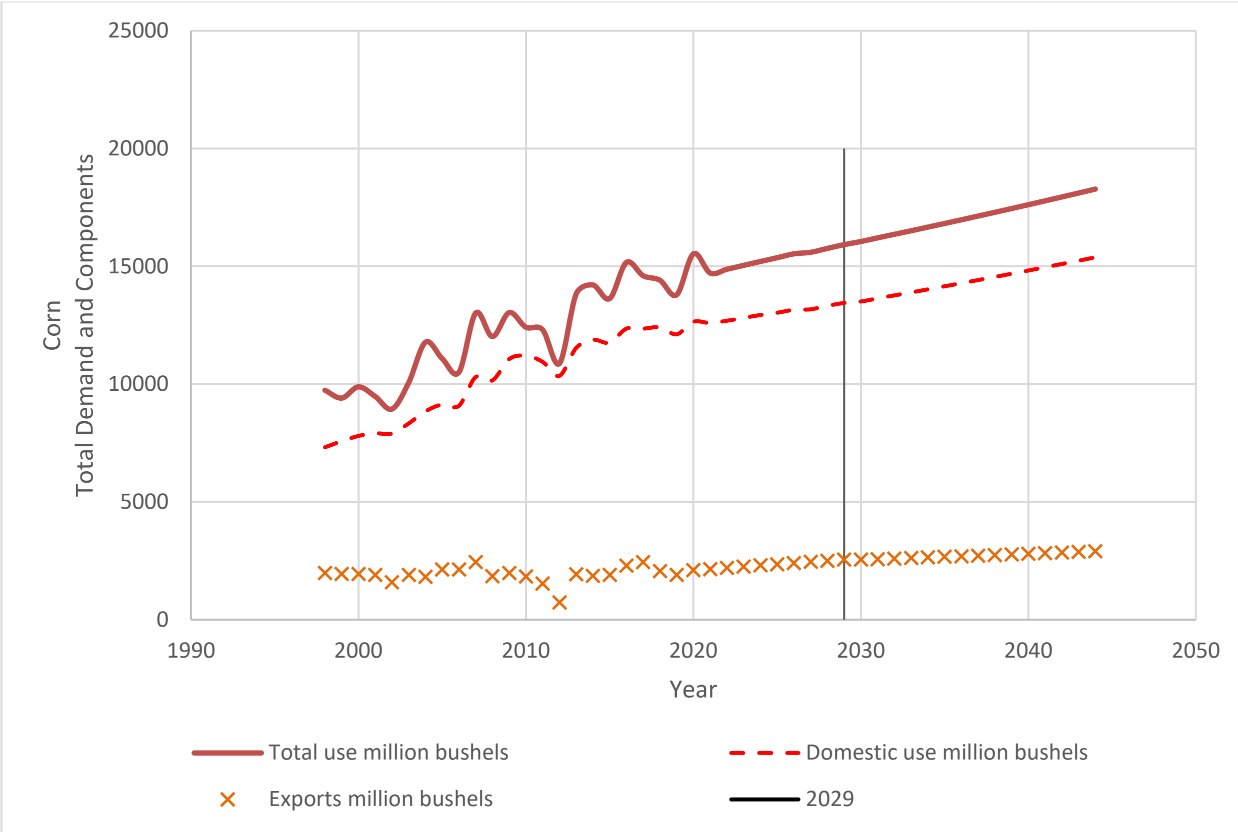

Figure 17. Corn Total Demand and Components

Source: USDA 2020-2029 projection; Volpe projection extends from 2029.

4.1.3 Wheat

At 0.3-0.4% per year, the growth in supply and demand for wheat is much lower than that of corn and soybeans. Domestic use and exports represent relatively equal shares of wheat consumption, with no large changes expected to occur over time. Figure 18 and Figure 19 show the wheat projections.

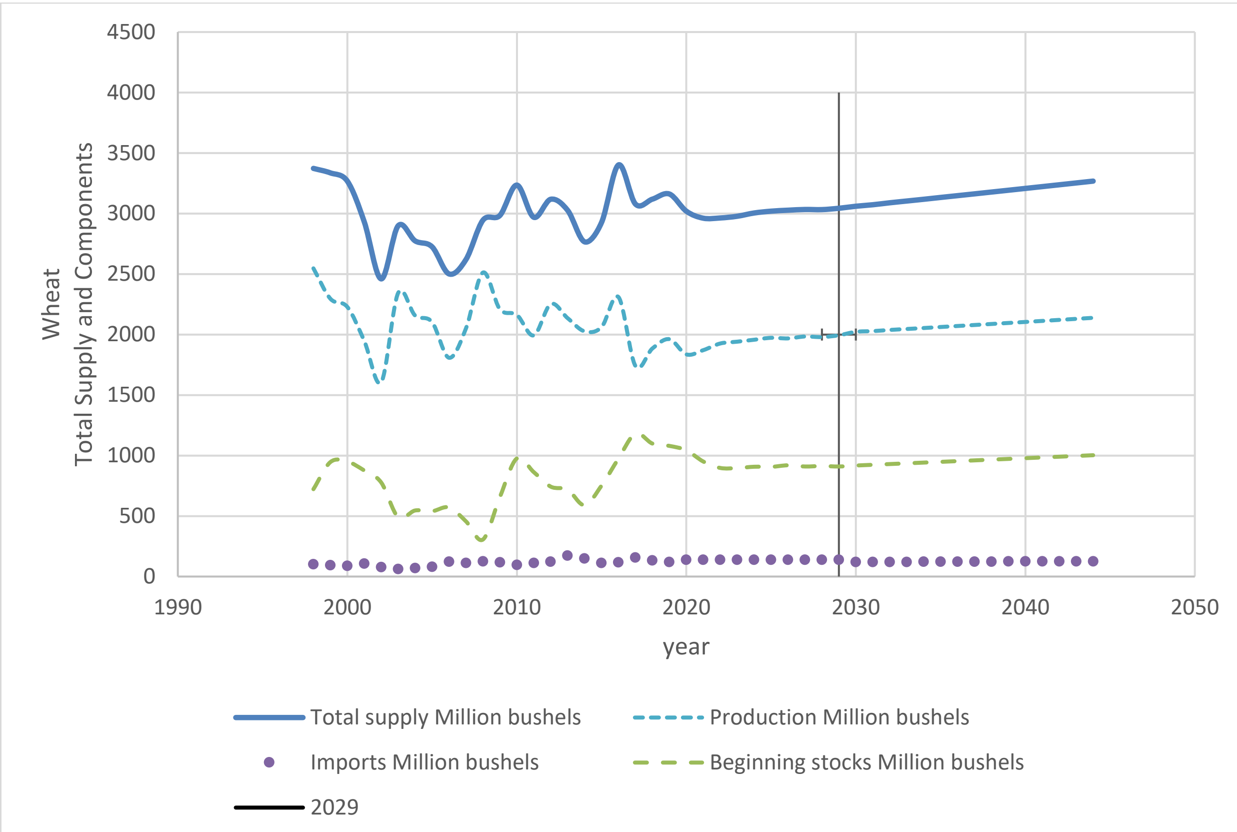

Figure 18. Wheat Total Supply and Components
Source: USDA 2020-2029 projection; Volpe projection extends from 2029.

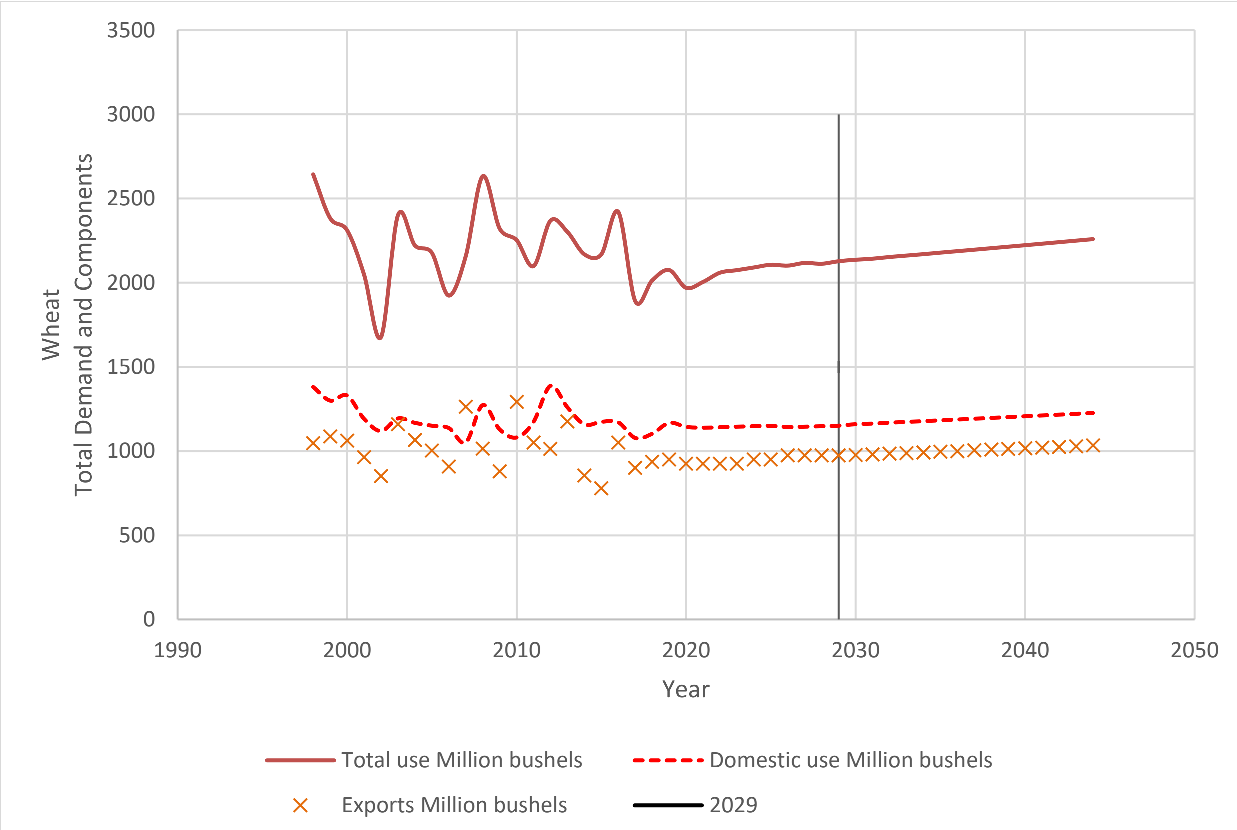

Figure 19. Wheat Total Demand and Components
Source: USDA 2020-2029 projection; Volpe projection extends from 2029.

4.1.4 Beef

Supply and demand for beef are projected to grow at more slowly than soybeans and corn. Changes in consumer preferences could contribute to a slowing demand for red meat, but consumption is still expected to increase overall. The vast majority of beef is consumed in the United States, with only a small fraction exported to other countries. Figure 20 and Figure 21 show the beef projections.

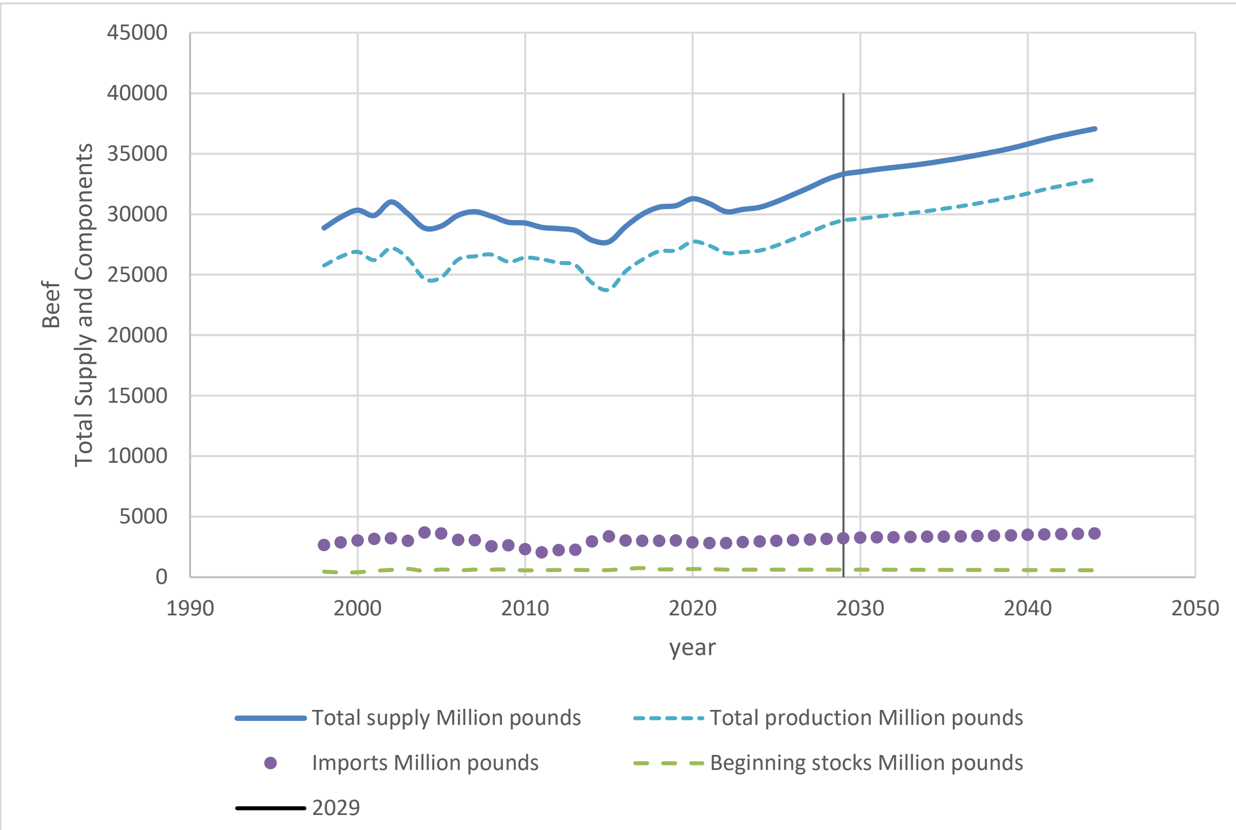

Figure 20. Beef Total Supply and Components
Source: USDA 2020-2029 projection; Volpe projection extends from 2029.

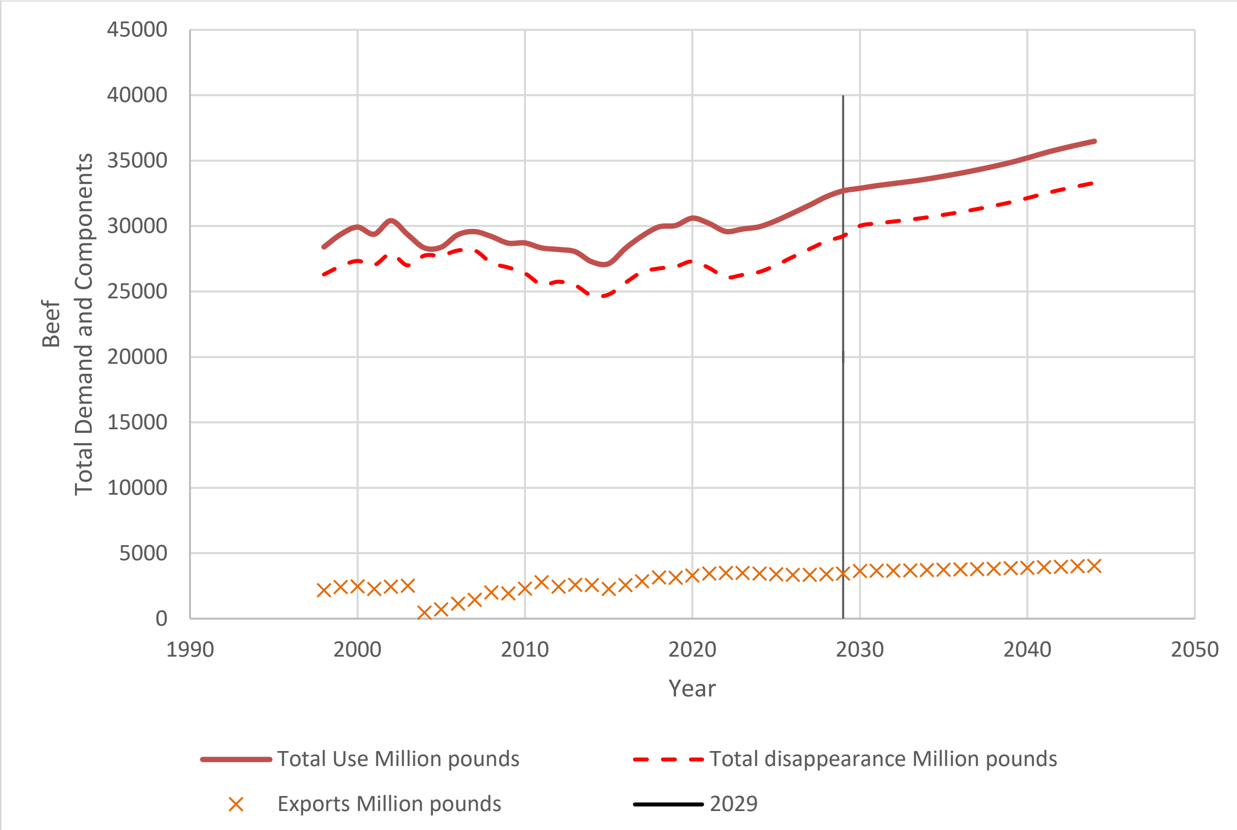

Figure 21. Beef Total Demand and Components

Source: USDA 2020-2029 projection; Volpe projection extends from 2029

4.1.5 Pork

Supply and demand for pork are expected to grow fairly steadily, particularly compared to beef. Additionally, the United States exports a larger share of pork than beef. Projections show the exported share of pork staying relatively constant over time. Figure 22 and Figure 23 show the pork projections.

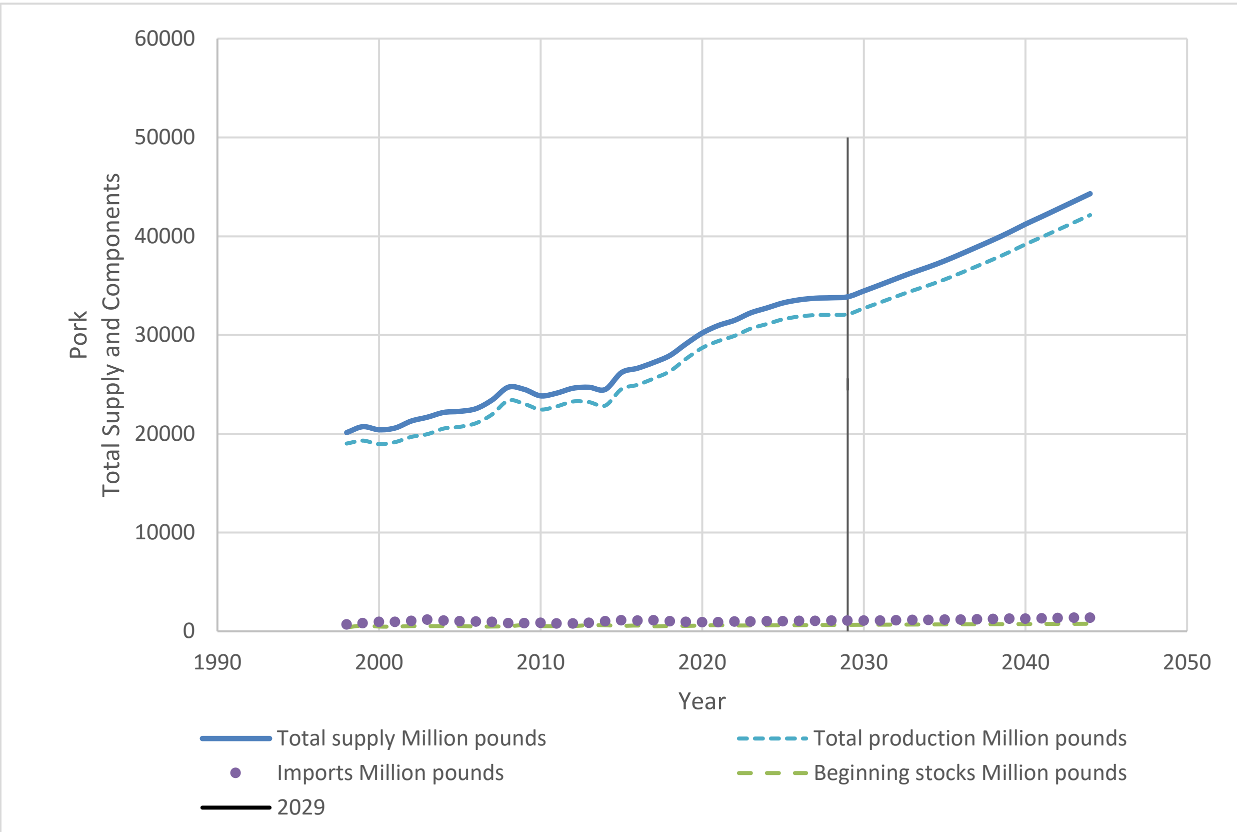

Figure 22. Pork Total Supply and Components

Source: USDA 2020-2029 projection; Volpe projection extends from 2029

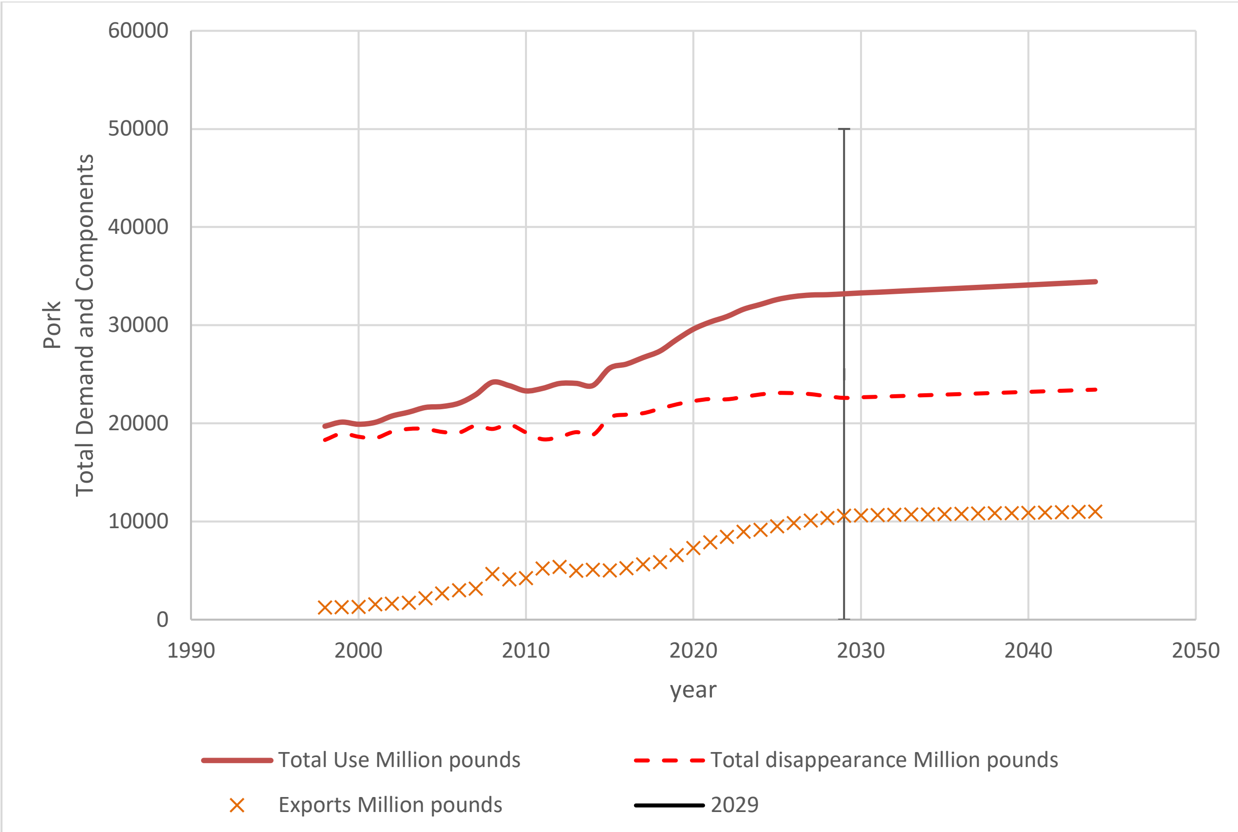

Figure 23. Pork Total Demand and Components

Source: USDA 2020-2029 projection; Volpe projection extends from 2029

4.2 Overall Trends and Expected Impacts

Robust conclusions cannot be drawn from the 25-year projections, given the uncertainty surrounding them. However, this section attempts to draw some general themes based on the overall trends in the projections. Across the agricultural industry as a whole, projections generally show continued growth, meaning the industry will continue to grow throughout the next 25 years. The United States will continue to be a large, competitive agricultural exporter.

An increase in the number of commodities produced and shipped across the country will result in a larger strain on surface infrastructure and the trucking industry. More goods mean more trucks and miles traveled, increasing congestion on already congested roads. Overall, vehicle miles traveled (VMT) are expected to grow at a rate of just under 1 percent per year through 2047, and VMT for combination and single-unit trucks will grow at 1.5 percent and 1.9 percent annually, respectively (FHWA, 2019b).

Based on the expected growth rates, agriculture's share of all freight traffic may not shift much. It is difficult to draw an accurate comparison as a 1-percent increase in agricultural products does not necessarily result in an equivalent 1-percent increase in the truck traffic required to carry those products, because it depends also on the actual volume of the increase, how much freight a single truck can carry, and changes in freight demand in other sectors. These projections cannot say for certain how traffic will be affected by the predicted growth rate, but the fact that agricultural production is expected to continue to grow indicates that agriculture will continue to be one of the most important types of freight shipped in the United States.

It is also worth noting that the projections do not predict substantial changes in the share of agricultural production that gets exported. The total volume of exported goods will grow proportionally with total production, and the relative share of agricultural goods as a whole that are exported is expected to continue to follow current trends, although there will likely always be a certain amount of variation from year to year. If exports were to grow substantially, that increase could raise pressure on certain parts of the transportation system, such as inland waterways, railroads, ports, and the intermodal connections to them. It is difficult to predict exactly how agricultural flows across the country will shift over the next several years. However, the current geographic pattern of flows, which reflects the spatial distribution of producers, consumers, and export markets, remains a reasonable estimate of future flow patterns.

Multiple aspects of this analysis have been affected by the COVID-19 pandemic, which has affected agricultural production, processing, and shipments. At the time this report was prepared, the most recent USDA forecasts were from the February 2020 release, which did not reflect any pandemic-related impacts. Subsequent updates to these forecasts do include estimated impacts through October 2020, as well as a revised outlook for future years. Although there continues to be uncertainty over the near term, the 25-year forecasts presented here represent a reasonable estimate of future conditions over the longer term.

Improving the NHS and the larger roadway system in the United States will benefit all road users, but it will certainly benefit agriculture freight as well. Agricultural freight should continue to be a substantial portion of the overall system of freight for many years into the future.

5. Conclusion

U.S. surface transportation plays a large role in the country's economy. The transportation industry itself employs millions of workers, including truck drivers, but also serves to ensure various commodities can reach their intended markets for consumption. Agricultural products comprise a large portion of all inland truck movements, particularly for domestic shipments. However, U.S. roadways are aging and congested, which can increase the time required for a shipment, increase operational costs, reduce international competitiveness, and raise the final delivered price.

Studies have shown that improving transportation infrastructure does positively impact various industries, including agricultural. One study found that increasing investment by 1% could increase agricultural output in the same State by 0.2-0.3% (Tong et al., 2013). Larger increases in investment spending would then also cause larger increases in agricultural output. Investing in infrastructure to alleviate congestion could also reduce transportation costs, particularly for domestic goods, which travel primarily by truck. Exported goods travel more on rail and barges, limiting the ability to improve the movements of exported goods by solely improving trucking. There is, however, always a truck component to every journey. While the exact cost per ton mile varies, truck costs are typically higher than the costs for rail or barge, such that the truck component of a journey can be a major contributor to the overall cost. Higher truck transportation costs can reduce the prices paid to farmers and make exports less competitive in the international market.

Other benefits from investment in infrastructure include reducing costs to farmers and food producers or to domestic food consumers. Farmers often have small profit margins, and any reduction in transportation cost could increase their profit. For domestic consumers, reductions in transportation costs can reduce the final cost of the food, saving consumers money and potentially allowing them to purchase more commodities.

The efficiency of the U.S. transportation network helps reduce the cost of moving goods and increases U.S. competitiveness in the global agricultural market. Other countries, such as Brazil, are making strides toward improving their transportation systems, thereby making their commodities more attractive substitutes for American ones. Data have shown that Brazil's transportation costs used to exceed those of the United States, but Brazil's costs have trended steeply downward in recent years with improved infrastructure.

Transportation is vital to every industry, including agriculture. This report highlights the necessity of maintaining and improving transportation networks and the benefits these infrastructure projects will have for the entire U.S. agricultural sector. Future research on this project will include analyses of cost-effective investment patterns, roles of different levels of government, impacts of different levels of investment, and future research needs.

6. Appendix

6.1 Commodity Projections Development

Introduction

The approach used for developing a 25-year outlook is based on USDA's current 10-year projection. This leverages the existing USDA projections, and underlying trends, and means the new projection will be a 15-year extension built on the existing 10-year projection that ends in 2029. The full range of the long-run projection will therefore be from 2019-2043—the first 10 years from the current USDA (2020) outlook, followed by a 15-year extension.

This approach has the advantage of being relatively easy to structure and implement, and implicitly incorporates the assumptions imbedded in the USDA projection. In practice, this means leveraging the 10-year projected growth rates for commodities in the USDA outlook to guide the 15-year extension, and incorporating the long-term supply-demand equilibriums that exist in these markets. (That is, there is a co-integrating relationship between supply and demand in these markets that can be used to guide the projection extension.) Concepts covered for each commodity projection are not homogenous, and the specifics of the approach will vary from case to case. The process also recognizes and maintains the relationships between the stock and flow concepts by establishing identities used to produce total supply and use projections. The projection extension methodology is described below: the three main steps include data review, projection development, and projection validation.

Data Review

The first step requires documenting and graphing all concepts tracked and projection by USDA in the agricultural projections report, covering the key metrics—domestic use and export volume/price—and all connected market information. These concepts include all components used to build up total supply and total use, such as beginning stock, harvested acres, yield, production, imports, domestic use, exports, and ending stock. This step also requires identifying any subcomponents within this structure that may require additional or separate modeling (e.g., ethanol production as a subset of corn use, which is unmeasured in total corn use). The domestic prices of commodities and the associated value of product consumed are also considered.

Initial Projection Development

The initial approach focuses on identifying and projecting the primary supply and demand components for each commodity. In particular, data will be examined to identify the historical relationship between commodity supply (without stocks) and total demand (domestic and export). In general, this relationship is fairly stable, with periods where demand exceeds supply being followed by an increase in supply to meet the higher demand (and, perhaps, a moderation in demand due to higher prices). In time series analysis, this is a co-integrating relationship, whereby in the long run, there is a stable and consistent relationship between the two series, even though in the short run, the two series may drift away from each other.[5] This relationship can then be leveraged to guide the projection extension and ensure it is consistent with the USDA projection, and also historical trends. The specific steps for deriving the basis of the projection extension are:

1) **Supply Projection:** the initial step begins with projecting the commodity supply (with no stock) and establishes the foundation for the 15-year extension. A moving average process is utilized for this projection, which grounds the extension trend in the USDA 10-year projection (the starting point for the extension is a 3-period moving average, but different lag-lengths may be tested/used for different commodities depending on variation in historical trends).
2) **Estimating Longrun Supply/Demand Relationship:** This process involves estimating the long-term relationship (average gap) between the supply (with no stock) and total demand (domestic and export). This relationship is estimated based on examining the USDA projection and historical data, providing a stable base from which to predict the evolution of both demand and supply in the projection extension. Importantly, the estimated longrun gap needs to allow for a smooth transition from the USDA projection and the extension. (That is, there should be no discernable jumps in the first year of the extension projection, nor should the extension trend be significantly different from the USDA projection.)
3) **Total Demand Projection:** In this step, total demand (domestic and export) is projected using the co-integrating gap estimated previously (total demand = supply (no stock) − co-integrating gap).
    a. Projection performance can be checked through applying the gap to historical supply and calculating the mean absolute percent error (MAPE) between the estimated and actual demand—smaller MAPEs imply a better estimation.
4) **Projecting Disaggregated Supply and Demand:** Individual components of supply and demand (e.g., domestic demand, production, etc.) are projected using a share allocation approach. Historical shares are used to guide this process, with the focus being on recognizing and maintaining the historical distribution of supply (demand) among the component shares, as well as recent trends in how these shares may be evolving.[6]
5) **Harvested Acres:** Where applicable by commodity, harvested acres are projected using a moving average methodology.
6) **Yield:** Projected using identity and appropriate unit conversions, which varied per commodity.
7) **Commodity Prices:** These are extended from the USDA base using a moving average approach.

Proceeding from projection development, the stock and flow relationships are developed for each commodity. For example, in the first year of the projection extension, the ending stocks in the previous year become this year's beginning stocks. Domestic and import supply (projection as noted above) are added to beginning stocks to provide total stocks. This process is done using the appropriate identities for demand to provide a year-by-year accounting of how the market for each commodity will evolve.

[5] For a more detailed discussion of co-integration, see Co-Integration and Error Correction: Representation, Estimation and Testing, R. Engle and C. Granger, Econometrica, March 1987.

[6] Historical average shares are used when the series is stable, but if this is not the case, then more recent data, or the USDA projection, are used.

Projection Validation

Projection validation requires determining whether the projection extensions produced reasonable, longrun trends. For this, projections are checked for internal consistency within each commodity market, looking specifically for:

- Reasonable and stable relationship between supply and demand with a projection trend consistent with the USDA outlook;
- Beginning and ending stocks plausibly bounded by historical ranges;
- Balance between consumption and supply, so that ending/beginning stocks do not decline to implausible levels (given historical trends);
- Extension projection trends broadly consistent with USDA 10-year outlook;
- Compound annual growth rates consistent with the 10-year projections (e.g. not significantly deviating from the prior projection);
- Yield and stock/use ratios also reviewed to determine consistency with historical and USDA projection trends; and
- General measures (e.g., demand per capita) compared to historical trends.

Commodity projections that appear unreasonable (e.g., negative values for stock components) are reassessed, with the initial adjustment being made in the supply projection.

6.2 Projection Identities

Commodity	Identities	Notes
Corn	Production = Harvest Acres X Yield Total Supply = Beginning Stocks + Production + Imports Beginning Stocks = Ending Stocks (previous period) Domestic Use = Feed & Residual + Food, Seed & Industrial Total Use = Domestic Use + Exports Ending Stocks = Total Supply − Total Use Stocks/use ratio, %	Ethanol and by-products are a standalone sub-component and does not factor into Domestic Use. Price is projected but not part of identities.
Sorghum, Barley, Oats	Production = Harvest Acres X Yield Total Supply = Beginning Stocks + Production + Imports Beginning Stocks = Ending Stocks (previous period) Domestic Use = Feed & Residual + Food, Seed & Industrial Total Use = Domestic Use + Exports Ending Stocks = Total Supply − Total Use Stocks/use ratio, %	Price is projected but not part of identities.
Wheat	Total Supply = Beginning Stocks + Production + Imports Beginning Stocks = Ending Stocks (previous period) Domestic Use = Food + Seed + Feed & Residual Total Use = Domestic Use + Exports Ending Stocks = Total Supply − Total Use Stocks/use ratio, %	Price is projected but not part of identities.
Soybeans	Total Supply = Beginning Stocks + Production + Imports Beginning Stocks = Ending Stocks (previous period) Domestic Use = Crush + Seed & Residual Total Use = Domestic Use + Exports Ending Stocks = Total Supply − Total Use Stocks/use ratio, %	Price, including crush margins, are projected but not part of identities. Production of soybean meal and oil are identities from soybean (When a bushel of soybeans weighing 60 pounds is crushed, the typical result is 11 pounds of soybean oil, 44 pounds of 48 percent protein soybean meal, 4 pounds of hulls and 1 pound of waste.)

Rice	Total Supply = Beginning Stocks + Production + Imports Beginning Stocks = Ending Stocks (previous period) Domestic Use & Residual Total Use = Domestic Use + Exports Ending Stocks = Total Supply − Total Use Stocks/use ratio, %	Price is projected but not part of identities.
Upland Cotton	Total Supply = Beginning Stocks + Production + Imports Beginning Stocks = Ending Stocks (previous period) Domestic Use Total Use = Domestic Use + Exports Ending Stocks = Total Supply − Total Use Stocks/use ratio, %	Price is projected but not part of identities.
Beef	Total Supply = Beginning Stocks + Total Production + Imports Total Production = Farm Production + Commercial Production Beginning Stocks = Ending Stocks (previous period) Domestic Use = Total Consumption Total Use = Total Consumption + Exports Ending Stocks = Total Supply − Total Use	Prices varied across product uses. Prices are not part of any identity but projected. Prices: Beef cattle, Calves, Steers (5-area), Feeder Steelers (Oklahoma City) Inventory in different units/measure were also projected but is not part of any identity. Total Cow Inventory Beef Cow Inventory Cattle Inventory

Pork	Total Supply = Beginning Stocks + Total Production + Imports Total Production = Farm Production + Commercial Production Beginning Stocks = Ending Stocks (previous period) Domestic Use = Total Consumption Total Use = Total Consumption + Exports Ending Stocks = Total Supply − Total Use	Price and inventory are projected but not part of identities.
Young chicken	Total Supply = Beginning Stocks + Total Production Federally Inspected Slaughter Beginning Stocks = Ending Stocks (previous period) Domestic Use = Total Consumption Total Use = Total Consumption + Exports Ending Stocks = Total Supply − Total Use	Prices varied across product uses. Prices are not part of any identity but projected. Prices: Broilers (Farm), Broilers)National Composite) Broilers - A broiler is any chicken that is bred and raised specifically for meat production.
Turkey	Total Supply = Beginning Stocks + Total Production Beginning Stocks = Ending Stocks (previous period) Total Use = Domestic Use + Exports Ending Stocks = Total Supply − Total Use	Prices varied across product uses. Prices are not part of any identity but projected. Prices: Turkey (Farm), Hen Turkeys (National)
Egg	Total Supply = Beginning Stocks + Total Production + Imports Beginning Stocks = Ending Stocks (previous period) Total Use = Domestic Use + Hatching Use + Exports Ending Stocks = Total Supply − Total Use	Prices varied across product uses. Prices are not part of any identity but projected. Prices: Eggs, Farm New York, Grade A Large

Dairy	Milk fat basis: Total Commercial Supply= Beginning commercial stock + Marketings + Imports Milk fat basis: Domestic Commercial Use = Total Consumption Milk fat basis: Total Use = Domestic Commercial Use + Commercial Exports Milk fat basis: Ending Stocks = Total Commercial Supply − Total Use skim solids basis: Total Commercial Supply = Beginning commercial stock + Marketings + Imports skim solids basis: Domestic Commercial Use = Total Consumption skim solids basis: Total Use = Domestic Commercial Use + Commercial Exports + CCC donations skim solids basis: = Total Commercial Supply − Total Use Ending Commercial stocks	The DPDP addresses low margins for dairy operations by using Commodity Credit Corporation (CCC) funds to purchase dairy products for donation to public and private nonprofit organizations that provide nutrition assistance to low-income populations. Some series reported in the USDA projection but not part of identities. Number of cows Milk per cow Milk production Farm use Marketings Prices: All milk Cheese Butter Nonfat dry milk Dry whey

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Appendix A

The Importance of Highways to U.S. Agriculture

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