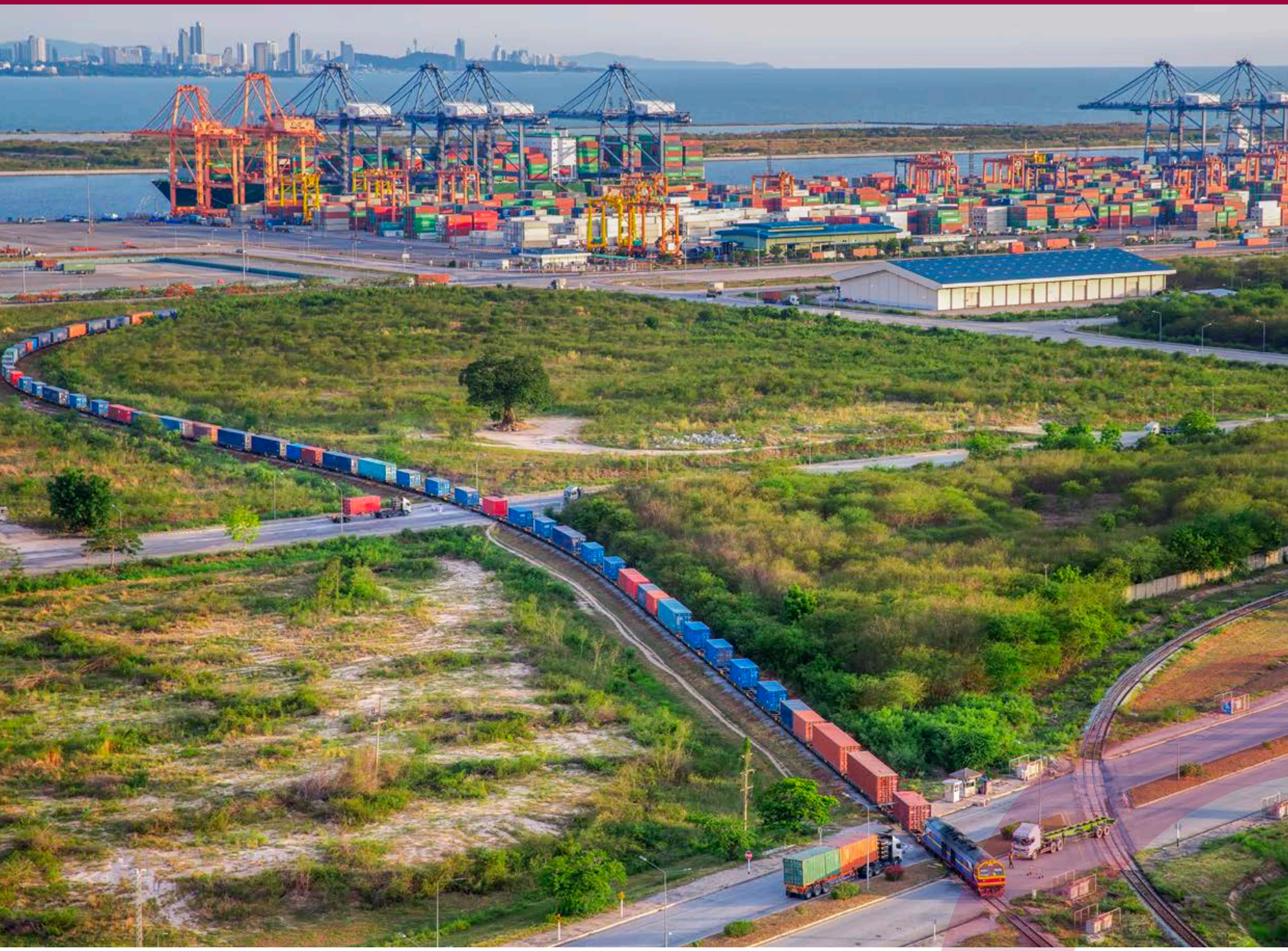

Toward greener and more sustainable freight systems

Comparing freight strategies in the United States and China

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EXECUTIVE SUMMARY

The United States and China both experienced tremendous growth in freight activities in recent decades, as a result of economic expansion. As China develops environmental and transportation strategies for the next 5 years, this report compares the historical and current domestic freight systems of the two countries and considers some of the underlying macroeconomic and policy factors. For example, heavy manufacturing still plays a large role in China's economy, resulting in significant coal use and transportation. Meanwhile, the United States has gradually moved away from coal. At the same time, both countries are increasing their use of renewable energy.

China and the United States rely the most on road transportation for freight, and more rail and pipeline activity took place in the United States in recent decades. During this time there was more waterway activity in China. Intermodal, (i.e., shipping with multiple modes), particularly truck and rail, was used for almost all types, from bulk products to manufactured products and longer-distance hauling, in the United States in recent decades.

We analyzed three products in depth—coal, iron ore, and motor vehicles. Shipping demand for those categories was much higher in China than in the United States, implying greater challenges for China in creating an efficient and green transportation system. Heavy bulk goods such as coal and iron ore were hauled mostly by rail in the United States, and mostly by truck in China. For conveying higher-value products such as motor vehicles, there was more diversity in China as rail and waterway accounted for 44% of shipping by number of vehicles.

In recent decades, U.S. policy efforts to create an efficient freight system led to productivity gains across all modes of transportation. The expansion of intermodal freight and the shift of rail's engagement most likely came from the new framework of transportation planning and policy in the United States. The intermodal approach was initiated under the Intermodal Surface Transportation Efficiency Act of 1991. The U.S. transportation system's growth, deregulation, and intermodalism coupled with economic growth, increased funding for infrastructure, and technological innovations reshaped the entire transportation system.

As China has taken steps toward marketization, a strategic plan with an intermodal framework would help capture similar gains and accelerate the transition toward a more sustainable transportation structure. With a well-integrated transportation network, rail could play an even more promising role in leading China's freight activity, especially for higher-value products. Further, a well-designed data collection protocol that focuses on mapping the flow of commodities would help any country to better assess the demand for things like transportation facilities and services, energy use, and more.

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LIST OF ACRONYMS

ACTA	Alameda Corridor Transportation Authority
BTS	Bureau of Transportation Statistics
CFS	Commodity Flow Survey
CMAQ	Congestion Mitigation and Air quality Improvement Program
FAST Act	Fixing America's Surface Transportation Act
FAF	Freight Analysis Framework
GHG	Greenhouse gas
ISTEA	Intermodal Surface Transportation Efficiency Act
ICC	Interstate Commerce Commission
MEE	Ministry of Ecology and Environment
MIIT	Ministry of Industry and Information Technology
MoT	Ministry of Transportation
MAP-21	Moving Ahead for Progress in the 21st Century Act
NAAQS	National Ambient Air Quality Standards
NDRC	National Development and Reform Council
NHS	National Highway System
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
TEA-21	Transportation Equity Act for the 21st Century
TIFIA	Transportation Infrastructure Finance and Innovation Act
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
DOT	U.S. Department of Transportation

INTRODUCTION

Freight movement accounts for a large share of global air pollution and greenhouse gas (GHG) emissions. Between 2000 and 2019, global freight tonnage expanded from 7.3 billion to 11.08 billion metric tons per year—an average annual growth rate of 2.2% (United Nations Conference on Trade and Development, 2020). With global freight demand expected to triple between 2015 and 2050, freight-related carbon dioxide (CO_2) emissions are projected to more than double, even taking into account already-announced mitigation strategies (International Transport Forum, 2019).

China has been one of the countries driving significant freight growth in recent years, and this trend is expected to continue. Without adequate control measures, freight-related emissions will increase substantially in the coming decades, considering China's rapid economic growth and significant international development and trade programs, including the Belt and Road Initiative and associated freight transport activities.

Regulations applying to the economic, logistical, and transportation elements of freight can reduce demand, fuel use, and GHG emissions even amid growing freight activity (Grenzeback et al., 2013). China has started on its path toward a green and sustainable freight transportation system. In the past few years, authorities have issued several central or sectoral policies concerning adjustment of the transportation structure. These include requiring that shipping of coal and bulk products shift from trucks to rail and waterway and a requirement that annual rail tonnage increase 30%, or 1.1 billion tons, by 2020 from the 2017 level.

However, these policies and targets are due for an update as China develops environmental and transportation strategies for the next five years. In this context, this study compares the United States and China in terms of historical and current freight transportation systems and the underlying macroeconomic factors. It highlights the experiences and lessons that can support China in developing strategies, policies, and targets that suit its specific development context and includes policy recommendations for China at the national and local levels.

The study is based on the most reliable and representative data available, in many cases supplemented with input from experts. The analysis relies on various statistical data and relevant studies, including from the U.S. Bureau of Transportation Statistics (BTS), the U.S. Freight Analysis Framework (FAF), and the U.S. Energy Information Administration (EIA), China's National Bureau of Statistics Yearbook, the World Bank, and direct communication with key experts. However, gaps still exist for a comprehensive deep dive, particularly for China. This highlights the great need to prioritize surveys that help understand freight characteristics by commodity.

CHARACTERISTICS OF FREIGHT TRANSPORTATION

This chapter will characterize and compare freight transportation trends in the United States and China by measuring three dimensions where data were available: weight, activity, and value. The weight (tonnage) is how much needs to be moved and is useful for assessing infrastructure requirements. The activity (in ton-miles or ton-kilometers) is useful for understanding the combined impacts of the loads and the distances hauled. Value is useful for highlighting the economic impacts and interdependencies. Due to limitations on data availability, we draw comparisons only at a high level. Note that for both countries, we focus only on freight moved domestically and do not consider international trade.

FREIGHT TRANSPORTATION IN THE UNITED STATES

In 2018, freight totaled 18.6 billion tons of commodities valued at almost $18 trillion. Activity totaled 8.4 trillion ton-km (see Figure 1). Trucks carried the majority of the goods that year by weight and value—nearly 12 billion tons (65%) and $13 trillion. Even though rail and waterways were used to ship a high volume of tonnage, given the relatively lower value of goods they shipped, these modes were not significant in terms of freight value.

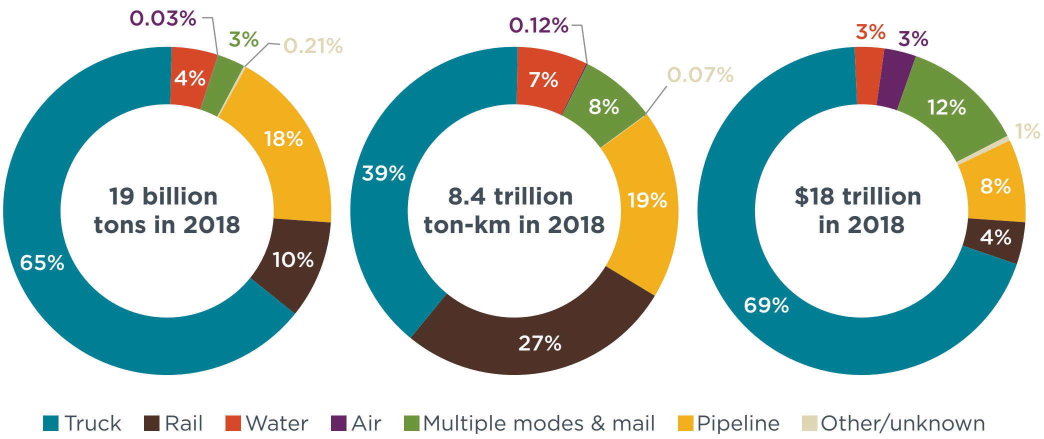


Figure 1. U.S. freight shipment by weight, ton-km, and value by transportation mode in 2018. *Source*: Oakridge National Laboratory (2021).

In comparison, air carriers were minimal in terms of tonnage or ton-miles but were mostly engaged in transporting high-value products. This is even more clearly illustrated in Figure 2, which shows the top 10 commodities by weight shipped by each transportation mode in 2018. Rail was used primarily for coal, agricultural products, and minerals, which together accounted for 60% of rail freight tonnage. Commodities hauled by truck were more diverse, including minerals, agricultural goods, petroleum, and manufactured products.

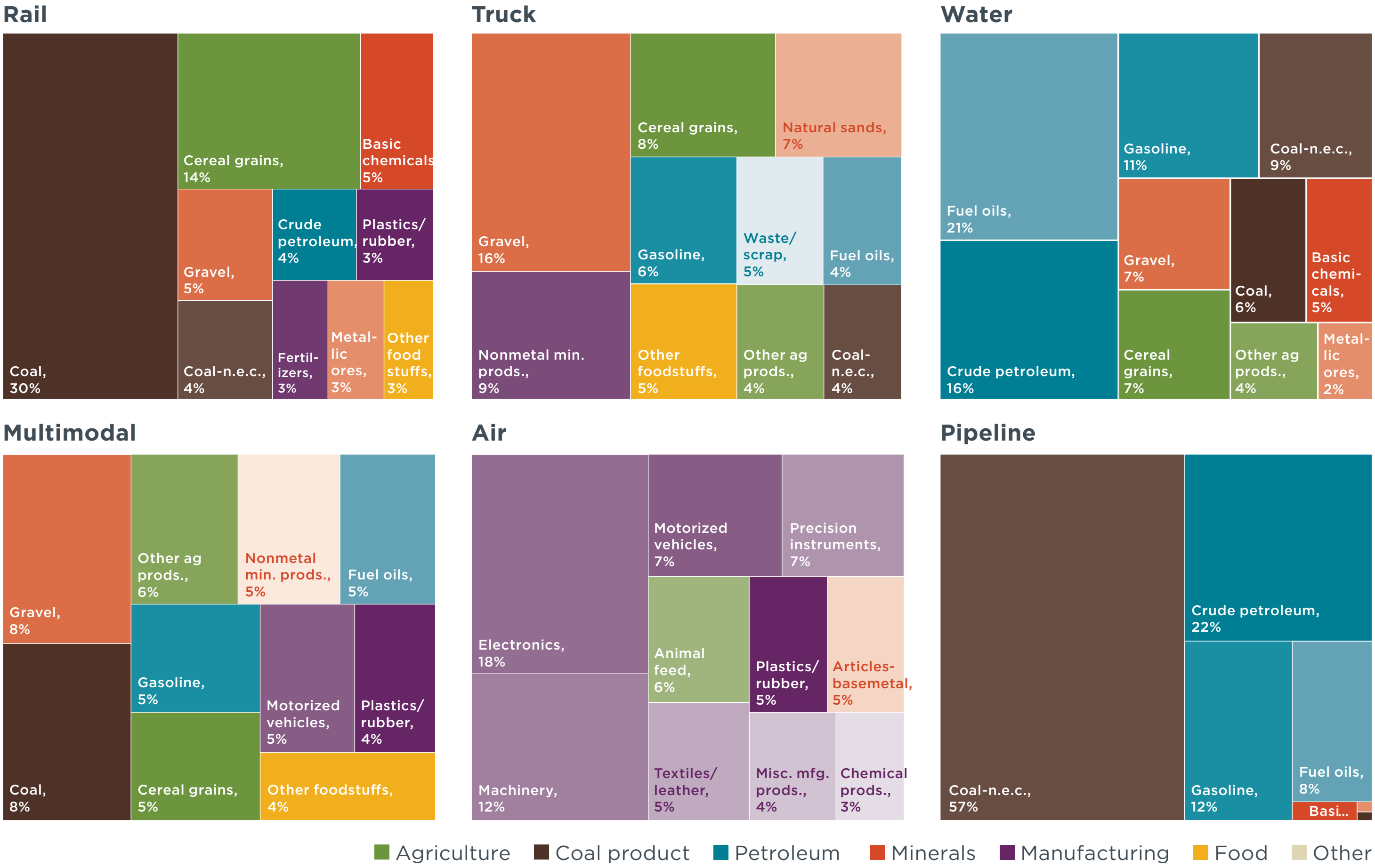


Figure 2. Top 10 commodities by weight shipped by mode in the United States, 2018.
Source: Oakridge National Laboratory (2021)
Lighter hues are used for commodities in sub-categories belonging to the major categories, in solid hues (in legend below).

Barges were predominantly used for shipping oil and petroleum products (nearly 50%), and coal and minerals. Pipelines were almost exclusively used for shipping coal slurry (coal, not elsewhere classified [n.e.c.] in the chart) and petroleum. Air was the common transportation mode for higher-value manufactured products such as electronics, machinery, precision instruments, textiles, and plastics. Commodities carried by multiple modes covered almost all types, from bulk products to manufactured products.

In recent decades there was strong growth in intermodal shipping, or use of multiple modes.[1] Comparing the freight system between 1993 and 2017 in Figure 3, we see that intermodal gained in weight transported, activity, and value. The increase of tonnage and ton-miles in intermodal freight was led by truck and rail, which undertook heavier, longer-distance hauling. The increase of freight value was dominated by parcel, U.S. Postal Service, or courier. This potentially reflects the growth of e-commerce and just-in-time shipping. Rail as a single mode was most affected by the expansion of intermodal, as there was more rail involvement in intermodal than there was of rail as a single mode of transport. The expansion of intermodal freight and the shift of rail's engagement probably came from the new framework of transportation planning and policy in the United States, the strategy for which included an intermodal approach first initiated by the Intermodal Surface Transportation Efficiency Act of 1991.

1 In this study, intermodal is used to represent the shipping approach that involves multiple transportation modes without any handling of the commodities when changing modes (only containers or vehicles).

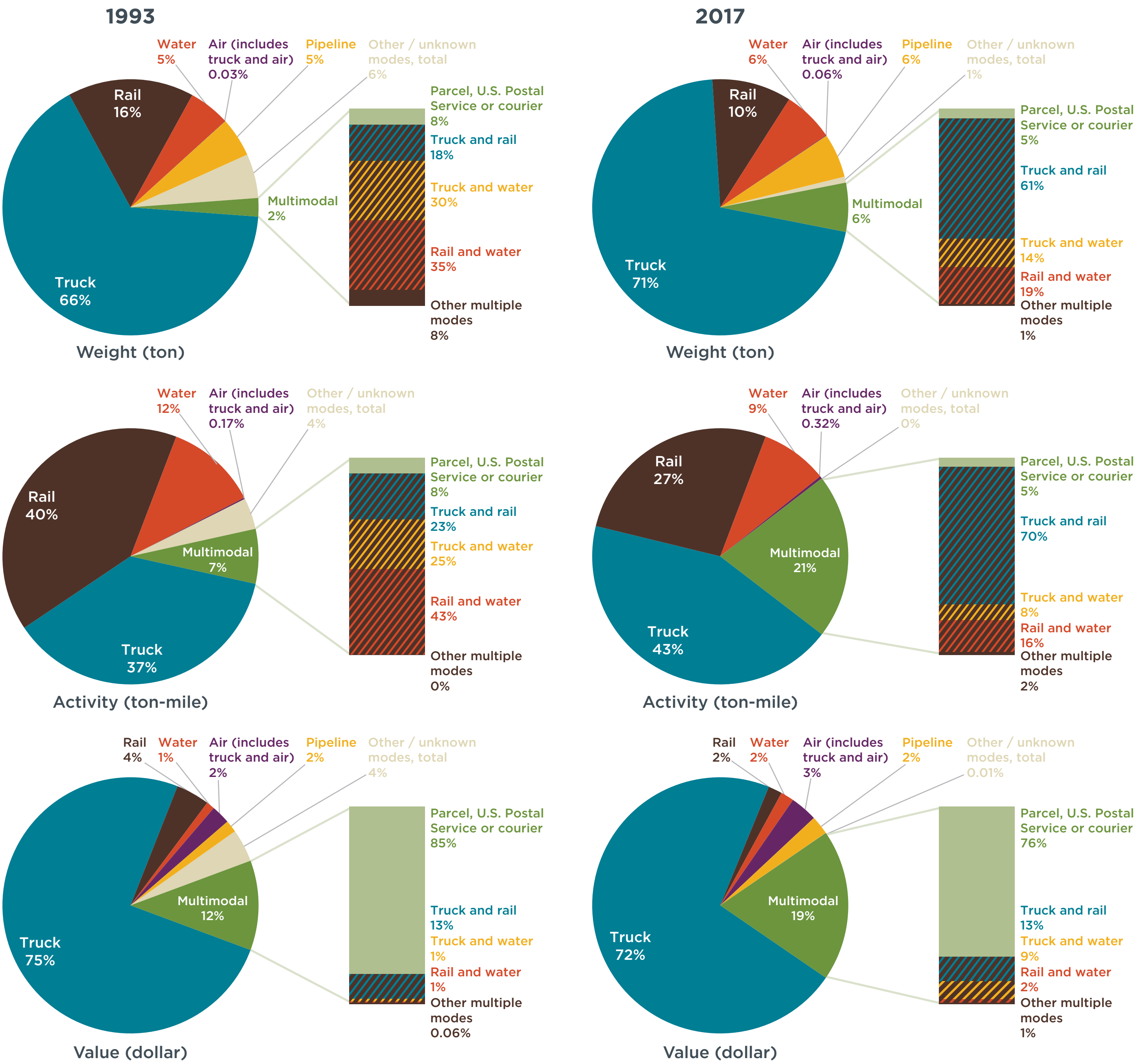


Figure 3. Freight activity in tons, ton-miles, and value by modes in the United States in 1993 and 2017.
Source: BTS (n.d.). (Chart presented based on the categorization used in the source.)

Along with the shift of mode share in the freight system, the average hauling distance by mode increased in recent decades (Figure 4). With the development of the interstate highway system, the average shipping distance of trucks almost doubled from less than 500 km in 1960 to almost 800 km in 2001. The growth of the average haul length for rail from 750 km to 1,700 km during the same period was affected by increased competition from trucks and the establishment of new land bridges between the east and west coasts as these made rail more competitive in longer-distance shipping.[2] The wide application of intermodal also increased the average rail hauling distance.

2 The North American Landbridge links the long-distance railway freight corridors of the two major gateway systems of the United States, Southern California and New York/New Jersey, via Chicago. It is recognized as the most efficient land bridge globally, and it reduces the shipping distance between the west and east coasts.

Air carriers traveled the longest average distance, increasing to almost 2,000 km in 2018 from 1,500 km in 1960. The drop in air transport during the mid-1990s shown in Figure 4 mainly reflects the creation of hub-and-spoke networks by major parcel distributors such as UPS and FedEx (Rodrigue, 2020).[3] The only mode that did not increase in average distance hauled was waterway, which remained almost constant at around 1,000 km and even decreased from its peak. This was probably due to the limitations of river access and competition from rail.

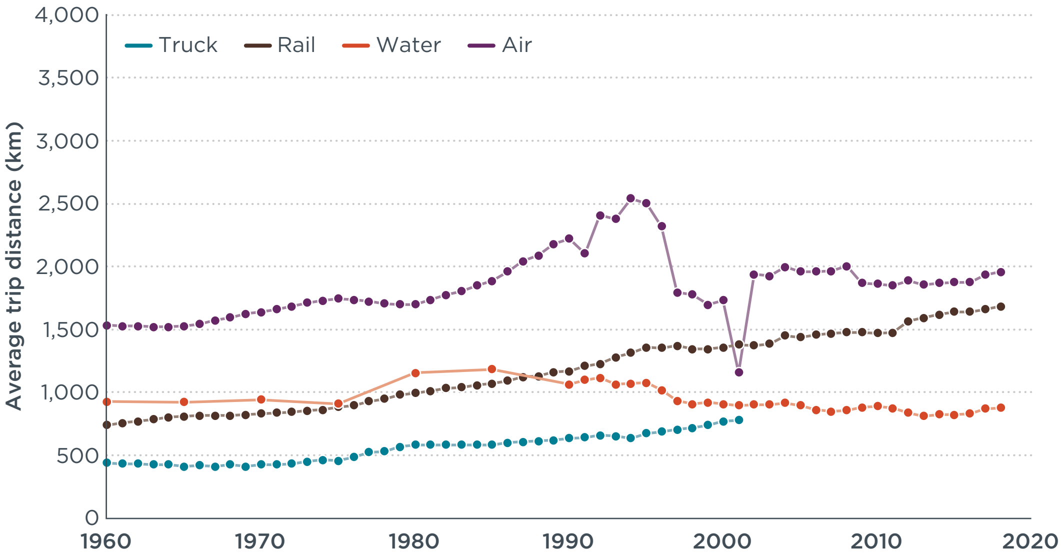


Figure 4. Average trip distance by mode in the United States, 1960–2018.
Source: BTS (n.d.).

Figure 5 shows the distribution of U.S. freight tonnage, ton-miles, and value by trip distance groups for all modes in 1997 and 2018. These freight transportation characteristics remained largely unchanged during this time. Most freight movements of short and medium distance, fewer than 800 km or 500 miles, were carried out by trucks, while rail dominated longer-distance movements of 800–3,200 km or 500–2,000 miles. Truck and intermodal transportation played the most critical roles in the longest trips, those of more than 3,200 km or 2,000 miles. One major difference between 1997 and 2018 was that the share of freight value for intermodal transportation increased by 10% for the longest-haul shipments, while the share of tonnage shrank by 5%. This implies that intermodal transport was increasingly engaged in longer-distance, higher-value shipments in more recent years.

3 Hub-and-spoke networks connect every location with a hub, which can reduce average length of haul when compared with a point-to-point network, which connects a set of locations directly.

Figure 5. U.S. freight tonnage, ton-mile, and value by trip distance bins (in miles) and by mode, 1997 and 2018, in value and percentage.
Source: Oakridge National Laboratory (2021).

U.S. freight transportation activity in ton-km has grown substantially over the past four decades with the exception of some declines associated with recessions. Figure 6 shows the historical ton-km of freight transportation by mode, and Figure 7 shows mode share. Truck and rail shipments increased constantly; pipeline shipments remained at almost the same level; and waterway freight movement declined over the period. Air transportation is hardly visible in Figures 6 and 7 because of its negligible share of ton-km, but Figure 10 shows that air transportation was the fastest-growing mode.

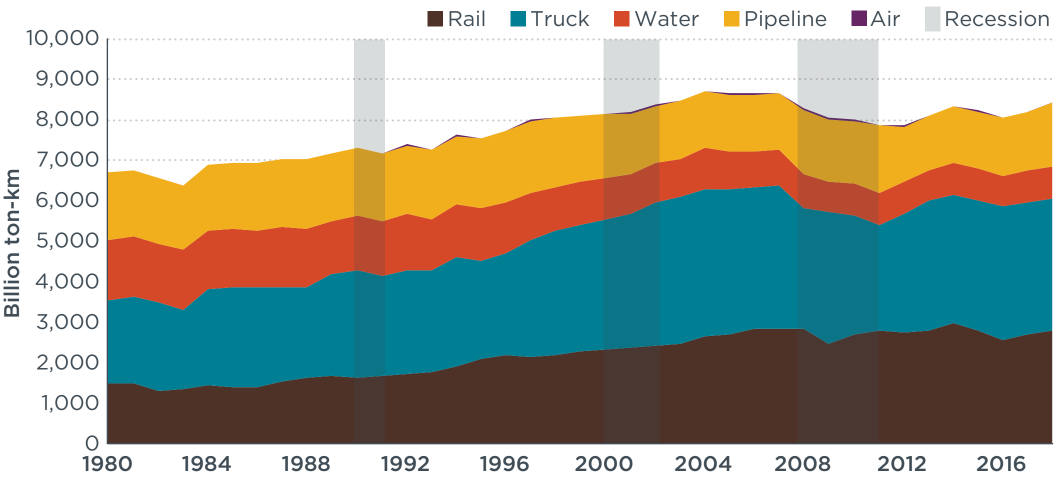


Figure 6. U.S. freight transportation ton-km by mode, 1980–2018. Recessions are represented by the shaded columns.
Source: BTS (n.d.).

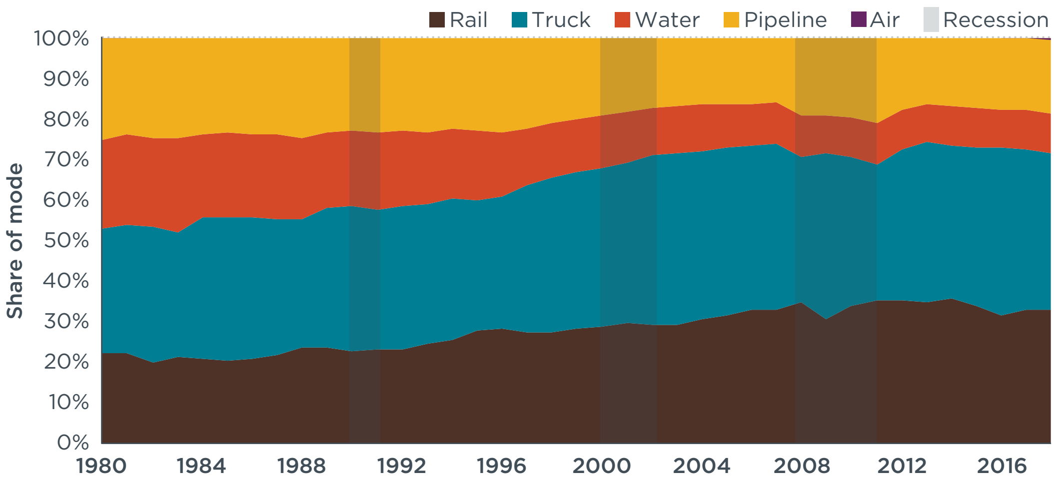


Figure 7. Mode share of U.S. freight transportation ton-miles, 1980–2018. Recessions are represented by the shaded columns.

Freight activity grew with the rapid expansion of the secondary and tertiary sectors of the economy in terms of absolute value (Figure 8).[4] The U.S. economy gradually shifted from being mostly involved in mass manufacturing and distribution toward custom manufacturing and retailing (BTS, 2014). The change resulted in more need for air and truck transport as they offer faster shipping and more flexibility in scheduling.

4 Details of how each sector is defined by the United States and China are in Appendix A.

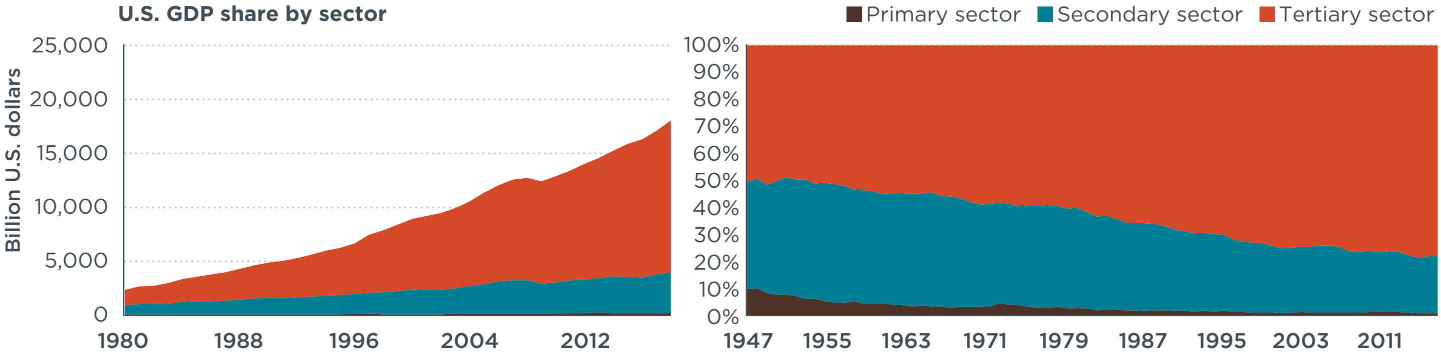


Figure 8. U.S. GDP trend by sector, 1947–2018.
Source: Bureau of Economic Analysis, U.S Department of Commerce (2020).

The United States also moved toward cleaner energy, which affected freight activity. In earlier decades coal satisfied a significant amount of energy demand, and coal was mostly hauled by rail. However, coal use has dropped significantly since its peak during 2007–2008 (Figure 9). As 92% of coal was for power generation, the retirement of coal-fired plants and lower coal plant utilization have the potential to reduce rail activity (Figure 6).

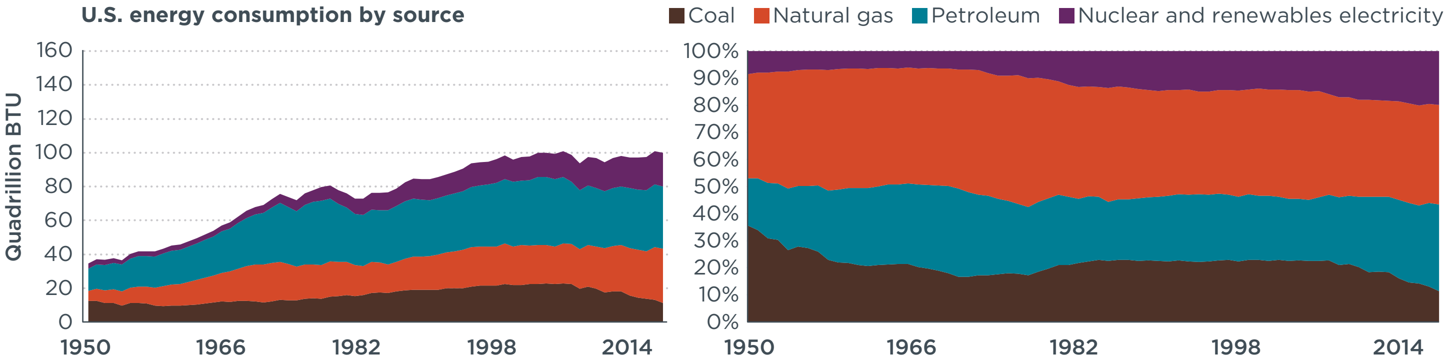


Figure 9. U.S. energy trend and share, 1950–2019.
Source: EIA (2020b).

Figure 10 shows the same freight trend data as an index with 1980 levels as the baseline and major recessions shown in grey. There were three major recessions in our analysis period. The different causes, scope, and features of the recessions had different effects by economic sector, as shown in Figure 11. The manufacturing, agricultural, and mineral sectors were more directly and immediately affected in the three recessions. The first was from about mid-1990 to early 1991, and followed the onset of the U.S. savings and loan crisis and coincided with the Gulf War; the second, during 2000 and 2001, derived from by the boom and subsequent bust in dot-com businesses; and the third was the Great Recession, which spanned from about 2007 to 2010 and was triggered by a subprime mortgage crisis in the United States. Oil, which is predominantly consumed by road transportation (Figure 12), and coal, mostly used for electricity generation, were the primary energy sources of the economy and were not as sensitive to these recessions.

Air transportation primarily carried manufactured goods and responded more directly to recessions. Waterway, mainly used for shipping oil and petroleum and other bulk commodities, declined as oil output contracted slightly. The growth of rail and trucking corresponded to increased production of coal, agriculture, minerals, and manufacturing. Pipeline transportation held mostly steady amid the overall constant output that resulted from oil contracting while coal (slurry) increased.

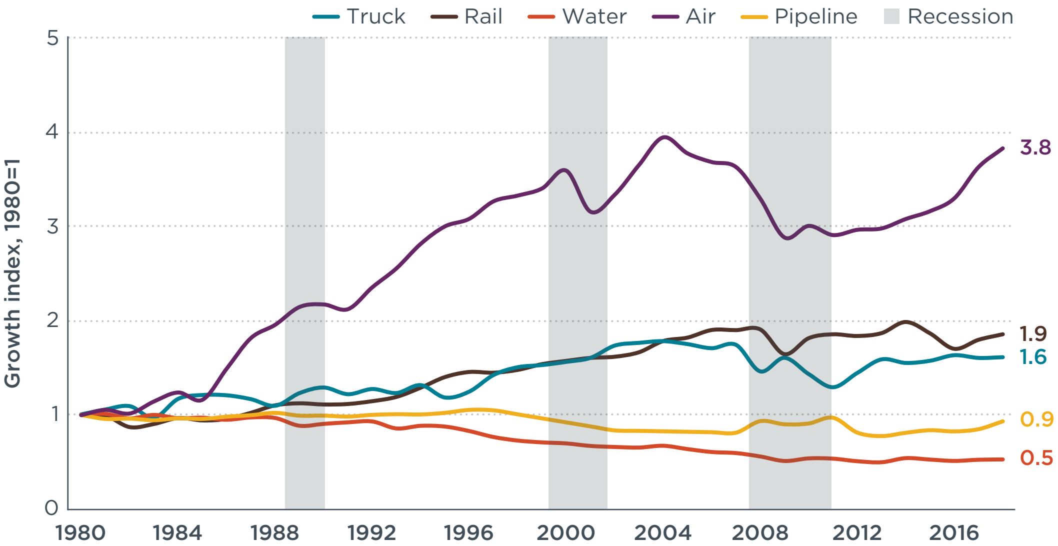


Figure 10. Growth trend of U.S. freight transportation by mode in ton-km index against 1980 baseline.

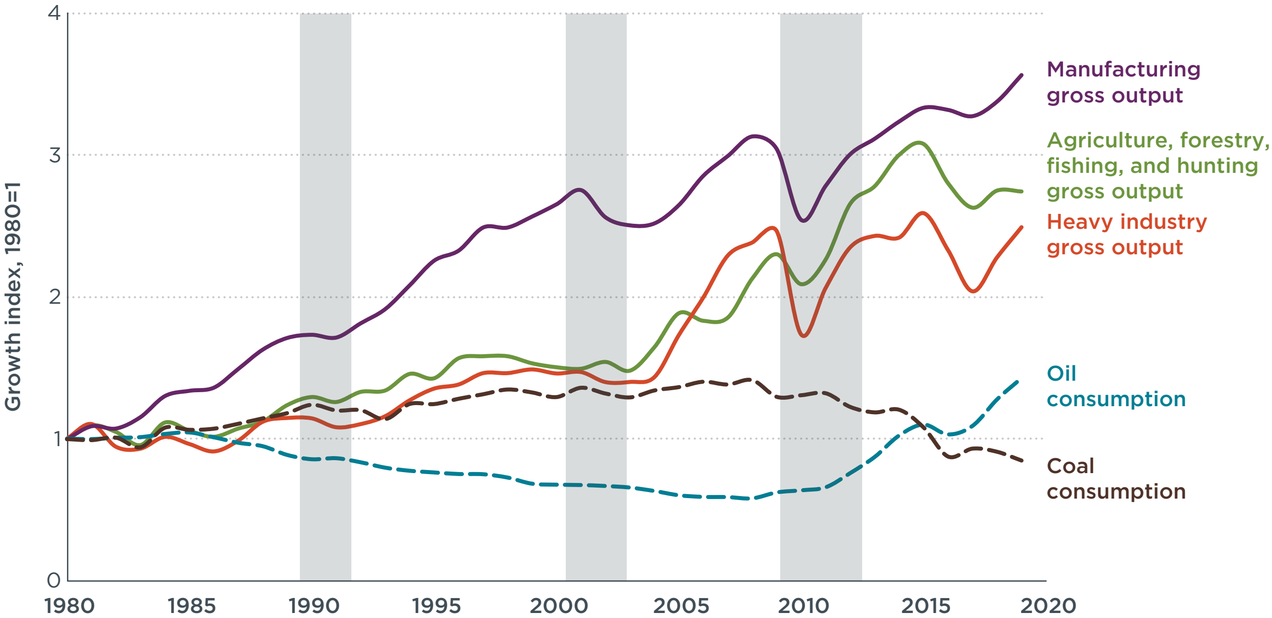


Figure 11. Growth trend of various U.S. economic sectors by gross output and oil and coal consumption index against 1980 baseline.
Source: Bureau of Economic Analysis, U.S Department of Commerce (2020).

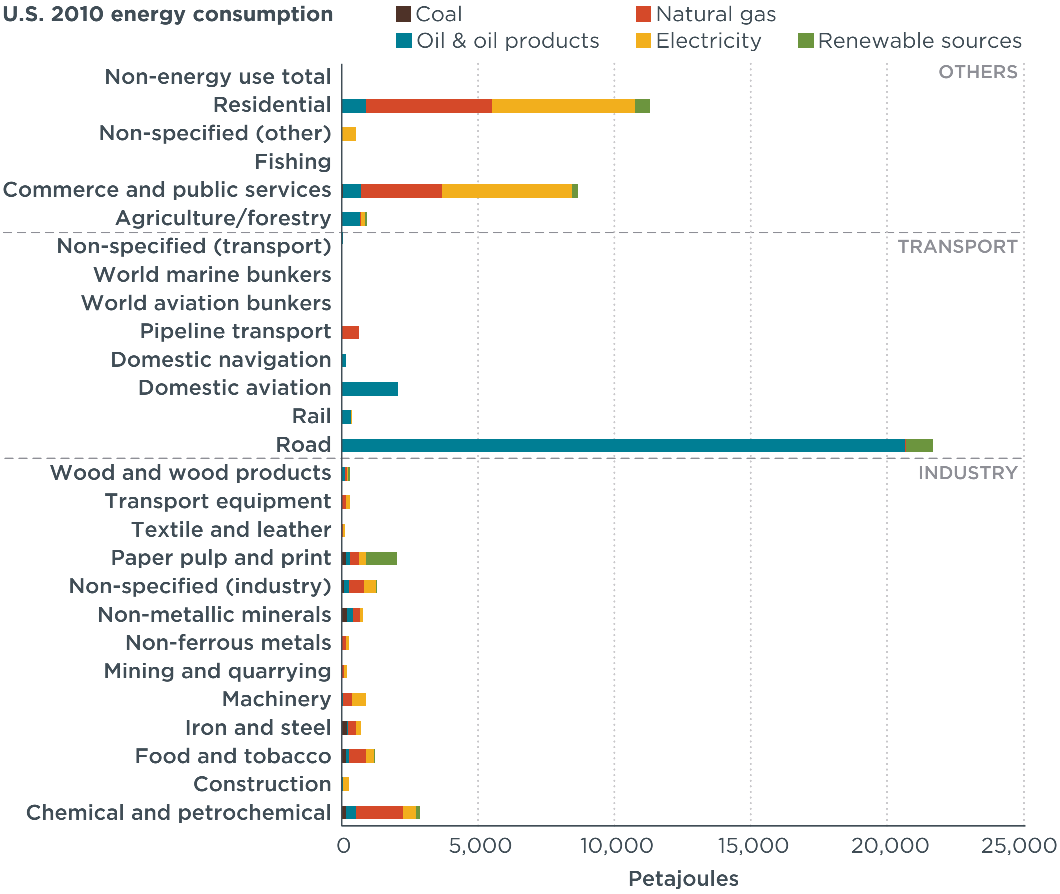


Figure 12. U.S. energy consumption by detailed sector, 2018.
Source: IEA (n.d.).

FREIGHT TRANSPORTATION IN CHINA

In 2018, China's transportation system moved 51 billion tons of freight and completed more than 15 trillion ton-km of transportation activity (Figure 13). Trucks were the dominant mode by weight and activity, carrying more than 39.5 billion tons of products and achieving 7.1 trillion ton-km of activity that year. Domestic waterborne was the second-largest carrier, with 6.3 billion tons of freight and 4.7 trillion ton-km in 2018.

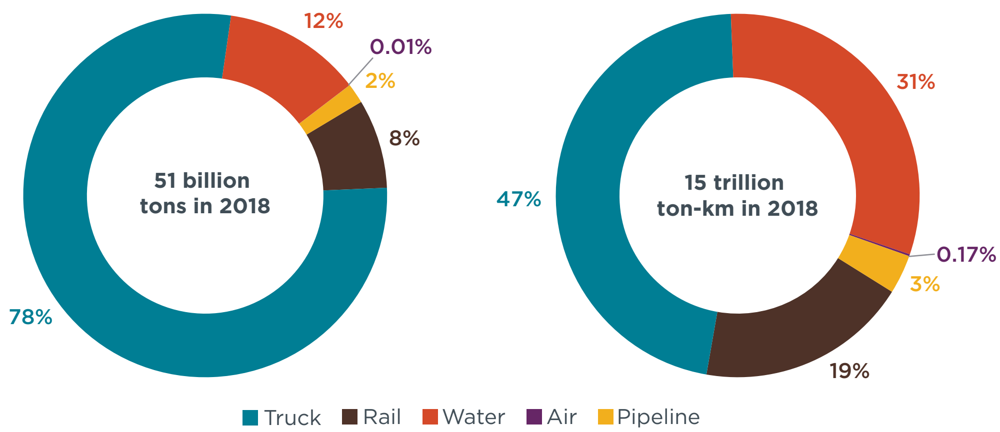


Figure 13. China freight shipment in weight and ton-mile by transportation mode in 2018.
Source: National Bureau of Statistics of China (2019).

The majority of the commodities hauled by domestic waterways were minerals (Figure 14). Rail accounted for about 2.9 trillion ton-km with freight weighing 4 billion tons in

2018; about 53% of that tonnage was coal and coal products, an increase from 46% in 1997. Rail also carried petroleum products, agricultural products, and containers, with a 10% share of that market. In contrast with trucks, the share of waterway and rail by ton-km was higher than the share by weight, indicating that barges and trains normally hauled freight for longer distances than trucks. In addition, the commodities carried by rail and water were very similar and mostly lower-value, bulk products.

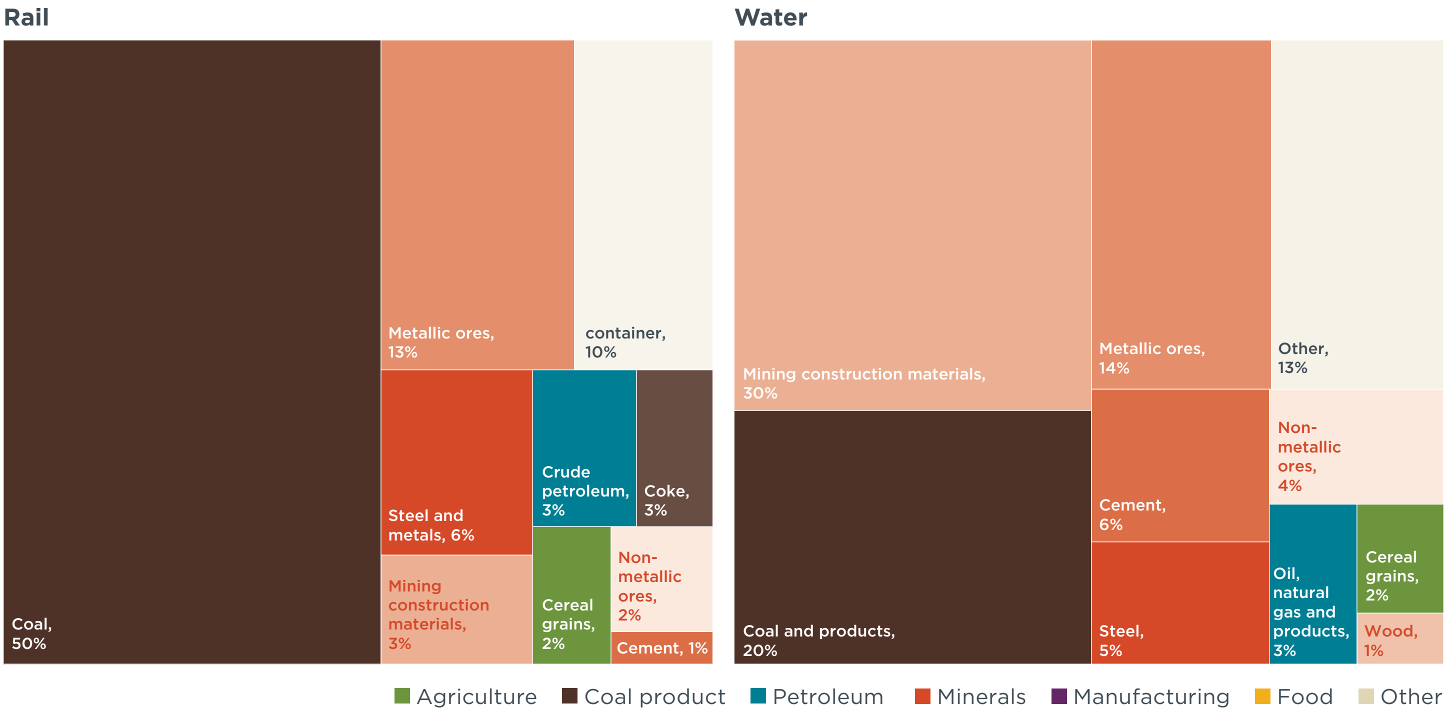


Figure 14. Top 10 commodities by weight shipped by mode in China, 2018.

Source: National Bureau of Statistics of China (2019).

* The lighter hues represent commodities in sub-categories belong to various major categories (solid hue in legend below).

** The top 10 commodities by waterway were calculated using inland port throughput due to lack of detailed information.

The average hauling distance varied significantly across modes in China, with competition only between rail and waterway (Figure 15). Airways were for the longest distances, followed by rail, waterway, then trucks. The hauling distance of air increased from 1,500 km in 1978 to more than 3,500 km in 2018. For trucks, the average hauling distance increased from 32 km to 180 km in the four decades observed, even though the changes are not fully displayed in Figure 15. The changes in shipping distance in rail and waterway were minor when compared with airway and trucks. The average shipping distance of rail increased from 485 km to about 716 km over the four decades, and for waterway the gain was from 301 km to 753 km. The average shipping distance was very similar between rail and waterway.

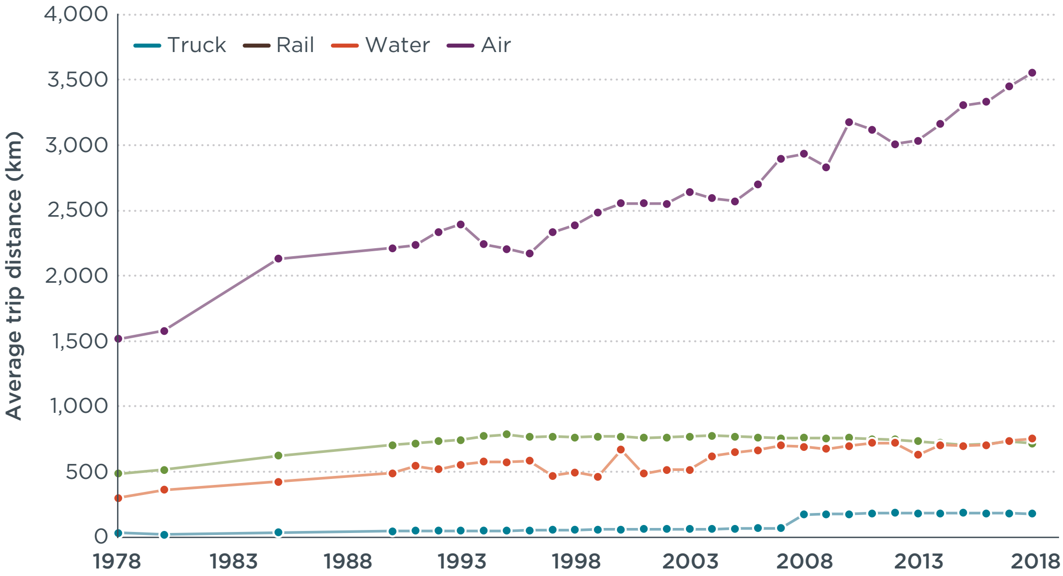
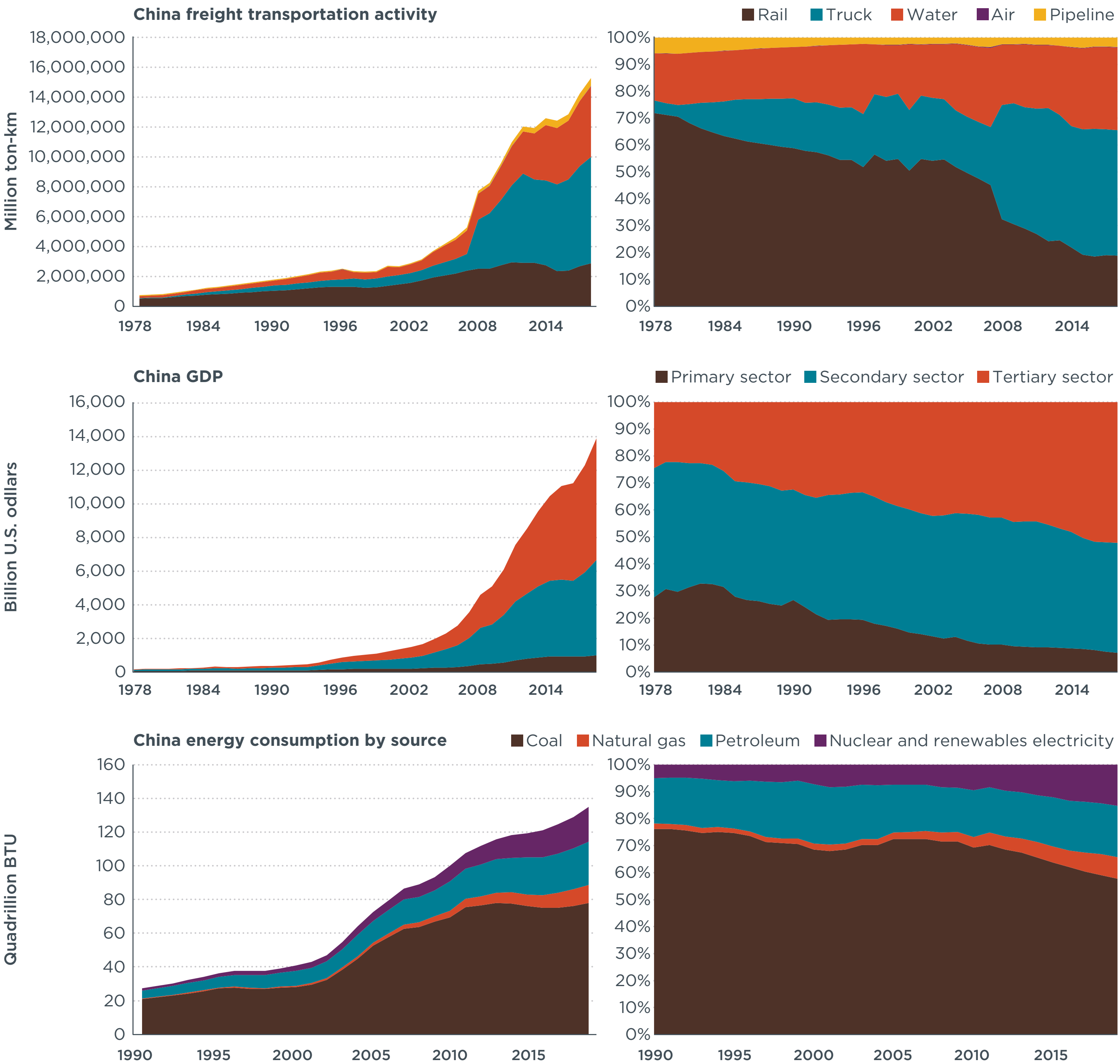


Figure 15. Average trip distance in China by mode, 1978–2018.
Source: National Bureau of Statistics of China (2019).

China's freight activity across various modes grew rapidly in recent decades (Figure 16 and Figure 17). Truck freight activity expanded by more than 200-fold; the initial takeoff in the early 2000s was followed by a double-digit annual average growth rate from 2004 to 2011. Then it slowed to about 6% annually in the past decade. Air shipping increased more than 270 times as China's manufacturing mushroomed and evolved toward higher-value goods. Water transport grew about 36-fold and maintained a 10% rate of expansion over the past decade. With increased demand for oil products, pipeline transport increased more than 10 times.



The rapid increase in truck activity after 2008 is partially the result of a change in statistical approach.

Figure 16. China's freight transportation activity and share by modes, GDP and share by economic sector, energy consumption and source, 1978–2019.
Source: National Bureau of Statistics of China (2019).

At the same time, rail activity has not exceeded its 2011 peak. The average annual growth rate for the past decade was less than 2%, even with transportation structural adjustment from road to rail and waterway for bulk products adopted at the national and local levels in 2018. However, the change succeeded in stopping a decline in rail activity between 2012 and 2015.

In terms of mode share, trucks in China have claimed most of the freight activity and overtook rail as the No. 1 freight carrier in 2008. Rail dominated the freight shipping market in 1978, with about 70% of the market, but that shrank to less than 20% in 2018—a 75% reduction in 40 years. Trucks' share increased from less than 5% in 1978 to almost 50% in 2018. Waterways took over some of the rail market as well, and the market share grew from 18% in 1978 to more 30% in 2018. Pipelines, reflecting their unique shipping needs and method, retained around 3% of freight activity through all the years recorded.

Despite the lack of detailed activity data by commodity type for China, it is clear that freight transport and trends reflect the nation's general economic development patterns, growing along with GDP. The dominant role of manufacturing, as shown in Figure 18, resulted in the rising need for transport of goods, from bulk products mostly shipped by rail and waterway to higher-value manufacturing goods mostly shipped by air and truck, which drove the rapid growth in transportation. With the more recent transition from a heavily manufacturing-driven economy toward a service-led one, shipping needs have shifted to lighter, higher-value, but time-sensitive products, and that led to explosive growth in air and truck shipping, as shown in Figure 17.

Energy consumption also influences freight activity and mode share trends in China. Overall energy demand, particularly for coal, increased considerably because of the rapid growth of manufacturing in the secondary sector. Coal was consumed substantially by sectors such as iron and steel, nonmetallic minerals, and chemical and petrochemical (Figure 19). The manufacturing industry used about half of China's coal, while the other half was for power generation. Even though coal and coal products accounted for 50% rail shipping by weight and 20% of waterway shipping by inland port throughput, China still relied on trucks for transporting coal. This contributed to the notable expansion of truck freight as shown in Figure 17.

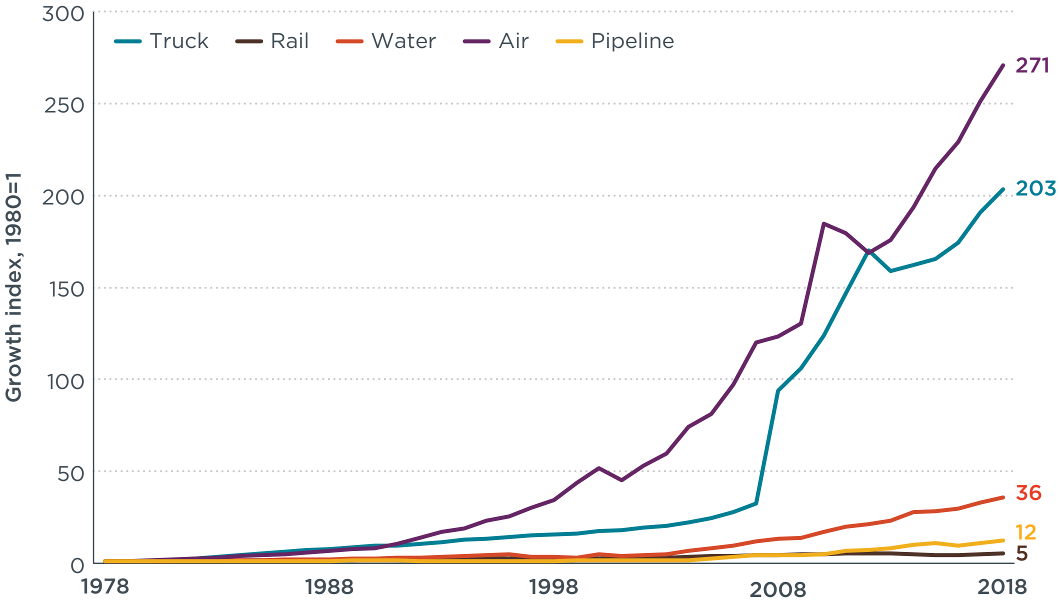


Figure 17. Growth trend of freight transportation in China by mode in terms of ton-mile index against 1978 baseline.

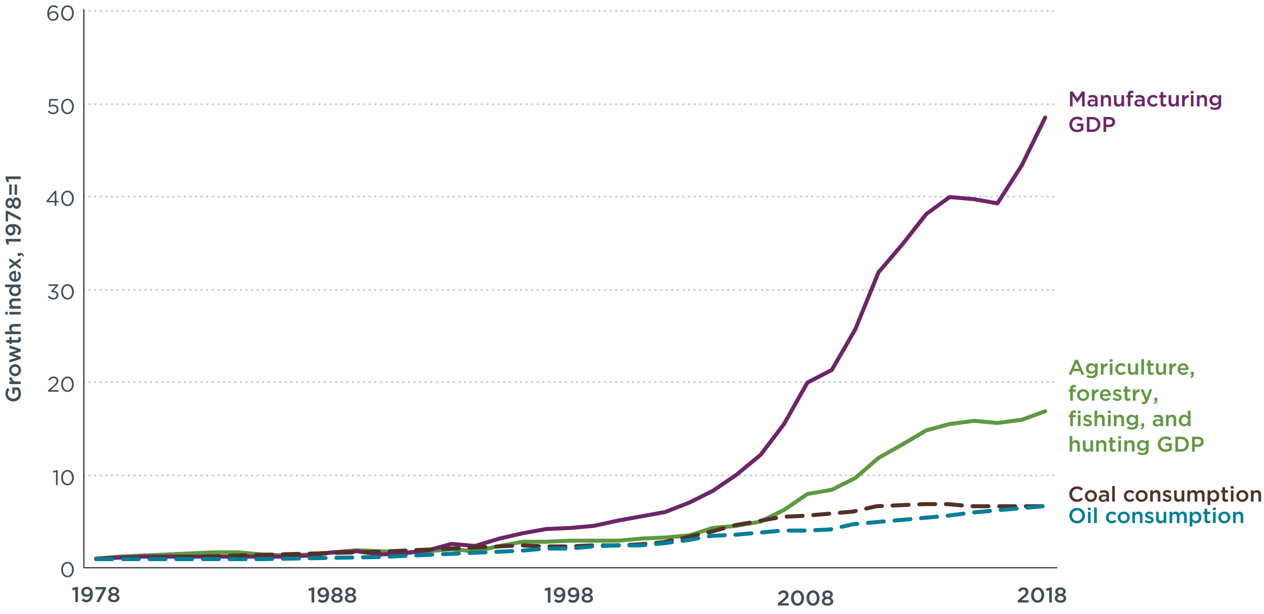


Figure 18. Growth trend of various economic sectors in China by GDP and oil and coal consumption index against 1980 baseline.
Source: National Bureau of Statistics of China (2019).

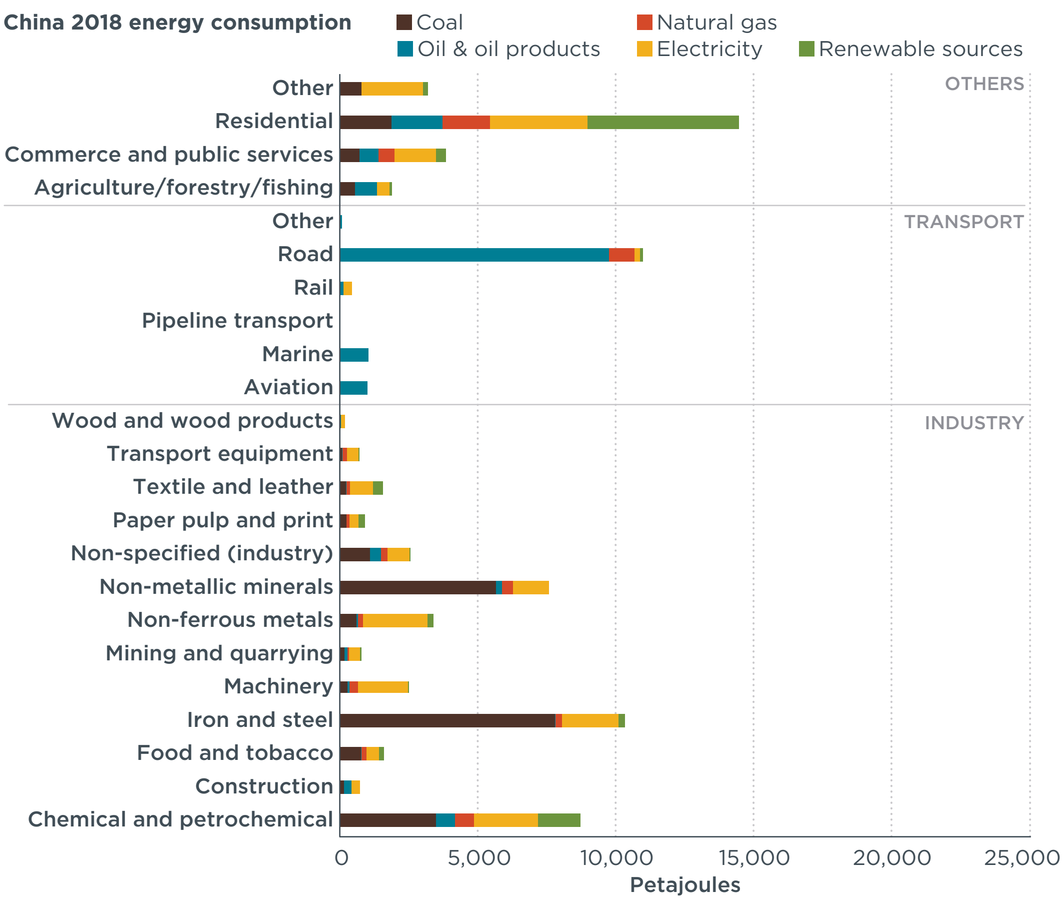
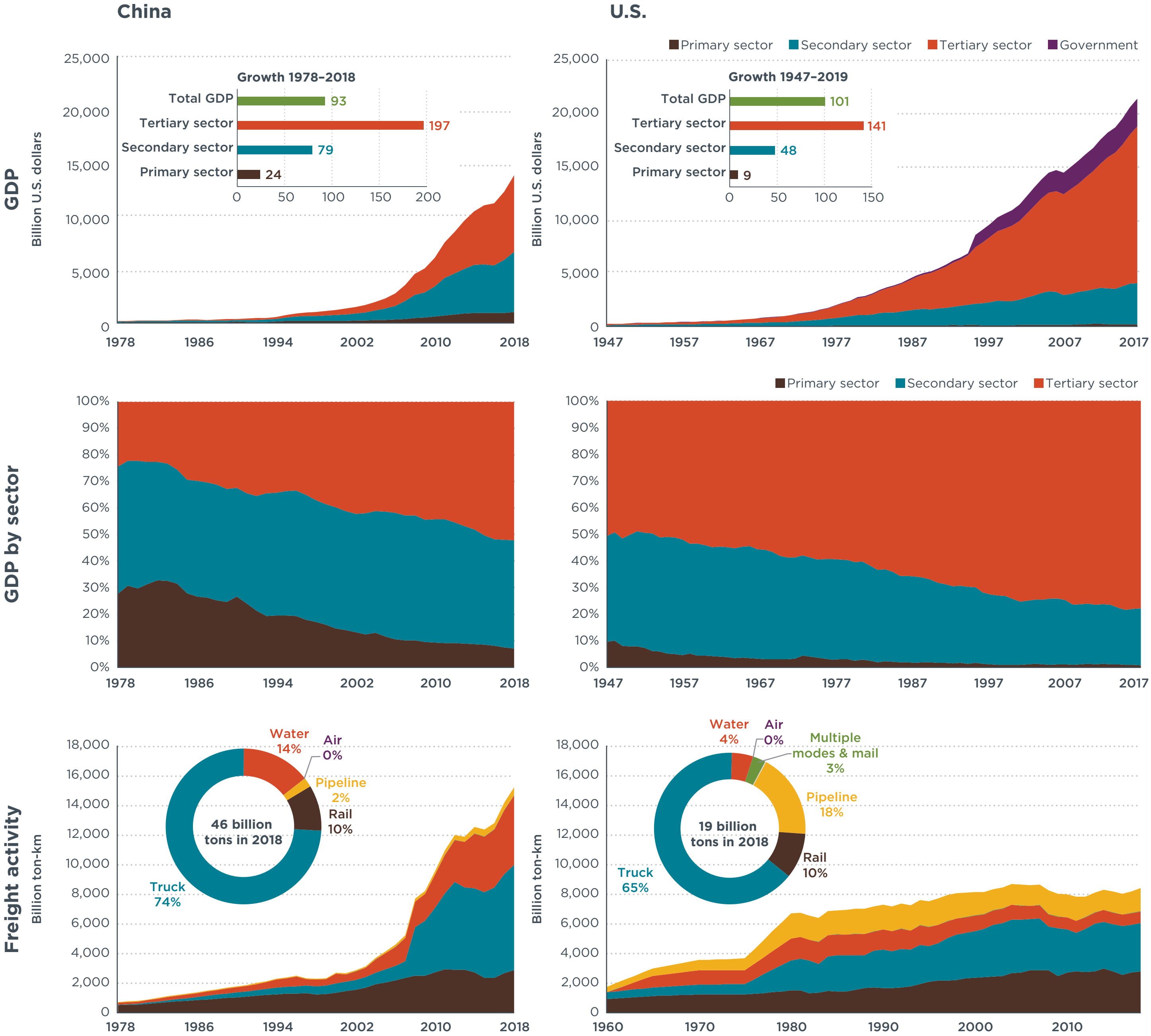


Figure 19. China's energy consumption by detailed sector, 2018.
Source: IEA (n.d.).

UNITED STATES–CHINA COMPARISON

Freight demand is commonly viewed as a dependent variable driven by changes in broader factors, including economic conditions, logistics, and transportation and by policy and regulations.[5] At the same time, the freight sector is also a key driver of economic activity (Grenzeback et al., 2013). The following comparison focuses on major trends in freight activity in the two countries and discusses potential drivers, with a key chart in Figure 20.



5 Logistics factors refer to elements in industrial supply chains, and transportation factors refer to the infrastructure, technologies, and fuels used to move goods.

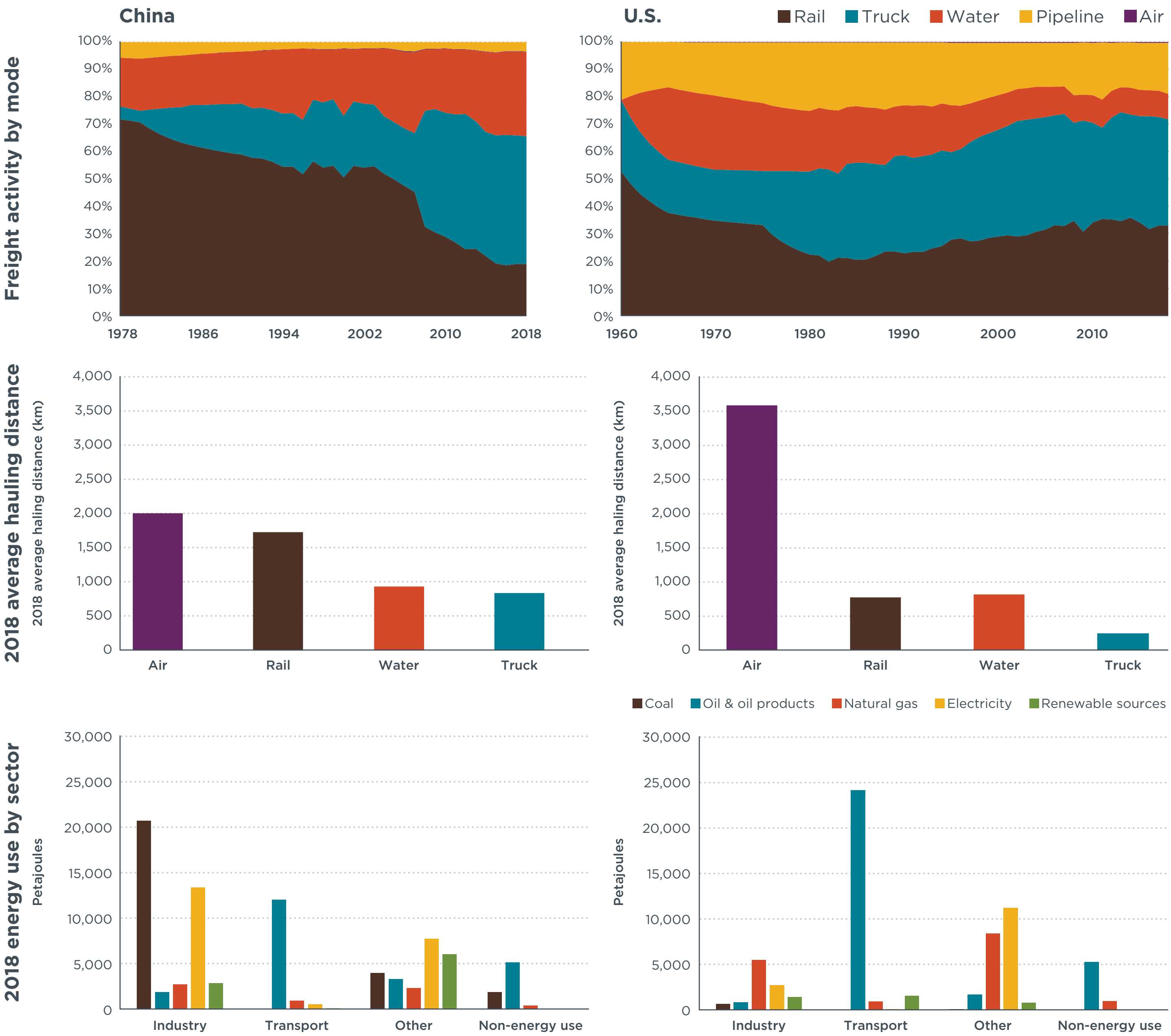


Figure 20. Comparison of main freight activity, economic indicators, and trends between China and the U.S.

» Both the United States and China experienced tremendous growth in freight activity in recent decades. This corresponded with economic growth, primarily the development of the service sector. In both countries, trucking's share of freight transportation in tons and ton-km grew the most and at the expense of rail and waterway. This reflects that the economies of the United States and China favored the production and shipment of higher-value-added and more time-sensitive products with a preference for trucks to move such goods. The trend applied to air shipping as well, though its share was minimal. Further, the rapid growth of the service/tertiary sector drove more demand for smaller and just-in-time shipments with requirements for more flexible and timely service, which favored more reliable trucking, air, and intermodal over carload rail and waterway freight shipment.

» Growth trends of rail, waterway, and pipeline freight shipments varied significantly between the two nations. Rail's share of U.S. shipping increased while waterway's decreased and pipeline's remained constant. But the growth of all three modes roughly synchronized with the increase in overall freight demand. The share of rail in China's freight shrank significantly while waterway increased slightly, and pipeline remained almost the same. Shipping via all three modes increased but not in proportion with overall freight activity. Waterway in China recorded strong growth, probably reflecting the high demand from the manufacturing sector for coal and minerals transport. Pipeline activity in China grew, but its market share was small because of the limited number of commodities carried, mostly oil and oil products. The growth of rail in China was small compared with the other modes, and it lost significant market share. The majority of the market was taken over by trucks, probably due to the upgrade to higher-value and more time-sensitive commodities that came with China's economic transition and because trucks offer lower cost and can use an extensive road network.

» Use of rail in the United States was more diverse. It accounted for about 40% of coal shipping in ton-km and a dominant share of intermodal shipping, in tons and ton-km. For China, even though coal and coal products accounted for more than half of rail hauling in tons, the use of rail still declined significantly due to its limited use for other commodities.

» The pipeline share of freight in the United States was much higher than in China. Pipeline was mostly used to transport petroleum, petroleum products, and coal slurry in the United States, but in China it was used only for oil and oil products. Consumption of oil and oil products in the United States was double the volume used in China. Further, shipment of coal slurry by pipeline grew about 50% between 1997 and 2018 in ton-km. As a result, pipeline consistently accounted for a fifth of total U.S. freight activity.

» The average hauling distance by rail and truck was much higher in the United States than in China. The pattern was reversed for air. Even though trucks were mostly used for shorter-distance shipping in both countries, they drove much farther in the United States. This might be because of greater shipping distances needed for "last-mile" delivery or more trucking demand for higher-value, more time-sensitive products. Meanwhile, with its leading role in intermodal shipping, rail in the United States carried goods over greater distances. Waterway, used mostly for heavy bulk products, maintained a similar shipping distance over time. The average air shipping distance in China was much longer than in the United States, even though the countries cover similar geographic areas.

» With projected growth in China's economic activity, freight transportation is expected to expand in response to rising demand for food, clothing, housing, energy, and manufactured goods. Given the expansion of the tertiary/service sector, the restructuring of the manufacturing industry, and the potential to shift away from coal to cleaner energy in the long term, China will have more need to ship smaller, more time-sensitive, and higher-value-add products than today. This will require more service from trucks and air, but more importantly, based on the U.S. experience, the adoption of intermodal systems for a faster, more reliable, and more cost-effective freight system.

» The limited availability of data for China's freight transportation sector prevented further analysis of how the freight system was shaped. The Commodity Flow Survey in the United States, which started in 1993 and is conducted every five years as part of the Economic Census, provides a comprehensive picture of national freight flows. It includes data on the types of commodities shipped, origins and destinations, values and weights, and modes of transport. Such information helps to assess the demand for transportation activity, map the patterns of commodity and vehicle flows, and track changes in the freight sector. However, most of China's data was relatively recent and lacked detailed information on how commodities are being transported.

FREIGHT STRATEGIES AND POLICIES

Policies and regulations adopted for achieving a green freight system have direct effects on the performance of each transportation mode, the costs of freight transport, the efficiency of the transportation system, and ultimately consumer choices. The following sections review the freight strategies and policies adopted in the United States and China to help understand the key policy drivers shaping the freight system.

STRATEGIES AND POLICIES IN THE UNITED STATES

The history of freight transportation policies in the United States for the past century is summarized in Figure 21.

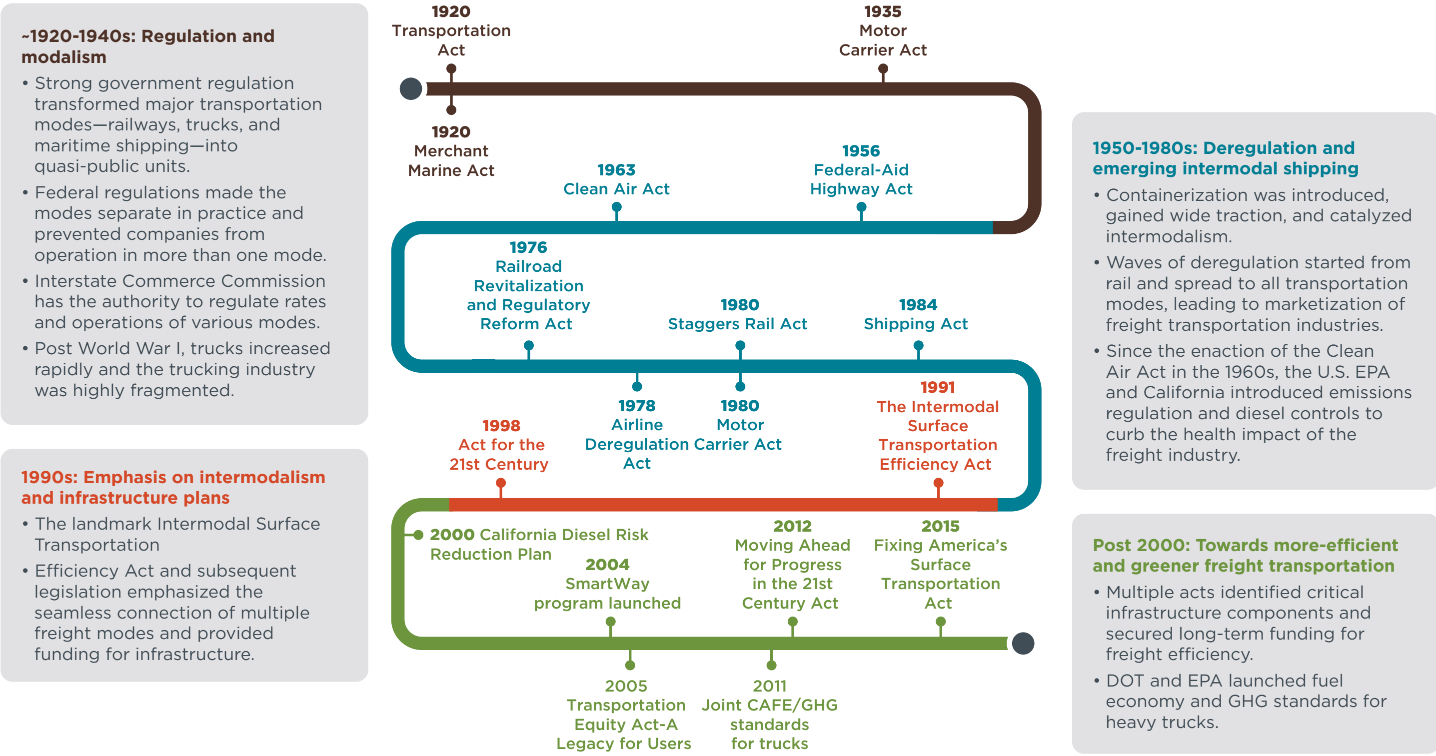


Figure 21. Timeline of key policies for the freight sector in the United States.

1920s – 1950s: Regulation and rise of modalism

In the early days of U.S. federal transit regulation, legislation restricted certain forms of competition and system-building. Organizations involved in major transportation modes—railroads, trucks, and maritime shipping—were transformed from private enterprises into quasi-public units (Donovan, 2000). Congress created the Interstate Commerce Commission (ICC) to regulate the operation and prices of various transportation modes and carriers starting with rail. Its jurisdiction was later expanded to motor carriers and ships. The Transportation Act of 1920, also known as the Esch-Cummins Act, authorized the ICC to approve or reject railroad mergers, set prices, and approve or reject abandonment of service in addition to other oversight responsibilities.

The number of cargo trucks and highways in the United States expanded quickly starting in the 1920s. Trucks began to take business away from railroads because their services were more flexible. The industry was highly fragmented. There were thousands of small companies and many single-truck owners. To better regulate the industry and prevent competition with rail and other modes, the Motor Carrier Act of 1935 required interstate motor carriers to obtain federal operating licenses. Consequently, motor carriers effectively became monopolies in shipping certain commodities on specific routes. The ICC had the authority to set minimum and maximum rates for trucking services, and it was illegal to charge less than the published rate.

Under this system, each segment of a given shipment was handled by a different company, each with mode-specific equipment and processes. Over several decades, very few new carriers managed to join the competition. This chapter of U.S. freight transportation history is often referred to as an era of modalism.

1950s – 1980s: Deregulation and emergence of intermodal shipping

Containerization was a major technology breakthrough. Introduced in the 1950s, it gained wide traction by the 1970s. Containerization promoted intermodalism by placing cargoes in standard-sized boxes that could be moved by all surface transportation modes without being opened and repacked (Donovan, 2000). This enabled streamlined and more cost-efficient freight movement across modes.

A second major breakthrough was a wave of deregulation. Under the restrained and separated regime of modalism, freight transportation industries in general became less efficient and more expensive while providing poorer services (Moore, 2002). In addition, cargo handling was labor-intensive, and no single company or method of cargo packing and handling could cover all phases of freight movement (Donovan, 2000). Technology and business innovations such as standard containers, piggybacking rail flatcars, and emerging intermodal shipment began to create a revolution in freight transportation management. There were simultaneously increasing calls to lighten regulatory burdens.

In response, Congress passed multiple acts, including the Railroad Revitalization and Regulatory Reform Act of 1976 and the Staggers Rail Act of 1980 for railroads, the Airline Deregulation Act of 1978, the Motor Carrier Act of 1980 for the trucking industry, and the Shipping Act of 1984. All of these aimed to deregulate and accelerate the marketization of freight transportation industries and enhance coordination between modes and regions. The ICC was eventually abolished in the early 1990s.

1990s onward: A more efficient, integrated, and greener freight transportation system

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) was a clear attempt to link previously separate modes of transport—highway, rail, air, and maritime shipping—by removing barriers and promoting cross-jurisdictional collaborations in the transportation system. The act designated a National Highway System (NHS) in 1995, comprising the Interstate Highway system, principal urban and rural arterials, highways, and intermodal connectors. The NHS tied all transportation modes together through a network of intermodal connectors. This served as the backbone of the transportation system. The intermodal connectors that exist today include 517 freight-only intermodal terminals and 99 airports. All of them need to meet key criteria such as level of activity and impact on the local economy. They provide last-mile road connections between major rail, port, airport, and intermodal freight facilities (U.S. DOT, 2021). The act and its successors, including the 1998 Transportation Equity Act for the 21st Century (TEA-21) and the 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act-A Legacy for Users (SAFETEA-LU), provided a record level of funding for highway programs and projects of national and regional significance, such as the Heartland Corridor (see details of this corridor below in the *Intermodal infrastructure* section).

At this time, each freight mode was still mostly operating on its own. Increased economic and trade activities led to slower, less efficient, and less reliable freight movement. To help address this, Congress passed measures focused on improving efficiency that addressed the transportation system as a whole (Goldman, 2019). The Moving Ahead for Progress in the 21st Century Act (MAP-21) in 2012 identified infrastructure components critical to freight transport, and together with the Fixing America's Surface Transportation Act (FAST Act) of 2015 it directed federal funds to projects that improved the efficient movement of freight. Besides appropriating funds for freight infrastructure, Congress created programs to support research and development of new transportation technologies.

Along with the development of the surface transportation network came environmental concerns. Since the 1960s, California and the U.S. Environmental Protection Agency (EPA) have introduced and escalated the stringency of standards for motor vehicles and engines to reduce emissions of hazardous air pollutants such as hydrocarbons and oxides of nitrogen. In the 1980s, the scientific understanding of air pollution and the adverse effects of fine particulate matter on health and premature death improved. Diesel engines, widely used in the freight industry, were recognized as a large source of fine particles. California introduced the first particulate matter exhaust standard for new heavy-duty diesel trucks in 1987. In the 1990s, the EPA aligned national heavy-duty tailpipe emission standards with those in California. Limits on primary pollutants in the current U.S. 2010 heavy-duty tailpipe emission standards are less than a tenth of the levels allowed in 2000, resulting in a 95% reduction in heavy-duty vehicles' primary pollutants and a more than 90% reduction in black carbon. In 2000, the California Air Resources Board published a Diesel Risk Reduction Plan, and the EPA initiated the National Clean Diesel Campaign to clean up freight emissions. In 2004, the EPA initiated the SmartWay Transportation Partnership program to demonstrate, verify, and promote fuel-saving technologies and strategies for freight movement. In 2011, the United States adopted the first joint GHG emissions and fuel consumption standards for medium- and heavy-duty vehicles and has since tightened them over time.

To summarize, the U.S. transportation system's growth, deregulation, and intermodalism coupled with economic growth, increased funding for infrastructure, and technological innovations reshaped the transportation sector and produced enviable productivity gains across all modes. Goals for freight transportation logistics now focus on efficiency of the entire freight system rather than each mode individually. The ability to interconnect and interchange among modes to optimize transport of freight from end to end is vital. At the same time, individual modes continue to fill market niches such as high-speed or low-cost within the intermodal framework. The history of the U.S. transportation system also implies that marketization of transportation modes can support prosperous development.

The wave of deregulation across modes together with the support of the surface transportation acts created a new framework for regulating and planning the national freight system as a whole rather than mode by mode. This restructured the freight system, reestablished market rates, and provided more flexibility in choice of modes. Meanwhile, the Clean Air Act initiated a series of actions reducing emissions from the freight sector, including tailpipe emission standards, the Diesel Emission Reduction Act (DERA), GHG emission standards, and innovative programs such as the SmartWay program. Over the years, all of these policies and regulations have driven down emissions from the transport sector (Figure 22) and importantly have improved air quality.

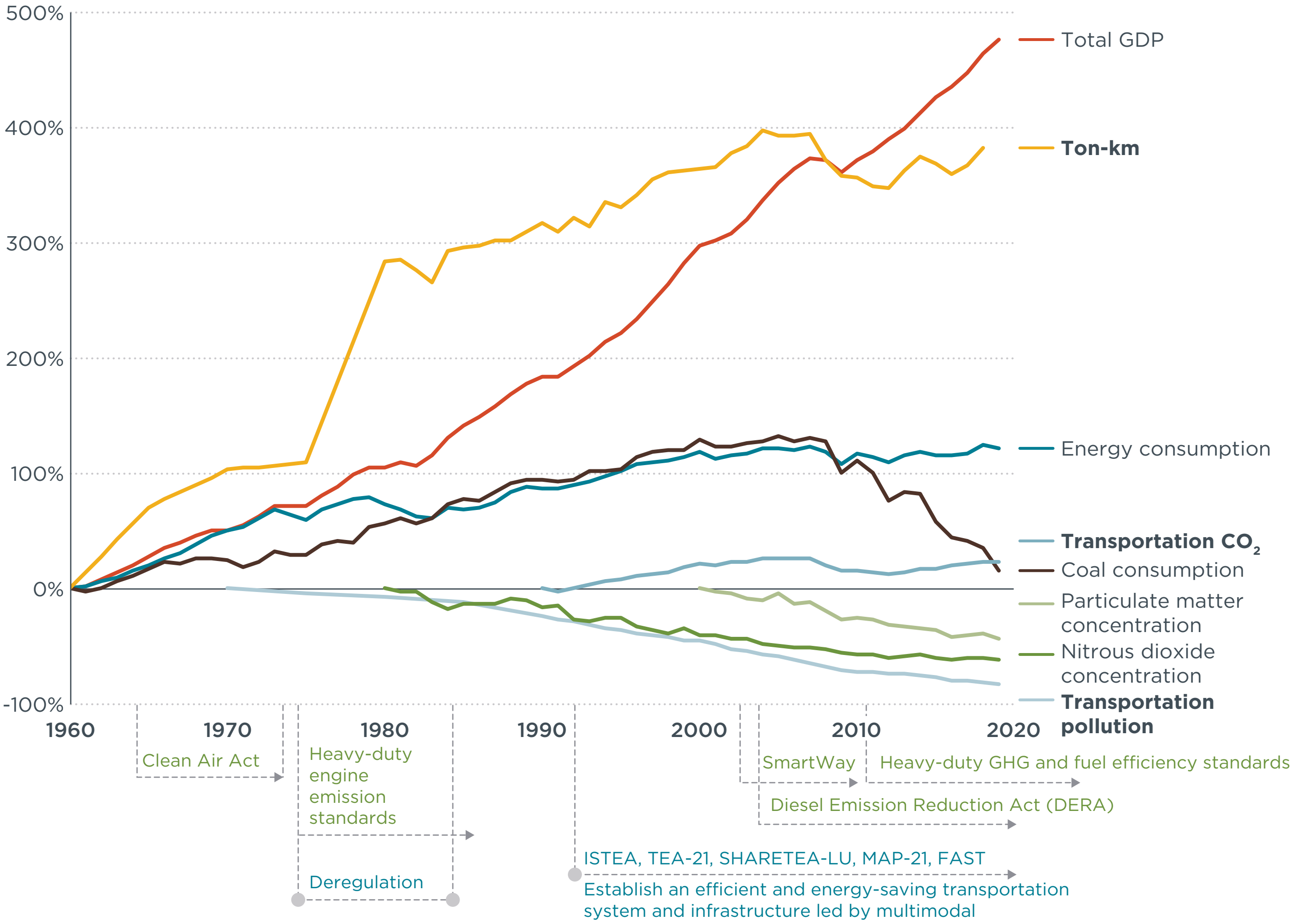


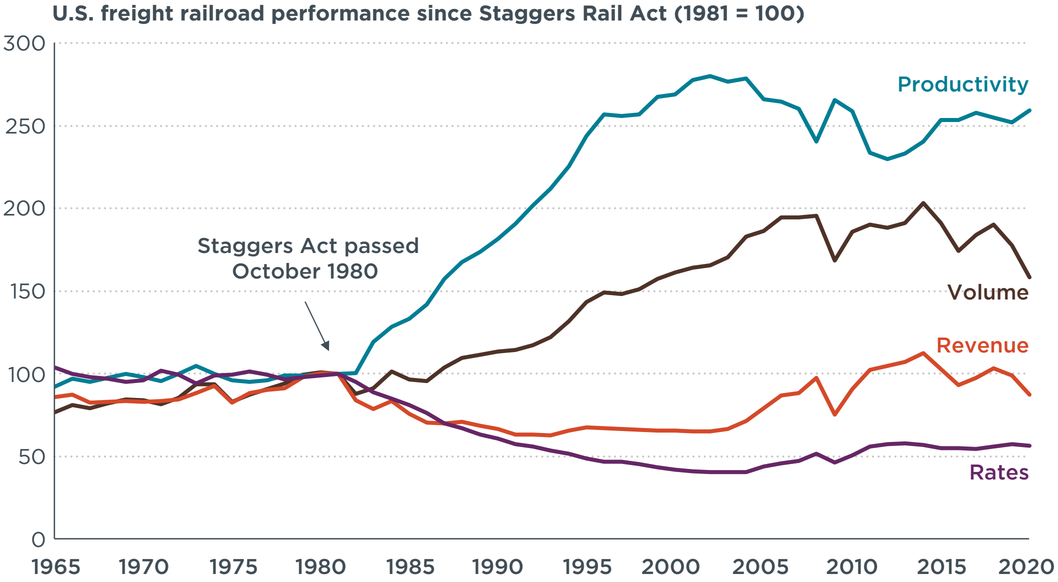
Figure 22. Comparison of trends in the U.S. economy in terms of transportation activity, energy use, air pollution, and emissions, 1960–2019.

Note: Particulate matter concentration and nitrous dioxide concentration are based on national average data.

Below we summarize the key programs, policy measures, and elements that have shaped the way the U.S. freight system has evolved, with examples.

Deregulation and marketization policies

The Staggers Rail Act of 1980 eliminated the ICC's regulatory structure and replaced it with a customer-focused and market-based approach (AAR, 2020b). The act allowed the railroads to determine the price, routes, and services for maximum efficiency and recognized their need to earn adequate revenue. The impact on the railroad industry, which had been sliding into bankruptcy in the 1960s and 1970s, was pronounced, as illustrated by the trends in productivity, volume, revenue, and price shown in Figure 23. Still, regulators retained the authority to prevent unreasonable railroad conduct and unreasonable pricing (AAR, 2020b).



Rates: Inflation-adjusted revenue per ton-mile. Volume: Ton-miles. Productivity: Revenue ton-miles per constant dollar operating expense. Revenue: Operating revenue in 2020 dollars.

Figure 23. U.S. railroad performance, 1964–2007.
Source: AAR (n.d. a).

Funding and financing acts and policies

The Highway Trust Fund came from the Federal-Aid Highway Act of 1956 and the Highway Revenue Act of the same year. Pursuant to this, a 3 cents per gallon fuel tax was deposited into the fund, and in 1959, it was increased to 4 cents per gallon. The revenue increased funding available to expand highway programs. By 1993, the taxes totaled 18.3 cents per gallon for gasoline and 24.4 cents per gallon on diesel. The rates have since remained unchanged. Other sources of revenue for the Highway Trust Fund include a sales tax on tractors and heavy trucks, an excise tax on tires for heavy vehicles, and an annual use tax on those vehicles (Tax Policy Center, 2020).

The Transportation Infrastructure Finance and Innovation Act (TIFIA) program was created in TEA-21 to provide federal credit assistance to significant surface transportation projects and fill market gaps with supplemental or subordinate debt (U.S. DOT, 2005). SAFETEA-LU further enhanced and encouraged private sector investment via support from private activity bonds from state and local governments and state infrastructure banks.

Modern freight and intermodal technologies

The invention of containers in the 1950s opened the potential for intermodalism. Containers can be moved between trains, ships, and trucks without opening and repacking cargo. In 1977, double-stack trains were invented for railroad cars carrying two layers of containers. In 1984 came specially designed cars that reduced the height and improved the safety and security of double-stack trains (Figure 24). The implementation of double-stack containers was a significant development as they account for about 70% of U.S. domestic intermodal (TRAC Intermodal, n.d.).

Figure 24. An example of double-stack trains.

Today autonomous and connected vehicle technologies are potentially applicable to the freight sector. However, many federal regulations were written assuming that a single person is in full control of a vehicle at all times. The 115th Congress of 2017–2019 debated federal policy regarding autonomous vehicle technology at length. H.R. 3388, passed by the House, sought to establish new rules for testing and adoption of autonomous technology for cars and light trucks, but it had no provisions pertaining to commercial vehicles. These provisions were relevant to a technology being tested in the trucking industry known as platooning (Figure 25). In a platoon, trucks follow each other closely enough to save fuel by reducing drag at high speeds. The benefits are around 10% for a following truck and 5% for the lead truck.

Figure 25. A concept depiction of a fleet of autonomous trucks platooning on highway.

Intermodal infrastructure

There are 517 freight-only terminals on the NHS, including 253 ocean and river ports, 203 truck/rail terminals, and 61 pipeline/truck terminals. There are an additional 99 major freight airports that handle passengers and freight, based on the review required by TEA-21 (U.S. DOT, 2000). Though this network amounts to less than 1% of total NHS mileage, these roads are critical for the timely and reliable movement of freight (U.S. DOT, 2000).

To reduce bottlenecks on highways, where the largest freight flows are concentrated on a relatively small number of routes (U.S. DOT, 2017), the United States invested in freight corridors, mostly compatible for double-stack trains. One pilot project was the Alameda corridor, which was built and is maintained and managed by the Alameda Corridor Transportation Authority (ACTA). ACTA is a joint-powers authority formed to connect the Port of Los Angeles and Long Beach and the transcontinental railway near downtown Los Angeles. ACTA received federal funding authorized by the TEA-21 and also obtained a federal loan authorized by the Federal Omnibus Consolidated Appropriations Act of 1997 under the Railroad Revitalization and Regulatory Reform Act of 1976 (U.S. DOT, 1999). Other primary sources of funding included a revenue bond offering, state and local tax revenue from the Los Angeles County Metropolitan Transportation Authority, and contributions from the ports (U.S. DOT, 1999). The corridor consolidated rail lines into a more direct route with faster speeds, eliminated the vehicular wait time and emissions that came from roadway blockages at rail crossings, and allowed more cargo to be transported by rail. All of this achieved environmental benefits for the area (ACTA, 2021).

Later, SAFETEA-LU designated funding for the construction of corridors to promote economic growth and international or interregional trade. The National Corridor Infrastructure Improvement Program promoted projects of national and regional significance that could achieve the largest benefits in terms of safety, security, and efficiency. For example, the Heartland Corridor that connects the Mid-Atlantic (Norfolk, Virginia ports) and two Midwest destinations—Chicago and Columbus, Ohio—was built and managed by a public-private partnership between the Norfolk Southern Railway, the Federal Highway Administration, and the states of Virginia, West Virginia, and Ohio. This corridor, along with the other intermodal facilities built along the route that are double-stack trains-compatible, directly promoted a shift to intermodal with reduced cost and distance and improved efficiency (Center of Excellence for Sustainable Urban Freight Systems, 2021). Additional benefits included improved mobility of other transport because of diverted truck traffic, environmental benefits from reduced truck emissions, economic and social benefits along the corridor, and improved access to global trade routes (Center of Excellence for Sustainable Urban Freight Systems, 2021).

Environmental policies

The EPA established progressively more stringent emission standards starting in the mid-1970s for on-road heavy-duty vehicles and in the early 1990s for off-road engines and equipment like locomotives, ships, and aircraft. Coinciding with these came ultralow-sulfur fuel standards. The EPA also coordinated with the National Highway Traffic Safety Administration to issue GHG and fuel economy standards in 2011 as Phase 1 for medium- and heavy-duty trucks manufactured in model years 2014–2018. Phase 2 was finalized in 2016 for model year 2027 and includes more stringent fuel efficiency requirements. The agency also promotes the adoption of alternative fuels that reduce dependence on oil and reduce emissions.

Additionally, the EPA launched the SmartWay Transportation Partnership program in 2004. Its goal is to accelerate the adoption of advanced technologies and strategies that improve fuel efficiency and reduce GHG and other emissions from the freight sector. SmartWay, a voluntary government-industry collaboration, has advanced sustainable transportation supply chains in the United States with more than 150 million tons of air pollution (nitrogen oxides, particulate matter, and CO_2) avoided and more than 312 million barrels of oil-equivalent saved (U.S. EPA, 2021). It also helps the EPA's development of new standards by demonstrating the effectiveness of fuel-saving technologies and strategies (Grenzeback et al., 2013).

Additional programs were introduced targeting states not meeting the National Ambient Air Quality Standards (NAAQS). The Clean Air Act requires each state to develop a plan to attain any standards that they don't meet. The federal government offers supporting programs such as the Congestion Mitigation and Air Quality Improvement (CMAQ) program, created by ISTEA and reauthorized under TEA-21 and SAFETEA-LU. It provides a flexible funding source for states to reduce traffic congestion and improve air quality.

Research and data

DOT's Bureau of Transportation Statistics and the Census Bureau conduct a survey of shippers every five years called the Commodity Flow Survey (CFS). It provides information on outbound shipments and was designed to provide a high-level understanding of the national activity of freight transport. Its sample size is small, so it does not provide enough data to form a reliable understanding of any specific urban area. The survey does not record through traffic and does not distinguish between imports and domestic freight. In the FAST Act, Congress requested DOT to "consider any improvements to existing freight flow data collection efforts that could reduce identified freight data gaps and deficiencies." It is still an open question whether the federal government should be responsible for providing adequate freight data for state and local transportation planners.

The Freight Analysis Framework (FAF), a publicly accessible tool administered by DOT's Federal Highway Administration, builds on CFS data and develops long-term forecasts for commodity flows between domestic and international origin-destination pairs (Hwang et al., 2016). The FAF also incorporates international trade data from the Census Bureau and data about agriculture, resource extraction, power utilities, construction, and other sectors. (BTS, 2021). The FAF model makes estimates for recent years and projections out to 2050.

Other efforts in the United States include a Surface Transportation Program established by SAFETEA-LU to conduct fundamental, long-term highway research. The work is aimed at significant research gaps, emerging issues with national implications, and research related to policy and planning (U.S. DOT, 2005).

STRATEGIES AND POLICIES IN CHINA

The history of China's shipping structure adjustment can be traced back only to 2017, when coal products were no longer allowed to be shipped into the ports of Tianjin, Tangshan, and Huangye by truck. In 2018, the State Council, national ministries, local governments at all levels, and key enterprises then formulated a series of transport structure adjustment policy documents to achieve "road to rail," "road to waterway," and intermodal transportation. The goal is to reduce the burden on and the environmental impacts of road transportation. Detailed targets were set for key regions and at the national level. Nationally the goal was a 30% increase in rail freight volume from the 2017 level by 2020. These requirements were prioritized for certain commodities: Only rail and waterway transport were allowed for all inbound coal shipping by the end of 2018 in the key coastal ports. This applied to all other bulk products such as ores and cokes before the heating season of 2020, which starts normally around November.

The recently issued Outline of Building a Strong Transportation Country set a goal of developing an integrated transport system in China. The plan supports the construction of a comprehensive freight transportation network and hubs to improve efficiency in transport. Importantly, the program also highlights the importance of building a greener, more sustainable transport system supported by innovative technologies.

China has a much longer history of addressing emissions from the freight sector. The first heavy-duty tailpipe emission standards, China I, were phased in around 2000, and even earlier in key cities such as Beijing. Over the past 20 years, the standards have progressed to China VI, recognized as among the most stringent standards in the world. Fuel consumption standards for heavy-duty vehicles were first introduced in 2011 as Phase I and moved to Phase III in 2019. The new Air Pollution Prevention and Control Law, adopted in 2016, clarifies the authority of the Ministry of Ecology and Environment to reduce emissions from the transportation sector.

China managed to improve air quality despite the tremendous increase in freight activity that came with the expansion of the economy and increased energy consumption (Figure 26). The growth of vehicular emissions was much less than the expansion of freight activity, and the emissions trend in recent years swung from increase to decrease.

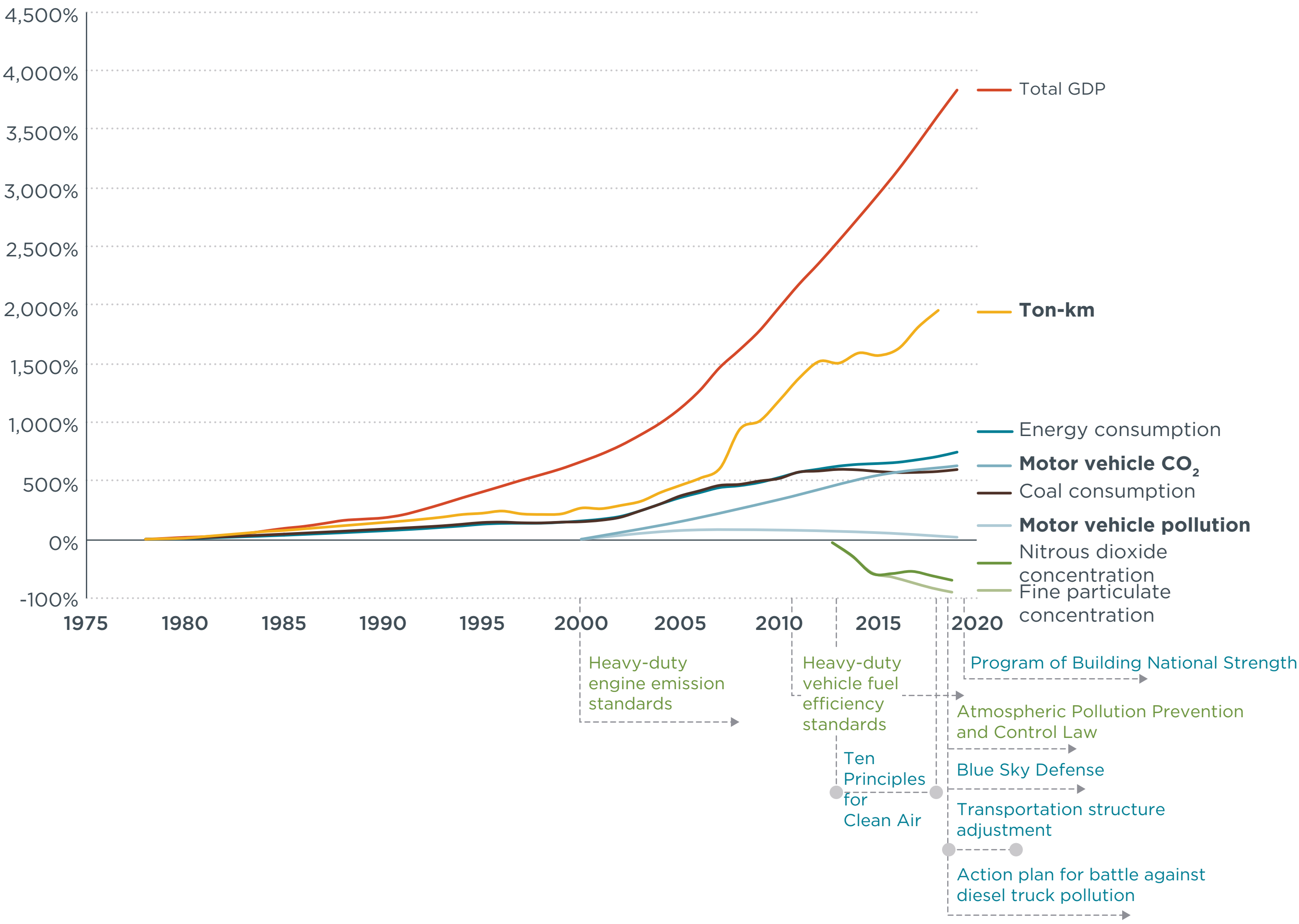


Figure 26. Timeline of China's growth and changing emissions from 1978 to 2019.

Note: Particulate matter concentration and Nitrous dioxide concentration are based on national average data.

Below we summarize the key programs, policy measures, and elements that have shaped the way China's freight system has evolved, with examples.

Deregulation and marketization policies

China regulated each transportation mode more or less individually for decades, but that changed in recent years. Road and waterways were managed by the Ministry of Transportation (MoT) starting in 1975. Railways were owned by the state and managed by the Ministry of Railway, and air transportation was managed by the Civil Aviation Administration of China (CAAC). All airline companies were state-owned until around 2000, when the first private airline company was established. The MoT was subsequently taken over by the CAAC in 2008. China dissolved the Ministry of Railway in 2013 and established the China Railway Corp. for construction and management. In 2019, the corporation was reorganized as China State Railway Group Co. Ltd., a state-owned sole proprietorship formed to undertake rail passenger and cargo transportation services. The Railway Group is expected to compete with other modes, offering more flexibility in service, pricing, and scheduling.

FUNDING AND FINANCING ACTS AND POLICIES

Financial support to promote use of rail and waterways focused on reducing operating costs for shippers. Cuts reached about 20%, as jointly requested by the MoT and the National Development and Reform Commission (NDRC), China's top economic planning agency.

Regional governments including Jiangsu Province, Yunnan Province, and the city of Tangshan are providing fiscal incentives to accelerate adjustment of the freight structure. Funding in Jiangsu Province directly subsidizes the transition to intermodal. For example, incentives of about ¥200 (~$31) per twenty-foot equivalent unit (TEU) or ¥500 (~$78) per carload are provided for using intermodal combinations such as rail and water or truck and rail.

Modern freight system and intermodal technologies

One of the investments to support shipping structure adjustment of rail and waterway was to build on-dock rail terminals at ports, avoiding the need for trucks for the first and last mile of delivery. The MoT and the NDRC provided financial support based on revenues from vehicle purchase taxes during the 13th Five-Year Plan period of 2016–2020 to construct about 2,000 km of on-dock rail facilities in ports.

The recently issued Program of Building National Strength in Transportation further highlighted the goal of creating a modern, high-quality nationally integrated transportation system. As a backbone of a comprehensive transportation network, the goal is to connect interregional, urban, inter-provincial, and international transportation. The program will promote a system with multiple modes and develop and construct intermodal infrastructure hubs that integrate rail, highways, inland navigation, seaports, transportation pipelines, and aviation.

Environmental policies

China's Ministry of Industry and Information Technology (MIIT), with the primary authority for setting fuel efficiency standards, implemented Phase III fuel consumption standards since 2015. Led by the Ministry of Ecology and Environment (MEE), China moved from unregulated all the way to the stringent China VI heavy-duty tailpipe emission standards over just 20 years and implemented ultralow-sulfur fuel standards for on- and off-road vehicles. MEE also issued the latest China IV emission standards for off-road engines and equipment with particulate limits.

Authorized by the 2016 air law, the MEE led supervision of air pollution prevention and control, monitoring compliance with ambient air quality standards. Key regions initiated supervision beginning in 2018, including Beijing-Tianjin-Hebei and surrounding areas, the Fenwei plain, and the Yangtze River Delta. The goal was to increase the number of good air quality days, with designated supervision of freight structure adjustment, including shifting all bulk products away from trucking by the end of 2018.

For key industries such as iron and steel and sand and gravel, the MEE issued detailed suggestions to achieve very low emissions. For example, the MEE ordered that more than 80% of shipments of iron ore, coal, coke, and other bulk goods and products entering and leaving steel enterprises be transported by rail, waterway, pipeline, or conveyor belt. Only in cases where the other modes are not available, new-energy vehicles or China VI-compliant vehicles can be used.

UNITED STATES – CHINA COMPARISON

Table 1 is a high-level summary of key measures and strategies in the two countries. Both have focused on deregulating rail and empowering greater market forces to enable a more-efficient freight system, building up infrastructure for intermodal transport and using policy to curb pollutant emissions.

However, we observe that the deregulation and marketization was broader and deeper in all transportation modes in the United States. Additionally, the United States allocated large and sustainable funding for intermodal infrastructure and technologies through legislation and has done more to emphasize freight transport science, activity tracking, data analysis, and modeling, all of which provide a critical foundation for developing data-driven freight efficiency policies.

Table 1. Comparison of policy efforts to shape the freight system.

	United States	China
Deregulation and marketization policies	• *Railroad Revitalization and Regulatory Reform Act of 1976* and the *Staggers Rail Act of 1980* for railroads. • The *Airline Deregulation Act of 1978* for airlines. • The *Motor Carrier Act of 1980* for the trucking industry. • The *Shipping Act of 1984* for ocean carriers	• China State Railway Group Co. Ltd. was established to manage rail and replaced the Ministry of Railway • Private airline companies were established
Funding and financing acts and policies	• Acts that directed funds to intermodal infrastructure and freight efficiency improvement. • Creative approaches to attract private investment to meet infrastructure investment needs	• Funding provided for reducing the operational costs of using rail and waterways • Provincial and regional level governments provided funding to promote mode shift to rail and waterway, and the use of intermodal
Modern freight and intermodal technologies	• Wide adoption of containers • Promotion of autonomous and connected vehicle technology for improved efficiency	• Promotion of the construction of national and provincial intermodal transportation pilot projects
Intermodal infrastructure	• Built adequate and reliable infrastructure connecting multiple modes • Built corridors	• Connected rail with waterway smoothly at ports with on-dock train tracks • Building a multi-level and integrated transportation system with improved efficiency
Environmental policies	• Air quality standards • Tailpipe emission standards • Fuel quality standards • Fuel consumption standards • Promotion of alternative fuels • SmartWay government-industry partnership to improve fuel efficiency • Other supporting programs such as CMAQ program	• Air quality standards • Tailpipe emission standards • Fuel quality standards • Fuel consumption standards • Strong national campaign against diesel emissions including modal shift and emission control targets for key regions or industries
Research and data	• Commodity Flow Survey is conducted every 5 years • Freight Analysis Framework with public access • Research program aimed at long-term needs	—

CASE STUDIES

Here we analyze the shipping patterns of three representative commodities: coal, iron ore, and motor vehicles. These were chosen because of they represent bulk products and high-value products (motor vehicles) and for their key roles in China's current and near-term future economic development. Shipping information for these products was relatively easier to obtain in China, facilitating the analysis. This comparison is designed to better understand the characteristics in freight activity, mode choice, and potential trends in coming years associated with certain products for China. We use a uniform structure in the following sections, but due to certain gaps in data collection across the commodities, the level of detail varies between the two nations.

SHIPPING PATTERNS OF SELECTED PRODUCTS IN THE UNITED STATES

Coal

The majority of coal use (92%) is for electricity generation, and the rest is for manufacturing (8%). Coal use rose steadily in the United States until 2007–2008, when consumption and production peaked with demand exceeding 1 billion tons (Figure 27). More recently consumption has dropped to half that and is back at the level of the early 1970s. Coal's share of U.S. energy consumption has declined due to the availability of cheaper and cleaner energy sources (Cherney, 2021). Since 2010, a wave of coal power plant retirements has come amid increasingly stringent environmental standards and significant economic pressure from the availability of cheaper natural gas and renewable sources (EIA, 2019).

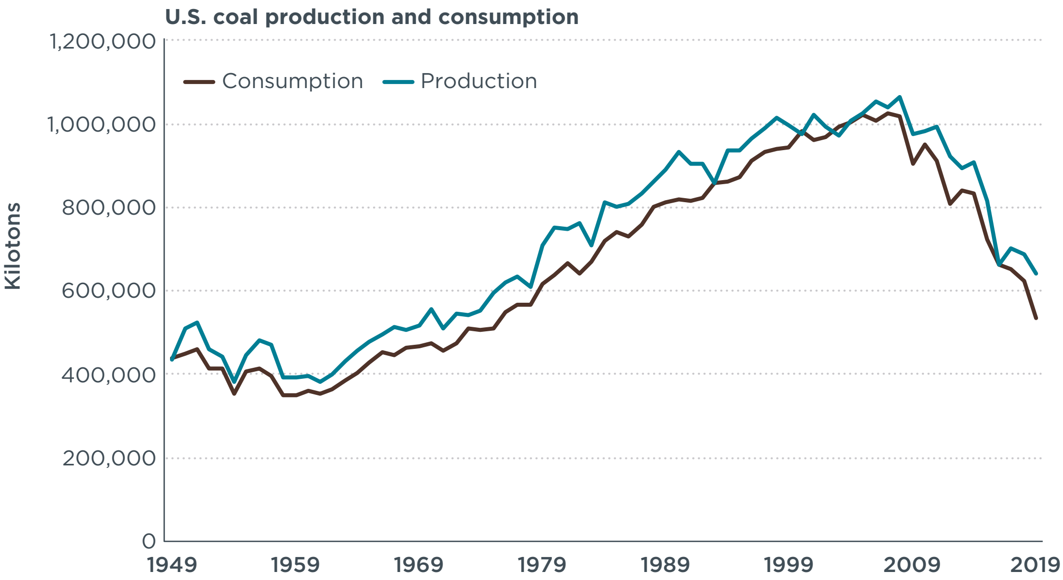
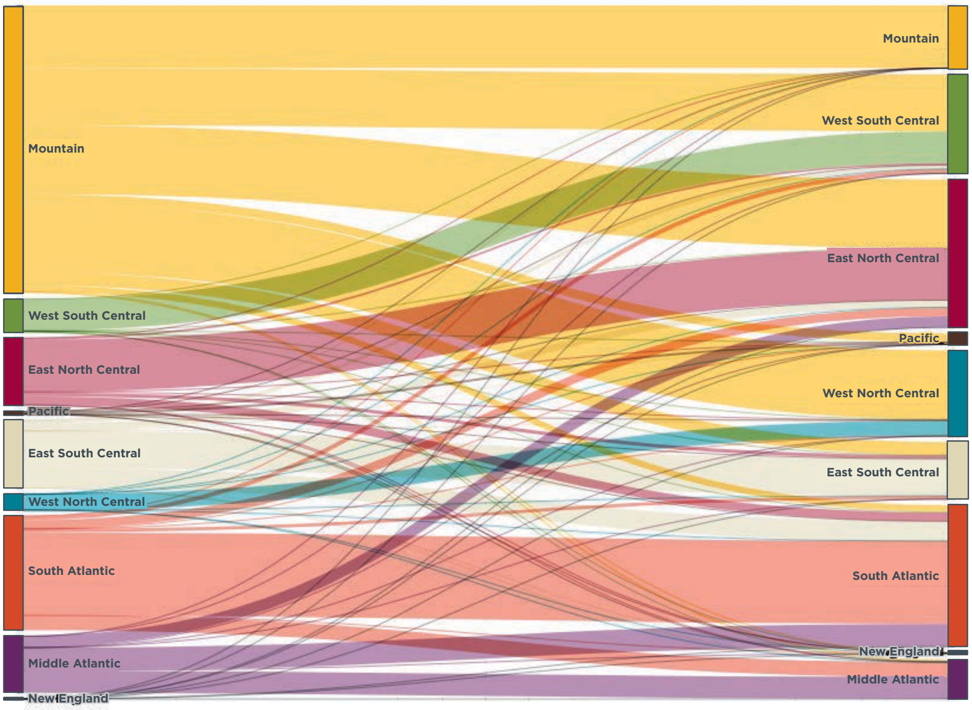


Figure 27. U.S. coal production and consumption, 1949–2019.
Source: U.S. EIA (n.d.)

The 2018 data in Figure 28 shows that the production and consumption of coal was concentrated in a few regions. About half of the coal moved from the Mountain region, followed by the South Atlantic, East South Central, and East North Central, all of which are regions with major coal mines. The top four destinations for the coal were the East North Central, South Atlantic, West South Central, and West North Central regions, which received about 73% of the total coal hauled in the United States. Although coal was consumed across the country, the areas with particularly high consumption are highly dependent on this resource for electricity needs and have many coal-fired power plants. Many of these areas were previously close to coal production, but with output moving to the Mountain regions to meet lower sulfur content requirements,[6] transporting substantial quantities of coal across the country is now necessary to supply many of the power plants.



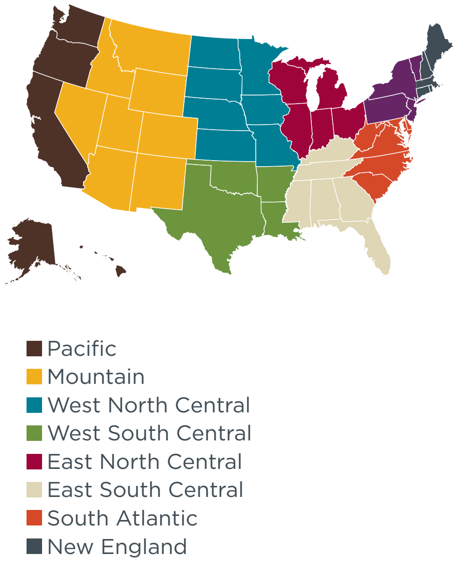


Figure 28. Coal shipping map by region and weight, 2018.
Source: Oakridge National Laboratory (2021).

Coal movement from all major producing regions has been dominated by rail. Figure 29 shows that about 70% by weight was shipped by train at least part of the way (Mintz, Saricks, & Vyas, 2015; EIA, 2020d). Coal accounted for about 14% of U.S. freight train carloads and 25% of originated tonnage for U.S railroads, more than any other commodity (AAR, n.d. b). Rail accomplished most of the long-distance shipping, and that led to an even higher share of coal shipping when evaluated in ton-km (Figure 30). The pattern of significant reliance on train shipping has made coal an important commodity for the U.S. rail system.

6 Coal is classified by its heat and sulfur content. The total sulfur in coal ranges from 0.2% to 10% by weight (Khan & Philips,1989). Low-sulfur coal generally contains 1% less sulfur by weight or less than 0.6 pounds of sulfur per million British thermal units (MMBtu).

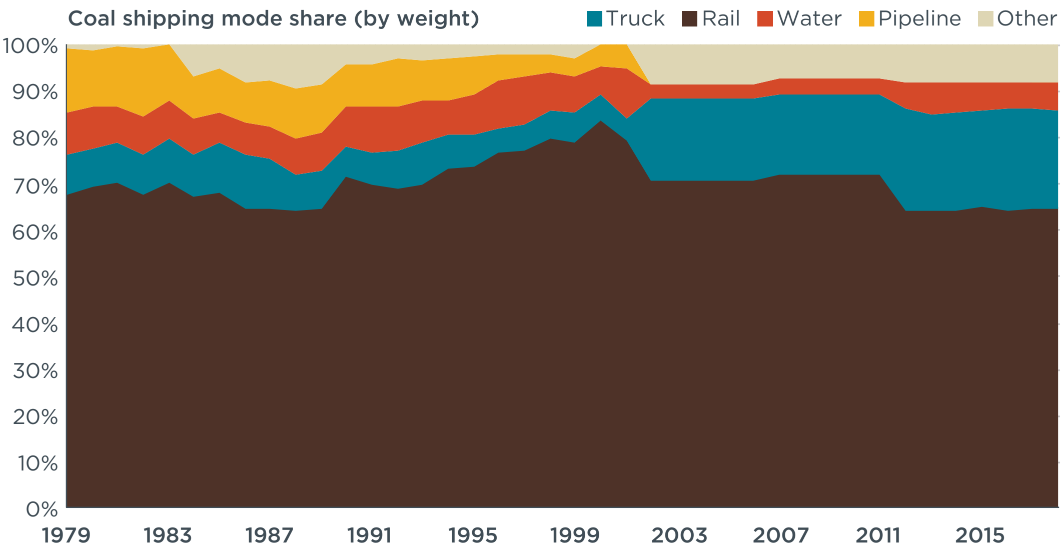


Figure 29. U.S. coal shipping mode share by weight, 1979–2019.
Source: 1979-2001: U.S. EIA (n.d. a); 2002–2018: Oakridge National Laboratory (2021).

*The 1979–2001 data from U.S. EIA includes a broader category of coal products, including coal n.e.c., which was listed separately after 2001. Coal n.e.c was shipped mostly by pipeline, so there was a fair amount of pipeline shipping used before 2001.

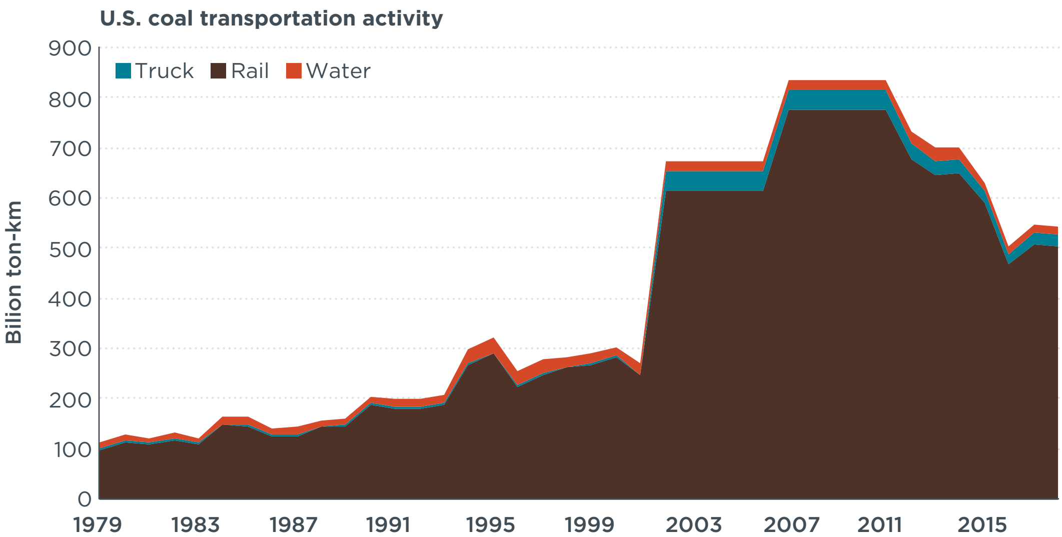


Figure 30. U.S. coal shipping activity in ton-km, 1979–2019.
Source: 1979–2001: U.S. EIA (n.d. a); 2002–2018: Oakridge National Laboratory (2021).

Many factors led to the preference of rail for shipping coal products. Rail has proven to be the most fuel-efficient and oftentimes the most feasible form of surface transport for large tonnage of coal over long distances (U.S. Department of Agriculture, 2008; Mintz et al., 2015). The average hauling distance of rail increased from 600 miles in 1997 to almost 950 miles in recent years, in part because the demand for coal with lower sulfur content meant production moved to the West, and shipping via waterway was no longer an option (U.S. Department of Agriculture, 2008) (Figure 31). The ability to haul long distances and large capacities also drove relatively lower rates for coal when shipped using rail.

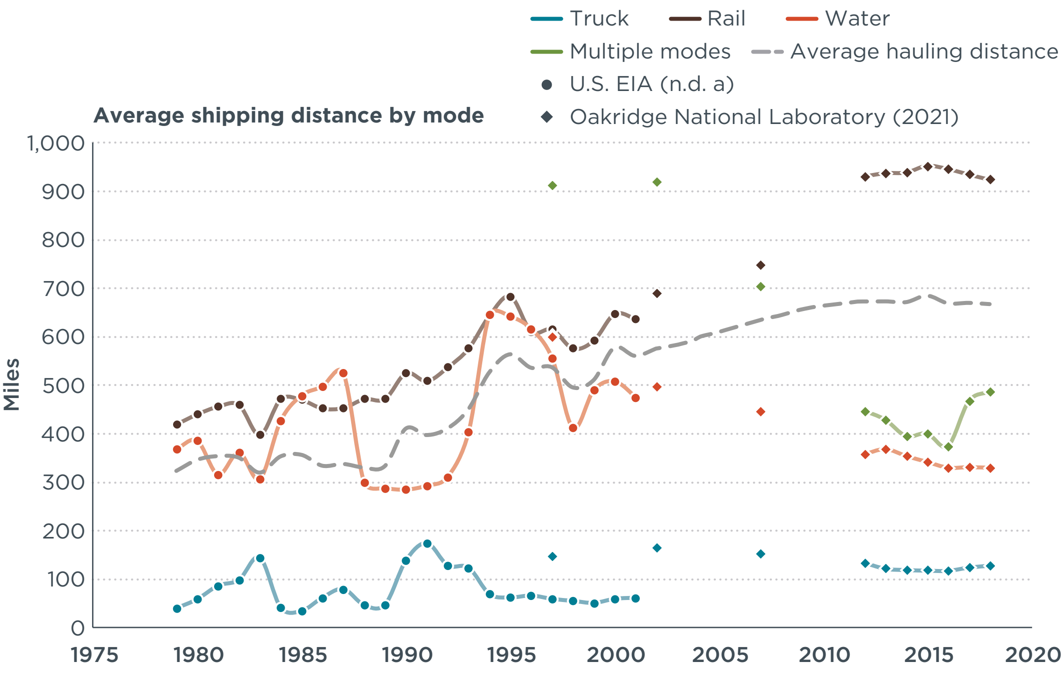


Figure 31. U.S. coal average shipping distance by mode, 1979–2019.
Source: ● :U.S. EIA (n.d. a); ◆ :Oakridge National Laboratory (2021).

Despite rail's dominant role, the truck share of coal shipping has grown to more than 20% in recent years. This might reflect a difference in data collection, but it could also indicate an increase in rail rates on shorter hauls since 2002 (Mintz et al., 2015). Trucks provide greater flexibility for pick-up and drop-off locations, and the average truck hauling distance held at around 100 miles in recent years (Figure 31). Truck is often used for "last-mile" delivery to or from intermodal hubs.

Shipping on inland waterways and the Great Lakes was also an important form of coal transportation and accounted for around 10% of U.S. coal tonnage, with some ups and downs in recent years (National Research Council, 2007). Coal represented a significant share of shipping on inland waterways as well, accounting for about 20% of total cargo (National Research Council, 2007). The development and use of water transportation was unbalanced across regions. Barge traffic was particularly important in the midwestern and eastern states along the Ohio River, but it is not available in western coal producing areas (National Research Council, 2007; U.S. Department of Agriculture, 2008). This was mostly because of limited waterway access rather than cost as waterway is the most cost-effective way to ship coal.

Based on the EIA's survey of coal transportation rates to the electric power sector (U.S. EIA, 2020a; U.S. EIA, 2020c), the average transportation cost of coal dropped from $17.21 per ton in 2017 dollars in 2008 to just over $15 per ton in 2019. However, the contribution of transportation costs in coal's delivery costs increased from one-third in 2008 to more than 40% in 2019 because the price of coal itself declined, making it more sensitive to shipping costs (EIA, 2020c). Of the three transport modes, waterway was the most cost-efficient for large quantity shipments of coal, but its use is limited due to relatively few coal plants located on suitable rivers. Shipping by truck was competitive in terms of cost but only for short distances. Rail dominated coal hauling. Nevertheless, the average shipping revenue per ton-mile for coal was almost the lowest across all commodities—about 50% lower per ton—and was only 2.17 cents per ton-mile in 2018. For all commodities other than coal, the average revenue was 4.82 cents (AAR, n.d. b).

Iron ore

Iron ore production and consumption has been stable in recent years. In 1904, the United States was the world's largest iron ore producer and accounted for about 60% of total world output (Kirk, 2000). In 2019, reported production was less than 50 million tons, just 1.9% of world production (U.S. Geological Survey, 2020). Consumption peaked in the 1960s and 1970s, reaching almost 140 million tons, as shown in Figure 32. The majority of iron ore—98% in 2019—was used in the steel industry (U.S. Geological Survey, 2020). The United States long relied on iron ore imports because domestic production mainly from Michigan and Minnesota could not fully meet demand. This pattern changed around 2009, though, when exports of iron ore exceeded imports by a slight margin, and the United States has been a net exporter ever since.

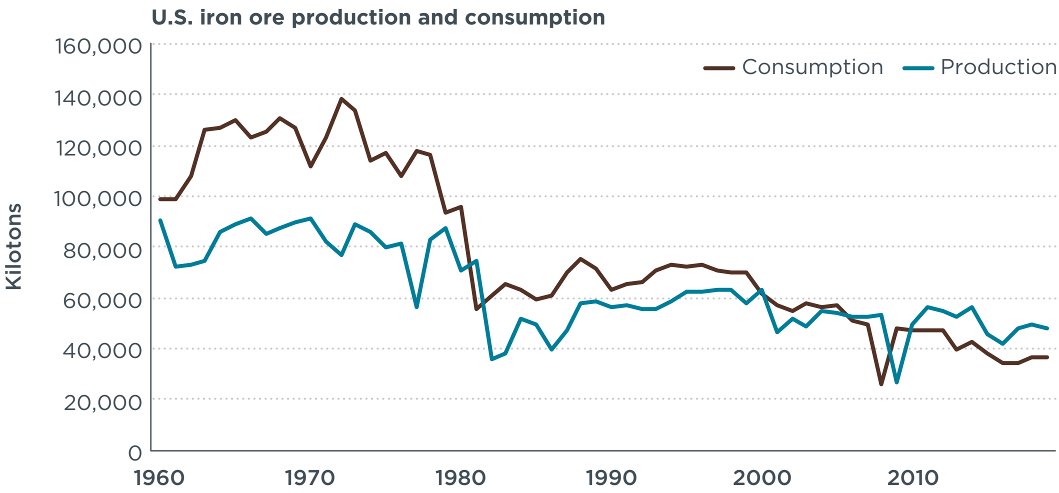


Figure 32. U.S. iron ore production and consumption, 1960–2018.
Source: U.S. Geological Survey (n.d.).

Due to a lack of detailed shipping information for iron ore, data for all metallic ores was used as a proxy for trends and patterns in iron ore. Most metallic ores in the United States are shipped to neighboring regions or within the regions where they were mined, as mapped in Figure 33. More than half of the metallic ores in the United States came from the West North Central region, followed by West South Central and East North Central regions. These three areas contributed 86% of metallic ore production. The East North Central region consumed more than half of the ores, and the West South Central and West North Central regions ranked next. Even though most of the metallic ores were produced and consumed within the same regions, the largest shipping demand was between the West North Central and East North Central regions (Figure 33). The top regions for metallic ore shipping activity have excellent access to waterways with the potential to use barges.

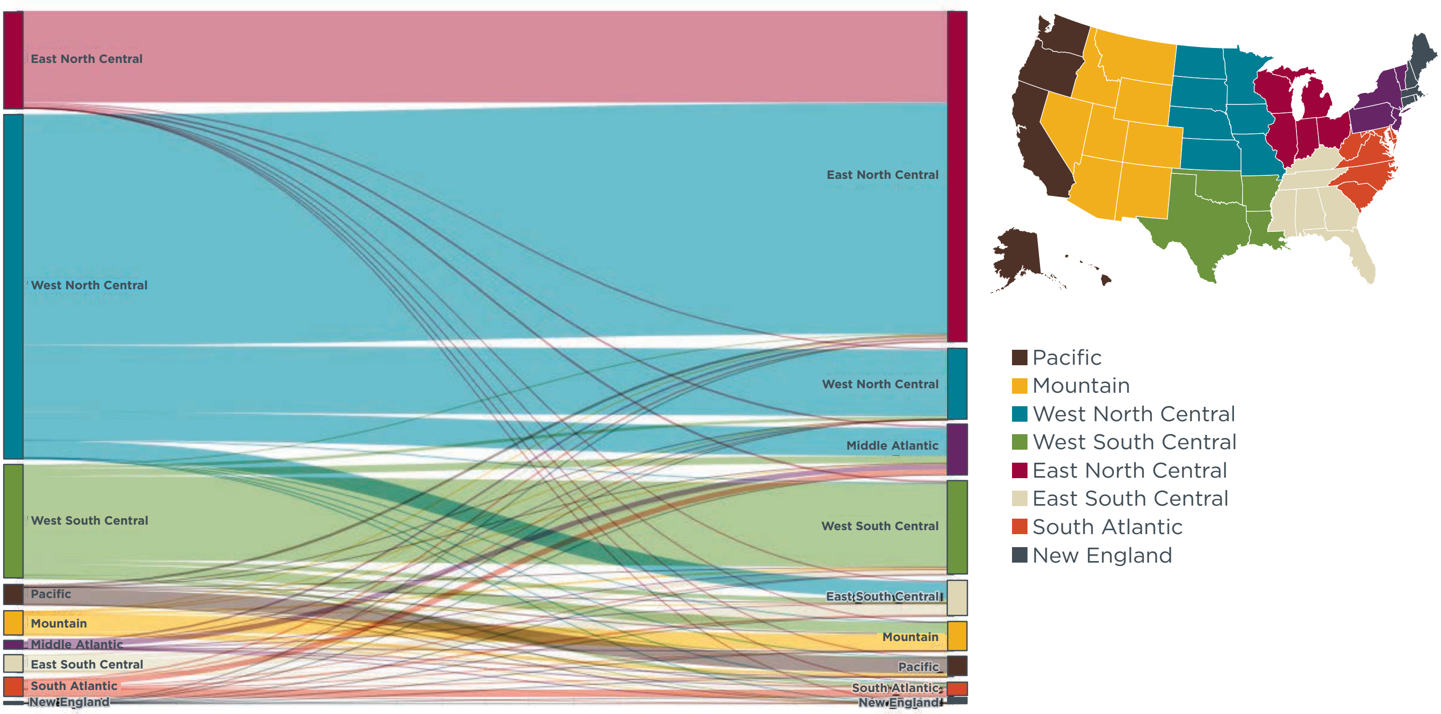


Figure 33. Metallic ore shipping map by weight, 2018.

Source: Oakridge National Laboratory (2021).Transporting iron ore requires long-distance shipping, often involving multiple modes. The trend over at least the past 10 years has been to transport iron ore from mines to transportation hubs via heavy trucks (Tuck, 2017). From there, ore was either hauled by trains to facilities across the country or by waterway across the Great Lakes or through the St. Lawrence Seaway to the Atlantic Ocean (Tuck, 2017). Based on the shipping approaches of metallic ores shown in Figure 34, about half of the hauling by weight involved rail. The next largest share was by truck, and then waterway. Intermodal shipping was also a key element, contributing over 10% of the market. This pattern has been relatively stable for the past couple of years, with a slight increase in waterway's share. This was mostly because mines in Michigan and Minnesota take advantage of the Great Lakes to ship ore to steel companies. Figure 35 presents similar data as Figure 34, but in ton-miles.

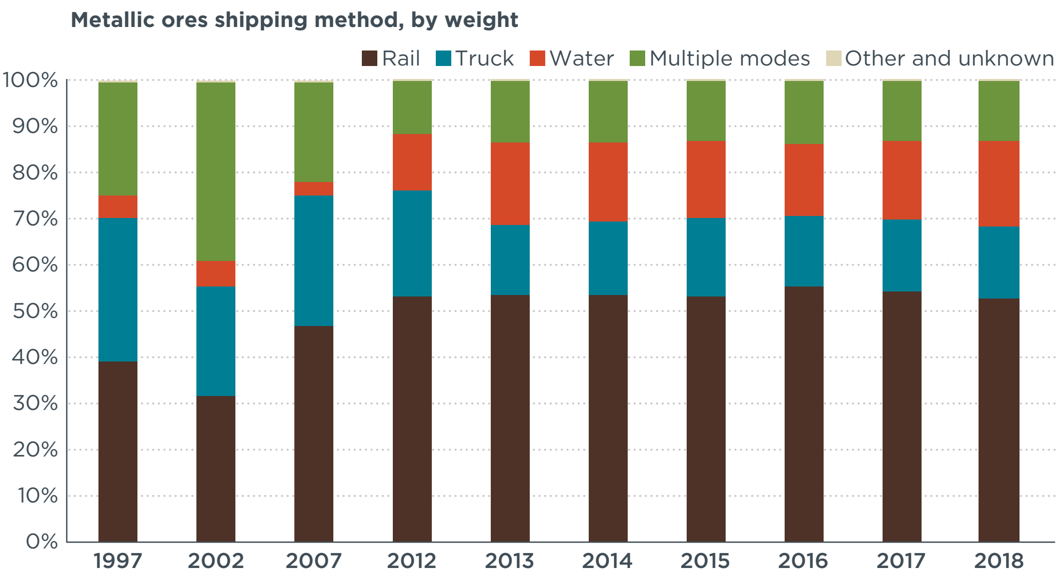


Figure 34. U.S. metallic ore shipping share by weight.
Source: Oakridge National Lab (2021).

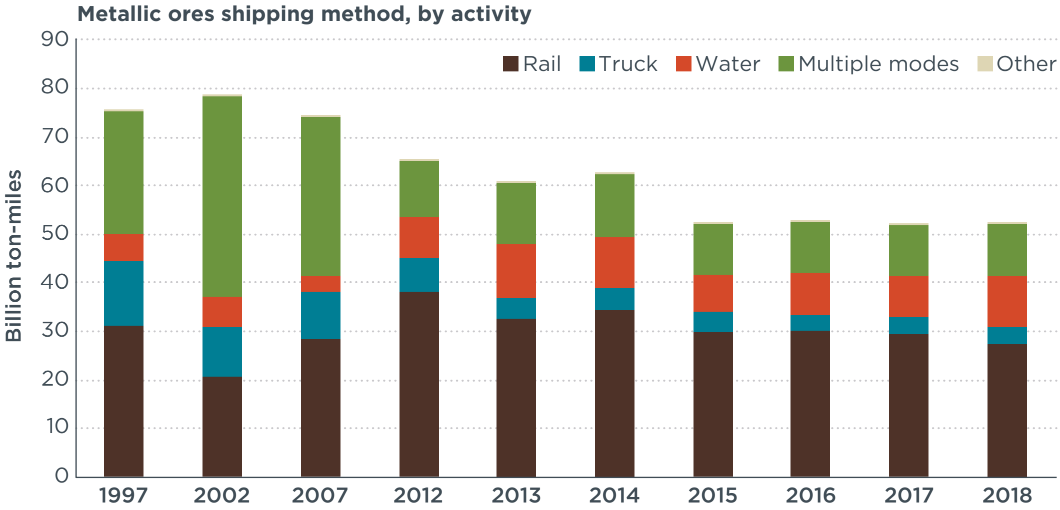


Figure 35. U.S. metallic ore shipping in ton-mile.
Source: Oakridge National Laboratory (2021).

The average shipping distance was also relatively constant by mode in recent years. Rail and waterway shared similar hauling distance, around 500 miles. (Figure 36). Trucks were mostly for shorter-distance hauling (200 miles), connecting mines or steel companies with trains and barges. Intermodal was mostly for longer distances of 800 miles on average in the past decade.

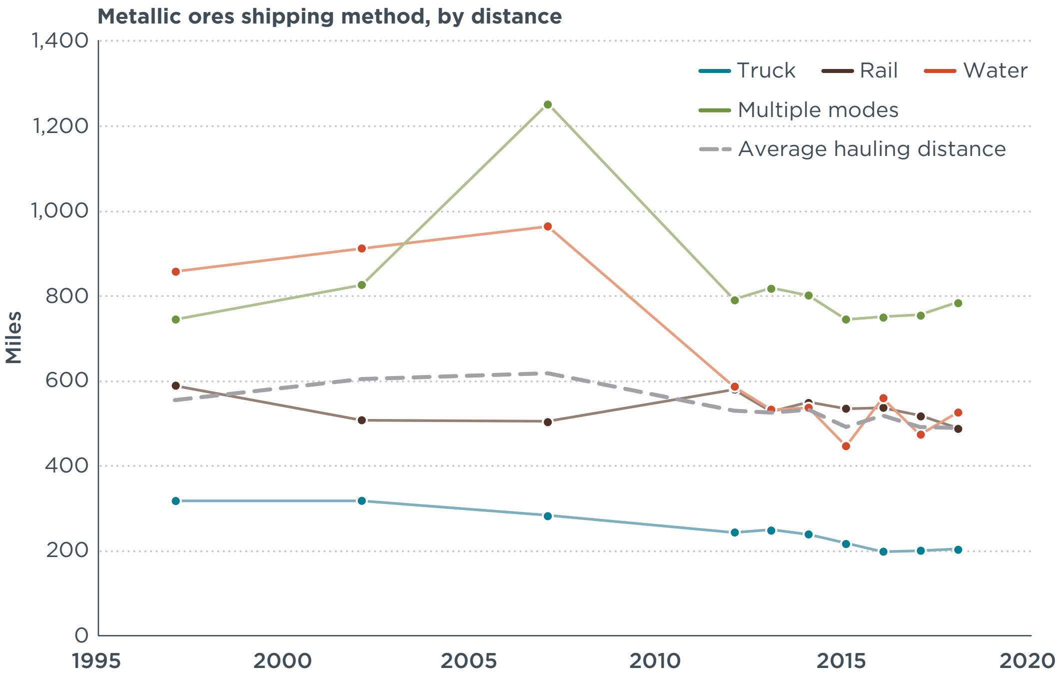


Figure 36. U.S. metallic ore average shipping distance by mode.
Source: Oakridge National Laboratory (2021).

Motor vehicles

The U.S. automobile industry underwent significant expansion after the end of the Second World War with the creation of the Interstate Highway System and a boom in the economy (Samuels, 2019). The production of motor vehicles in the United States increased consistently for many years until a sharp drop during the Great Recession of 2007–2008 (Figure 37). But it bounced back quickly. Domestic production cannot meet all of the demand, and there is a heavy reliance on imports. In 2018, automobiles made up about 8% of total imports into the United States and were the most-imported commodity (Samuels, 2019). Motor vehicles were also one of the products with the highest value shipped in the United States in recent decades (Oakridge National Laboratory, 2021).

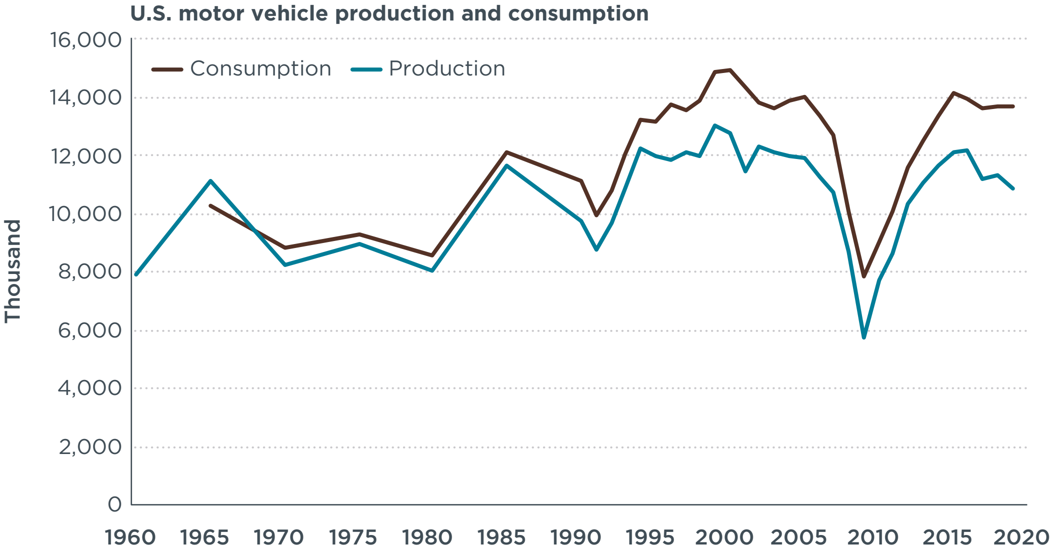


Figure 37. U.S. motor vehicle consumption and production by units.
Source: BTS (2020).

Shipment of motor vehicles is spread out relatively evenly by region, with most of the hauling within regions. The East North Central region had the largest transport needs by weight, and most of the shipping was within the region (Figure 38). This is the region where many vehicle factories are located as it is close to steel manufacturers and mineral mines. Additionally, a fair volume of vehicles by weight were hauled from coastal regions like the Pacific where imported autos are unloaded from ports. The New England and Mountain regions, where population is low, had relatively less shipping need. The regions with more people had more transport of motor vehicles.

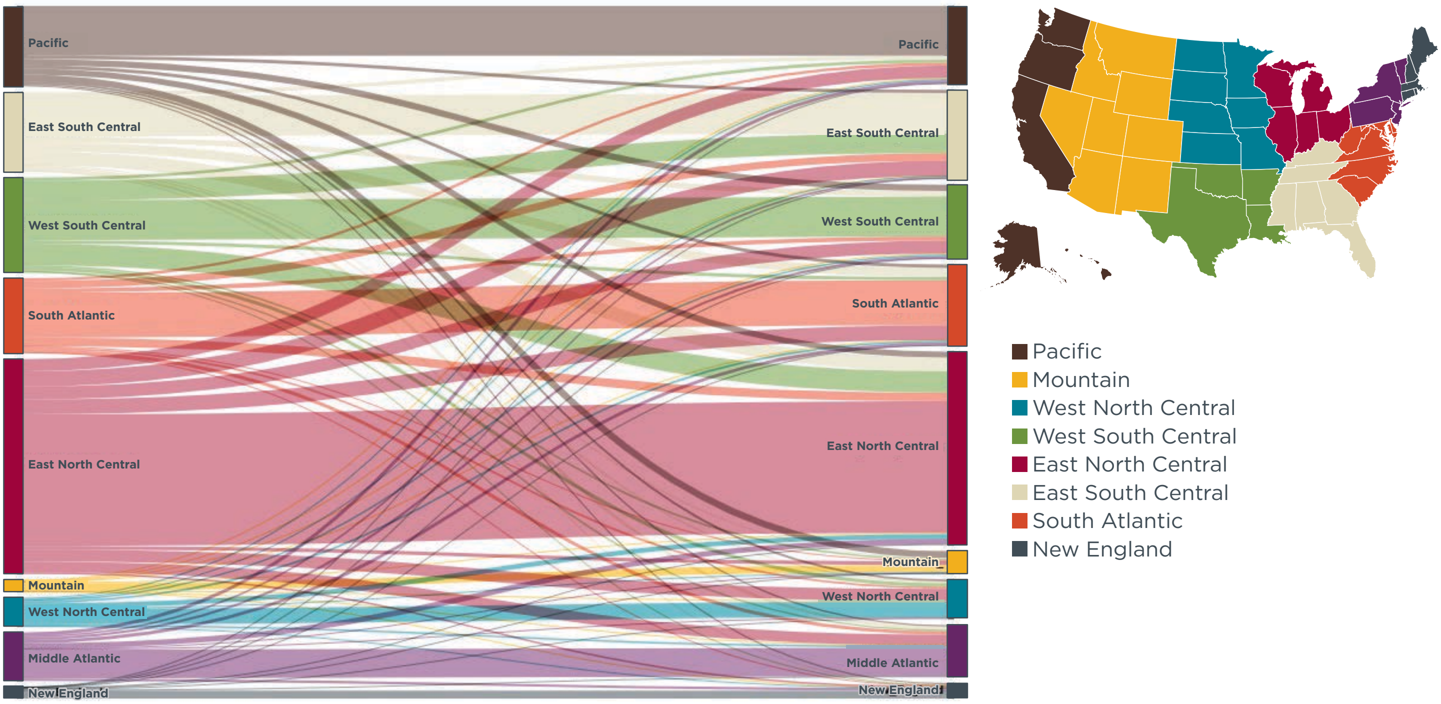


Figure 38. Motor vehicle shipping map by region and weight, 2018.
Source: Oakridge National Laboratory (2021).

The majority of the vehicles by weight were transported by truck as shown in Figure 39. Trucks have been the dominant mode for shipping motor vehicles. Today's tractor-trailers carry as many as 12 autos (Magda, N.D.). Intermodal was a key element accounting for more than 10% by weight and 20% by activity in recent years (Figure 40). Rail has the advantage of being cheaper, but it is limited in destination locations and the availability of specialized equipment required for loading the vehicles. Rail cars specially designed to transport vehicles were upgraded to carry as many 26 units each in the early 2000s, including pickups, SUVs, and sedans, on as many as three levels in one railcar (AAR, 2020a; Union Pacific Railroad, 2020). The share of rail by weight has decreased, but not the share by activity over recent years. It has been estimated that 65%–75% of all new vehicles travel by rail before shifting to tractor-trailer for final delivery (Magda, N.D.; AAR, 2020a). This shows that rail is being used more for longer-distance shipping and is employed less as a single mode than as an important element in intermodal. Waterway, on the other hand, is rarely used for motor vehicles and has recently accounted for less than 1% of auto shipping.

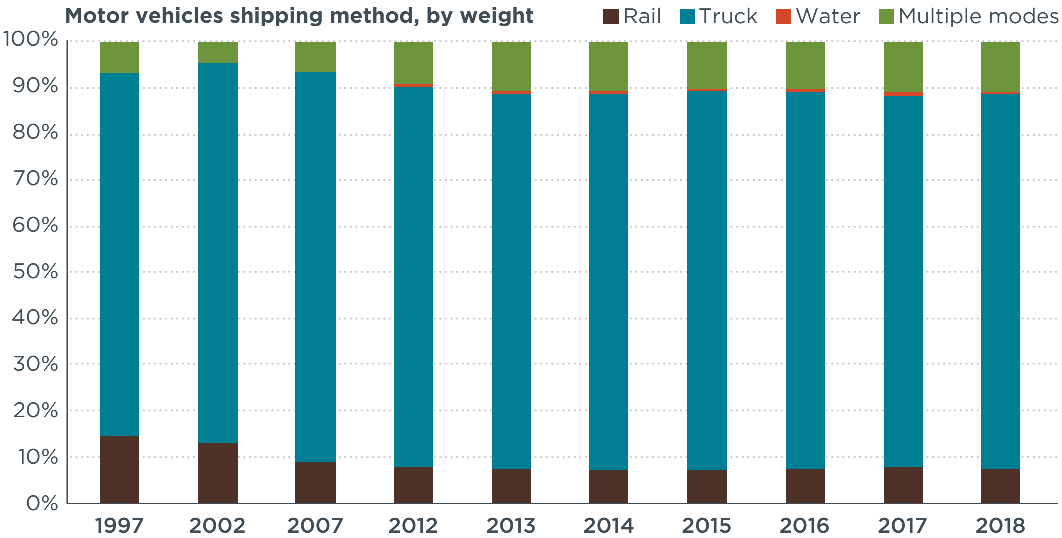


Figure 39. U.S. motor vehicle shipping mode (by weight).
Source: Oakridge National Laboratory (2021).

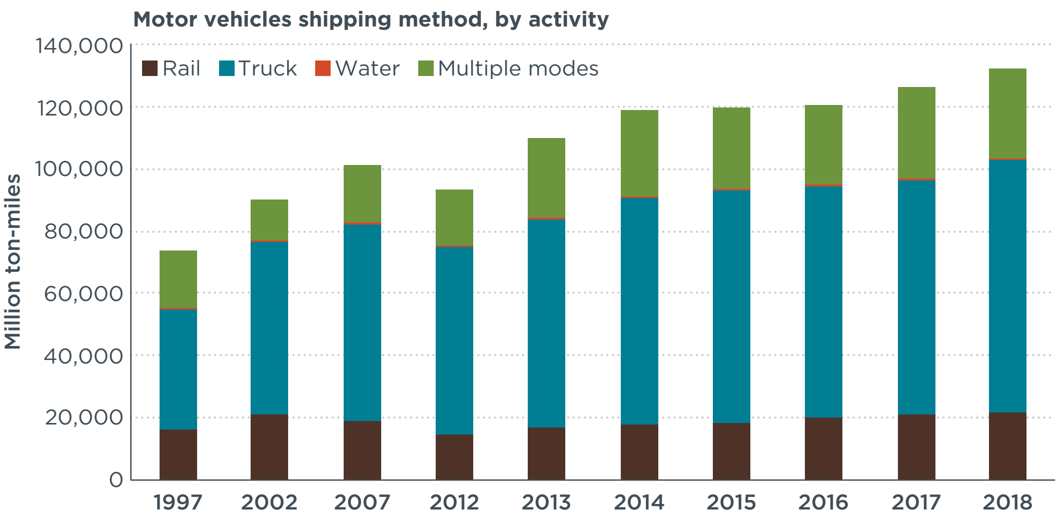


Figure 40. U.S. motor vehicle shipping activity in ton-mile.
Source: Oakridge National Laboratory (2021).

Rail and intermodal were adopted for longer-distance hauling of motor vehicles, and trucks for shorter distances. The average hauling distance of rail and intermodal was consistent in recent years, around 1,200 miles (Figure 41). Trucks drove an average shipping distance of almost 500 miles, which was relatively constant over the time analyzed. Waterway shipping distance had ups and downs but reached a level that is close to the average hauling distance of road transportation.

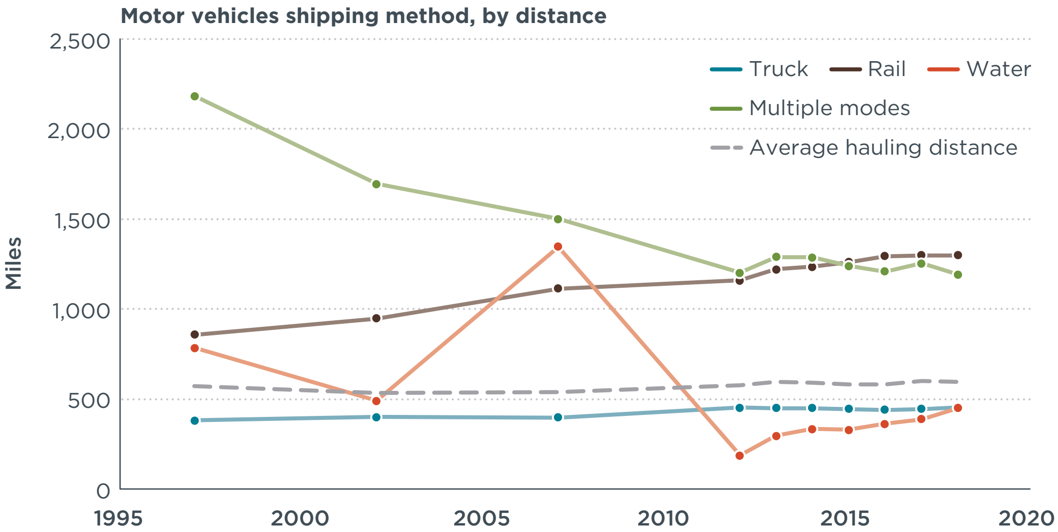


Figure 41. U.S. motor vehicle average shipping distance.
Source: Oakridge National Laboratory (2021).

SHIPPING PATTERNS OF KEY PRODUCTS IN CHINA

The information in this section is taken from a special investigation of road freight volume in 2019, reports on the economic situation of relevant industries, annual reports concerning the development of relevant industries, traffic statistics bulletins, and other sources.

Coal

China's coal production and transportation demand have grown since 2000. The trend reached a peak around 2013, but after a trough in 2016, there was again growth (Figure 42). All coal demand was met domestically until 2011, when imports became needed. To better capture the characteristics of coal shipping, the hauling needs for coal products are shown as shipping demand in Figure 42. Shipping demand captured total coal consumption in China—domestic production and imports—but excluded volumes used at pithead coal-fired power plants, which accounted for about 5% of consumption.[7]

7 Coal transportation to pit-head power plants basically belongs to intra-enterprise transportation and does not require social transportation capacity.

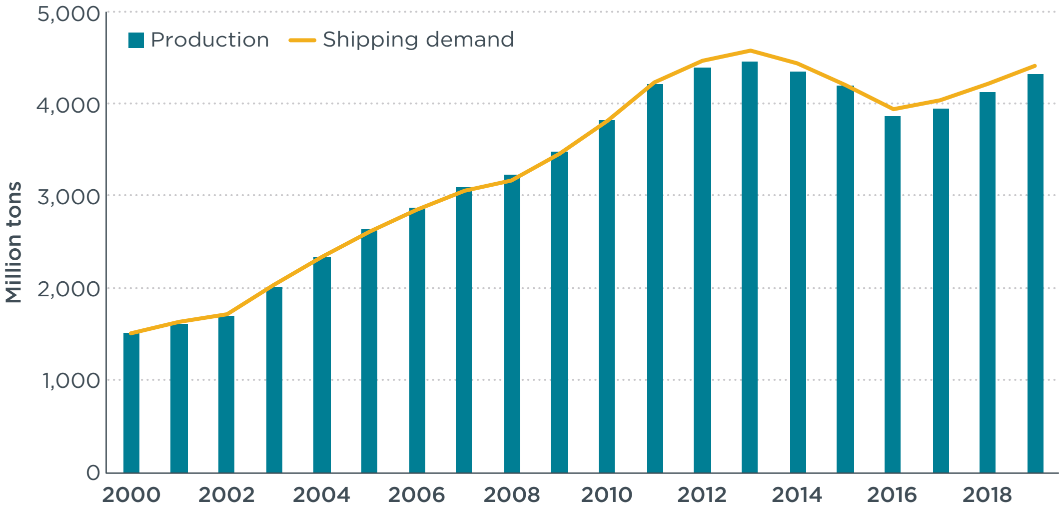


Figure 42. China's coal production and transportation demand.

As presented in Figure 43, coal transportation has been dominated by road freight in recent years and accounted for 56% of the system by weight. The share of trucking in coal transport peaked in 2016. Rail shipping volume and share increased from 26% in 2016 to 28% in 2019 (Figure 44). The growth mainly came from the transportation structural adjustment as coal was prioritized for mode shift. Even though this adjustment applied to waterway shipping as well, the impact on coal was minimal. The average number of transfers during shipment was about two.

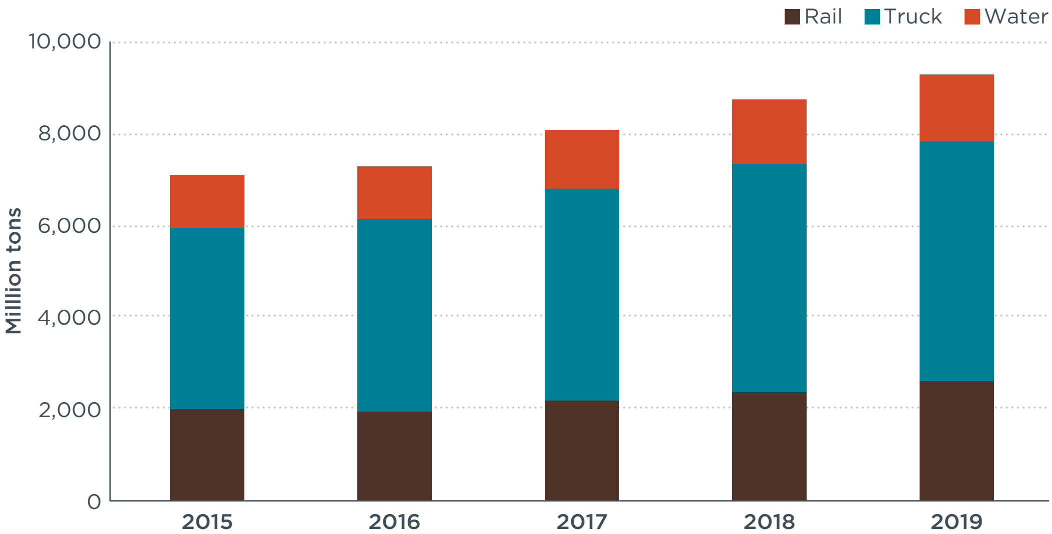


Figure 43. China's coal shipping demand by weight

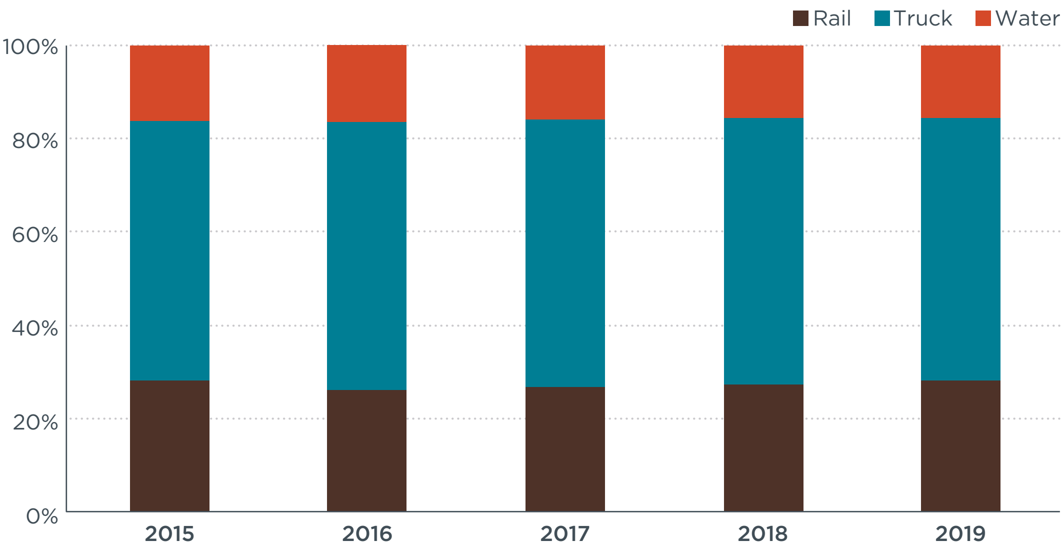


Figure 44. China's coal shipping mode share by weight.

Iron ore

Driven by the rapid expansion of the steel industry, China's demand for iron ore surged in recent years. Consumption of iron ore peaked in 2014 at 2.45 billion tons, eased, then rebounded to 2.32 billion tons in 2019 (Figure 45). The majority of the iron ore came from domestic mining, but imports increased over time and fulfilled almost half of demand from 2017 onward. China also exported a small volume of iron ore. Similarly, shipping demand as shown in Figure 45 reflects only the need to transport iron ore by surface transportation (truck, rail, and water), as steelmakers moved to coastal areas and rely on conveyor belts for ore movement.

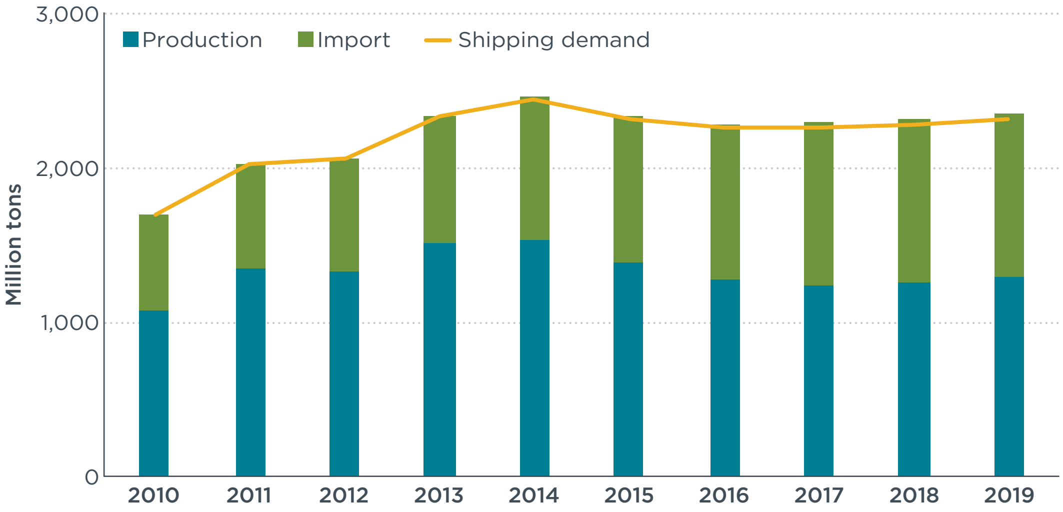


Figure 45. China's iron ore shipping demand, 2010–2019.

Iron ore transportation has recently been dominated by truck. Between 2015 and 2018, the share of trucking increased from 55.8% to 57.1%, then declined to 56.8% in 2019 (Figure 46). The share of rail represented an increase of 0.6% in 2019 under requirements in the transportation structure adjustment (Figure 47). However, as most of the steel plants are located in Hebei and other coastal provinces, the shipping distance was relatively short, and road shipping was more efficient. Thus, the growth of rail was not significant. Moreover, with the requirements of promoting ultra-low emissions in steel production, many steel companies moved to coastal ports and used conveyor belts for moving iron ore, which was not included in shipping demand. It is expected that more steel enterprises will relocate to coastal areas to rely on belts for transporting imported iron ore.

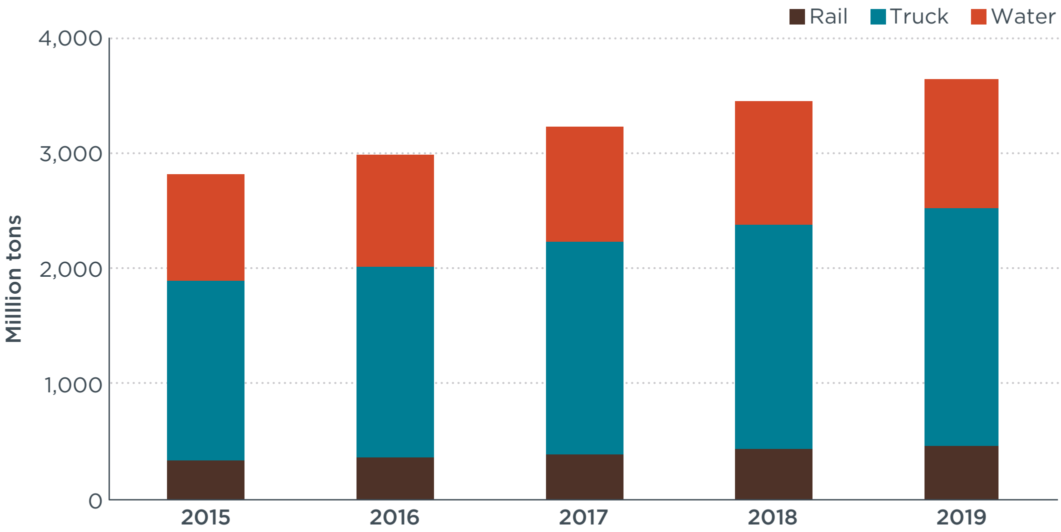


Figure 46. China's iron ore shipping by mode.

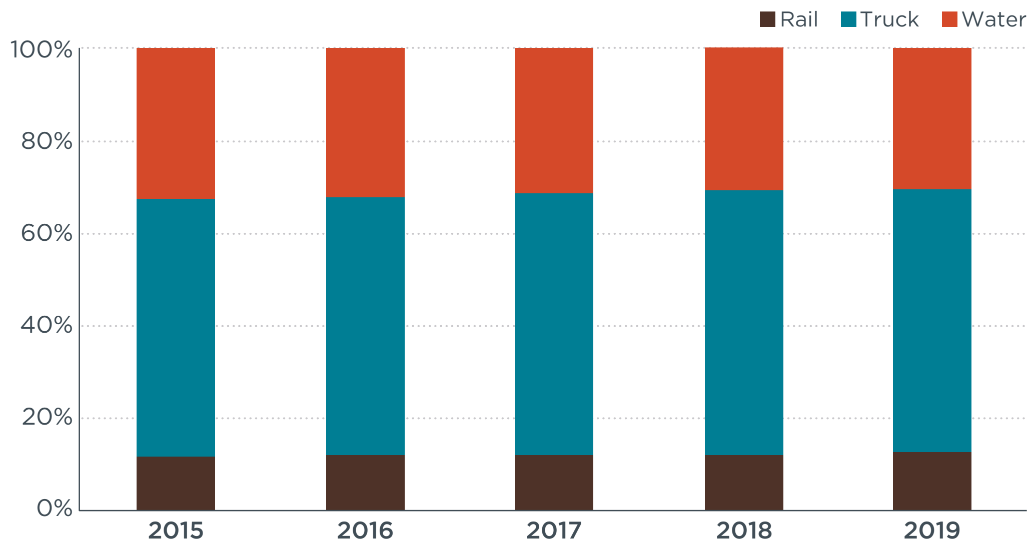


Figure 47. China's iron ore shipping mode share by weight.

Passenger vehicles

The majority of passenger vehicle demand in China was met by domestic manufacturing.[8] Production and import volumes remained relatively stable between 22 million and 26 million units in the past few years, with imports of about 1 million, as shown in Figure 48. Shipping demand for passenger vehicles by units is presented here, including domestic production and imports.

8 Considering that the majority of motor vehicles in China and the United States are passenger vehicles, the shipping pattern of autos in China is fairly comparable with that of the United States.

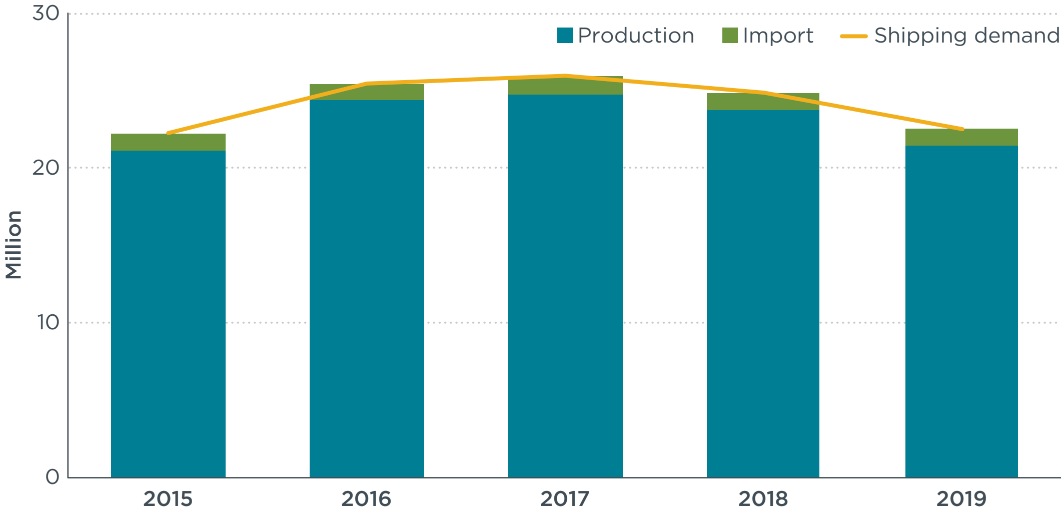


Figure 48. China's passenger vehicle demand, 2015–2019.

The shipping trend for passenger vehicles shifted from truck to rail and waterway due to policy intervention. In 2015, shipping was dominated by truck with a market share of 83% by units, while rail and waterway accounted for less than 15% (Figure 49). Several ministries jointly issued regulations in 2016 requiring an increase in rail and waterway hauling for passenger vehicles and barring illegal modification and overload/oversize operation of freight vehicles. The government further emphasized the changes again in 2018.[9] The regulations and requirements reduced the share of trucking in passenger vehicle shipping and increasing the rail share from 8.6% to 29.2% and waterway from 8.5% to 15.1% in just four years (2015–2019). See Figure 50. Even though trucks were still the dominant mode of passenger vehicle shipping, rail and waterway jointly claimed almost 45% of the transport market.

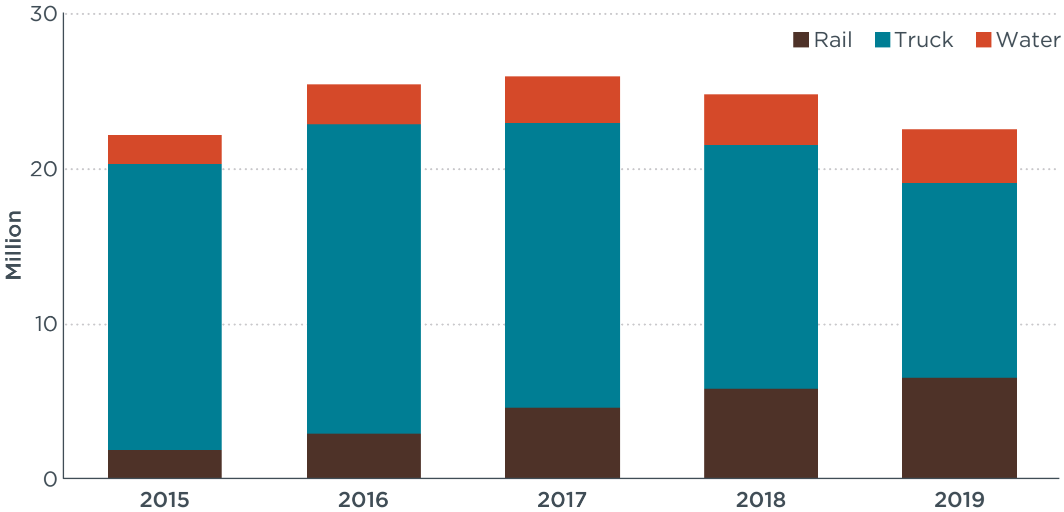


Figure 49. China's passenger vehicle shipping mode, by units.

9 Ministry of Transport, Ministry of Public Security, Ministry of Industry and Information Technology as well as two other Departments jointly issued the "Work Plan for Regulating Vehicle Freighting Vehicles" (MoT Office [2016] No. 107) in 2016 to regulate activities on illegal modification and overload/oversize operation of vehicles transporting vehicles. In 2018, the authorities issued the "Notice on Further Promoting the Regulation of Vehicle Freighting Vehicles" (MoT Office [2018] No. 702) to further strengthen the regulations.

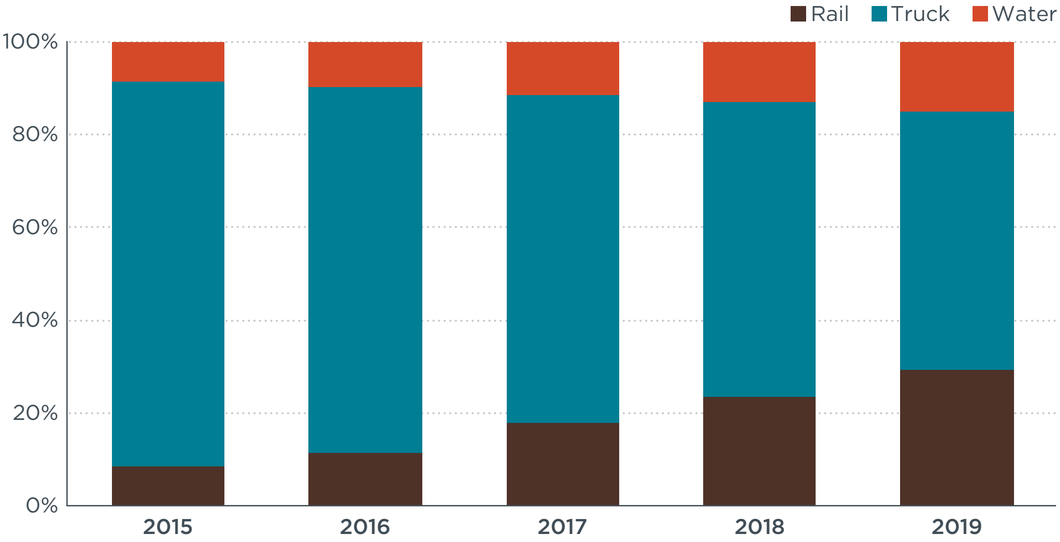


Figure 50. China's passenger vehicle shipping mode share.

UNITED STATES–CHINA COMPARISON

The shipping needs of the three selected commodities were much higher in China than in the United States, as illustrated in Figure 51. This implies greater challenges for China in maintaining an efficient and green transportation system for these goods. This is especially true for heavy, bulk products such as iron ore and coal. Consumption of iron ore in China was about 63 times that of the United States. More than eight times as much coal was used in China as in the United States. Moreover, coal and iron ore use has peaked in the United States, while it is still hard to forecast a peak in China. In addition, with the transition of China's economy, the need to ship higher-value products such as motor vehicles will probably continue expanding as well.

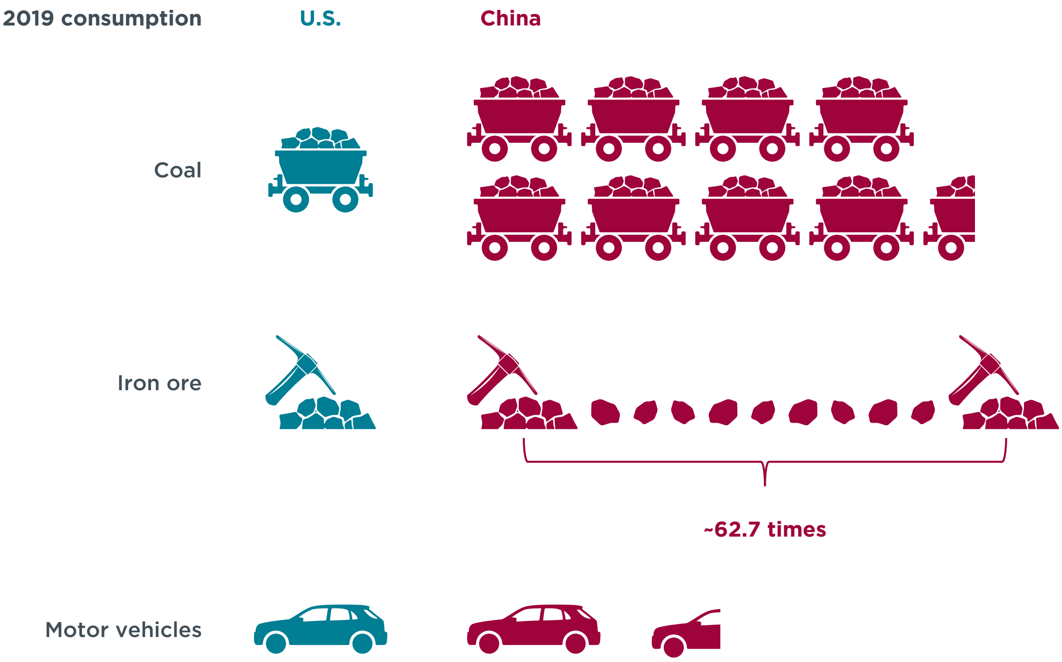


Figure 51. A comparison of shipping demand for selected commodities in United States and China in 2019.

The shipping modes employed were quite different across the selected commodities in the United States and China (Figure 52). Coal and iron ore were hauled mostly by rail in the United States and mostly by truck in China. For coal transport in the United States, waterways were used less after production moved to the Mountain region; for metallic ores, barges were more widely adopted because the mines were usually close to the Great Lakes. In China, rail and waterway were important elements for bulk products, with more rail adopted for coal shipping and more waterway for iron ore.

Both countries relied on road transportation for hauling motor vehicles, but more diversity was seen in China's case as rail and waterway added almost 45% of the shipping market by units. Intermodal has become a noticeable segment of the U.S. freight system, contributing 5%–13% of the market by weight. Information on intermodal was not available for China.

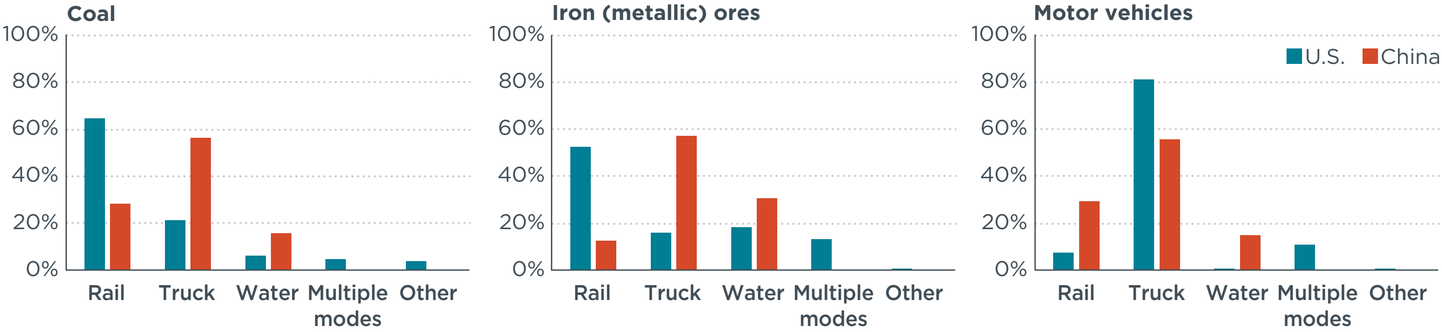


Figure 52. Comparison of shipping mode share by weight (number of units for China's motor vehicles) for selected commodities, 2018 for the United States and 2019 for China.
"Other" represents other shipping modes such as air, pipeline, and modes that are unclear.

Figure 53 highlights the change in mode choice for the selected goods to review the impacts of policy efforts. Between 1997 and 2018, more rail and waterway by weight were adopted for metallic ores in the United States; this came with a better optimized freight system and infrastructure, which offered better connections and lower shipping costs for rail and waterway for heavy, bulk products. The pattern for coal was different as trucks and intermodal replaced a large share of rail and waterway. This is probably because rail and waterway engaged more in intermodal after being promoted as part of ISTEA in 1991. For motor vehicles, the share of trucking increased as did the share of intermodal. In China, the share of rail and waterway increased for all of the studied commodities with the transportation structure adjustment between 2015 and 2018. But the increase was most significant for motor vehicle shipping after the imposition of enhanced regulations on overload and oversize road transportation and specific requirements on the industry.

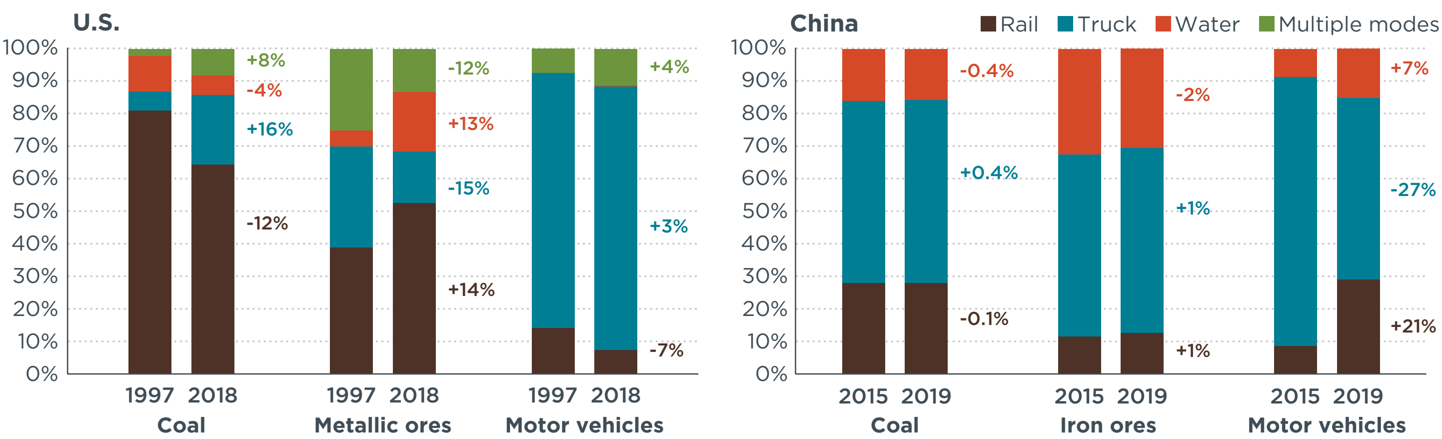


Figure 53. Comparison of shipping mode change by weight (number of vehicles for China's motor vehicle) for selected commodities, 2018 for the United States and 2019 for China.

Figure 54 compares the change of activity data (ton-mile) by commodity in the United States with both weight and distance considered. Coal and metallic ores had an increased preference on rail and waterway. The share of rail's activity in 2018 was almost 20% more than in 1997 for coal, and about 12% more for metallic ores; the share of waterway in 2018 was 12% more for the ores, but 4% less for coal. This is probably due to less waterway access with production shifting west. Meanwhile, growth in trucking was observed for motor vehicles. Even though intermodal still had a noticeable share in the activity of the three selected products, its market share shrank. Additionally, the average hauling distance increased for coal and motor vehicles but decreased for metallic ores.

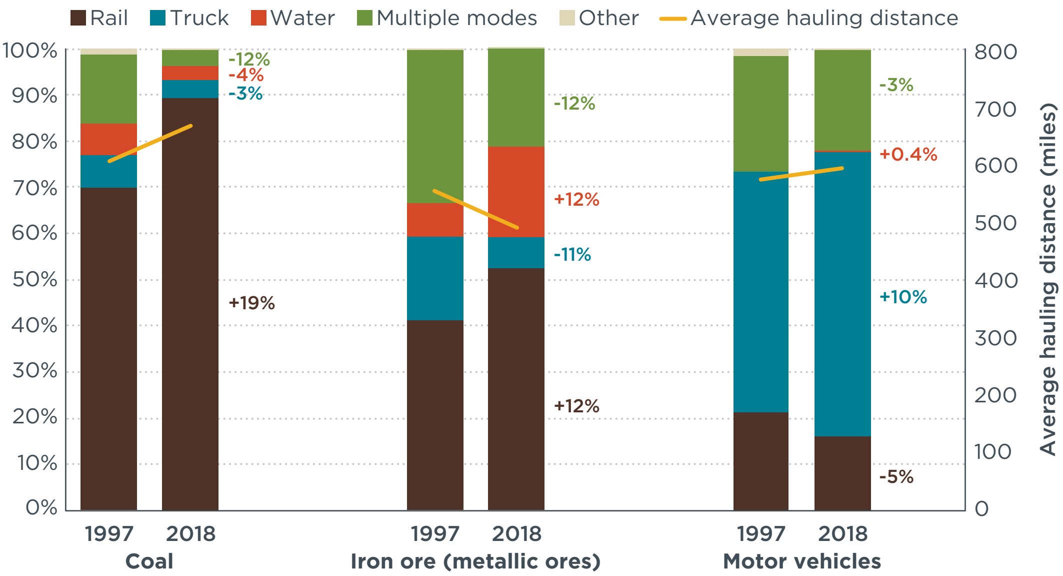


Figure 54. Change of freight activity (ton-km) by mode and average hauling distance between 1997 and 2018 for key commodities in the United States.

FINDINGS AND RECOMMENDATIONS

KEY FINDINGS

- » Overall, China has experienced explosive growth in freight activity. It surpassed the United States in 2009. China's transportation system moved 51 billion tons of freight with 15 trillion ton-km of activity in 2018. That same year, the United States moved 19 billion tons of freight with 8.4 trillion ton-km of activity.
- » In both countries, *trucks* were the primary shipping mode, responsible for 40%–50% of freight activities. But the trends vary. Trucking's share of shipping activity in the United States remained relatively stable in recent decades, while the share of truck activity in China grew from 5% to almost half of the market in the past 40 years.
- » The share of *rail* shipping in the United States was higher than in China. As of 2018, rail shipment was 27% of freight activity in the United States, versus 19% in China. The trend of rail shipping since the 1980s has been dramatically different in the two nations: The share in the United States increased 50% in the past 40 years compared with a nearly 75% reduction in China.
- » *Waterway* was mostly for moving lower-value, bulk products in both countries. The waterway share shrank to 10% in the United States in 2018. That same year, the waterway share in China increased to 31%, and it garnered the second-largest share of freight activity among the modes.
- » The two nations use *pipeline* shipping quite differently. In 2018, the share of freight transportation activity by pipeline was 19% in the United States versus 3% in China. Pipelines played an important role in U.S. shipping for oil, oil products, and coal slurry. In China, pipelines were mainly used for oil and oil products.
- » The largest growth in activity was recorded in *airway* in both the United States and China. Even though the share remains rather minimal compared with the other modes, airways experienced about a fourfold increase in the United States and a 271-times gain in China, both in the past 40 years. The change came from growing demand for just-in-time delivery of higher-value goods in both countries.
- » The United States widely applied *intermodal*, particularly for longer-distance shipping, but such data were not available in China. The strong growth of intermodal in the United States in recent decades was mostly led by rail and truck.
- » In contrast with the United States, China's heavy, bulk products are still the dominant share of commodities. The role of the secondary sector in China's economy, particularly the heavy manufacturing sector, generates enormous need for coal and minerals, and the reliance on coal-fired electricity further boosts coal consumption. These heavy, bulk products drove the rapid growth of China's freight activity for all modes.
- » After deregulation and marketization in the 1980s, the United States initiated strategic planning and policies promoting a transportation system with an intermodal framework for more efficient, integrated, and greener operations. China's strategy of transportation structure adjustment was adopted in 2017. The adjustment shifted the heavy, bulk products mostly to rail and waterway and was complemented by some other supporting requirements on industry. Ultimately, both countries have invested in policies and technologies with the goal of reducing GHGs and criteria pollutants from the freight sector.

RECOMMENDATIONS FOR CHINA

A shift to a services-led economy and cleaner energy sector are the fundamentals. Freight activities are closely associated with and affected by economic factors, which determine the types and quantities of commodities that need to be shipped, the location of production and consumption, and the mode preferred for transit. The U.S. economy focuses more on the services sector, leading to less demand for shipping heavy bulk products like coal and minerals. The development of the U.S. energy sector to rely more on natural gas and renewable sources further reduces the need for coal shipping. Experience in the United States confirms the important influence of the economy and energy on freight activity. China could accelerate its own transition toward a service-led economy and cleaner energy sources.

Continue to tighten energy efficiency regulations and standards for carbon emissions, fuel quality, and criteria air pollutants. Experience in the United States and China shows that standards and regulations are effective in reducing transportation pollution and improving air quality, even with the rapid growth of freight activity and increased energy demand. In addition, China should take a leadership role in electrification of the freight sector, just as it has with light-duty vehicles and urban buses, to further accelerate a transition to a green and sustainable freight system.

Plan for and promote an efficient freight transportation system with a central focus on intermodal. For multiple decades, U.S. freight policies for a more efficient freight system have focused on coordinating between modes and across states and regions. Policy efforts focused on improving the efficiency of the entire freight system have successfully produced enviable productivity gains across all modes of transportation in the United States. This experience proves that collaboration between transportation modes can help realize an efficient freight system. As China has taken initial steps toward marketization, a strategic plan with the framework of intermodal is crucial for accelerating the transition to a more efficient transportation structure.

Invest in freight facilities and infrastructure to enable efficient intermodal shipping. The United States has allocated a significant amount of funding for its transportation network and infrastructure for all modes with funding from federal, state, regional, and even private actors. Intermodal hubs, connectors, and facilities were built to tie all transportation modes together, and this was accomplished with directed funds. China needs to secure and enhance long-term funding to ensure that its future infrastructure and facilities match the tremendous demands of modern, intermodal freight shipment. In addition to funding from the central, regional, and local levels, China could engage more stakeholders, including from the private sector.

Leverage more strategy and policy to diversify the freight activity of bulk products. The impacts of the 2018 transportation structure adjustment were limited, based on the analysis of coal and iron ore; this might come from a lack of detailed data, or a lack of more ambitious policy efforts. There remains great potential for more action in boosting use of rail, and more studies are needed to help set goals and strategies for using modes other than trucks. This includes the full potential of rail, waterway, pipeline, and intermodal in China.

Use the full potential and capacity of rail for higher-value products with improved cost-effectiveness. As the backbone of the U.S. freight system, rail has a leading role in hauling coal, agricultural products, and minerals, and in longer-distance shipping and intermodal. These characteristics were not yet fully identified in China's rail system. As China has invested in building a well-integrated network and is devoted to lowering costs for shippers, rail could have a more promising role in leading China's freight activity.

Advanced modern freight efficiency technologies are much needed. The invention of the container paved the way for intermodal transport, as commodities could be held, hauled, transferred, and handled with the same, standardized package across modes. The wide adoption of containers in freight shipping improved efficiency and helped better connect modes. The United States invests significant resources in new technologies, and the recent advent of truck platooning technology enables energy saving at high speed. Cross-mode technology is likely to be vital for China in promoting the adoption of multiple modes and in improving efficiency and reducing costs and emissions.

Fundamental research and data collection is key. This project has identified the gap in China's freight data collection. Compared with the CFS conducted in the United States every 5 years, data and information were very limited for China. The annual China Statistical Yearbook offers a high-level understanding of the performance of the transportation sector, but it lacks details such as the type of commodities shipped, their origin and destination, their value and weight, and mode(s) of transport for the freight sector. A well-designed data collection system focusing on mapping the flow of commodities that uses analytical tools would help policymakers, business owners, private researchers, and analysts better assess the demand for transportation facilities and services, energy use, and even safety risks and environmental concerns.

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APPENDIX A

The United States and China track their economic development by sector. Even though methods are not entirely the same between the two countries, the overall categories are largely consistent. Table A1 is an overview of the categories of the two countries using guidance from China on three economic sectors: primary (agriculture, forestry, fishing, and hunting), secondary (manufacturing, construction, and mining), and tertiary (service-related industries).

The primary and secondary sectors are especially consistent between the two countries. There are some variations in defining segments of the tertiary sector, but they are still comparable.

Table A1. Economic sector comparison between the United States and China.

<table>
<tr><th>(China) Economic Industrial Classification "Classification of National Economic Industries" GB/T4754—2002)</th><th>United States Economic Industrial Classification</th><th>China Economic Industrial Classification</th></tr>
<tr><td>Primary sector:
Agriculture, forestry, fishing, and hunting</td><td>Agriculture, forestry, fishing, and hunting</td><td>Agriculture, forestry, fishing, and hunting</td></tr>
<tr><td rowspan="4">Secondary sector:
Mining
Utilities
Construction
Manufacturing</td><td>Mining</td><td>Mining</td></tr>
<tr><td>Utilities</td><td>Utilities</td></tr>
<tr><td>Construction</td><td>Construction</td></tr>
<tr><td>Manufacturing</td><td>Manufacturing</td></tr>
<tr><td rowspan="17">Tertiary sector:
Wholesale and retail trade
Transportation and warehousing
Information transmission, software and information technology service
Finance
Real estate
Rental and leasing
Scientific research, technical services and geological prospecting industry
Resident services and other services
Educational services
Health care, and social assistance
Entertainment, sports, and creation service
Other service
Public Administration and Social Organization
International organizations</td><td>Wholesale trade</td><td rowspan="2">Wholesale and retail trade</td></tr>
<tr><td>Retail trade</td></tr>
<tr><td>Transportation and warehousing</td><td>Transportation and warehousing</td></tr>
<tr><td>Information</td><td>Information transmission, software and information technology service</td></tr>
<tr><td rowspan="3">Finance, insurance, real estate, rental, and leasing</td><td>Finance</td></tr>
<tr><td>Real estate</td></tr>
<tr><td>Rental and leasing</td></tr>
<tr><td rowspan="2">Professional and business services</td><td>Scientific research, technical services and geological prospecting industry</td></tr>
<tr><td>Resident services and other services</td></tr>
<tr><td rowspan="2">Educational services, health care, and social assistance</td><td>Educational services</td></tr>
<tr><td>Health care, and social assistance</td></tr>
<tr><td>Arts, entertainment, recreation, accommodation, and food services</td><td>Entertainment, sports, and creation service</td></tr>
<tr><td>Other services, except government</td><td>Other service</td></tr>
<tr><td rowspan="2">Government</td><td>Public Administration and Social Organization</td></tr>
<tr><td>International organizations</td></tr>
</table>

APPENDIX B

Various actions by China's central government and governments at the regional level have generated progress in shifting bulk products to rail and waterway. Table B1 offers details regarding China's transportation structure adjustment.

Table B1. Key regulatory actions in China's transportation structure adjustment.

No.	Authority	Document	Date	Key contents
1	The State Council	Opinions on comprehensively strengthening the protection of ecological environment and fighting the battle of pollution prevention and control	June 2018	It is proposed to "promote road to rail shift of key industrial enterprises and industrial parks in the sectors of steel, electric power, electrolytic aluminum and coking. To significantly increase the proportion of rail and waterway bulk freights in key areas as well as increase the proportion of rail freight in the sector of outbound port container transportation in coastal ports."
2	The State Council	Notice of the State Council on three-year national plan of blue-sky defense	July 2018	It is proposed that "by 2020, the national rail freight volume shall increase by 30% compared with 2017, 40% increase shall be achieved in Beijing-Tianjin-Hebei and its surrounding areas, 10% for Yangtze River Delta, and 25% for Fenwei plain area. To vigorously promote water (sea) & rail intermodal transportation and achieve the goal of an average annual growth of more than 10% in the volume of rail & water intermodal container freights in key ports of China." It is required that "in the Bohai Rim region, Shandong Province and Yangtze River Delta region, the gathering port coal freight of main coastal ports, Tangshan port and Huanghua port shall be shifted to rail or waterway by the end of 2018; the bulk goods freight such as ore and coke of coastal ports, Tangshan port and Huanghua port shall be mostly shifted to rail or waterway before the heating season of 2020."
3	The State Council	Notice on diesel truck pollution control battle plan	December 2018	It is proposed to "promote the medium and long-distance bulk goods and container freight from road to rail."
4	The State Council	Notice of the general office of the State Council on three -year action plan for promoting transportation structure adjustment (2018–2020)	September 2018	The document made systematic deployment and arrangement for the national transportation structure adjustment and proposed three-year goals and "six major actions" for transportation structure adjustment.
5	The State Council	Notice of the CPC Central Committee and the State Council on the outline of establishing competitive transport system	September 2019	It is required to establish a green and efficient modern logistics system, optimize transportation structure, accelerate the construction of key projects of "road to rail shift" such as gathering/outbound port railways, dedicated railways in logistics parks and large industrial and mining enterprises, and promote the orderly shifting of bulk goods freight and medium & long-distance goods freight from road to rail and waterway.
6	The State Council	Guiding opinions of the State Council on accelerating the establishment of green low carbon and circular development economic system (State Council [2021] No.4)	February 2021	It is required to actively adjust transportation structure, promote rail & water, road & rail, road & water, and other intermodal transportation modes, and speed up the construction of dedicated railway lines. To strengthen the management of logistics transportation organizations, accelerate the construction of relevant public information platforms, and realize information sharing, as well as develop drop & pull and joint transportation.

No.	Authority	Document	Date	Key contents
7	**Ministries**	Notice of the Ministry of Transport and nine other departments on implementing the three -year action plan for promoting transportation structure adjustment (2018-2020) (MOT Office [2018] No.142)	October 2018	It is required to refine the goals and tasks of transportation structure adjustment, refine and decompose the incremental goals of rail freight, put forward to establish transportation structure adjustment demonstration zone in Beijing-Tianjin-Hebei and its surrounding areas, and make a list of key construction projects of gathering/outbound port railways and dedicated railways of industrial & mining enterprises and logistic parks.
8		Notice of the National Development and Reform Commission and the General Administration of Market Supervision on further normalizing railway freight charges (NDRC [2018] No. 1959)	December 2018	It is required to thoroughly clean up and normalize local government charges, continue to clean up and simplify miscellaneous charges of rail freight, strengthen the management of maintenance and other service charges for dedicated rail lines, reasonably reduce local rail freight rates, and further normalize the charging of rail freight operators.
9		Guidance on accelerating the construction of dedicated railway lines (NDRC Basic [2019] No. 1445)	September 2019	It is required to make full use of the existing rail facilities and speed up the construction of dedicated railway lines so as to achieve the "last kilometer" freight by rail, improve efficiency through co-construction and sharing, improve service quality and increase rail freight volumes. Highlighted key projects of dedicated railway lines.
10		Opinions on promoting ultra-low emission in steel production industry (MEE Atmosphere [2019] No.35)	April 2019	It is proposed that "iron ore, coal, coke, and other bulk goods and products entering and leaving steel enterprises shall be freighted by rail, waterway, pipeline, or belt with a proportion of no less than 80%"
11		Opinions on promoting high quality development of machine-made sand and gravel industry (MIIT [2019] No. 239)	November 2019	It is proposed to promote the "road to rail" and "road to water" shift in the sector of medium and long-distance transportation of machine-made sand and gravel so as to reduce road freight volume, increase rail freight volume, and improve the inner water transportation network and gathering/outbound port distribution system. To orderly develop intermodal transportation, strengthen connection effectiveness between different transportation modes, vigorously develop road & rail intermodal transportation for container freight, and effectively improve the transportation capacity of machine-made sand and gravel. To speed up the construction of closed freighting belt corridors and gradually reduce the open-air loading and unloading volume of bulk cargos.
12	**Local governments**	Implementation programs released by provinces (autonomous regions and municipalities directly under the central government) for promoting the adjustment of transportation structure.		These documents specify how to implement the State Council's plan for transportation structure adjustment, including systematic deployment of all aspects of the work and how to accelerate implementation.
13	**China Railway Group**	Action Plan of Railway Freight Increment (2018-2020) (China Railway Freight [2018] No.104)	July 2018	Proposes to systematically increase rail freight activity, put forward a target for rail freight shares and create detailed implementation programs for coal, ore, vehicle products, and container freight, and define the key projects.
14	**Key enterprises**	Implementation programs of transportation structure adjustment		Implementation programs of transportation structure adjustment proposed by port enterprises, enterprises of coal, steel, and electric power industries, and rail transportation operators.

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