Online Appendix
How Far Goods Travel:
Global Transport and Supply Chains from 1965-2020

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A Additional Background on Key Variables

A.1 Transport Use and Normalized (Real) Transport Use

We examine the usage of transportation services as primarily consisting of two components: (1) the amount of goods that are transported, and (2) how far these goods are transported. The first component can be reasonably approximated by international trade flows. The second measure is important to incorporate as goods that are shipped further require more transportation. This transport use measure captures what is often missing in traditional trade measures—the role of distance. If trade increases, but only between nearby countries and between locations that are far apart, then the global need for transportation may only marginally increase. But if trade between distant locations increases, then transportation needs will dramatically increase. Including distance directly captures transport use.

Specifically, we measure transport use, in either ton weight or dollar values for Figures 1(a) and 1(b) respectively, as follows:

$$\begin{aligned} \text{Transport Use}_t &= \text{Total Trade Transported (tons or \$)} \times \text{Distance Transported (km)} \\ &= \sum_o \sum_d X_{odt} \times D_{od} \;\text{ where }\; o, d \in N \end{aligned} \tag{1}$$

where X_{odt} is the total amount of trade between origin country o and destination country d in year t measured in tons or dollars, and D_{od} is the population-weighted great circle (as-the-crow-flies) distance between these countries measured in kilometers. Conventional trade statistics generally focus on the trade value between origin and destination countries (X_{odt}), which is included in our measure of transport use in addition to the distance between these countries. The underlying databases convert currencies into current US Dollars. All values are converted into year 2000 US Dollars using price index data from the World Input-Output Database (WIOD) database (Timmer et al 2015), Penn-World Tables, and BEA US GDP deflators.

While data on the value of trade is available over our entire sample period, weight data is only widely available after 2000. We impute weight data from prices using a variety of data sources. See Appendix B for full details.

Next, we account for the rapid growth in the world economy and normalize total transportation usage by real global consumption, in ton weight and dollar values for Figures 1(c) and 1(d) respectively. This *real or normalized transport use measure*, detailed below, captures the cumulative distance traveled by intermediate inputs in production, in addition to the distance traveled by the final good to its ultimate destination for consumption:

$$\begin{aligned}\text{Real Transport Use}_t &= \frac{\text{Total Trade Transported (tons or \$)} \times \text{Distance Transported (km)}}{\text{Total Gross Domestic Product}} \\ &= \frac{\sum_o \sum_d X_{odt} \times D_{od}}{\sum_o \text{GDP}_{ot}} \quad \text{where } \; o, d \in N\end{aligned} \tag{2}$$

where all elements in the numerator replicate Equation (1) between origin country o and destination country d in year t, normalized by the GDP of country o.

A.2 Transport Cost

Next, we show how we approximate aggregate global transport costs. Instead of focusing on a subset of transport costs, which often do not include costs at the origin or destination, we use both our aggregate measure of transportation usage from the previous section, as well as the total expenditures in the transportation sector to recover the price to ship either a ton or real dollar of goods for one kilometer. We then return to the share accounted for by transportation in the overall economy—a function of both usage and the price for transportation services.

In order to compare the cost of transport over this long period, we calculate the cost to transport one ton or one real dollar of goods for one kilometer in each year t for Figure 3(a) as:

$$\begin{aligned}\text{Transport Cost}_t &= \frac{\text{Spending on Transport (\$)}}{\text{Total Trade Transported (tons or \$)} \times \text{Distance Transported (km)}} \\ &= \sum_o \sum_d \frac{T_{odt}}{X_{odt} \times D_{od}} \quad \text{where } \; o, d \in N\end{aligned} \tag{3}$$

where T_{odt} is the amount of spending on transport between an origin country o and destination country d in year t measured in real dollars, X_{odt} is the total amount of trade value between these countries measured in either tons or dollars, and D_{od} is the distance between these countries measured in kilometers.

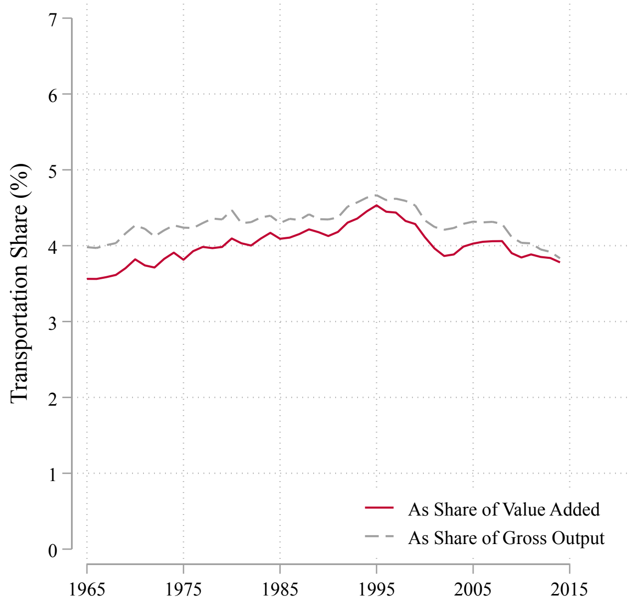
For the numerator in Equation (3), we use data on transportation and storage expenditures from the WIOD database (ISIC codes I60-I63 (rev 3) and H49-H52 (rev 4)). While we consider storage and warehousing as an important part of transportation costs, the data has the undesirable feature of including passenger transportation as a component.[1]

A.3 Transportation Share of Global Economy

Given that transport costs have fallen but the global economy is using more transport services, has aggregate spending on transport services risen or fallen? We calculate global transport spending as a share of total gross output using the WIOD databases. As seen in Figure A1, the expenditure share on transport for these countries have mostly stayed constant: started around 4 percent in 1965 and increased to more than 4.7 percent by 1995, before declining back to 3.8 percent in 2015.

[1] A richer analysis would decouple passenger and freight transportation; however detailed US BEA value added data imply that passenger transportation expenditures follow a similar trend to freight transportation and accounts for less than 20% of the sector.

Figure A1: Aggregate Spending on Transport, 1965-2014



Notes: Consistent sample of 24 countries representing 90% of world GDP. For an alternative measure of Figure A1, see Appendix Figure A2 for UN data until 2020. Source: WIOD (Timmer et al 2015).

Gross output measures capture the flows of goods every time these goods cross a border. These measures include the cost of inputs as well as the value added to the product by each country, leading to double counting (Johnson and Noguera 2012). An alternative measure of transport spending considers the value added of goods from 1965-2015. The value-added expenditure share for transport is slightly lower than the gross share, but mirrors the gross output trend throughout the entire time period.

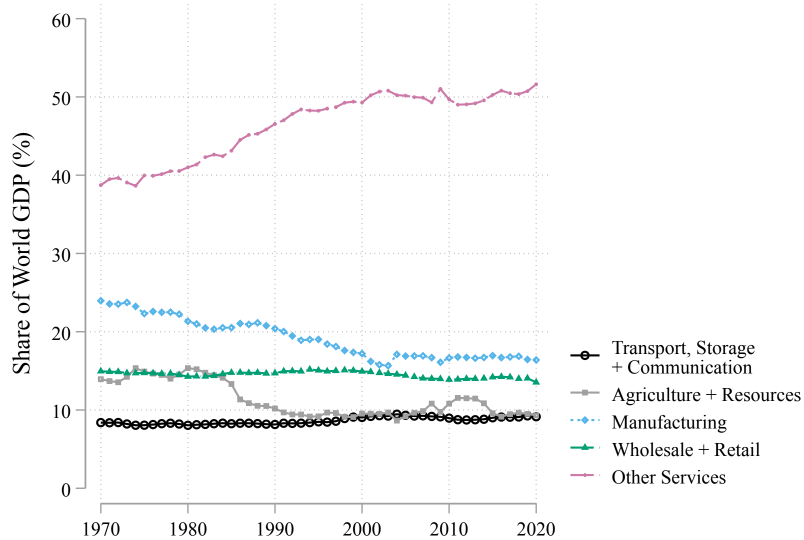
We further use all countries in the United National GDP by Sector data base, as opposed to those with consistent time series in the WIOD database to create Figure A2. Figure A2 chart breaks down global GDP into components, transportation (including storage and communication), natural resources (agriculture, forestry, and mining), manufacturing, retail/wholesale distribution, and all other services. While the value added from manufacturing and resources is falling, the value added from transportation continues to stay constant. However, unlike the WIOD data used in the main text, this time series mixes communications and other transportation services.

A.4 Composition of Trade: Intermediate and Final Goods

As a robustness check, we examine the role of final and intermediate good consumption as defined by the WIOD global input-output database (Figure A3).

When transportation usage is measured by weight-by-distance, intermediate goods use accounts for the majority of transport use, accounting for 85-90 percent of transport use over the whole time period (Figure A3a). We also find that the increase in transport use in ton-kilometers over this period primarily reflects growth in intermediate good consumption,

Figure A2: Global Sectoral Value Added, 1970-2020



Notes: This chart breaks down global GDP into components, transportation (including storage and communication), natural resources (agriculture, forestry, and mining), manufacturing, retail/wholesale distribution, and all other services. While the value added from manufacturing and resources is falling, the value added from transportation continues to stay constant. However, unlike the WIOD data used in the main text, this time series mixes communications and other transportation services. Source: UN Statistics Division (2022a).

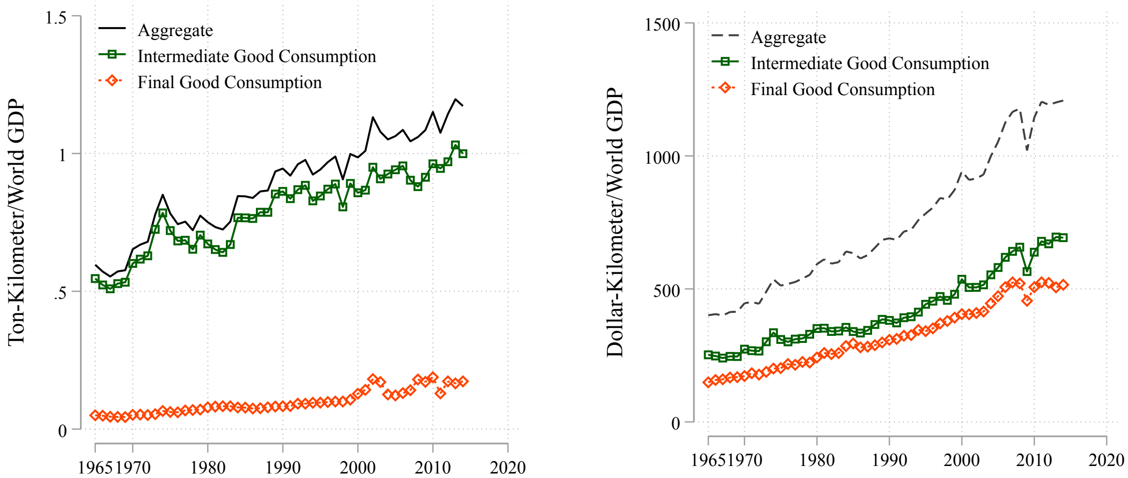
which increased by 83 percent over this time span. Final good consumption transportation usage, starting at much lower levels, increased dramatically by 246 percent over this same period. This effect of this increase on overall transportation use is limited, as final goods today only account for 17 percent of transportation usage, and whose share has held steady since the early 2000s and fallen since 2010.

However, when transportation usage is measured by value-by-distance, as in Figure A3b, the transport use of intermediate goods account less—roughly 60 percent of aggregate transport use throughout this period. This pattern is consistent with Johnson and Noguera (2012) finding that intermediate goods account for two-thirds of 2004 global trade in value. The transport use trends are initially in parallel for both intermediate and final goods. But since 2008, all the growth in transportation usage as measured by value has been in intermediate good usage. This finding, that intermediate goods consumption has contributed to the large increase in transport use by value, is consistent with Hummels, Ishii, and Yi (2001) who finds a 30 percent increase between 1970-1990 in the value of imported inputs used in producing exported goods for 10 OECD and four emerging market countries (which account for three-fifths of world trade).[2] As final goods typically have higher value-added and the transport usage for final goods have increased by much more than intermediates up until 2008, our results are also broadly consistent with the negative correlation between distance and bilateral ratio of value added to gross exports in Johnson and Noguera (2017) from 1970-2009.

[2]See Hillberry and Hummels (2008) for analysis considering only domestic US trade and intermediate goods.

Figure A3: The Role of Final vs Intermediate Goods, 1965-2014

(a) Transport Use by Weight and Distance (b) Transport Use by Value and Distance



Notes: We end in 2014 due to data availability. The WIOD global input-output database ends in 2014 and we require I-O tables to separate final goods from intermediate good consumption. The real transport use measured in ton-distance, indicated by the solid black line in Figure A3a, is reproduced from Figure 1c for comparison. The remaining two lines in Figure A3a are calculated by breaking down the real transport use measure in weight into two sub-components that total the aggregate figure: final and intermediate good consumption (green line with squares and orange line with diamonds respectively). The real transport use measured in dollar-distance, indicated by the dashed black line in Figure A3b, is reproduced from Figure 1d for comparison. The remaining two lines in Figure A3b are calculated by breaking down the real transport use measure in value into two sub-components that total the aggregate figure: final and intermediate good consumption (green line with squares and orange line with diamonds respectively). See Figure 1 notes and the Data Appendix for further details.

A.5 Just-in-time production and inventory system

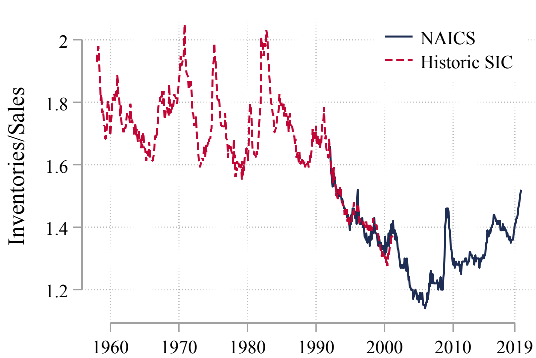
We now highlight the mechanism of one of the examples above–Just-in-time deliveries (JIT) (also called lean manufacturing). The JIT system is a strategy that aligns input orders from suppliers directly with production schedules, so that the inputs are received only as needed for the production process. The JIT system has resulted in smaller, more frequent shipments to reduce warehousing costs at the receivers' end. This, in turn, has increased demands on shipment costs and reliability to ensure the uninterrupted implementation of planned production processes. At the same time, JIT has led to a changing relationship between transport and warehousing costs. As this system is adopted by more and more businesses, the need to hold inventory on-site decreases. We start by establishing this trend for the US.

Figure A4 reports the inventory to sales ratio trends from the Census Bureau.[3] This ratio

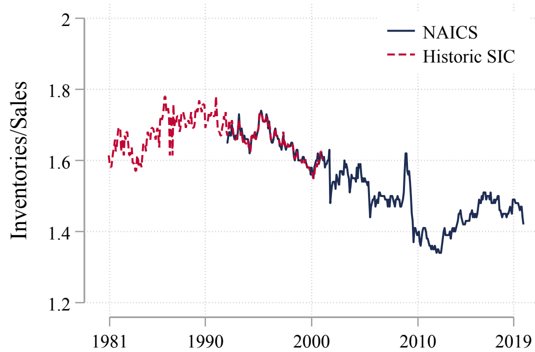
[3] The Census Bureau reports this data based on three surveys: the Manufacturers' Shipments, Inventories, and Orders Survey, the Monthly Wholesale Trade Survey, and the Monthly Retail Trade Survey. More recent data, from 1992 onward, is based on the North American Industry Classification System (NAICS) while historic data was based on the Standard Industrial Classification (SIC) codes. The SIC was phased out in

measures the amount of inventory that businesses hold relative to their sales. A higher ratio indicates that businesses hold more merchandise relative to their sales in a period. Figure A4a reports this ratio for the manufacturing sector, which is the longest publicly available time series from January 1958 onwards.

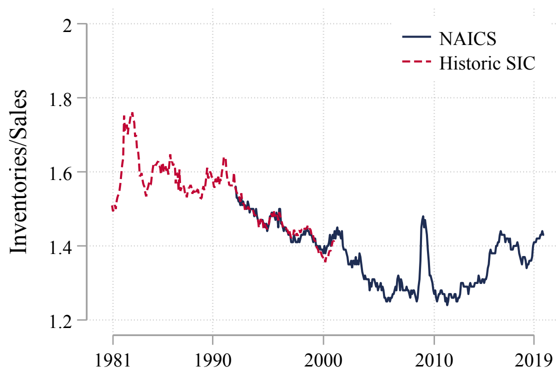
Figure A4: Inventory to Sales Ratio



(a) Manufacturing, 1958-2019



(b) Retail, 1981-2019



(c) Total, 1981-2019

Note: The historic SIC data is normalized relative to the recent NAICS data. NAICS data for all three panels is from the Manufacturing & Trade Inventories and Sales data page. In Figure A4a, historic SIC data for Manufacturing is from the Census Manufacturing Branch under the Historical Time Series. In Figure A4b, historic SIC data for Retail is from the Census Retail Indicator Branch under the Historical Data section. In Figure A4c, the historic SIC series is constructed using the historic manufacturing, retail, and wholesale data. Historic SIC data for Wholesale is from the Wholesale Indicator Branch under the Time Series Data (Prior to NAICS) section. The shorter time period in retail and total series is due to lack of digitized data on the Census Bureau website. See Data Appendix for further details. Source: US Census Bureau

The average manufacturing inventory to sales ratio was around 1.7 before 1990. Since then, there has been steady decrease in the amount of inventory that businesses hold—the average ratio is about 1.3 between 2000-2019. This is an average decrease of about 24 percent. We do note that the manufacturing industry is shrinking as a share of GDP over this period—its value added share of GDP was 25% in 1960 (BEA (1947-1997)) and by 2019 it was about 11% (BEA (1998-2021)).

1997 by US statistical agencies. See Fort and Klimek (2018) for a discussion on the how the classification change impacted the measurement of US economic activity.

Figure A4b reports this ratio for the retail industry, where there is more muted but similar downward trend. The average was around 1.7 before 1990 and it decreased to about 1.5 between 2000-2019. An 11 percent decrease. The value added of the retail industry accounted for 6.8% of GDP in 1981 (BEA (1947-1997)). There are similar declines using the total series reported by the Census (Figure A4c).

As an alternative measure, we use more comprehensive BEA times series data. Figure A5 uses BEA data series on total private inventories (as opposed to the US Census series collected at the sectoral level). We present three versions. The black line delineates average annual inventories over U.S. gross domestic output. The second line only includes goods consumed or used for investment as the denominator. The third line subtracts exports and adds imports to the denominator. All show a substantial decline in private inventories at the national level. All series echo each other and demonstrate a significant decrease in inventories as a function of both the total economy's size, as well as the size of the economy that deals with physical goods.

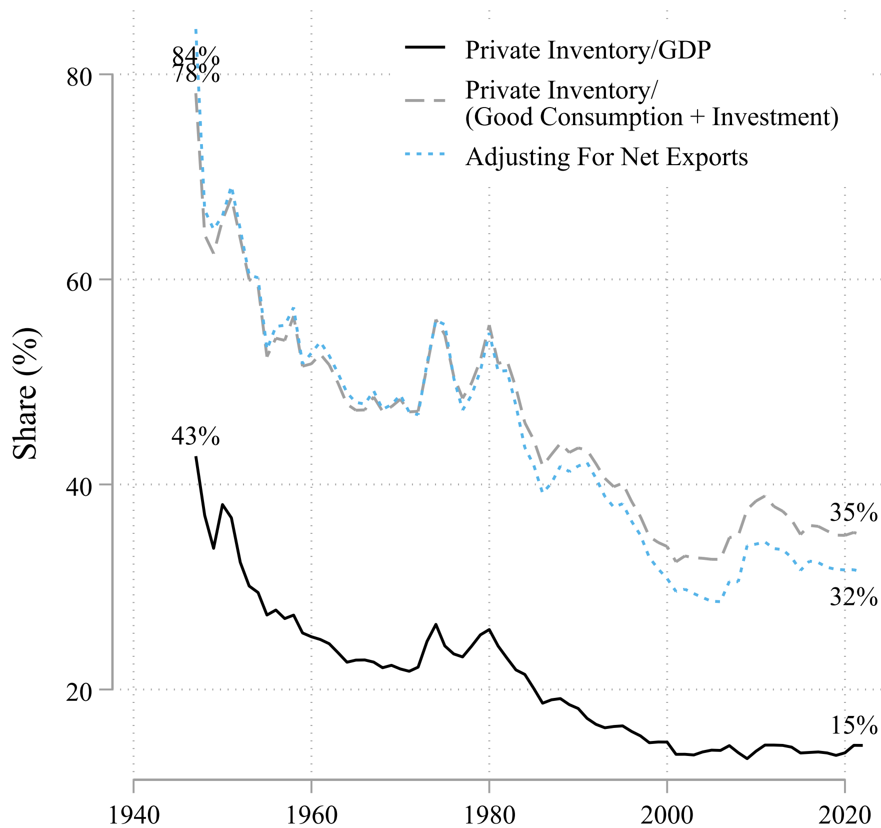
While we are focused on these inventory patterns over a long period of time, there has been studies on how inventory holdings respond during periods of bad shocks. Focusing on 2008-2010 at the height of the trade collapse, Alessandria, Kaboski, and Midrigan (2011) shows that firm inventory holdings are much higher in response to persistent negative shocks. For developing countries, the cost of trade is much larger and inventory can serve as a buffer for these costs (Alessandria, Kaboski, and Midrigan 2010). Carreras-Valle (2021) studies the recent reversal of the declining trend in the manufacturing industry since 2005 and how much of it can be attributed to the longer delivery times and delays from sourcing foreign inputs that are further away.

As a final measure, we investigate estimates of logistics expenditures broken into inventory or warehouse spending, and transport spending from the Council of Supply Chain Management Professionals (CSCMP).[4] In Figure A6, the inventory or warehouse spending estimates, as a percent of GDP, are similar in magnitude to transport in 1980 (around 7.6% and 7.4% respectively). While both the Census and CSCMP inventory decreases have decreased, the decrease in CSCMP inventory costs is much sharper at 67%.[5]

[4]See Federal Highway Administration (2005) for discussion on the estimates.

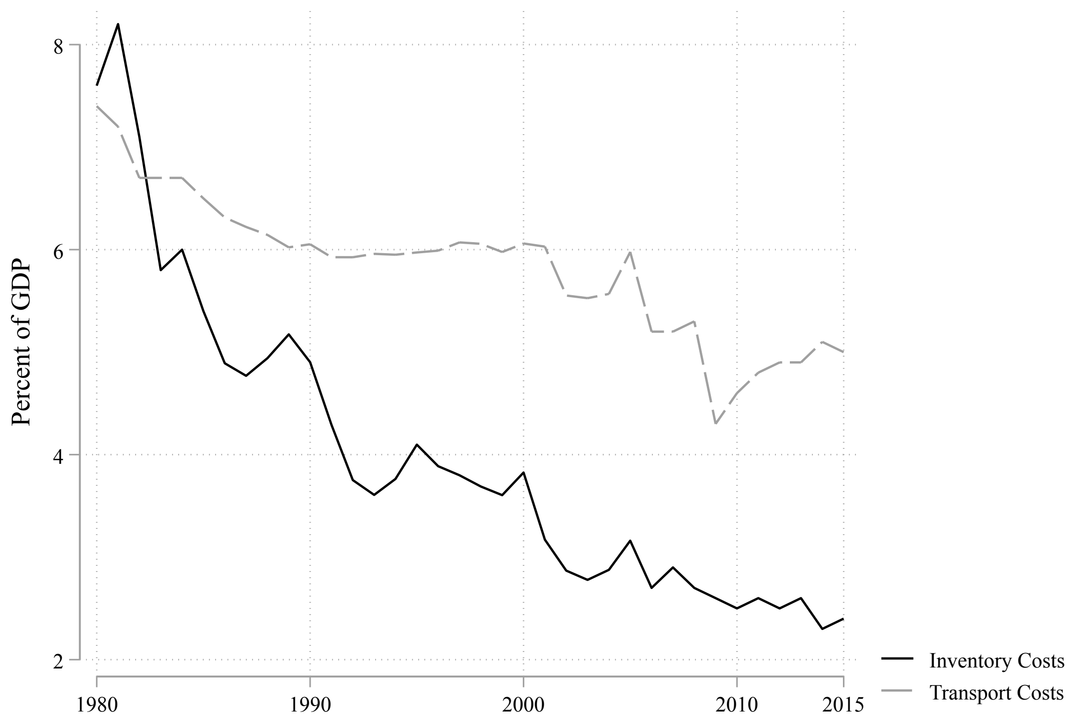
[5]Domestic transport spending also decreased but by a smaller rate 32%.

Figure A5: Inventory to Sales Ratio - National



Note: This chart uses BEA data series on total private inventories (as opposed to the US Census series. There are three series. The black line delineates average annual inventories over U.S. gross domestic output. The second line only includes goods consumed or used for investment as the denominator. The third line subtracts exports and adds imports to the denominator. All show a substantial decline in private inventories at the national level. Sourced from US BEA data and accessed through the FRED database.

Figure A6: Inventory and Transport Costs, 1980-2015



Notes: Digitized series of the annual *State of Logistics Report* of the Council of Supply Chain Management Professionals. The Council of Supply Chain Management Professionals produces annual estimates of logistics expenditure for the United States. See Federal Highway Administration (2005) for discussion on the estimates. Logistics expenditure are broken down into inventory/warehousing, transport, and administrative. Administrative spending make up a very small portion of GDP and are omitted here.

B Data Appendix

Our dataset of transportation usage and trade costs extends from 1965 to 2020 and requires the use of multiple sources. Data from the end of World War II to 1965 is not included due to the rapid pace of decolonization from European powers during that period. We start with two major sources of trade statistics.

BACI Database For 1995-2020, we use the BACI database from Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). This database reports values on quantities (in weight) and value for all bilateral trading relationships in the underlying UN Comtrade database. The researchers at CEPII correct underlying data to a consistent classification nomenclature, imputing data when necessary. We use the 2022 release of this data in 1992 Harmonized System nomenclature.

NBER-UN Comtrade Data For complete trade data in value from 1965-2000, we use the NBER-UN Comtrade database compiled by Feenstra et al. (2005).

For the overlap period from 1995-2000, we take the BACI values as given and line up the UN Comtrade data adjusting by the average difference in the datasets between 1995 and 2000. We perform similar procedures wherever there is an overlap, taking the newer data levels as correct and adjusting up and downward by the period of overlap.[6]

For various denominators and supply-chain statistics, we turn to alternative sources of data.

World Input–Output Database (WIOD) We use the combined Long-Run and updated World Input–Output Database (WIOD) to cover valued added and gross output statistics from 1965-2014. While the datasets only contain detailed statistics for 24 and 43 countries, that cover over 90 percent of would output, with the remainder of countries consolidated in a "Rest of World" Aggregates.[7]

We additionally use the WIOD to provide sectoral level price deflators from 1965-2014.

Penn World Tables and UN National Accounts Databases For aggregate GDP and global price deflators, we use data from the Penn World Tables Version 11 (PWT) from 2014-2019 at the aggregate level, and from the United Nations Statistics Division (UNSD) National Accounts Main Aggregates database for aggregates and sectoral level data not covered by the PWT. Due to differences in measurement of sectoral output between the UNSD and the WIOD, we refrain from extending our time-series on transportation costs and value added beyond 2014.[8] Just for 2019 and 2020, we additionally use the US Bureau of Economic Analysis GDP price indices assessed through the FRED database.

[6] Please see the Stata subroutine 'splice' in our replication package.

[7] As an alternative, for data from 1995-2021, we also can use the OECD Input-Output Database. Due to differences in dataset design and industrial codes, we refrain from merging the two.

[8] Appendix Figure A.2 shows how UN Data conflates communication services with transportation, making it difficult to continue the time series.

Value to Weight Conversions prior to 1995 After 1995, we directly use weight data from the BACI database. Prior to 1995, we backwards impute weights using BACI data and aggregate price series from the WIOD database. To do so, we use price index data from the WIOD. This works well, except for natural resource and oil shipments from 1973-1985. We directly use oil price and oil import data from 1973-1985 to adjust quantity data over that time period for those exports and imports. We use oil price and shipment data from OPEC, as well as import statistics from the US Energy Information Administration and the price of domestic crude oil (West Texas Intermediary) to recover real shipment weights.

We concord all data to ISIC Rev. 3 (Prior to 2000) and ISIC Rev. 4 (After 2000) codes at the level of aggregation in the WIOD Database (2-digit sectoral aggregates). We use concordances from the UN Trade Statistics Division, OECD and the World Bank.

Gravity Data For all countries we use population-weighted distance data from the CEPII Gravity Database (the 2022 revision).

Inventory to Sales Ratio The Census Bureau reports this data based on three surveys: the Manufacturers' Shipments, Inventories, and Orders Survey, the Monthly Wholesale Trade Survey, and the Monthly Retail Trade Survey. More recent data, from 1992 onward, is based on the North American Industry Classification System (NAICS) while historic data was based on the Standard Industrial Classification (SIC) codes. The historic SIC data for Manufacturing is from the Census Manufacturing Branch under the Historical Time Series (https://www.census.gov/manufacturing/m3/historical_data/index.html) section. The historic SIC data for Retail is from the Census Retail Indicator Branch under the Historical Data (https://www.census.gov/retail/mrts/mrtshist.html) section. Historic SIC data for Wholesale is from the Wholesale Indicator Branch under the Time Series Data (Prior to NAICS) (https://www.census.gov/wholesale/www/historic_releases/monthly_historic_releases.html) section. The SIC was phased out in 1997 by US statistical agencies and is normalized relative to the recent NAICS data. NAICS data is from the Manufacturing & Trade Inventories and Sales (https://www.census.gov/mtis/index.html) data page. The shorter time period in retail and total series is due to lack of digitized data on the Census Bureau website.

BEA Private Inventory and US GDP Data We use BEA private inventory data for Figure A5. We use the following time series from the FRED database: Private inventories (A371RC1Q027SBEA), Real final sales of domestic business (A809RX1Q020SBEA), Gross Domestic Product (GDPA), Personal consumption expenditures: Goods (DGDSRC1A027NBEA), Gross Private Domestic Investment (GPDIA), Current payments to the rest of the world: Imports of goods (A255RC1A027NBEA), and Current receipts from the rest of the world: Exports of goods (A253RC1A027NBEA)

Annual State of Logistics Report Datapoints We digitize tables from historic Council of Supply Chain Management Professionals (CSCMP) "Annual State of Logistics Reports" to create figure A6. The Council of Supply Chain Management Professionals produces annual estimates of logistics expenditure for the United States. Logistics expenditure are broken down into inventory/warehousing, transport, and administrative. Administrative spending make up a very small portion of GDP and are omitted here.

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