Energy Prices and the Expansion of World Trade

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Abstract

The oil shocks of the 1970s coincided with a number of economic disturbances. However, it has been difficult to develop models where oil shocks have a quantitatively important impact on the economy. In this paper, I show that the disturbances in transportation caused by the oil shocks can significantly affect the economy. I argue that changes in energy prices were responsible for a worldwide slowdown in the growth of trade and may help explain the apparent change in the price-trade elasticity. While tariffs have fallen steadily since 1970, trade growth slowed in the mid-1970s and has grown rapidly since the mid-1980s. In a standard trade model, this pattern implies that the price-import elasticity increased sharply in the mid-1980s. In this paper, I argue that the oil crises of the 1970s led to higher transportation costs. In 1986 energy prices fell to their pre-crisis level, reducing transportation costs and by extension trade barriers. I present a trade model with an energy using transportation sector. In model simulations, I show that total trade costs (transportation cost plus tariffs) are constant from 1974 to 1982. Once transportation costs are accounted for, the price-import elasticity no longer needs to radically change. I also show that trade expansion since 1960 is 50 percent higher in a standard trade model that includes a transportation sector compared to one that does not.

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1 Introduction

In 1973, OPEC imposed an oil embargo that significantly increased the price of energy. Soon afterward, there were several major economic disturbances: Stock prices halved, a severe worldwide recession began and productivity growth slowed.

While empirical studies often find that energy prices and output are related, it has been surprisingly difficult to develop models where energy prices are a quantitatively important source of economic disturbances. Cochrane (1994) surveys models with oil price shocks and concludes that they cannot account for much of observed macroeconomic fluctuations. One important reason for this is that energy expenses represent a small portion of production costs. Without a significant magnifying mechanism, energy represents too narrow a channel to have large effects on macroeconomic variables.

I examine a channel that has not been explored before: transportation. Consuming most goods requires transportation to carry them to market, so disruptions in transportation will affect other industries. Since transportation's energy intensity is higher than that of the general economy (energy cost's share of revenue is double that of the overall economy for most modes of transportation), it is an enormous user of energy.

In this paper, I show that the disturbances in transportation caused by the oil shocks can significantly affect the economy. In particular, I study the effect of the transportation channel on trade expansion. I argue that the oil shocks of the 1970s are responsible for a worldwide slowdown in the growth of trade and may help explain the apparent change in the response of trade to price changes.

A widely known development in the world economy is the large increase in the share of output that is internationally traded. Worldwide exports as a share of output has more than doubled since 1960. However, export share of output has not increased steadily. After increasing during the 1960s, export share remained constant from the mid-1970s through the mid-1980s. Since the mid-1980s, export share has been increasing.

During this period, trade policy has become less restrictive. Successive rounds of General Agreement on Tariffs and Trade (GATT) negotiations have reduced tariffs. However, standard trade models have had difficulty generating the intuitive explanation that lower tariffs were responsible for this expansion of trade. While trade growth slowed in the 1970s, tariffs have declined steadily since the late 1960s. A standard trade model with tariffs alone would have a difficult time explaining this observation since it implies the price-import elasticity increased sharply in the mid-1980s. Yi (2003) argues that the elasticity would have had to have more than doubled to account for the data.

In this paper, I argue that changes in transportation costs can explain the apparent change in the price-import elasticity. Transportation is an energy intensive industry and it is difficult for shippers to substitute away from energy as an input. As a result, the oil shocks of the 1970s raised the cost of transportation and offset the decline in tariffs. Total trade costs (tariffs plus transportation costs) were constant beginning in the mid-1970s. When energy prices began to fall in 1982 (collapsing in 1986), total trade costs also fell.

This paper presents a general equilibrium model of trade with a transportation sector. Trading goods requires a shipping technology that uses energy as an input. I calibrate the model and run simulations using data on energy prices and tariffs.

In the simulated model, I show that trade costs do not decline from the mid-1970s to the early 1980s. The energy price shocks of the 1970s led to an increase in transportation costs of the same magnitude as the decline in tariffs. The pattern of trade costs generated by the model are much closer to the observed pattern of trade expansion. Once transportation costs are accounted for, the price-import elasticity no longer needs to radically change.

I also show that accounting for falling transit costs significantly increases the predicted amount of trade growth. The model implies trade expansion that is almost 50 percent higher than a model without transportation. Transportation industries have developed a number of new technologies that have increased their productivity faster than the general economy and reduced the cost of shipping goods. Since 1960, transportation costs has been generally declining, reducing trade costs.

1.1 The Trade Slowdown

It is conventional wisdom that successive multilateral rounds of negotiations under GATT have steadily reduced trade barriers since World War Two. Summarizing trade policy into easily comparable statistics continues to be a controversial topic. One important measure of trade policy, tariffs, have declined over the last 40 years. Figure One shows world export share of GDP and GATT tariffs for industrialized countries as compiled by Yi (2003)[1]. The countries covered by the data in Yi (2003) account for about two thirds of world trade over most of this period. After a large drop in the 1960s, tariffs have fallen steadily since the early 1970s.

There is evidence that tariffs in the rest of the world follow a similar pattern. Clemens and Williamson (2002) report the average import-weighted tariffs for 35 countries, including a significant number of developing countries. Tariffs have declined beginning the late 1960s with a small increase in the mid-1980s.

It seems unlikely that tariffs alone can explain the trade slowdown in the 1970s. Tariffs decline steadily in the 1970s without increasing trade share. Starting in the mid-1980s, export share increases while tariffs decline at a similar rate as the 1970s.

1.2 Transportation and Trade

Transportation costs are a central theme in international trade theory. For example, their decline are typically given a central role in the trade growth of the late 19th Century[2].

The barriers that result from transportation costs are typically found to be as large or larger than those from tariffs. Finger and Yeats (1976) study United States Customs data from 1965 and find that transport costs are of a similar magnitude to tariffs. According to Yi (2003), US tariffs in 1994 were 4.5 percent. Hummels (1999) finds that US import weighted transportation costs were 3.9 percent in the same year.

While transportation costs are considered important, they have typically been studied much less than tariffs. A major reason for this neglect is the lack of good data. Systematic measures are either lacking or of poor quality. Hummels and Lugovskyy (2003) argue that the one source of comprehensive international transportation data, the IMF's CIF/FOB ratios, is very flawed. High quality and systematic customs data is limited to a couple rich countries for recent time periods.

Even when they do exist, these data underestimate transportation costs since they only account for one part of the logistics chain that cargo passes through. The

[1]I thank Kei-Mu Yi for his tariff data. Detailed information about sources is available in the Appendix.

[2]For example, see North (1958).

usual measurement of these costs is the CIF/FOB ratio derived from customs data. This measure misses the cost of moving cargo from the domestic production point to the port of exit and from the point of entry to its point of consumption.

The domestic legs of the journey represent a significant portion of the cost. Rousslang and To (1993) examine data from the Input-Output tables for the United States in 1977. They find that the import weighted nominal protection from domestic freight is 3 percent of producer value compared to 5.2 percent for international freight. Sletmo and Williams (1981) cite an OECD study that finds that the inland portion accounted for 40 percent of freight costs for goods shipped by sea in 1967. The US Department of Agriculture's *Grain Transportation Prospects* contains data on the cost of transporting grain from the US to Japan. Depending on the point of production and mode of transportation, domestic freight accounts for 20 to 75 percent of the cost of shipping wheat to Japan. Reichert and Vachal (2000) give detailed breakdown of the cost of shipping soybeans to Japan. Ocean freight represents about only a quarter of the total cost. Hauck (1979) finds that the ocean leg accounts for only 40 percent of the cost of shipping a computer from Pittsburgh to Rome.

1.3 Energy and Transportation Costs

The oil shocks in the 1970s led to large and sustained increases in energy prices. Figure Two shows the producer price of energy deflated by the GDP deflator in the United States. After a slow decline during the 1960s, the price shot up by 50 percent in response to the Oil Embargo in late 1973. Energy prices stayed at this level until they nearly doubled in the late 1970s as a result of the second oil crisis. They declined from their peak in the early 1980s and collapsed back to the pre-second oil crisis level in 1986. They have generally declined since then.

Fuel prices are an important determinant of transportation costs. Lundgren (1996) regresses fuel prices on bulk goods transportation costs. He finds that the coefficient on fuel prices is significant and positive in explaining transit prices. For the coal and grain trades between the US and Europe, a 1% increase in bunker fuel prices lead to about a 0.4% increase in freight rates. In fact, the link between energy prices and transportation prices is often explicit. In water shipping, a surcharge called a Bunker

Adjustment Factor (BAF) is often added on to the cost of shipping. The BAF is linked to the price of shipping fuel (known as bunker fuel), increasing the cost of shipping if the price of fuel increases.

There is evidence that the energy price increases of the 1970s led to a substantial increase in cost for shippers. Sletmo and Williams (1981) examine the accounts of container liners engaged in the North Atlantic trade. "In 1972, fuel costs represented only about 40 percent of container vessel operating costs (exclusive of fuel). Two years later, fuel costs were 1.6 times higher than vessel operating costs." (p. 164)

When energy prices increase, transportation prices also tend to increase. Hummels (1999) provides evidence that water transportation charges increased in the 1970s concurrent with the oil crisis. Transportation cost data is generally fragmentary. However, Hummels (1999) does present two data sources that provide relatively long, consistent series. The first comes from the German Ministry of Transport and the second is US customs data.

The German Ministry of Transport has maintained a price index of liner shipping rates for Germany and the Netherlands. There is a substantial, sustained increase in the real cost of shipping in 1974. The cost falls below the pre-Oil Crisis level in 1986.

US customs data provides information about import prices and transportation costs by product and year. Hummels (1999) regresses transportation costs against a number of controls, including distance and year and commodity dummies. Holding commodity and distance constant, he finds that transportation costs increased in the mid-1970s and declined after 1985.

Additional evidence comes from data from the Australian Bureau of Transport and Regional Economics. Figure Three shows coastal water rates in Australia. They follow the pattern of the US Customs data: Increasing in the mid-1970s and declining in the mid-1980s.

Figure Four shows a measure of price, real revenue per ton-kilometer, for air freight, barge, truck and rail transportation in the United States. Rail, barge and air freight rates show a downward trend. However, air and barge rates increase in the 1970s and continue to decline after the second oil crisis. The decline in rail rates slows during the two oil crises and truck rates show a small increase during the second oil shock.

While there were increases in transportation costs in the 1970s, overall transportation costs have declined since 1960. At the aggregate level, customs data provides evidence. Finger and Yeats (1976) finds that United States nominal protection from (trade-weighted) transportation costs in 1965 to be 9 percent of import value. Hummels (1999) finds that the 1994 value to be 3.8 percent. At a more disaggregated level, Lundgren (1996) examines freight rates in bulk commodity trade. He finds that rates have declined by almost 70 percent since the early 1950s.

Energy price changes have a large impact on transportation costs since they represent an important part of expenses in the transportation business. The modes of transportation that are the most important for international trade tend to be more energy intensive than the rest of the economy. Nominal expenditure on energy was 6.8 percent of GDP in the business sector in 1997. The energy share of revenue was 12 percent in both water transportation and civil aviation in that year. (Energy share in land modes is lower: eight percent for trucking and nine percent for railroads.)

Beginning in the 1960s, changes in transportation made energy a more important input. Ocean shippers adopted a number of new technologies. A variety of automation and remote control technologies allowed ships of all types to become larger and more capital intensive. General cargo ships, those that carry distinct items such as manufactured goods, began to containerize its cargo. On container ships, the cargo is placed in large standardized boxes as opposed to break bulk ships, where each piece of cargo is loaded into the hold individually.

Containerization made ships more vulnerable to fuel costs. Container ships can be unloaded faster than break bulk ships, so they spend less time in port and a greater share of their time at sea. Therefore, sailing at higher speeds has a bigger impact on capital productivity for container ships. Increasing capital productivity (and reducing capital costs) also became more important as ship sizes increased. Running more voyages lowers a ship's capital cost per voyage. Container ships are usually built to be faster than break bulk ships to maximize the number of voyages a ship can run in a year. However, higher speeds require more energy use per weight carried than low speeds. Sletmo and Williams (1981) note that in the early 1970s, service speeds nearly doubled on some routes, doubling or tripling fuel consumption per unit of capacity.

Since the 1960s, goods have been moving from low to high energy intensity modes of transit. Shippers have shifted overland goods from railroads to trucks and overseas goods from ships to airplanes. On average, about 75 percent of US foreign trade by value was shipped by overseas modes (Air and water) between 1965 and 2000. Air freight's share was 6.2 percent of import value in 1965 but now represents almost 25 percent. Over this period, ocean shipping has declined 70 percent of import value to less than half.

Energy prices pass through to the final cost of transportation since it is difficult for transportation industries to substitute away from energy. Energy's share of revenue matches the price of energy very closely, indicating that shippers cannot substitute away from energy, at least in the short term. The lack of substitutability of energy is a feature of most industries. (Atkeson and Kehoe 1999)

Figure Five shows fuel share in various transportation modes compared with energy prices. Each mode shows a similar pattern. Energy's share of revenue matches the price of energy very closely, indicating that shippers cannot substitute away from energy very easily.

In water shipping, one margin to reduce energy use is to reduce the speed of a vessel. Running a vessel at a lower speed reduces the energy requirement to move a load. While Sletmo and Williams (1981) provide evidence that some of the fastest vessels did sail at lower speeds in the mid-1970s, they also argue that speed reductions do not provide a very powerful margin for reducing costs. Reducing speeds increase capital costs by lengthening voyages, reducing the number of voyages a ship can run. Engines are designed to run at particular speeds and running at lower speeds can stress them.

In air freight, there are few margins to reduce energy use. Statistics Canada (1993) discusses a number of measures taken to reduce energy costs, including changing cruising altitudes and taxiing with one engine. The savings from these techniques seem unlikely to provide much of a reduction in fuel use.

No work that I am aware of considers the effect of the oil shocks on the pattern of trade expansion. Backus and Crucini (2000) examine the effects of oil shocks on terms of trade. They draw some implications for trade balance, but are not directly concerned with the historical expansion of trade.

The organization of the rest of the paper is as follows: Section Two presents the model. Section Three defines equilibrium and solves the model. Section Four calibrates the model and presents the results. Section Five discusses extensions and concludes.

2 Model

2.1 Households

There are three countries each with an infinitely lived representative household. Households have preferences over a consumption good represented by:

$$U = \sum_t C^i(t) \tag{2.1}$$

where $C^i(t)$ denotes consumption in period t for $i \in \{0, 1, 2\}$. The associated price is $P^i(t)$. Each country is endowed in each period with a constant amount of labor N^i. The wage is given by $W^i(t)$

2.2 Intermediate Goods Sector

There are two intermediate goods I_j for $j \in \{1, 2\}$. Countries 1 and 2 are industrial countries. They are endowed with technologies to produce the intermediate goods, given by

$$I^i_j = \phi^i_j N^i \tag{2.2}$$

If $i = j$ then $\phi^i_j > 0$. If $i \neq j$ then $\phi^i_j = 0$. The intermediate good with the same name as the country $(i = j)$ is called the domestic good for country i.

2.3 Energy Sector

The remaining country $(i = 0)$ is an energy producer and owns technology to produce an energy good E using labor:

$$E = \theta N^0 \tag{2.3}$$

The price of energy in country i is $P^i_E(t)$.

2.4 Transportation Sector

The countries may trade the goods they produce with each other. Shipping intermediate goods between the industrial countries requires a transportation technology. (Intermediate goods shipped to and energy goods shipped from the energy producer do not require the technology.) This technology uses energy E and input of the domestic good I_T, which must be purchased at the country of origin. The input required to ship I units of the intermediate good to the other country is given by $I = Min(AE^i, BI_T)$ where A and B are productivity parameters.

2.5 Final Goods Sector

Each country has a technology to combine the two intermediate goods into a final good.

$$C = \sum_{j=1,2} \frac{(I_j)^{1-\sigma}}{1-\sigma} \tag{2.4}$$

2.6 Government

The industrial countries each have a government that can impose an ad valorem (net of transportation fees) tariff $\tau^i(t)$. The government gives the domestic representative household transfers $T^i(t)$ and maintains budget balance in each period. Each country's budget constraint for period t is given by:

$$T^i(t) = \tau^i P_j^{-i}(t) I_j^i(t) \tag{2.5}$$

3 Equilibrium

3.1 Definition

Households sell labor and purchase goods. There is no borrowing or lending. They maximize U subject to the period budget constraint

$$P^i(t)C^i(t) = W^i(t)N^i(t) + T^i(t) \tag{3.1}$$

Energy firms buy labor and sell energy. They face competitive markets. They solve:

$$Max \sum_{i=1,2} P_E^i \theta N_i^0 - W^0 N_i^0 \tag{3.2}$$

where N_i^0 denotes the labor to producing energy for sale in country i.

Transportation firms buy domestic goods and energy and sell exports. They face competitive markets. They solve:

$$Max P_i^{-i} Min(AE, BI_T^i) - P_i^i I_T^i - P_E^i E - P_i^i Min(AE, BI_T^i) \tag{3.3}$$

Feasibility for each intermediate good requires that:

$$I_1^i(t) + I_2^i(t) + I_E^i(t) + I_T^i(t) = \phi_i^i N^i \tag{3.4}$$

Feasibility for energy production requires that:

$$\theta N^0 = \sum_{i=1,2} E^i \tag{3.5}$$

The definition of equilibrium follows.

Definition 3.1. *Given tariffs, an equilibrium is consumption, intermediate goods and energy allocations and prices in each period such that:*

1. *Households solve their problem,*
2. *Transportation and energy firms solve their problem,*
3. *The government balances its budget,*
4. *The allocation is feasible.*

3.2 Solution

Since there are no dynamic links between periods, the equilibrium can be solved in each period independently. The dynamic solution is the solution to a sequence of static problems.

Symmetry allows a closed form solution of the model. In the rest of the paper, I impose symmetry between the two industrial countries. Under symmetry, we have the following lemma.

Lemma 3.2. *If $N_1 = N_2$, $\tau_1 = \tau_2$ and $\phi_1^1 = \phi_2^2$, then $P_1^1 = P_2^2$*

For interior solutions, equilibrium prices and quantities are given by the following. In each period, I normalize $P_1^1 = 1$. Given the lemma, this implies that $P_2^2 = 1$. From no arbitrage, we have $P_2^1 = P_1^2 = 1 + \tau + P_T$. The price of transportation is given by $P_T = \frac{P_E}{A} + \frac{1}{B}$. The price of energy P_E is defined by:

$$\theta = \frac{\frac{P_E 2N}{AN^0}}{1 + \frac{P_E}{A} + \frac{1}{B} + [1 + \tau + \frac{P_E}{A} + \frac{1}{B}]^{\frac{1}{\sigma}}} \tag{3.6}$$

Equilibrium quantities are given by the following equations.
Input of domestic good in final goods production:

$$I_1^1 = I_2^2 = \frac{\phi_i^i N^i [1 + \tau + \frac{P_E}{A} + \frac{1}{B}]^{\frac{1}{\sigma}}}{1 + \frac{P_E}{A} + \frac{1}{B} + [1 + \tau + \frac{P_E}{A} + \frac{1}{B}]^{\frac{1}{\sigma}}} \tag{3.7}$$

Input of foreign good in final goods production:

$$I_1^2 = I_2^1 = \frac{\phi_i^i N^i}{1 + \frac{P_E}{A} + \frac{1}{B} + [1 + \tau + \frac{P_E}{A} + \frac{1}{B}]^{\frac{1}{\sigma}}} \tag{3.8}$$

Energy output:

$$E^1 = E^2 = \frac{A\phi_i^i N^i}{1 + \frac{P_E}{A} + \frac{1}{B} + [1 + \tau + \frac{P_E}{A} + \frac{1}{B}]^{\frac{1}{\sigma}}} \tag{3.9}$$

Intermediate goods shipped to energy producer:

$$I_E^1 = I_E^2 = \frac{\frac{P_E}{A}\phi_i^i N^i}{1 + \frac{P_E}{A} + \frac{1}{B} + [1 + \tau + \frac{P_E}{A} + \frac{1}{B}]^{\frac{1}{\sigma}}} \tag{3.10}$$

Transportation input:

$$I_T^1 = I_T^2 = \frac{\frac{1}{B}\phi_i^i N^i}{1 + \frac{P_E}{A} + \frac{1}{B} + [1 + \tau + \frac{P_E}{A} + \frac{1}{B}]^{\frac{1}{\sigma}}} \tag{3.11}$$

4 Simulations

4.1 Parameters

In the exercise that follows, I will feed in actual data on tariffs and energy prices over the period 1960 to 2000. Therefore, I set θ such that the price of energy in each industrial country is equal to the producer price of energy deflated by the GDP deflator for the United States. Tariffs are the world tariff series from Yi (2003). I set the productivity parameter for the domestic industrial goods ϕ_i^i and the labor endowment for each country N^i equal to one in each period.

There are three parameters that remain to be calibrated: σ, A, and B. The value of parameters A and B in 1960 are selected to match the energy share in transportation in 1960 ES and the transportation cost as a percentage of the final cost TC. These conditions are given by:

$$A = \frac{P_E(1960)}{TC * ES}$$

and

$$B = \frac{A}{\frac{P_E(1960)}{ES} - P_E(1960)}$$

I use a value of 0.086 for ES, to match the 8.6 percent energy share in Canadian Water Transportation in 1960. Water transportation is the most important mode of transportation in international trade. During the 1960s and 1970s, about two thirds of US imports (by value) arrived by water. In the 1990s, this number declined to about a half as air transportation became more important. Land modes represent about a quarter of import value. About 90 percent of trade (by weight) is transported by sea. (Frankel 1990) Canada is the only country that I am aware of that provides detailed statistics on revenue and costs in water transportation from 1960 on.

I use 0.158 as the value of TC. Waters (1970) examines data from the 1958 input-output tables and find that the nominal protection rate of transportation costs to be 10 percent. Rousslang and To (1993) find that domestic freight costs account for 40 percent of the nominal protection from transportation costs. I scale up the value trade costs to match this observation, giving a final value of 15.8 percent.

There is productivity growth in the transportation technology. I use average total factor productivity growth in transportation from O'Mahony (1999) minus total factor productivity in the business sector from the US Bureau of Economic Analysis. The growth rate of parameter B, γ_B, is 0.7 percent a year. Murtishaw and Schipper (2001) find that energy intensity in transportation in the United States has remained almost constant. To keep energy intensity constant, I set the growth rate of the energy parameter A, γ_A, equal to γ_B in each period.

There is considerable controversy about the trade-tariff elasticity. Estimates range from 1 to 13. (Erkel-Rousse and Mirza 2002) While this elasticity affects how much trade expands in response to changes in trade costs, it does not affect the model's predictions of trade costs themselves. As a baseline, I use a value of 0.25, which corresponds to an elasticity of 4. This the upper range of what is typically used in the international business cycle literature. (Yi 2003)

The following table summarizes the calibration.

Table 1: Parameters

$A(60)$	$B(60)$	σ	γ_A	γ_B
91.91	6.94	0.25	1.007	1.007

4.2 Results

In this section, I report the results of the baseline calibration. In the simulation, total trade costs are flat during the late 1970s. The model closely matches the behavior of energy share in transportation and transportation costs.

Trade Costs

Figure Six plots the model's predictions for total trade costs. After falling rapidly during the 1960s, trade costs remain constant from 1973 to 1982. To the extent that trade expansion is the result of declining trade costs, the model indicates that trade expansion should be flat over that period.

Trade costs are flat due to an increase in transportation costs resulting from the oil crises of the 1970s which counteracts falling tariffs over this period. The increase in energy cost is large enough to cause transportation cost to rise despite growing productivity.

To show the contribution of energy prices and tariffs to total trade costs, Figure Six shows trade costs predicted by the model under two counterfactual scenarios.

The "Tariffs Only" series shows predicted trade cost if transportation cost held steady at the 1960 level. All of the decline in trade costs is due to falling tariffs.

The "No Energy" series shows the predicted trade cost if energy prices held steady at the 1960 level. Trade costs in the model continue to fall throughout the late 1970s. Energy prices cause trade costs to remain constant in the late 1970s and early 1980s relative to the model without energy. The productivity growth in transportation amplifies the overall decline in trade costs that result from the fall in tariffs.

The model does miss somewhat with the timing of the upturn in trade share in the 1980s. In the data, export share begins to expand in 1986. The model predicts that trade costs begin to decline in 1983. While oil prices famously collapse in 1986, energy prices fall from their second oil crisis peak beginning in 1983.

This discrepancy may be due to an increase in tariffs in the mid-1980s in non-industrial countries. Clemens and Williamson (2002) examine import weighted tariffs for a large number of countries, including developing countries. The behavior of average tariffs follows the Yi series closely aside from a small spike in tariffs in the 1980s. The spike is the result of increasing developing world tariffs that are not accounted for in the Yi series.

Transportation Energy Use

The model matches the behavior of the transportation industry. Figure Seven shows the energy share from the model against data from Canadian water transportation. The energy share matches very closely. The model overshoots the energy share somewhat during the second oil crisis, but otherwise matches the data closely.

Transportation Cost

The model predicts a long run decline in transportation prices. As mentioned above, data on transportation costs is fragmentary. However, the model's predictions about the magnitude of the fall in transportation costs matches this fragmentary data closely.

Baier and Bergstrand (2001) find that 33 percent of the increase in trade that is attributable to a fall in trade costs is due to declining transportation costs. The model attributes 34 percent of the decline in trade costs to falling transportation costs.

Hummels (1999) finds that import weighted transportation costs (on a FOB/CIF basis) in the United States fell by 1.2 percentage points between 1974 and 1994. Deflating its predictions by 40 percent (removing the inland leg) to place them on a FOB/CIF basis, the model predicts a transportation cost decline of 1.1 percentage points.

Bernard, Jensen and Schott (2002) find that import weighted transportation costs (on a FOB/CIF basis) for United States manufacturing fell by 1.5 percentage points between 1982 and 1992. The model predicts a transportation cost decline (on a FOB/CIF basis) of 1.3 percentage points.

Trade Expansion

Bergoeing and Kehoe (2001) argue that "New Trade Theory" cannot account for the expansion of world trade. They argue that changes in trade policy is the most promising avenue for a theory of trade expansion. However, standard models using the price-import elasticity estimated from the international business cycles literature do not predict the level of trade expansion that is observed in the data. Yi (2003) argues that an elasticity of 11 or 12 is required to generate actual trade expansion. Typically, the elasticities closer to 2 to 4 are estimated in the data, although as discussed above the correct value for this elasticity is controversial.

Productivity growth in transportation implies that trade costs fell by more than the amount generated by falling tariffs alone. Therefore, trade expands more for a given elasticity when transportation is added to the model.

Tariffs fell by about 10 percentage points from 1960 to 2000 according to Yi (2003). In the baseline calibration, changes in transportation yield an additional 4 percentage points decline in trade costs. The model predicts that trade costs fell by about 40 percent more than that which can accounted for simply with tariffs.

Total trade expansion due to falling trade costs is 43.4 percent higher when falling transportation costs are included. In the baseline calibration, the model predicts an increase in export share of 26.6 percent due to falling tariffs. Adding transportation, the model predicts an increase in trade share of 38.1 percent. (In the data, export share increased by 138 percent.) While the total increase in trade share due to falling trade costs depends on the elasticity, the extra impact that falling transportation costs implies does not. Trade expansion is about 45 percent higher when improvements in transportation are accounted for, independent of the elasticity.

Price Dispersion

The gap between domestic and foreign prices increases when transportation costs increase. The price spread between the export price of a good and the import price in the model is $\tau(t) + P_T(t)$. The model predicts constant or increasing price dispersion (depending on the behavior of tariffs) during the period of the oil shocks due to increasing transportation costs.

There is evidence that commodity price dispersion increased during the oil shocks. Figure Eight shows the real spread between prices quoted at different stages of the logistics chain for number of commodities. Price dispersion significantly increases in response to the oil shocks and declines thereafter.

4.3 Sensitivity Analysis

Given the lack of data on the world transportation industry, the parameters that enter the calibration cannot be estimated with a high degree of precision. In this section, I examine the sensitivity of the results to different parameterizations.

Productivity Growth and Trade Costs

If energy intensity is unchanged ($\gamma_A = \gamma_B = \gamma$), the percentage point change in transportation prices that results from an increase in productivity is given by the equation:

$$\Delta P_T = -TS * \frac{1-\gamma}{\gamma}$$

Given a transportation share of 15.8 percent, a productivity growth rate of 0.7 percent implies a 0.1 annual percentage point decline in trade costs. Over the course of forty years, that implies a 4 percentage point decline. Doubling the productivity growth rate to 1.4 percent implies a 0.22 annual percentage point decline in trade costs or 8.7 percentage point decline over forty years.

Higher productivity growth reduces the relative impact of energy price changes on trade costs. For an energy price spike to raise total trade costs when tariffs are falling, transportation costs must increase. Transportation costs increase in response to higher energy prices only if the higher energy costs overwhelms the fall in costs due to productivity growth. When productivity is growing faster, energy prices must increase more to lead to an increase in transportation prices.

Energy Prices and Trade Costs

The percentage point change in transportation prices that results from an increase in energy prices is given by the equation:

$$\Delta P_T = TS * ES * \Delta P_E$$

The impact of a change in the price of energy on the price of transportation is greater for higher values of both transportation share TS and energy share ES. In what follows, I will examine how different values of TS and ES affect the change in the price of transportation.

In the simulated economy in 1972, ES is equal to 7.42 percent and TS is equal to 14.25 percent. Energy prices increased by 183.6 percent from 1972 to 1981. Over this period, tariffs fall by 2.0 percentage points. For these values, transportation costs increase by 1.94 percentage points. In what follows, I examine the magnitude of the transportation cost increases for alternative values of TS and ES. (The following analysis does not include changes in productivity.)

Energy share for various modes of transportation in 1972 range from 3.5 for railroads to 10.6 for air freight. Using this range of energy share, the range of transportation cost increases is 0.92 percentage points to 2.78 percentage points.

Different goods have different transportation requirements. The nominal protection from transportation for individual commodities given in Finger and Yeats (1976) ranges from 3 (Agricultural Machinery) to 39 percent (Sawn Wood). (This does not include inland legs.) Scaling up to include the inland leg gives a range of 5 to 65 percent. The range of transportation cost increases is 0.68 percentage points to 8.85 percentage points.

With the alternative values for ES and TS, changes to transportation costs caused by the oil crises are significant. Even at the low range of these estimates, energy costs lead to a quantitatively important increase in transportation costs compared to the 2 percent decline in tariffs. The smallest impact (0.68 percentage points) is still a third the size of the decline in tariffs and the upper range of the estimates are significantly larger than the change in tariffs.

5 Discussion

5.1 Voyage Length

Additional evidence for the importance of energy costs for trade can be found by examining the distance a shipment is sent. Energy costs increase with the length of a voyage. Therefore, we would expect that importers would attempt to mitigate an increase in transportation costs due to energy shocks by importing more from nearby producers. In fact, Hummels (1999) shows that importers do change the mix of importing countries to minimize transportation costs. High energy prices should be associated with goods being shipped shorter distances.

There is evidence that voyage length declined in response to higher energy costs. The worldwide haul length declined. Figure Nine shows the average length of voyages for world seaborne trade. After increasing in the late 1960s and early 1970s, the average voyage length falls in the mid-1970s. It begins to slowly grow in the mid-1980s.

Additional evidence can be found at lower levels of aggregation. In general, products with a high value to weight ratio are more vulnerable to transportation price increases since a transit fees represent a larger share of delivered value. Therefore, products with a high value per ton should be less affected than those with a low ratio.

The US Commodity Flow Survey collects data average length of haul of goods for Economic Census years. I regress the change in haul length on the average value per ton for two digit SIC code manufacturing industries. The variable ALH77 is the percentage increase in average length of haul from 1972 to 1977. The variable ALH72 is the percentage increase from 1963 to 1972. The variable VAL77 is the average value per ton in 1977. Table 2 presents the results.

Table 2: Average Length of Haul Regressions

Dep. Variable	ALH77	ALH72
Variable	Coeff. (t-Stat.)	
Constant	-0.336 (-5.67)	0.051 (0.96)
VAL77	0.031 (2.19)	-0.001 (-0.072)
Adj.-R^2	0.173	-0.059

The positive coefficient on VAL77 for the 1972 to 1977 period implies that average haul length fell more (or grew less) for heavier products during the oil shock period. In contrast, haul length growth was unrelated to shipment value before the oil shock. (Low value industries' haul length grew significantly faster than high value industries from 1963 to 1967.) The oil shock seems to have had a larger effect on haul length for low value shipments relative to high value shipments.

5.2 Other Explanations

The model in this paper shows that changes in transportation cost due to the Oil Crises can account for the slowdown in trade expansion in the mid-1970s. In this section, I consider alternative explanations.

Non-Tariff Barriers

A potential alternative explanation is non-tariff barriers (NTBs). NTBs became a more important trade issue around the time of the trade slowdown. Bhagwati (1988) notes that NTBs increased during the mid-1970s in what is often referred to as the "New Protectionism". However, there are weaknesses in the case for non-tariff barriers.

Relative to transportation costs and tariffs, NTBs have little effect on trade volumes. Bhagwati (1988) notes that most NTBs are easily circumvented. He suggests that they are enacted by politicians to appear to be providing protection to trade competing industries while providing little actual protection. Harrigan (1993) finds that NTBs were large in 1983 but finds that they had little effect on trade relative to tariffs and transportation costs.

While the timing of the rise of NTBs seems to match the trade slowdown, this explanation requires a similar decline barriers in the mid-1980s. Time series data on NTBs is difficult to come by. Productivity Commission (2000) provides data on the assistance to Australian industries from a variety of sources, including tariffs, NTBs and subsidies. Assistance to Australian manufacturing mostly takes the form of tariffs and non-tariff barriers. Since 1968, this assistance has been steadily declining. Overall trade restrictiveness does not show an increase during the years of the trade slowdown.

Vertical Specialization

Yi (2003) argues that vertical specialization helps explain the apparent change in price-import elasticity. Hummels, Ishii and Yi (2001) present evidence that vertical integration trade has become an important part of international trade. Yi (2003) suggests that adding transportation costs would amplify his results.

The theory put forth in this paper emphasizing transportation changes is complementary to vertical specialization. It may explain the timing of the large increase in trade. Vertical specialization theory indicates that trade may expand in a non-linear fashion as trade costs fall. Falling energy prices may explain why the big increase in trade occurred in the mid-1980s. Transportation changes may be particularly important in the 1970s, when energy prices changed a great deal, while more recent trade expansion may owe more to increasing vertical specialization.

The decline in transportation costs may have encouraged the increase in vertical specialization. Breaking the production process into stages that are done in different locations incurs higher transportation costs than production that is done within a single location. A part may be transported many times, incurring multiple shipping fees. In addition, to maintain a sufficient supply of parts while keeping inventory costs low, vertically integrated production often relies on faster, more expensive modes of transportation. Trucks and air freight offer same day or overnight service, but at a much higher cost than rail and water transit. When transportation costs are high, it may be impractical to ship parts many times using relatively expensive modes of transportation. However, as these costs decline, the gains to vertical integration trade may outweigh the additional cost of transportation. It would be fruitful to examine the role of transportation in vertical specialization.

5.3 Conclusion

In this paper, I argue that the oil crises of the 1970s increased transportation costs and can account for the trade slowdown in the mid-1970s. I add an energy using transportation sector to a simple model of trade and find that energy prices can lead to a large enough increase in transportation costs to offset the decline in tariffs in the 1970s.

Transportation may be a fruitful avenue of inquiry to investigate the effect of the oil shocks on other aspects of the economy. For example, it could be used to examine the effects of the oil shocks on productivity growth. Trade competing firms and industries are typically found to be more productive than those that are protected. An interesting topic to address is the role of the trade slowdown in the worldwide productivity slowdown. In the context of the Nineteenth Century United States, Schmitz (2003) shows that reductions in transportation costs can increase productivity by allowing more specialization. Changes in transportation prices may have had similar effects in the Twentieth Century.

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A Appendix: Data Sources

A.1 Trade Data

World export share is ratio of the indices of real world exports and GDP from the World Trade Organization's *International Trade Statistics in 2002* multiplied by nominal world export share in 1990 from the World Bank's *World Development Indicators.*

A.2 Tariff Data

Tariffs are "World Tariffs" from Yi (2003).

A.3 Energy Data

Energy prices are US producer prices weighted by usage from US Department of Energy's *Annual Energy Review* deflated by the GDP deflator.

A.4 Freight Rates

Australian coastal shipping and price index comes from Australia's Bureau of Transport and Regional Economics *Information Sheet* 19.

All US revenue per ton-mile series are deflated by the US GDP deflator. Railroad data are from the Association of American Railroads' *Yearbook of Railroad Facts.* Truck and barge data are from the Eno Foundation's *Transportation in America.*

A.5 Energy Revenue Share Data

The water transportation data are from Statistics Canada's *Water Transportation.*

Civil aviation data are from Statistics Canada's *Canadian Civil Aviation.* Data refer to all civil aviation, including passenger transportation.

Railroad data are from the Association of American Railroads' *Yearbook of Railroad Facts.*

A.6 Commodity Prices

All commodity price spreads are deflated by the US GDP deflator.

Sugar spread is Caribbean/UK Freight and Insurance Element from the International Sugars Organization's *Sugar Yearbook*. The portion of the series in British pounds is converted to US dollars using *Sugar Yearbook's* conversion factor.

Cotton spread is mill price minus farm price from US Department of Agriculture's *Cotton Yearbook*.

Corn spread is Argentina CIF North Sea Ports spot price minus US No. 3 yellow FOB Gulf Ports spot price from the World Bank's *Commodity Trade and Price Trends*.

A.7 Seaborne Trade

Average length of haul is calculated by dividing "Tons-Miles" by "Tons" from Fearnley's Maritime Trade data available in the OECD's *Maritime Transport*.

Figure One:
World Export Share of GDP and Tariffs

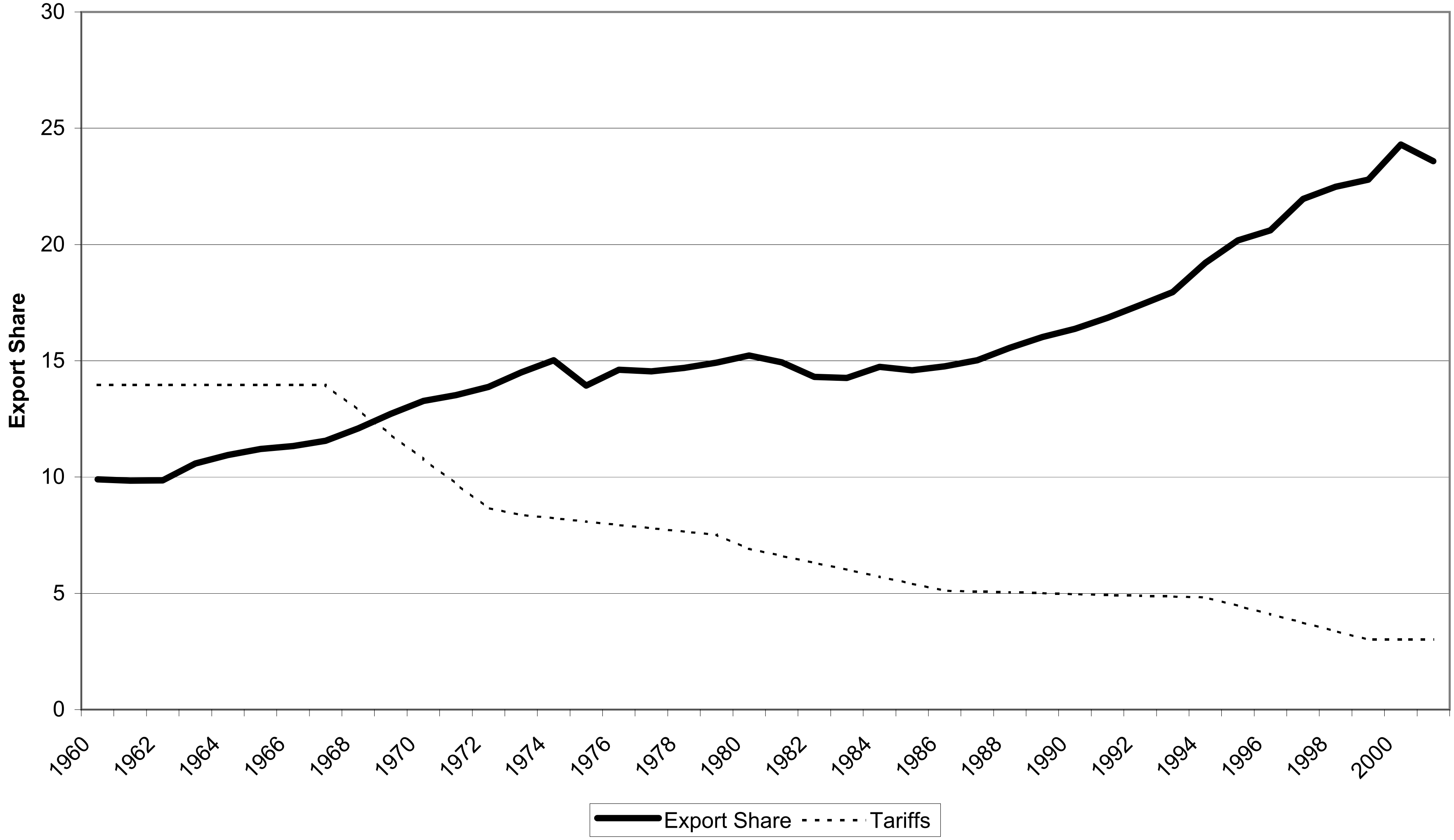

Figure Two:
US Producer Prices of Energy/GDP Deflator

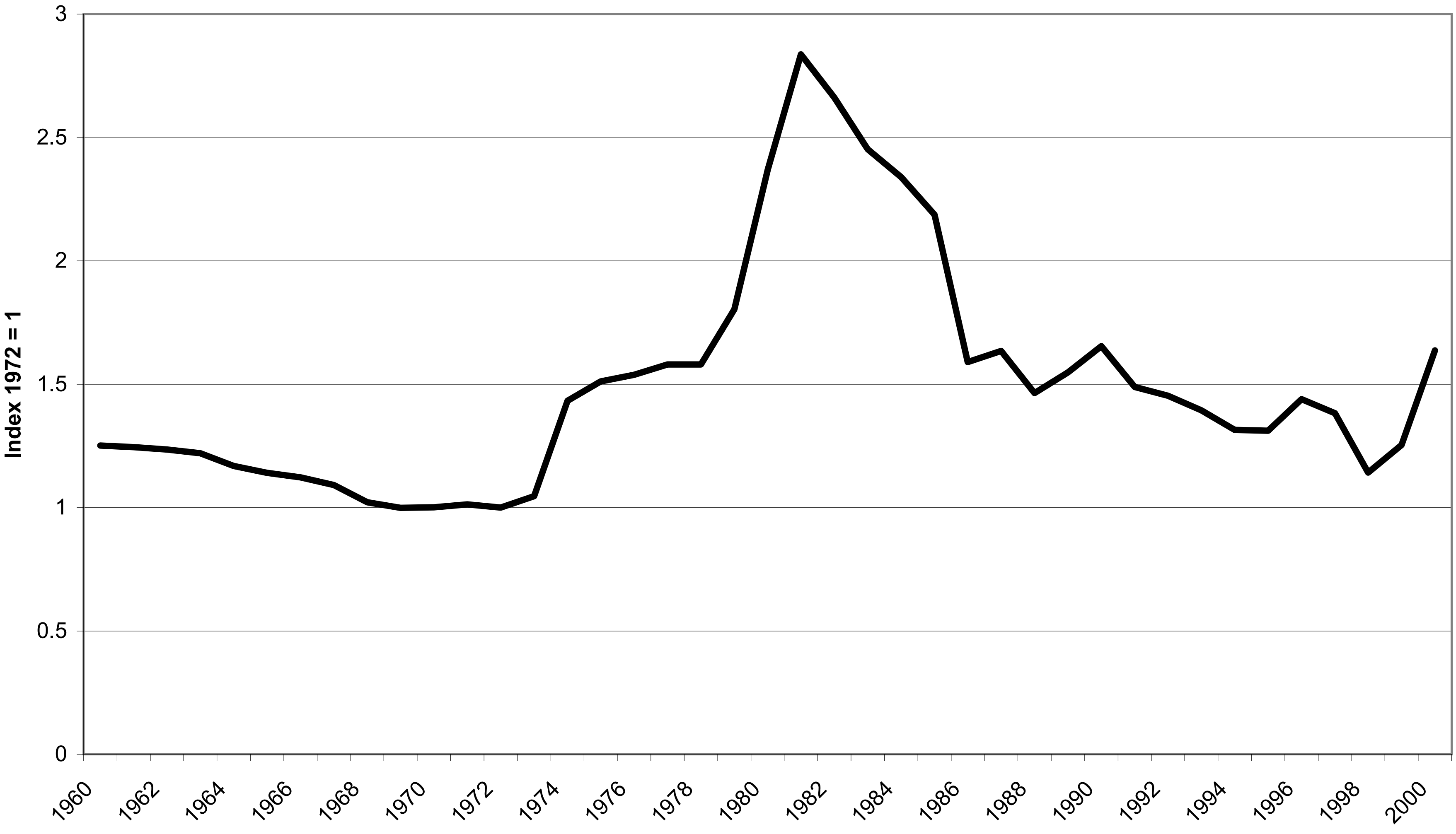

Figure Three:
Australian Coastal Freight Rates and Energy Prices

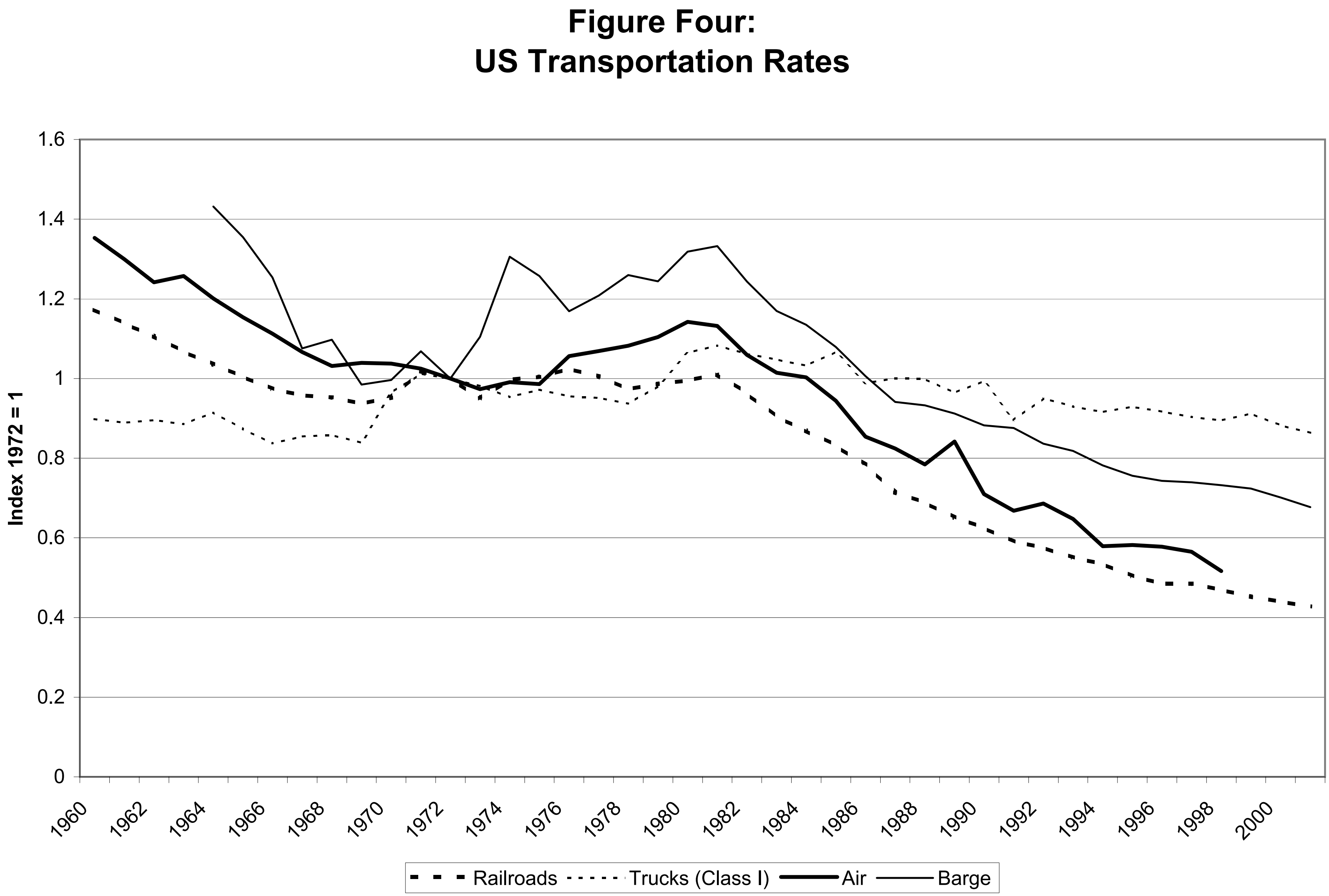

Figure Four:
US Transportation Rates
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Index 1972 = 1
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
Railroads
Trucks (Class I)
Air
Barge

Figure Five:
Energy Price and Revenue Share
Various Transportation Industries

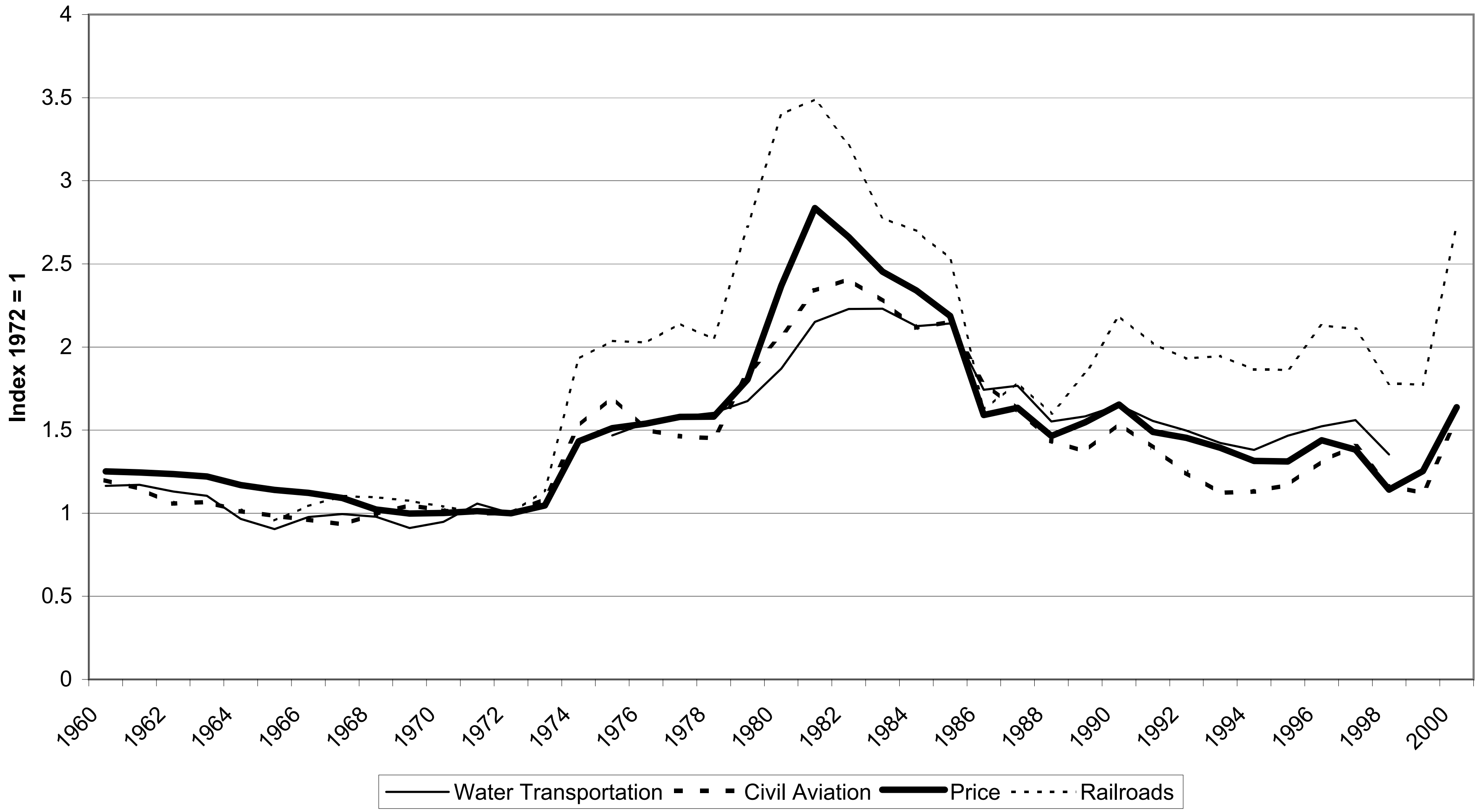

Figure Six:
Model Total Trade Cost

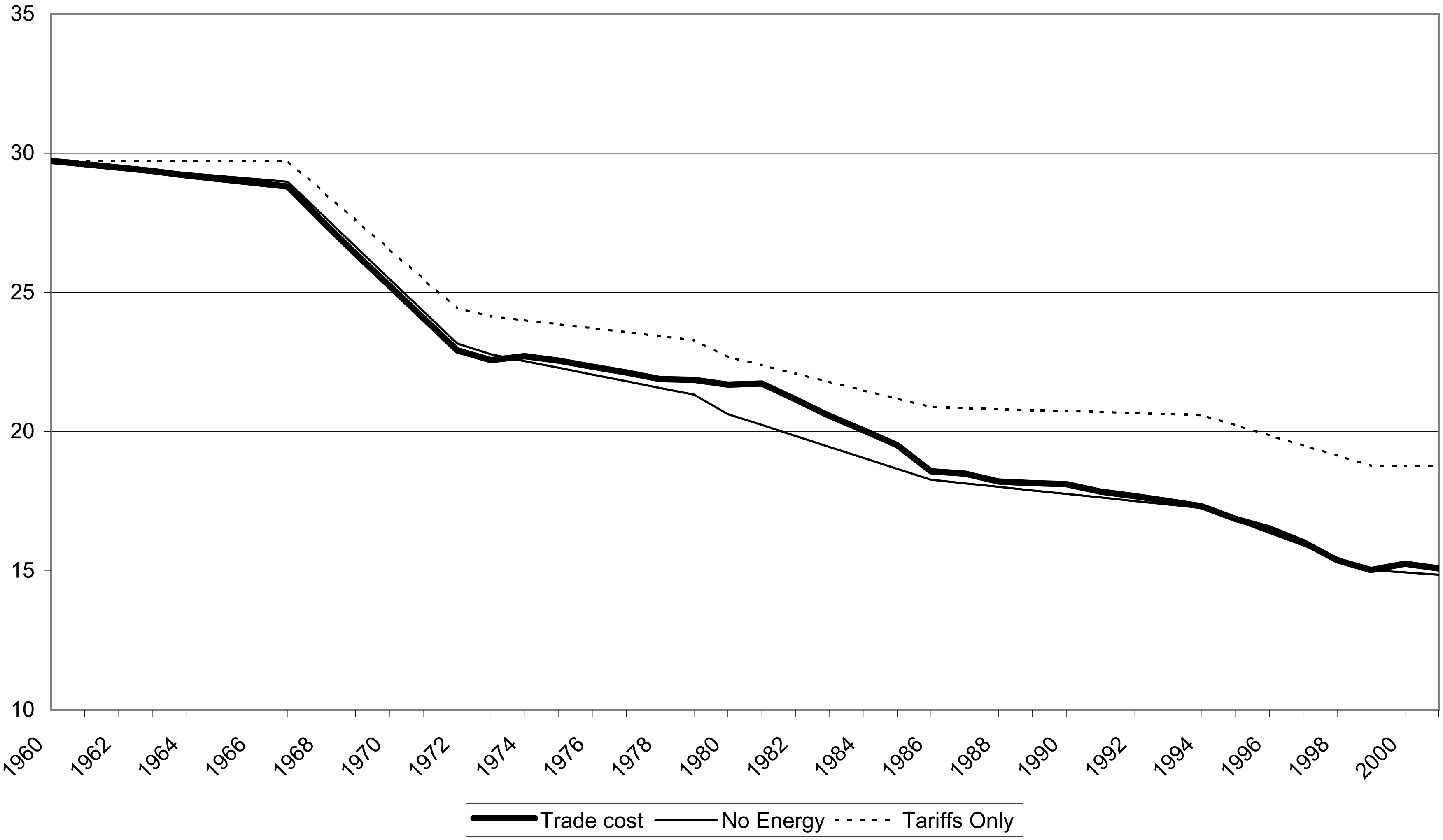

Figure Seven:
Energy Share in Transportation

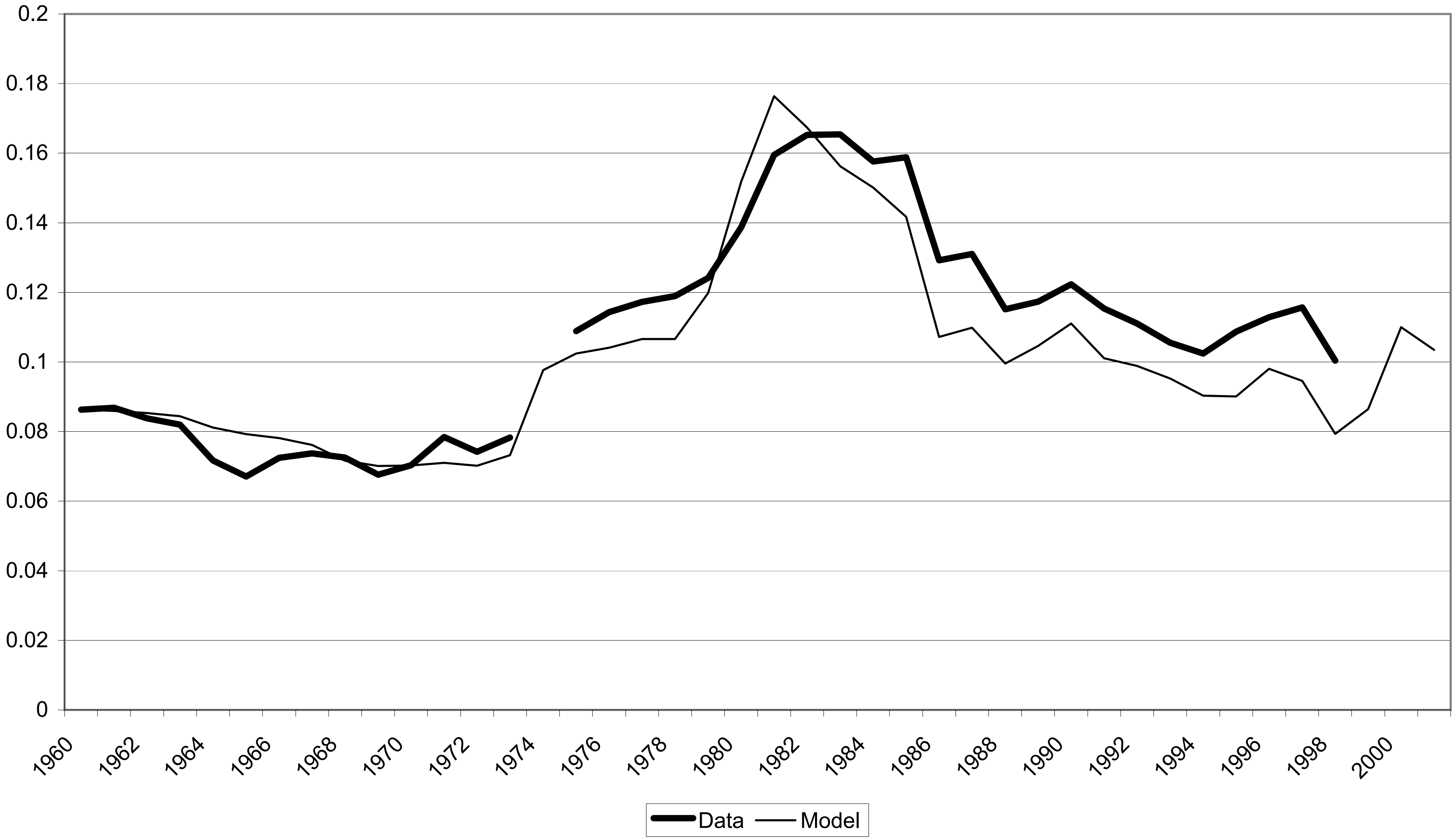

Figure Eight
Price Spread

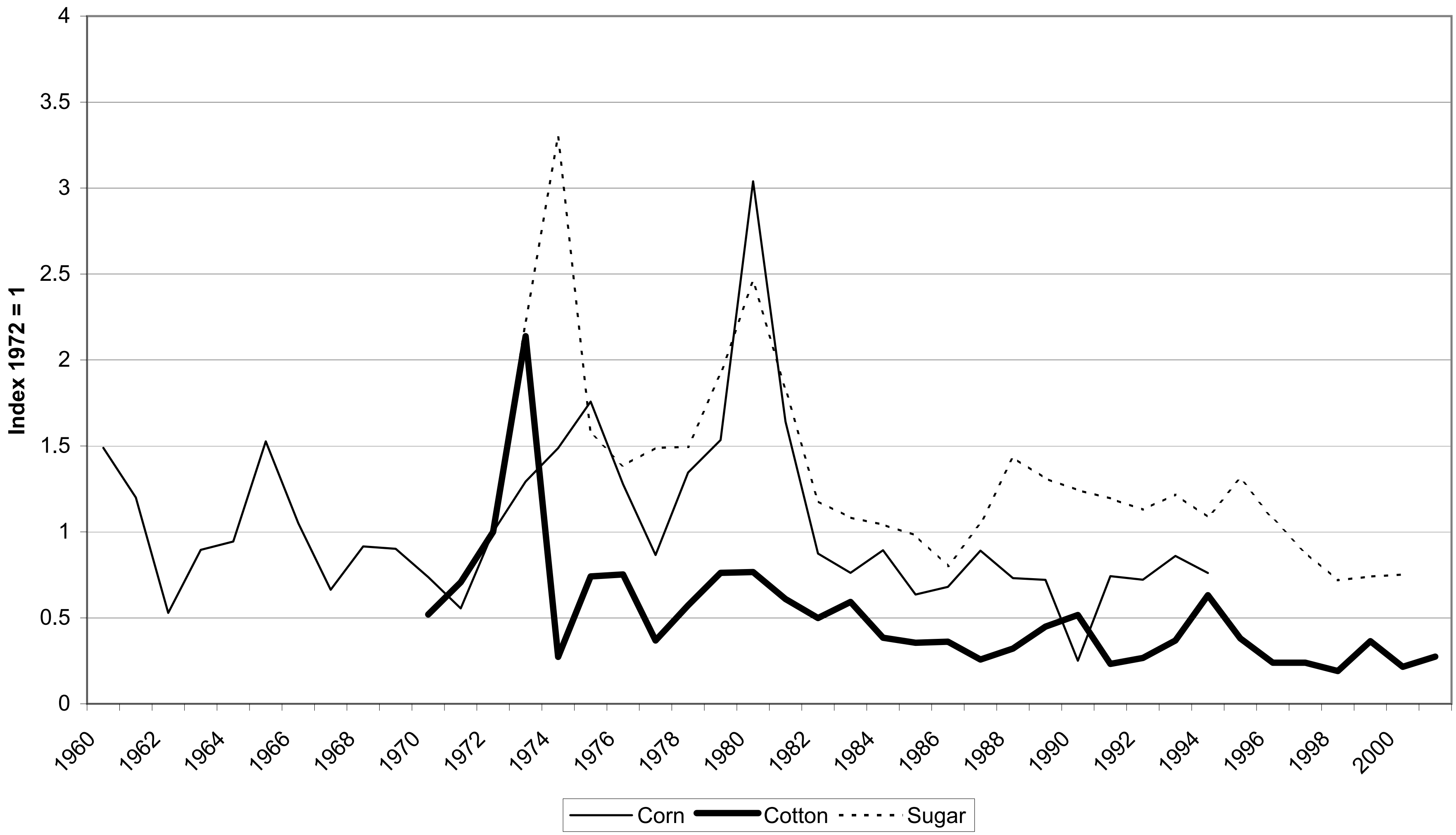

Figure Nine:
Average Length of Voyage
World Seaborne Freight