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PORT FACILITIES AND THE INTERNATIONAL COAL MARKET

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Abstract—This study examines the relationship between the increased demand for U.S. coal in the early 1980s, and the coal pier congestion that accompanied and hampered it. We find an export price elasticity for U.S. coal of −16.7, and a port service price elasticity of −0.8, suggesting deadweight losses of approximately $4 million per month. We then separate the short-term from the long-term changes in the demand for U.S. coal exports. The long-term demand estimates predict increases of 77% in U.S. coal exports, compared to the actual 83% increase in shipping capacity provided by coal shippers.

Changes in world energy markets in the late 1970s and early 1980s led to increased demand for U.S. coal. These changes included substitution of coal for oil following the second round of oil price increases, favorable exchange rates (the U.S. dollar was low relative to other currencies), a declining U.S. price relative to the world price, and uncertainty about the coal supplies from the other major world exporters, Australia, Poland, and South Africa.

Transportation problems in the United States hindered responses to the increased demand. The coal and the rail cars to bring it to the ports were apparently available; the port facilities (particularly loading piers) were not, and lines of ships formed at all ports handling U.S. coal. Policy-makers feared that port coal shippers would either react too slowly, or would overbuild in response. The first alternative would hinder foreign trade. The second would result in millions of dollars of wasted investment. This led to calls for national planning policies in an industrial sector that has not traditionally coordinated policies.

The appropriate response to port bottlenecks involved both transportation and trade analyses. The transportation problem was the shortage of facilities that limited trade. The trade analysis required accurate predictions of the international coal market (particularly the U.S. share), since the construction of large single-use facilities could represent very expensive mistakes.

This article evaluates the subsequent construction of facilities (in the context of the demands for national planning) as decentralized responses to both short-run bottlenecks costs and to long-run demand projections. It begins by formulating a model of port services demand and using it to examine the magnitude of the short-run bottleneck costs, separated into ship-waiting costs and deadweight losses. The former have been estimated at $6 per ton; we estimate the latter at $1 per ton (unless otherwise noted, stated tonnages are in short tons). Together they represent an increase of 70% in the port value added per ton. Had capacity existed at the time, port throughput might have been 28% to 33% higher.

Short-term bottleneck costs are not good indicators of the investment necessary to accommodate long-term coal demand. We estimate an international coal demand model to separate short-term from long-term changes in U.S. export demand. The model estimates long-term changes in demand requiring expansion of U.S. coal pier capacity by 77%. These estimates are similar to the increases of 83% in Baltimore and Norfolk, the two ports most affected by the bottlenecks; nowhere else in the United States were large piers brought into use.

1. DEMAND FOR COAL AND PORT SERVICES

The demand for port services can be directly derived from the demands and supplies of goods going through the ports. We focus on coal exports, although bottlenecks have occurred with grain at U.S. Gulf Coast ports, and with other goods elsewhere in the world. Transport costs comprise more than half of coal's delivered price; port costs are a substantial portion of transport costs. For example, in 1981 the minemouth cost of West Virginia steam coal ($33 per ton) comprised less than half of its Japan **cif** price of $70.

The analysis assigns transport service demand (including shipment assembly, line-haul, and handling) to brokers who buy coal **fob** minemouth and sell it **cif** abroad (see Harvey, 1981, or Walters, 1968). In

In the share equation, decreases in the U.S. price are associated with an increases in its sales share to these eight countries. Similarly, decreases in Polish production are associated with increases in the U.S. share, as importers look elsewhere to obtain their coal.

The equations can be used to explain the surge in U.S. coal exports in 1980 and in 1981. From 1979 to 1981 coal exports increased by 70%, from 58.8 million metric tons to 100.0 metric tons. Coal exports to the countries in the sample increased by 55%. Factors increasing U.S. exports (Table 5) were the 19% drop in Polish coal production, the 7% increase in electricity production from coal, the 3% exchange rate decrease, and the 7% Australian price rise (relative to the 4% U.S. price rise). Only a fall in coke production of 4% exerted restraint on U.S. coal exports. Combining all of these changes with the estimated elasticities presented earlier, the net effect was to raise U.S. coal exports by 16%.

This approach explains some, although not all, of the change in U.S. coal exports from 1979 to 1981. The effect of the Polish coal miners' strike is probably understated. Although production was 19% lower in 1981 than in 1979, exports fell by 38%. We also assume that coal is used for either coke production or electricity generation, ignoring uses such as cement production. Coal demand for these other uses was 14% higher in 1981 than in 1979.

U.S. coal exports were almost surely boosted by congestion at other world ports. Further, there was a series of lengthy strikes by coal miners in Australia, badly shaking Australia's reputation for supply reliability. General uncertainty in the coal trade also led to increases in the stocks held by importing countries. Stocks increased by 11.0 million metric tons in 1980, and by 9.5 million metric tons in 1981.

Of the various factors contributing to the surge in U.S. exports, the drop in Polish coal production, the decline in coke production, the exchange rate movements, the Australian and American strikes, and the stock-building probably caused short-term increases in foreign demand. The decline in coke production in the eight countries was largely due to a world recession. (The shift in steel production to less-developed countries merely shifts the demand for coking coal from the developed countries).

On the other hand, the increase in electricity generation, the change in foreign coal production, and the change in U.S. prices relative to the world, appear to be long-term shifts in the coal demand function. The data presented in Table 5, for the two-year period 1979–1981, can be extrapolated into the future. They indicate an average annual increase of about 1.4% for U.S. coal. In addition, it seems reasonable that the long-term shift in the demand for coal for other uses adds another 1.5% per year to the demand for U.S. coal. Over a 20-year period (the economic life of a coal pier) this growth rate of 2.9% per year would lead to a 77% increase in U.S. exports. (Even if **no** long term shift is noted, the 1.4% per year increase implies a 32.1% increase in port facilities over the 20-year period.) This estimate is conservative. The world was in recession during this period and this probably dampened the observed shift from oil to coal.

5. SHIPPERS' RESPONSES

By late 1980, shippers at nearly every port on the East, West, and Gulf Coasts had announced plans to build new coal piers. Articles in the trade journals expressed concern that the competition among ports would lead to overinvestment in facilities. By fall

Table 5. Causes of export change

CAUSE	Pct Change 1979-81	Elasticity	Pct Change in Exports
Coke Production	-3.7	1.119	-4.1
Electricity Production	6.5	0.936	6.1
Domestic Coal Production	3.6	-1.084	-3.9
Polish Coal Production	-18.9	-0.880	16.6
U.S. Price	3.5	-0.199	-0.7
Australian Price	6.8	0.199	1.4
Exchange Rate	-2.7	-0.199	0.5
U.S. Exports	55.3	-----	---

parability of the different energy inputs (coal, oil, natural gas, and electricity) in a firm's production function. The firm then uses a two-stage process in which fuel mix, and then quantities of capital, labor, and energy, are optimized. We add a third stage, choosing first the allocation of coal purchases from the different suppliers, then the optimal mix of fuels, and finally the quantities of capital, labor, and energy.

Coal imports of country i, $IMPORT_i$, depend on the amount of electricity generated from coal, $ELEC_i$, the amount of coke produced, $COKE_i$, and the level of domestic coal production, $PROD_i$. Data for all eight countries were pooled and dummy variables added, to account for qualitative country-specific influences:

$$IMPORT_i = f(ELEC_i, COKE_i, PROD_i, C_1, \ldots, C_7), \quad (12)$$

where C_1 through C_7 are 0–1 dummies, referring to West Germany, Netherlands, United Kingdom, Canada, France, Italy, and Japan respectively (Belgium-Luxembourg excluded). Annual data for 1971 through 1983 are used (precise definition and data sources are available from the authors on request).

The United States share, $SHARE_i$, is modeled as a function of the price of U.S. coal relative to the world price. Further, it is dependent upon the availability of Polish coal. A separate variable is added for Polish production for several reasons. Under Poland's centrally planned economy, coal exports are not directly related to the world price. There was a disruptive strike by Polish coal miners in 1980, and a shortened work week in 1981. As with the import equation, dummy variables for each country in the pooled sample (except Belgium-Luxembourg) were included:

$$SHARE_i = g(PRICE_i, POLISH, C_1, \ldots, C_7), \quad (13)$$

where POLISH is coal production in Poland.

All of the variables (Table 4) are significant and have the correct signs (except for some insignificant dummies). Increases in either electricity generation or coke production lead to increased imports (holding domestic production constant). Increased domestic production leads to reduced imports.

Table 4. Import and share equations

	Import Equation			Share Equation	
Variable	Coef.	T Stat.	Variable	Coef.	T Stat.
CONSTANT	1121.000	0.72	CONSTANT	0.516	4.03
ELEC	0.767	8.31	PRICE	-0.054	2.05
COKE	1.250	6.58	POLISH	-1.95E-06	1.99
PROD	-0.516	7.01			
C1	-10670.000	1.48	C1	-0.012	0.30
C2	248.700	0.17	C2	0.280	7.10
C3	-11835.000	1.25	C3	0.127	3.23
C4	8459.000	5.73	C4	0.764	19.07
C5	2415.000	1.08	C5	-0.048	1.23
C6	1382.000	0.97	C6	0.106	2.68
C7	5042.000	0.64	C7	0.076	1.92
SER	3218.000		SER	0.100	
R-SQ	0.97		R-SQ	0.86	

DUMMY VARIABLES

C1 - GERMANY
C2 - NETHERLANDS
C3 - U.K.
C4 - CANADA
C5 - FRANCE
C6 - ITALY
C7 - JAPAN

is calculated as \$56.14 per ton (\$1981) by subtracting \$14.00 in ocean freight (IEA, 1983a, pp. 3–4) from \$70.14 cif in France (IEA, 1983b, p. 45). The **fas** price is \$45.67. Subtracting the **fas** price from the **fob** price results in a port value added of \$10.47 per short ton.

At bottleneck level Q^C, (7) and (8) can now be calibrated. The appropriate supply and demand equations recognize a supply price (value added) of \$10.50 (prices in effect before the bottlenecks began) and a demand price of \$16.50 (supply price plus waiting time costs). As a result:

$$T_S = 10.5\ Q_S^{1/E_S} \qquad (7')$$

$$T_D = 16.5\ Q_D^{-1.25}. \qquad (8')$$

The calculated demand elasticities refer to coal transported from the United States as a whole. Most U.S. coal exported overseas was passing through Baltimore and Norfolk (with Norfolk exporting four times as much as Baltimore). Since both ports reached capacity simultaneously, the analysis can apply to the two in concert, adjusting the numbers by 80% for Norfolk and by 20% for Baltimore.

Since supply elasticities are not available, plausible values will be assumed. If port facilities are available, the supply elasticities are probably quite high, although not infinite, as shipping and railroad costs would rise as quantities increase. At Q^C, supply is quite inelastic.

Table 3 uses a range of supply elasticities to test the sensitivity of bottleneck impacts. Consider the impacts with a supply elasticity of +1.5, the lower end of the range. Q^* equals 1.27, implying that coal exports would have been about 27% (1.4 million tons) higher than the 5 million tons per month that were going through the two ports. The cost of port services would have been approximately \$4.21 lower; i.e. \$16.50 minus \$12.29. The monthly deadweight loss would have been about \$3.75 million, compared to a total monthly value-added of \$52.5 million (\$10.50 per ton for five million tons), and monthly demurrage fees of \$30 million (\$6 per ton for the 5 million tons).

The range of supply elasticities leads to a range of monthly deadweight losses (bottlenecks varied by month). The low (high) elasticity estimate is +1.5 (+3.0), giving losses of \$3.75 (\$4.50) million per month, or \$0.80 to \$0.90 per ton. Had capacity existed, shipments might have been 27% to 33% higher.

These may be upper bounds in several ways. First, the assumption of completely inelastic supply at Q^C overstates the size of the deadweight loss. Second, all of the demurrage fees have been attributed to lack of pier facilities. Third, we assume that coal demand, choked off in one month, could not be made up in the next month, and was purchased from competitors instead. If buyers could catch up by increasing future orders, the calculated losses may be overestimated.

4. OPTIMAL PORT INVESTMENT AND LONG-TERM DEMAND

Port congestion costs may not be the most appropriate investment criteria since the congestion was due in part to short-term problems. Since port facilities represent long-term investments, it is necessary to forecast the long-term demand for U.S. coal as well.

Two equations can be derived to explain U.S. coal exports to eight countries representing the entire export market (and providing good data). They address both the levels and the U.S. shares of the imports. The eight countries accounted for 88% of U.S. exports in 1971 and 73% in 1983. Even though they are a declining share of coal exports, changes in their imports are highly correlated with total exports. Correlation of rates of change of exports to these eight countries with rates of change to the other countries is 0.87.

Multi-stage decision models of energy demand are common. Pindyck (1979) assumes homothetic se-

Table 3. Losses due to port bottlenecks

Demand Elasticity	Supply Elasticity	Q*	T*	L	Monthly L
-0.8	0.00	1.000	16.50	0.000	0.000
-0.8	0.10	1.041	15.69	0.129	0.646
-0.8	0.25	1.090	14.82	0.276	1.378
-0.8	0.50	1.149	13.87	0.443	2.216
-0.8	0.75	1.191	13.26	0.556	2.779
-0.8	1.00	1.222	12.84	0.637	3.184
-0.8	1.50	1.266	12.29	0.745	3.727
-0.8	2.00	1.295	11.95	0.815	4.074
-0.8	2.50	1.315	11.72	0.863	4.315
-0.8	3.00	1.330	11.55	0.898	4.492
-0.8	4.00	1.352	11.32	0.947	4.735
-0.8	5.00	1.366	11.18	0.979	4.894
-0.8	10.00	1.398	10.86	1.049	5.246
-0.8	INF	1.436	10.50	1.131	5.653

parameters. In equilibrium, T_D equals T_S, implying:

$$\ln Q^* = \frac{(\ln a_D - \ln a_S)}{\left[\left(\frac{1}{E_S}\right) - \left(\frac{1}{E_D}\right)\right]} \tag{9}$$

Deadweight loss, L, is calculated as the integral of the difference between the demand and supply curve, evaluated Q^C and Q^*, or:

$$L = \int_{Q^C}^{Q^*} a_D Q_D{}^{1/E_D} - a_S Q_S{}^{1/E_S}\, \mathrm{d}Q, \tag{10}$$

where $Q_D = Q_S = Q$. Normalizing Q^C to equal 1:

$$L = \left[\frac{E_D a_D}{(E_D + 1)}\right]\left[\left(\frac{T^* Q^*}{a_D}\right) - 1\right] - \left[\frac{E_S a_S}{(E_S + 1)}\right]\left[\left(\frac{T^* Q^*}{a_S}\right) - 1\right], \tag{11}$$

where T^* is the market price for port services evaluated at $Q_D = Q_S = Q^*$.

3. ESTIMATING SHORT-TERM ECONOMIC LOSSES

It is necessary to assign values to the parameters in (11), including relevant demand (E_D) and supply (E_S) elasticities, value of waiting time (demurrage), and value of port services, T. The elasticity of port demand (E_D) was estimated above as -0.8. The other parameters are now discussed.

Table 2 documents the numbers of ships involved and the lengths of the queues. At the peak (March 1981) there were 27 colliers queued at Baltimore and 144 at Norfolk, with an average wait of 40 to 60 days. Since optimal waiting time is probably positive, not all of the waiting times should be included as economic losses. Further, many vessels were not under charter, but were waiting because they had no alternative business, anticipating a contract to transport coal by the time they reached the head of the queue. This is normal operation, not specifically related to the coal bottlenecks. Estimates of waiting time costs, representing a 40,000 DWT collier, range from \$6 to \$15 per ton (U.S. Office of Technology Assessment, 1981). The spot market for colliers fluctuated considerably during the period of port congestion; we use \$6 as a conservative estimate (higher values would give larger deadweight losses).

A port adds value to goods by making them more accessible to the final user. We calculate value added using market information about the goods in transit. This approach subtracts the good's price as it leaves the port, from the price as it enters. The Census Bureau publishes **fas** value of exports, which can be treated as a good's price as it enters the port. If free-on-board (**fob**) prices at the port were available, the difference between the **fob** and **fas** prices would be the value added to the good by the port. Data are not always so convenient, but the approach allows the use of secondary data to approximate value added.

Consider steam coal exports. The **fob** ship price

Table 2. Collier queues and waiting times in 1981

	Hampton Roads		Baltimore	
Week of	Number	Average Wait(Days)	Number	Average Wait(Days)
6 March	144	62-63	27	40-45
10 April	83	NA	15	21
8 May	54	70	0	0
8 June	51	NA	27	40-90
6 July*	55	45	24	51
7 August	61	20-37	19	45
7 September	38	13-22	13	110
19 October	49	11-30	11	120
9 November	45	8-36	6	111

NA - Not Available

*Beginning of 'Away with Permission' Registration System

Source: Coal Age (McGraw-Hill), Various issues

Table 1. Foreign prices and elasticities

COUNTRY	U.S. fas Price as Pct of Del.Price	Demand Tons	Non-U.S. Supply Tons	Demand Elasticity	Supply Elasticity
India	0.6	122.9	122.8	-1.2	2.0
U.K.	0.8	122.4	122.4	-1.2	2.0
S. Africa	0.5	98.3	98.3	-1.2	2.0
Japan	0.6	90.4	67.0	-1.3	2.0
W. Germany	0.8	90.8	86.9	-1.2	2.0
France	0.8	46.0	32.4	-1.6	2.0
Australia	0.5	39.9	40.0	-1.3	2.0
S. Korea	0.6	29.7	28.2	-1.2	2.0
Canada	0.9	20.9	4.7	-1.3	2.0
Italy	0.8	17.1	7.0	-1.2	2.0
Spain	0.7	20.2	14.5	-1.4	2.0
Belg-Lux	0.8	15.4	11.5	-1.3	2.0
Denmark	0.8	10.5	7.0	-1.2	2.0
Brazil	0.8	9.1	6.7	-1.2	2.0
Mexico	0.8	8.5	8.0	-1.2	2.0
Netherlands	0.8	6.6	0.3	-1.4	2.0
Colombia	0.5	4.9	4.9	-1.2	2.0
Other	0.8	42.2	32.4	-1.2	2.0

various regions of the United States. Kolstad and Wolak (1985) use an elasticity of +4.35 for western U.S. coal. We use a conservative estimate of +2.0 for each country's supply elasticity from non-U.S. sources.

Transport costs from the United States to each of these countries (International Energy Agency [IEA], 1983b, p. 45) include U.S. port and ocean freight costs, but do not include unloading costs at the destination port. Table 1 presents the ratio of the U.S. price at the port before it is loaded (**fas** price) to the delivered price. This ratio varies from 0.50 for Australia for 0.89 for Canada.†

These parameters lead to the demand elasticity for U.S. coal. Coal demand in each of the 18 countries which make up the U.S. export market, and the demand met from non-U.S. sources, are presented in Table 1. From (6b), the export elasticity is −16.7. This implies a port services demand elasticity (E_D) of −0.8, as defined by (4), based on values of 2.0 for n_S and 0.32 for t. It is used below in calculating bottleneck costs.

2. A PORT CONGESTION MODEL

Transportation bottlenecks impose both waiting-time costs and deadweight losses. Almost any analysis shows some positive level of congestion, even with optimal congestion tolls. On the other hand, rents accruing to ships' crews and the increased cost of getting the coal through the port, suggest that the congestion facing Eastern U.S. ports in the early 1980s was not optimal.

Consider the demand for port services (D_0), such that Q^C tons of coal are shipped, where Q^C represents shipping capacity (quantity shipped could be less than Q^C). Suppose that the coal demand increases, due perhaps to conversion of electricity generating plants from oil to coal. Without capacity constraints, supply and demand for coal-related transport services should equalize at quantity $Q^* > Q^C$. At that point, any broker willing to pay price $P^* > P^C$ for services, which include applicable charges, congestion tolls (if any), and normal ship waiting time, can load the ships and send the products abroad (see Bobrovitch, 1982, for a good characterization of port costs). With a bottleneck, however, shipments will be constrained to Q^C.

In effect, the supply of port services is totally inelastic at Q^C.‡ Two losses occur in this case. First, lines of ships develop, leading to longer waiting times and attendant costs (this assumes that the price of port services is constrained from rising; if not, then demurrage costs become the port's monopoly rents). Second, the constraint leads to deadweight loss (determined by the constrained quantity, the supply curve, and the demand curve).

Assume that port services demand and supply have the forms:

$$T_D = a_D Q_D^{1/E_D} \tag{7}$$

$$T_S = a_S Q_S^{1/E_S}. \tag{8}$$

E_S and E_D refer to respective port supply and demand price elasticities, and a_D and a_S subsume all non-price

†Reasonable rates are assumed in the calculations for countries not included in the source publication.

‡In fact, supply did not become completely inelastic. In Baltimore, for example, there was some barging of small amounts of coal at very high marginal costs. This short-term expedient was dropped after the first year of the bottlenecks. Alternative shipping routes through the St. Lawrence Seaway also presented very expensive means of increasing short-term supply.

a competitive market, transport demand is the difference between the demand and the supply schedules for coal.

Consider demand and supply functions, and unit transport cost, T:

$$P_D = P_D(Q_D),\ P'_D < 0, \quad (1)$$

$$P_S = P_S(Q_S),\ P'_S > 0, \quad (2)$$

$$T = P_D - P_S, \quad (3)$$

where P is coal price, Q is quantity, and subscripts D and S indicate demand and supply. Differentiating (3) fully yields the demand elasticity (E_D) for transport services (measured as tons of coal transported):

$$E_D = \frac{tn_S n_D}{[n_S - (1 - t)n_D]}, \quad (4)$$

where t is the ratio of transport cost T to the delivered (**cif**) price P_D.

Equation (4) requires estimates of the foreign demand for U.S. coal. One of the more durable methods (Horner, 1952), relies on the identity that U.S. exports, Q_D, equal the demand of its export market D_e (consumption and changes in inventories) minus the amount of obtained from other sources, S_e (home production less exports, plus imports from countries other than the U.S.):

$$Q_D = D_e - S_e. \quad (5)$$

A practical criterion for defining the export market is whether a change in the U.S. price elicits a market response. If either supply or demand responds (the relevant elasticity is non-zero), the country belongs in the U.S. export market. Because most coal-using countries are integrated to some extent into the world trading system, one could argue that the export market facing the United States is the entire world. The major exceptions are the centrally planned economies, in which producer and consumer prices may not be related to domestic supply and/or demand, or to world prices. Coal supplies of these countries may also be constrained by labor availability and the implementation of central plans.

Other exceptions are countries with import (West Germany) or export controls (South Africa). Even with specific controls (like South Africa) or controlled economies (like Poland), there is often some market response. For years South Africa's annual export quota was 28.5 million metric tons. Exports did not approach the limit until 1980. When they did, the quota was raised to 44 million and then to 88 million tons (Wilkinson, 1981, 1982, 1983).

The centrally planned economies† produce (consume) 49 (48)% of all coal. They export more than 50 million metric tons to market economies, representing 19% of the international trade in coal. Since the effect through prices is neither direct nor easily quantified, it is necessary to adjust the calculated elasticity according to subjective opinion about supply and demand from centrally planned economies (Abbott, 1979, treats this systematically).

Equation (5) is differentiated with respect to U.S. price to obtain the U.S. export demand elasticity:

$$n_D = \left[\frac{P_S}{(P_S + T')}\right]\left[\left(\frac{D}{Q_D}\right)I_{DP} - \left(\frac{S}{Q_D}\right)I_{SP}\right], \quad (6a)$$

where (I_{DP}) and (I_{SP}) are demand and supply elasticities (in terms of the importer's domestic price), and where the importer's domestic price (P'_D) equals the U.S. price (P_S) plus the cost of transporting the coal (T'):

$$P'_D = P_{Su} + T'.$$

Ignoring transport costs, (6a) shows demand elasticity for U.S. coal to be the difference between the demand and supply elasticities of its export market, weighted by the level of demand and supply relative to U.S. exports. One can also work with a disaggregated version of (6a). Instead of the entire export market, consider each country or group of countries:

$$n_D = \Sigma\left[\frac{P_S}{(P_S + T_i')}\right]\left[\left(\frac{D_i}{Q}\right)I_{DPi} - \left(\frac{S_i}{Q}\right)I_{SPi}\right], \quad (6b)$$

where i indexes the n countries in the export market. Equation (6b) is similar to (6a). n_D is obtained by summing the export demand elasticities and subtracting the supply elasticities. Elasticities are weighted by the country's demand from non-U.S. sources relative to total U.S. exports.

Estimating each country's demand and supply elasticities in a major task in itself. The literature shows considerable variation in demand elasticities, depending upon the use of the coal. Metallurgical-grade ("met" coal) is used for coke; steam coal is used for generating electricity. Since there are few substitutes for met coal, its demand elasticity is quite small, about −0.2. There are good substitutes in electricity generation, however, so an elasticity of about −1.0 is reasonable (Bohi, 1981, summarizes research on coal demand). Overall demand elasticity is calculated as a weighted (ratio of average coal price to the price of a particular grade) average of the two. Elasticities for countries in the U.S. export market (Table 1) range from −1.2 to −1.6.

There are fewer estimates of supply elasticities, and the range is quite large. Labys and Yang (1980) find supply elasticities ranging +4.4 to +8.8 for

†Referring to China, Mongolia, North Korea, Vietnam, Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Romania, Soviet Union, and Yugoslavia.

1986, the only new large-scale coal-specific investments were in Baltimore (2 piers, 23 million tons) and in Norfolk (2 piers, 27 million tons). Together these represent a capacity increase of 83%, slightly more than the 77% increase in long-term demand that we estimated, although substantially more than the 33% (upper-bound) increase from the bottleneck calculations.

Several other proposals for expanded loading capacity have been either postponed or canceled (some, in fact, started construction but did not finish). In the short term (since the early 1980s), the added capacity has been largely unused. The high exchange rates of 1983–85 hurt U.S. coal in world markets, as has the 1986 fall in oil prices. Coal exports through Baltimore (Norfolk) for 1984 were 7.2 (35.6) million tons, and these represent **increases** over 1983.

Most plans lapsed due to prohibitive landside costs. The marginal cost of shipping coal by rail ($0.0315/ton-mile) is about 20 times the cost by water (Goodman, 1984). Even though mines in the western United States can produce coal at one-third to one-half the cost of eastern mines (minemouth price of $30–35 per ton), rail shipping costs to Seattle or Long Beach limit competition with the East Coast ports, even for coal shipped to Japan. Only the Port of Mobile (with 8.9 million tons in 1984) seems to be competing with Baltimore and Norfolk, and this is due to improved inland water transportation.

One should be cautious about unbridled praises of decentralized responses to transportation bottlenecks, given the vagaries of prediction and the recent excess capacity. Nonetheless, without centralized planning, coal shippers responded to monthly bottleneck costs of $30 million in demurrage and $4 million in deadweight losses by constructing new facilities or converting older ones (the Consolidation Pier in Baltimore was converted from an older grain facility).† Although many facilities were planned, few were built. The 83% increase in capacity provided by the market, although larger than currently needed, and considerably larger than the 33% increase suggested by short-run bottleneck costs, compares favorably with 77% expansion suggested by a long-run model of U.S. coal export demand.

†Although there was considerable discussion of local government construction or operation throughout the United States, the four facilities (in Baltimore and in Virginia) were privately owned and operated. All four obtained subsidized borrowing through industrial revenue bonds, but that was not unusual among industrial investments at that time. The subsidy was available anywhere in the United States, and was not limited to port investment. If anything, its availability most likely increased competition (and the possibility of overbuilding) among ports.

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