PORT PLANNING AND FINANCING FOR BULK CARGO SHIPS

THEORY AND A NORTH AMERICAN EXAMPLE

By Allen C. Goodman*

Port planning has taken a variety of forms throughout Western commercial society in modern times. The United States has given responsibility for harbour facilities to the federal government, but has then allocated responsibility for port capital to individual ports. European and African countries, on the other hand, have generally adopted more centralised planning systems, in which the national governments control both harbour and capital investments. Bennathan and Walters (1979) present an excellent discussion of port planning philosophies.

Increases in ship sizes, as well as increases in trade, have generally led to perceived economies of scale in port operation and to the concentration of port activities in fewer locations. As a result, each port may exercise more monopoly power over foreign trade than could have been possible in the past. This suggests that individual port decisions may not be as economically efficient as they should be in the competitive model, and that centralised planning could internalise some external economies and so remedy the inefficiencies.

This analysis is particularly germane to ports in the Mid-Atlantic region of the United States. Baltimore, Norfolk, Wilmington (Delaware) and Philadelphia all share some common port hinterland for exports of coal, grain, and general and containerised cargo, and for imports of oil, automobiles, and general and containerised cargo. On-shore port facilities are, of course, important, but depth of channel has recently gained great importance with the development of deep-draft tankers and colliers.[1] A further complication is the fact that recently, breaking with long-term policy, the United States federal government has determined that

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[1] Channel length and/or breadth may also form a constraint on access to and from the sea, especially with respect to transport through locks.

each local port should pay a large portion of its dredging costs through a set of local "user fees".[2] These fees could have the impact of diverting substantial traffic from one port to another, pending the completion of the project that is being financed.

This paper applies a simple economic model to the treatment of port-specific capital improvements relative to bulk cargo.[3] The model looks explicitly at ship waiting time as a real port cost, and also at the implications of user financing of port improvements. In addition, it considers various types of strategic behaviour of competing ports. Finally, the model provides mathematical expressions for which empirical data exist, and these data make it possible to estimate the possible impacts of capital financing schemes for the specific case of Baltimore and Norfolk.

COST TRADE-OFFS BETWEEN PORTS

The costs attendant on shipping goods through ports can be divided into four general categories. First, there are the differential ocean costs from using one port rather than another. Second, there are landside transport costs to the users. The third type includes port capital costs and user charges. The fourth type includes ship waiting times, as ships must pay their crews while waiting for port berths. Bobrovitch (1982) provides a substantial theoretical base for several types of conclusions; we will not reiterate them in detail, but we will discuss several salient points.[4]

When we consider the allocation of goods among two or more ports, it is apparent that cargo that is close to one port is "captive"; that is, it costs so much more to go to an alternative port that switching ports is unlikely. Instead, we examine conditions that will cause marginal cargoes to switch. The condition for a shipper to be indifferent between two ports (following Bobrovitch, 1982) is (assuming ocean transport costs are the same):

$$T^1 + W^1 + P^1 = T^2 + W^2 + P^2, \tag{1}$$

where

T^i = landside transport costs from port i

W^i = waiting time at port i

P^i = charges per ship at port i,

and i = 1,2.

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[2] The general nature of these proposed fees is fairly vague; they often rather resemble a type of broadly-based benefits tax.

[3] The multi-port itineraries typical of liner trades, as well as complicated inland transport pricing systems, suggest that a more detailed model would be necessary to treat general and containerised cargo.

[4] Kolstad and Wolak (1983) present a similar model in the context of monopolistic severance tax policy for coal in the western states of Montana and Wyoming.

Bobrovitch points out that, though port authorities do not have direct control over the allocation of ships between ports, they do exercise indirect control through the pricing of port services. He calculates that the efficient port price equates this parameter to the marginal cost of bringing the ship in, plus the increment of increased waiting time that the ship imposes on all other ships in the harbour, a congestion cost.[5]

The decision for individual shippers, though, is based on a combination of port charges and waiting costs (both per unit of cargo). This can be written as:

$$\widetilde{P} = P + R + W\{Q,\, K(R), M[K(R)]\}, \qquad (2)$$

in which

$\widetilde{P}$ = port user cost per unit of cargo
P = charges per unit of cargo, exclusive of special improvement charges
R = charges for special improvement, such as channel dredging
W = average waiting time costs
M = maximum ship size to enter a port
Q = port throughput (in DWT)
K = port capital facilities

where

$$\frac{\partial W}{\partial Q} \geqslant 0\,, \; \frac{\partial W}{\partial K} \leqslant 0\,, \; \frac{\partial K}{\partial R} \geqslant 0\,, \; \frac{\partial W}{\partial M} \leqslant 0\,, \; \frac{\partial M}{\partial K} \geqslant 0\,.$$

This is a straightforward extension of the Bobrovitch model. Here, R is a policy variable, directly analogous to a user fee. Maximum ship size M could refer to draft, width, and/or length, for example, and implies maximum cargo capacity per ship. Thus an increase in M, holding Q constant, implies fewer ships in the port, and so lower average costs of waiting time.

There are several interesting aspects of port managers' decisions to increase port charges. First, special improvement charges are only a part of port user costs. It is perhaps more important that the improvements and higher costs that come to pass serve to offset the increase in R. To see this, ignoring P, differentiate expression (2) totally and rearrange:

$$\frac{\mathrm{d}\widetilde{P}}{\mathrm{d}R} = \left[1 + \frac{W}{R}\eta_{KR}\,(\eta_{WK} + \eta_{WM}\eta_{MK})\right] \Big/ \left[1 - \eta_{WQ}\eta_{Q\widetilde{P}}\frac{W}{\widetilde{P}}\right] \leqslant 1\,. \qquad (3)$$

The expression in the denominator refers to changes on the demand side. If there were no offsets, $\mathrm{d}\widetilde{P}/\mathrm{d}R$ would equal 1. An increase in $\widetilde{P}$ results in diversion of

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[5] A slight reduction in the load of a bulk carrier can give a considerable saving in draft. The same effect can be achieved with twin port operations: the large ship calls at the shallower of the two ports and loads up to the shallower draft, then "tops off" at the deeper port. This leads to a more detailed model that must determine whether two (or more) calls are made, and, if so, how much is loaded at each port. The trade diversion resulting from competitive port behaviour (the main thrust of the paper) is qualitatively similar to the results shown in the model in which only one port is visited, so the exposition following Bobrovitch will be used.

trade from the port, irrespective of how that increase is used. Since $\eta_{Q\tilde{P}}$, the elasticity of quantity shipped with respect to user cost, is negative, and η_{WQ}, the elasticity of waiting time with respect to quantity shipped, is positive, the denominator must be at least one.

Further offsets occur on the supply side. η_{MK} refers to the elasticity of maximum ship size with respect to capital stock and η_{WM} is the elasticity of average waiting time with respect to maximum ship size. The former is positive and the latter negative; therefore their product is negative. η_{WK} refers to elasticity of waiting time with respect to capital stock, and should also be negative; η_{KR} should be positive. All these have the impact of reducing $\tilde{P}$, and the numerator must be less than one. It could, in fact, be negative, if:

$$\eta_{KR}(\eta_{WK} + \eta_{WM}\eta_{MK}) < \frac{-R}{W} . \tag{4}$$

That is, if R is very small relative to W, a small increase in R could lead to a substantial enough drop in W to lead to a fall in $\tilde{P}$.

Bobrovitch (1982) notes that in the United States and Western Europe there is strong competition between ports, and asks whether a competitive port system can be optimal. He finds, in general, that it cannot. A port's specific location causes its inverse demand function to be a decreasing function of the quantity of cargo. Multi-port systems can be shown to be oligopolistic. Several types of behaviour can be posited, and in general the results depend crucially on assumptions of one port's reactions to the action(s) of (an)other(s).

One of the more benign assumptions is that the operators of Port 1 maximise profit on the premise that the operators of Port 2 do not alter their conduct in response. This presumes, for example, that port planners in Baltimore assume that Norfolk port planners do not respond to Baltimore activities, even though Baltimore and Norfolk are only 200 miles apart. This is "Cournot behaviour", and leads to the marginal equilibrium condition of:

$$\begin{aligned} -Q^1\frac{\partial \tilde{P}^1}{\partial Q^1} + T^1(Q^1) + W^1(Q^1,K^1,M^1) + \Delta^1(Q^1,K^1,M^1) + MC^1(Q^1,K^1,M^1) \\ + R^1(Q^1) = -Q^2\frac{\partial \tilde{P}^2}{\partial Q^2} + T^2(Q^2) + W^2(Q^2,K^2,M^2) + \Delta^2(Q^2,K^2,M^2) \\ + MC^2(Q^2,K^2,M^2) + R^2(Q^2) \end{aligned} \tag{5}$$

where:

Q^i = quantity of cargo coming through port i

MC^i = incremental cost of the last cargo coming through port i

Δ^i = additional delay time costs incurred by all ships together as the consequence of the entrance of the last cargo (ship)

Equation (5) differs from (1) unless:

$$Q^1 \frac{\partial \tilde{P}^1}{\partial Q^1} = Q^2 \frac{\partial \tilde{P}^2}{\partial Q^2} ,$$

or, the (inverse) demand elasticities are equal.[6] The efficient charges[7] for the ith port, then, should be:

$$P^i = MC^i(Q^i,K^i,M^i) + \Delta^i(Q^i,K^i,M^i) + R^i - Q^i \frac{\partial \widetilde{P}^i}{\partial Q^i} \tag{6}$$

For the case in which policymakers have control over R (either as a user fee or as one type of revenue), this fee enters equation (5) as:

$$-Q^i \frac{\partial \widetilde{P}^i}{\partial Q^i} = -\widetilde{P}^i \eta_{\widetilde{P}^i Q^i} \equiv -\widetilde{P}^i [\eta_{Q^i \widetilde{P}^i}]^{-1} = -\widetilde{P}^i [\eta_{Q^i \widetilde{P}^i} \eta_{\widetilde{P}^i R^i}]^{-1} \tag{7}$$

$\eta_{\widetilde{P}^i R^i}$, of course, is equation (3) multiplied by $R^i/\widetilde{P}^i$. The necessary parameters for calculating various impacts are, in principle, available.

The Cournot solution presents some analytical problems, however. Each port operator acts as if his competitor's decisions would remain unchanged. In the "real world", it is hard to imagine North American port planners operating in this fashion. In a similar type of analysis Kolstad and Wolak (1983) posit various types of non-cooperative oligopolistic behaviour for the western coal producers; but their solutions, using simulation methods on "pseudodata", are not applicable here.

A POLICY MODEL

The preceding model can be modified to deal with specific impacts of port improvements in the Mid-Atlantic region. Consider the exports of U.S. goods, manufactured or mined in the hinterland, and exported through East Coast ports to Europe or Japan. The relevant ports in the Mid-Atlantic region are New York, Philadelphia, Wilmington (Delaware), Baltimore and Norfolk. Figure 1 displays the spatial aspects of the trade.

For simplicity it can be assumed that on its way to Europe all trade goes in the same direction until reasonably close to the U.S. coast. At that point it branches off to New York, to Philadelphia-Wilmington, or to Baltimore-Norfolk, since the line-haul costs on the water are much less than land line-haul costs. Subsequent figures show that substitution of water for land transport can decrease marginal costs by over 90 per cent.

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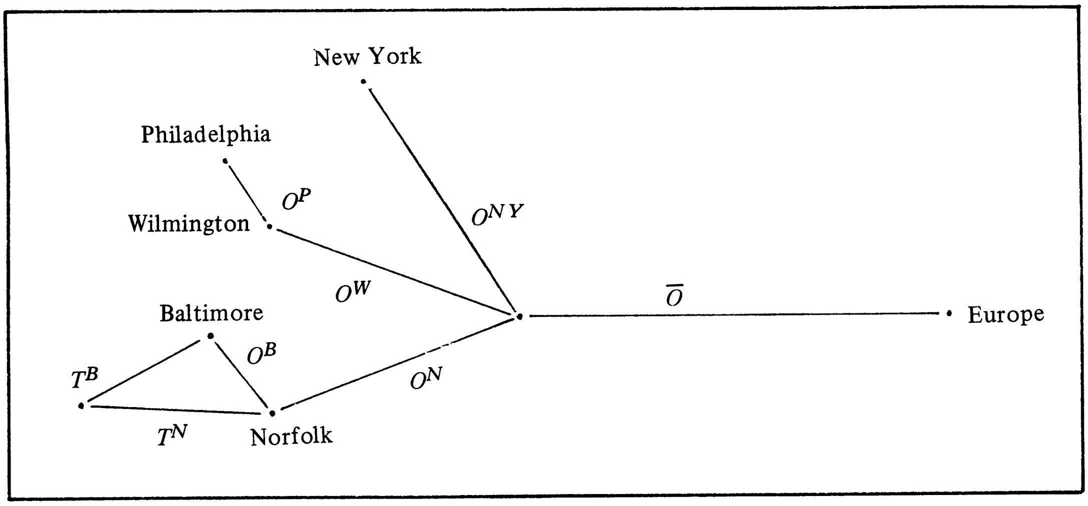
[6] One case where this does hold is in a two-port system in which the ports are located symmetrically and the geographical density function of cargo demand is also symmetrical.

[7] These are derived more fully in Bobrovitch (1982). Marginal costs here reflect possible economies or diseconomies of size in cargo handling. Measurement of these effects has provided mixed results. Heaver and Studer (1972) find decreasing marginal costs for grain loading in Vancouver from 1964 to 1967 for ships up to 35,000 DWT, and Robinson (1978) finds decreasing time costs for general cargo in Hong Kong in 1973. Jansson and Shneerson (1978) find that the size elasticity of the handling capacity is lower than all the size elasticities of factor costs for general cargo ships. If this were not so, there would be no constraint on the continuous growth of ship size from the shipowner's point of view.



Schematic of Ocean Freight Trade Routing

$\overline{O}$ = ocean freight cost from Europe to near U.S.
O^{NY} = incremental ocean cost to New York
O^W = incremental ocean cost to Wilmington
O^P = incremental ocean cost to Philadelphia
O^N = incremental ocean cost to Norfolk
O^B = incremental cost to Baltimore
T^B = land transport cost to Baltimore
T^N = land transport cost to Norfolk

The specific example will examine diversion of trade from Baltimore to Norfolk, though it can, of course, be generalised to more than two ports. An inland trader will be at the margin between ports if the following condition holds:

$$O^N + O^B + T^B + W^B + P^B + R^B = O^N + T^N + W^N + P^N + R^N \qquad (8)$$

where:
O^N = ocean line-haul cost from Mid-Atlantic to Norfolk
O^B = line-haul cost from Norfolk to Baltimore
T^B, T^N = landside transport costs to Baltimore or Norfolk
W^B, W^N = ship waiting time costs in Baltimore or Norfolk
P^B, P^N = port charges in Baltimore or Norfolk
R^B, R^N = special improvement charges for Baltimore or Norfolk

Since there are no differential tariffs between the two ports, and since port values added are roughly the same,[8] this expression simplifies to:

$$O^B + T^B + W^B + R^B = T^N + W^N + R^N \tag{9}$$

In terms of port improvement levies, the individual port has control, in the short term, of R^i only, though in the longer term W^i is also variable. T^i, O^B, W^i and R^i can be obtained for the individual ports. We need also a measurement of "marginal" commerce; that is, the percentage of the coal trade, for example, that might easily switch ports if there were a change in R and/or W. Coal is a salient example of this type of marginal good, and measurements of "marginal densities" are available.

Several types of behaviour can be simulated once the market area has been delineated through equation (9). Cournot behaviour basically assumes a change in R^B (for example) with R^N staying constant. One type of competitive behaviour compares changes in R^B and R^N. Various types of financing can also be simulated by assuming that a change in W^i is effected without much change in the port improvement fee. This might correspond to federal funding of harbour improvement through grants rather than through user fees.

TRADE DIVERSION RESULTING FROM INCREASED COSTS

Several elements of data are necessary to calibrate the model. Published rates and user estimates suggest that marginal rail freight rates for coal are approximately $0.0315/ton-mile.[9] De Borger and Nonneman (1981) estimate the marginal ocean costs of coal freight to be $0.00122/ton-mile in 1979 dollars.[10] Allowance for inflation may raise the rates as high as $0.0015. The simple comparison of rates shows why proximity to the mine is so important. Every mile for which water transport can be substituted for rail cuts marginal transport costs by over 90 per cent.

The second set of data elements properly defines the delivery hinterland. Table 1 shows 137 counties in 6 states which mine coal that is available for export. This table also shows the approximate driving distances to Norfolk and to Baltimore. (These distances may be used as approximations for rail distances, since routings are usually done through large cities.) Summing up over the counties, in 1980, 276.4 million tons of coal were mined. Not all this coal enters the export coal trade. On the other hand, it does represent a potential for export, subject to world demand and the availability of transport facilities.

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[8] $\widetilde{P}$ is the sum of port value added and various port charges. Baltimore and Norfolk are in the same region, with fundamentally the same technologies and cost structures. This implies that the value added to throughput, in making it more accessible to final users, is the same. Goodman, Puryear and Lenze (1983) discuss the derivation of port value added in considerable detail.

[9] Derived from average cost figures based on a rate of $10.00 for a trip of 350 miles. Using regression results from Harris (1977), these are adjusted to marginal costs of $0.0315/ton-mile (1981 dollars). (Source: Consolidated Rail Corporation).

[10] Brinkley and Harrer (1981) show comparable figures for the grain trade.

TABLE 1

Coal and Grain Production by County and Mileages to Norfolk and Baltimore

County of Origin	*Coal Tons (000)*	*Corn Bushels (000)*	*Wheat Bushels (000)*	*Mileage to Norfolk*	*Mileage to Baltimore*
Maryland					
Allegany	1060	142	5	313	141
Anne Arundel	0	754	14	237	32
Baltimore	0	2267	129	249	10
Calvert	0	600	14	204	70
Caroline	0	2592	244	293	82
Carroll	0	4475	301	282	33
Cecil	0	2688	99	317	64
Charles	0	1015	44	179	67
Dorchester	0	2694	179	308	99
Frederick	0	3156	295	257	47
Garrett	2711	305	6	343	189
Harford	0	2625	120	284	39
Howard	0	1451	68	237	22
Kent	0	6401	191	297	86
Montgomery	0	2734	182	225	40
Prince Georges	0	724	18	222	28
Queen Annes	0	6703	259	289	78
St. Marys	0	1076	54	190	93
Somerset	0	1278	22	347	136
Talbot	0	3870	191	285	74
Washington	0	2760	99	285	75
Wicomico	0	1761	32	330	119
Worcester	0	3032	22	360	149
West Virginia					
Barbour	3517	16	0	437	235
Berkeley	0	609	19	318	78
Boone	13710	0	0	437	441
Braxton	428	23	0	403	309
Brooke	879	51	0	555	341
Cabell	0	25	0	430	434
Calhoun	0	4	0	441	445
Clay	104	0	0	406	410
Doddridge	0	3	0	493	284
Fayette	2106	18	0	354	358
Gilmer	77	14	0	438	300
Grant	2411	58	5	382	169
Greenbrier	802	130	5	326	330
Hampshire	0	209	10	377	129
Hancock	0	25	3	514	303
Hardy	0	469	24	349	166
Harrison	3453	10	0	480	254

TABLE 1 (continued)

County of Origin	*Coal Tons (000)*	*Corn Bushels (000)*	*Wheat Bushels (000)*	*Mileage to Norfolk*	*Mileage to Baltimore*
Jackson	0	68	1	449	423
Jefferson	0	1570	52	304	64
Kanawha	8977	5	0	415	389
Lewis	845	22	0	452	188
Lincoln	211	12	0	453	427
Logan	10706	0	0	447	451
Marion	5408	11	0	483	269
Marshall	5102	36	0	522	308
Mason	0	474	14	454	428
McDowell	10255	0	0	429	433
Mercer	727	18	1	363	367
Mineral	363	118	5	401	151
Mingo	5582	0	0	463	467
Monongalia	12766	21	0	486	272
Monroe	0	166	10	336	340
Morgan	0	52	7	258	126
Nicholas	5510	39	1	371	375
Ohio	1369	58	1	539	325
Pendleton	0	238	2	341	220
Pleasant	0	56	0	493	300
Pocahontas	0	53	2	350	304
Preston	2807	235	6	474	223
Putnam	0	93	0	447	421
Raleigh	6715	12	0	364	368
Randolph	1390	106	0	410	228
Ritchie	0	16	0	477	298
Roane	0	9	0	432	436
Summers	0	39	1	330	334
Taylor	62	5	0	455	233
Tucker	199	38	0	435	208
Tyler	0	63	0	438	291
Upshur	2958	11	0	434	269
Wayne	378	37	0	491	470
Webster	548	5	0	387	302
Wetzel	0	15	0	510	295
Wirt	0	21	0	473	335
Wood	0	134	5	490	330
Wyoming	9984	1	0	416	420
Pennsylvania					
Adams	0	2880	227	295	82
Allegheny	3208	153	11	469	258
Bedford	374	1920	55	355	144
Berks	0	7011	512	368	146
Blair	0	1280	29	391	180
Bucks	0	2238	132	381	129
Cambria	6843	567	16	414	203

TABLE 1 (continued)

County of Origin	*Coal Tons (000)*	*Corn Bushels (000)*	*Wheat Bushels (000)*	*Mileage to Norfolk*	*Mileage to Baltimore*
Chester	0	5335	231	352	100
Cumberland	0	3838	247	362	110
Dauphin	23	2593	177	362	110
Fayette	2544	812	25	426	215
Franklin	0	4975	247	308	97
Fulton	49	785	57	327	116
Greene	9539	160	2	448	235
Huntingdon	25	1279	36	376	165
Juniata	0	1291	77	379	127
Lancaster	0	13852	854	319	67
Lebanon	0	3439	158	343	91
Lehigh	0	3401	294	386	134
Mifflin	0	1360	66	394	142
Montgomery	0	1432	96	385	133
Northampton	0	3820	244	406	154
Perry	0	1657	153	360	108
Schuylkill	3803	1864	98	388	136
Snyder	0	1622	97	399	147
Somerset	7061	1504	19	397	186
Washington	10221	932	36	450	239
Westmoreland	1304	1352	66	438	227
York	0	7764	848	306	54
Kentucky					
Bell	6061	0	0	513	636
Breathitt	7559	0	0	530	663
Clay	2595	0	0	550	681
Floyd	5482	0	0	480	634
Harlan	10824	0	0	451	594
Johnson	1224	0	0	498	569
Knott	5829	0	0	489	660
Knox	1942	0	0	533	738
Laurel	1653	0	0	560	707
Leslie	4206	0	0	502	656
Letcher	4887	0	0	461	675
Magoffin	2640	0	0	510	638
Martin	13223	0	0	502	567
Perry	6876	0	0	487	694
Pike	24110	0	0	447	613
Whitley	1414	0	0	548	729
Tennessee					
Anderson	1938	0	0	641	576
Campbell	2056	0	0	673	608
Claiborne	1413	0	0	504	535
Scott	1372	0	0	721	763

TABLE 1 (continued)

County of Origin	*Coal Tons (000)*	*Corn Bushels (000)*	*Wheat Bushels (000)*	*Mileage to Norfolk*	*Mileage to Baltimore*
Virginia					
Augusta	0	1180	108	204	204
Culpeper	0	1143	33	188	96
Fauquier	0	1696	75	204	77
Loudoun	0	3019	189	233	62
Madison	0	883	29	204	147
Orange	0	692	43	188	125
Page	0	328	61	231	121
Rockingham	0	2022	65	245	193
Shenandoah	0	673	42	262	145
Spotsylvania	0	543	21	156	93

Table 2 shows sequentially the set of counties that are located within 50 miles of the equidistance locus between Baltimore and Norfolk. These include 23 counties in West Virginia, one county in Virginia, and two counties in Tennessee. The production for these counties was 78.6 tons, or 28.4 per cent of the potential production. In other words, there is a considerable amount of coal that is distinctly marginal to both Baltimore and Norfolk.

We can re-write equation (9) as:

$$O^B = (T^N - T^B) + (W^N - W^B) + (R^N - R^B) \tag{10}$$

Consider, then, a 50,000-DWT collier that can choose to go either to Baltimore or to Norfolk. At \$0.0015/ton-mile, the trip to Baltimore is \$15,000 more expensive. Assuming for the moment that waiting time and special improvement fees are the same in each port, the differential in cost for rail transport can be evaluated as:

$$T^N - T^B = (\text{cost/ton-mile})\,(D^N - D^B)$$

where the D terms refer to distances to Norfolk and Baltimore. Since ocean costs are slightly higher to Baltimore, it would follow that the hinterland should be slightly closer to Baltimore as well, and it is. Substituting, and solving, $(D^N - D^B) = 9.5$ miles. Thus, though Norfolk is approximately 200 miles closer to Europe and to Japan, the differences in rail costs so far outweigh the differences in ocean costs that the hinterland is almost equidistant.

TABLE 2

*Counties Located within the 50 miles Equidistant Locus**

County of Origin	*Coal Tons (000)*	*Corn Bushels (000)*	*Wheat Bushels (000)*	*Mileage To Norfolk*	*Mileage To Baltimore*	*Difference† ($D^N - D^B$)*
Pocahontas	0	53	2	350	304	46
Jackson	0	68	1	449	423	26
Kanawha	8977	5	0	415	389	26
Lincoln	211	12	0	453	427	26
Mason	0	474	14	454	428	26
Putnam	0	93	0	447	421	26
Wayne	378	37	0	491	470	21
Augusta, Va.	0	1180	108	204	204	0
Boone	13710	0	0	437	441	–4
Cabell	0	25	0	430	434	–4
Calhoun	0	4	0	441	445	–4
Clay	104	0	0	406	410	–4
Fayette	2106	18	0	354	358	–4
Greenbrier	802	130	5	326	330	–4
Logan	10706	0	0	447	451	–4
McDowell	10255	0	0	429	433	–4
Mercer	727	18	1	363	367	–4
Mingo	5582	0	0	463	467	–4
Monroe	0	166	10	336	340	–4
Nicholas	5510	39	1	371	375	–4
Raleigh	6715	12	0	364	368	–4
Roane	0	9	0	432	436	–4
Summers	0	39	1	330	334	–4
Wyoming	9984	1	0	416	420	–4
Claiborne, Tenn.	1413	0	0	504	535	–31
Scott, Tenn.	1372	0	0	721	763	–42

*All counties are in West Virginia unless otherwise noted.
†Difference is: mileage to Norfolk – mileage to Baltimore.

Consider, now, a special improvement fee of \$1.00 per ton, levied by Baltimore but not by Norfolk.[11] From equation (10):

$$15{,}000 = 1{,}575\,(D^N - D^B) - 50{,}000, \text{ or}$$

$$D^N - D^B = 41.3 \text{ miles}$$

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[11] At the time of writing (1984), Baltimore is the only U.S. port authorised to dredge to a depth of 50 feet. The permitting process facing other ports is slow enough to suggest that this advantage will persist over several years.

In other words, a $1.00 per ton tax moves the hinterland nearly 32 miles closer to Baltimore. The 75.8 million tons of coal that could shift constitute 27.4 per cent of the potential going through Baltimore. Trade diversion could be severe.

This analysis is misleading, because a special improvement fee presumably leads to either faster turnround time or to use of the port by more efficient vessels, and thus to reduced costs. The forthcoming example considers this possibility. Charter data suggest that it costs between $7.50 and $10.00 per ton, one way, from Hampton Roads to Rotterdam, for a 50,000-DWT vessel. (See, for example, U.S. Department of Energy, 1979.) A conservative cost saving per ton for a 100,000-DWT vessel would be approximately 25 per cent (de Borger and Nonneman (1981) estimate over 50 per cent). Table 3 displays the cost differential between Baltimore and Norfolk if Baltimore can handle a 100,000-DWT collier, but Norfolk must use two 50,000-DWT colliers.

In the cost of ocean freight, it is $187,500 cheaper to use the larger collier as far as Norfolk. It costs an additional $30,000 to go on to Baltimore, and there is a $100,000 user fee in Baltimore, so the net cost differential is $57,250. Recalculating, the distance differential yields $D^N - D^B = -41.4$, or a shift in the hinterland toward Norfolk of almost 46 miles (i.e. 36.3 – (–9.5)). In those 46 miles there is an enormous amount of coal; this suggests that the elasticity of the quantity shipped to the user cost, or $\eta_{Q_i \widetilde{p}_i}$, may be substantial.[12] Obviously these effects on hinterland depend crucially on the exact specification of fees, waiting times, and freight rates. On the other hand, in view of the locations of coal in the Eastern United States, they are too important to ignore.

It should be pointed out that the cost of channel improvements can vary substantially, as conditions at the site affect capital and maintenance, dredging requirements and construction costs. Thus a special improvement fee to cover these costs may also vary significantly. A primary example of this is the Port of New Orleans, where maintenance requires extensive dredging as silt is deposited by the Mississippi River.

An interesting final aspect in this analysis is the mix of coal trade from the Eastern United States to the two biggest overseas users, Western Europe and Japan. Channel improvements would reduce costs per mile irrespective of the destination, but ships of deep draft cannot go through the Panama Canal. As a result, the port that dredged to accommodate deep draft ships would gain the European trade. The other might plausibly gain the Japanese trade from ships that prefer not to pay the financing charge for the harbour dredging, since it does not help them.

If Baltimore were to dredge, for example, with the accompanying financing, Baltimore might expect to get the supercolliers, while Norfolk would get the Panamax ships. The chief question in this case is whether there would be enough demand from Europe to fill the colliers. Projected demand levels suggest that given current facilities (that is, Baltimore and Norfolk only), there would be adequate demand to support this type of activity.

We spoke earlier of marginal shipments of grains between Baltimore and

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[12] Both the base costs per ton and the conservative cost savings lead to a conservative bias of the hinterland shift.

TABLE 3

Comparative Costs for Super-Colliers paying Channel User Fees

	Carriers			
	Baltimore *1 x 100,000 DWT*		*Norfolk* *2 x 50,000 DWT*	
		$		$
Ocean freight to Norfolk	@ $5.625/ton	562,500	@ $7.50/ton	750,000
Additional freight to Baltimore	@ $0.0015/ton-mile	30,000		0
User fee	@ $1.00/ton	100,000		0
Total ocean cost		$692,750		$750,000

Norfolk, but more detailed analysis shows the amounts to be inconsequential. Only 2.38 million bushels of corn (1980 production), or 1.7 per cent of the production, was marginal between Baltimore and Norfolk, within the 50 mile range. For wheat, only 143,000 bushels, or 0.02 per cent of the potential, was marginal. There may indeed be hinterlands that are marginal with the Great Lakes or Gulf Coast ports, but they are outside the scope of this analysis.

CONCLUSIONS

This paper has extended a model of competitive port behaviour to consider a question of significant relevance to United States maritime policy, the competitive aspects of channel dredging to accommodate deep-draft vessels. The model recognises the possible diversion of bulk cargo from one port to another, largely dependent on comparative cost aspects and on the locations of marginal cargoes. In the case of the North American ports of Baltimore and Norfolk, very plausible policy alternatives could lead to shifts in the coal hinterland of 50 miles or more. In these 50 miles rest over 25 per cent of all the coal mined in the Northern Appalachian coal fields.

Some caveats must be attached to the analysis presented. First, it assumes that railroad pricing policies will not change. The railroads have monopolistic power in this region, and could attempt by raising their rates to capture some of the rents attendent on lower port costs. Also, these changes are necessarily long-run; marginally located producers do not change their shipment locations immediately in response to cost differentials. Nevertheless, the model is suggestive of the policy implications of a whole range of options for port facilities in the system of East Coast United States ports.

APPENDIX A

Analysis of Hinterlands

This analysis was undertaken to determine the amount of coal or grain which might be diverted from one port to another if a special port charge were instituted by either Norfolk or Baltimore. Counties located approximately equidistant from Norfolk and Baltimore might be expected to send their coal to the other port if shipping charges at one port were increased. The analysis was aimed at identifying those counties which lay in this region.

Counties in eastern Tennessee and eastern Kentucky were included if they produced at least 1 million tons of coal. Tennessee or Kentucky counties that produced corn or wheat were not included, since we did not believe that corn or wheat would be transported as far as Baltimore or Norfolk. We selected counties from southern Pennsylvania and northern Virginia which produced 1 million tons of coal, at least 500,000 bushels of corn, or 50,000 bushels of wheat. Finally, all counties in Maryland and West Virginia were used in the analysis.

We computed the distance from each of these counties to Norfolk and to Baltimore. A midpoint of each county was selected, usually located either at a city or at a major main highway intersection. Mileages to cities en route to Norfolk or to Baltimore were then computed, using a combination of the mileage scale as given on the map, distances between points as indicated on the map, and the chart of driving distances. In general, for ease of computation, the routes selected went through larger cities, even if those cities were not on a direct line to the two ports. Finally, the mileages to each port were summed to get the total distance from each county to each of the two ports. As the routes used frequently did not follow a direct line to the ports, just as railroad routes do not, they can probably be used as fair approximations of the distances by rail.

The total amount of coal produced by the 137 counties, located in 6 states, was 276.42 million tons. The amount of corn produced was approximately 143.82 million bushels, and the amount of wheat was approximately 8.48 million bushels.

We then ranked the counties from those that were located substantially closer to Baltimore, to those that were located closer to Norfolk (denoted by negative numbers in Table 2). The amount of coal produced in the area within 50 miles of the equidistant point was 78.55 million tons; that produced within 100 miles was 97.97 million tons. Corn production for the 50 and 100 mile ranges was 2.38 million bushels and 8.78 million bushels, respectively; wheat production was 143,000 and 388,000 bushels respectively.

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