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Market power in transportation: Spatial equilibrium under Bertrand competition

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ABSTRACT

We examine spatial competition along a waterway when shippers are distributed over space. Competition is between barge and rail companies and among barge companies. Equilibrium prices are derived for two variations: oligopolistic rivalry between barge and rail operators, and oligopolistic rivalry among barge operators with terminals located at different points on the waterway. In the first variant, each mode has an advantage over some shippers and transporters' overprice cost advantages (price differences are too small in equilibrium). The second variant delivers a "chain-linked" system of markets, whereby cost changes in one market are passed through equilibrium prices to other markets. Barge operators with cost advantages parlay these into market size advantages.

1. Introduction

Suppliers of transportation have facilities to serve demanders located over geographic space, and spatial differences give rise to market power. We develop a model of equilibrium prices that explicitly recognizes the spatial heterogeneity of suppliers and demanders of transportation. The suppliers of transportation services offer rates from different locations to the final market (s). The demanders (or shippers) also are located at different points in space and as such have heterogeneous preferences across suppliers: ceteris paribus, a closer supplier is preferred. This latter feature imbues the suppliers with market power over those shippers located close by. We consider oligopolistic rivalry first between barge and rail and then among barge companies with spatial location differences. We examine the implications of spatial heterogeneity and market power on the effects of transportation infrastructure investment.

Two main variants are considered in order to address two different aspects of market power in spatially extenuated markets, namely, competition with alternative modes and competition with other operators in the same mode. We first set out the competitive version of the two variants, assuming that modes are priced at marginal cost. We then address market power in the transport sector by assuming that transport rates are set in a non-cooperative equilibrium by operators that have market power due to spatial proximity to some shippers. Even though competition is in prices (the "Bertrand" assumption), equilibrium prices are not set at own marginal cost or rival marginal cost (this is in contrast with spatially discriminatory Bertrand price equilibrium, as analyzed in Anderson and Wilson, 2008). The reason is that transport operators have some market power by dint of their closer location for some of the shippers, and they also are assumed to set a single rate for all shippers served (the no discrimination assumption).

In the first variant of the model, shippers face a mode choice of whether to ship by rail or river, and both modes are operated under market power. We find that whichever mode is cheaper (in terms of fundamental cost) is priced lower to shippers, and so attract more users. However, it will also carry a higher mark-up. This latter propensity of operators to overprice (resting on the laurels of a cost advantage) entails a market failure in the allocation of shippers to modes. Specifically, the fundamentally cheaper mode is actually under-utilized in equilibrium.[1] As we demonstrate, the social value of cost reductions for a mode e.g., barge exceeds the price reduction measured over shippers, but still falls short of that which would be realized if both rail and barge markets were competitive. Thus, only a portion of the cost reduction is passed on to shippers.

The second variant of the model is complementary to the first. Shippers can choose the transport provider to choose within a given mode (e.g., which barge operator). Competition by barge operators then gives rise to a market structure in which markets are vertically

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[1] Similar results were derived by Anderson and de Palma (2001) in a much different context, namely a logit demand model where firms differ by the quality of the product offered. To the best of our knowledge, these results have not been developed in the spatial context.

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stacked.[2] Barge operators compete with their nearest neighbors upstream and downstream. Their interactions lead to an equilibrium in which all markets are "chain-linked" as each neighboring market is affected by its neighbors.

The primary purpose of the paper is to introduce a model of imperfect competition among modes of transportation operating over a network. In the model, firms compete for demanders located over space and are supplied by both rail and barge. This framework is central to assessing the benefits and costs of infrastructure investments such as locks. Currently, waterway policy-makers use a single-mode competitive model to judge benefits. Yet, there are a number of studies (e.g., McDonald, 1987; Anderson and Wilson, 2008) which point to the effects of inter-modal competition on prices. Still others (e.g., Train and Wilson, 2004, 2008a,b) examine shippers' choices and find that markets (i.e., rail and barge) are connected through the demand side. In the present work, we examine the effects of market power over the network both within a mode as well as between modes.

Our work is motivated by the need to calculate benefits of waterway investment by planners in the U.S. but may be applicable in other cases as well. The U.S. Army Corps of Engineers maintain and manage the U.S. waterway system (see the map in the Appendix). The inland waterway system has a network of about 12,000 miles, and handles about 300 billion ton-miles annually (Vachal et al., 2005). The commodities transported are generally bulk commodities (e.g., agricultural, coal, petroleum) and composition varies across rivers – the Upper Mississippi downstream traffic is dominated by agricultural movements, Ohio River traffic is dominated by coal, etc.

Demand derives from spatially distributed shippers that make modal decisions which can and do vary over locations. Supply is provided by truck, rail and barge. While there are a large number of trucking firms, there are only seven major railroads with whom barge companies compete with for longer haul distances. There are large numbers of barge companies that provide service. However, the number of water carriers varies across rivers and within rivers. For example, supply on the Columbia-Snake River is dominated by a single carrier which competes vigorously with railroads (which fits well with the model presented in Section 3).

We also consider barge–barge competition. Indeed, while the number of barge companies that operate in the U.S. is seemingly large (Vachal et al., 2005), they tend to be somewhat specialized in location and service. Using data described in Wilson (2006) that pertain to the Upper Mississippi, we are able to shed more light. Those data consist of movements through the 29 locks of the Upper Mississippi waterway for the year 2000. There are 83 companies that haul commodities southbound. For overall traffic (all locks), the market shares are generally quite small but can be as large as 24 percent. In terms of standard market structure measures, the four firm concentration ratio for traffic passing through the locks is about 66 percent, with a Herfindahl index of 1253. At the lock level, a more narrow market definition, the number of carriers ranges from 2 to 67 at the 29 locks on the Mississippi waterway. The four firm concentration level ranges from 60 percent to 100 percent, and the Herfindahl ranges from 1189 to 9851 with an average value of 2179. It is clear that, based on these figures, the level of competition varies widely along the river. In some locations, the number of carriers is quite small, while in other locations the number of carriers is larger, but the overall indicators of concentration do point to the potential for barge–barge competition addressed in Section 4.

The next section sets out the basic model. Section 3 analyzes the first variant (rail vs. barge), while Section 4 gives the set-up and results for the second variant (intra-barge competition). Section 5 offers some conclusions.

2. The benchmark template for barge–rail and barge–barge rivalry

The geography of the benchmark model is shown in Fig. 1. There is a river running from the North to the South along the y-axis (i.e., $x=0$). Assume that the shippers are located with uniform density over a region of width δ contiguous to the river (this can be thought of as a river valley, say, of fertile land). In the first variant, there is also a parallel railway line at $x=\delta>0$ (the other side of the shippers' locations). There are river terminals at latitudes y_i, $i=1,\ldots,n$, indexed so that a higher value of y_i indicates a location further North. We denote by $\overline{b}_i$ the cost of shipping a unit of the commodity from latitude y_i by river (i.e., by barge) all the way to the final transshipment point (in this case, the southern-most point).[3] Per unit shipping costs rise with the distance shipped, so that $\overline{b}_i<\overline{b}_j$ as $i<j$. These costs denote the actual costs faced by the transport operators. The latter set rates above costs to shippers since the operators have market power.[4]

Likewise, in the first variant of the model when we focus on competition between barge and rail, the cost of shipping a unit of the commodity from latitude y_i by rail to the final transshipment point is $\overline{r}_i$, with $\overline{r}_i<\overline{r}_j$ with $i<j$. It is assumed that each river terminal has a parallel rail terminal (i.e., at the same latitude as the river terminal).[5] We assume that these locations are exogenous. We further assume that $\overline{b}_i<\overline{r}_i$ so that rail transportation is more costly. Since the rail terminal may be closer to some shippers' locations than the river terminal, this does not preclude rail being used by shippers. Moreover, shipping prices are determined by barge operators and by rail companies, and, in equilibrium, these prices reflect a trade-off between volume transported and markup earned. The first objective is to determine how these prices reflect competitive conditions and costs.

To focus on rail–barge rivalry, we assume away rivalry among barge operators (which is the focus of the next section). This we do by assuming that the latitudinal boundary between neighboring barge operators is fixed at $\overline{y}_i$, with $\overline{y}_i\in(y_i,y_{i-1})$. This assumption prevents competition across the latitudinal boundary and allows it only between rail and barge within a given band (or stripe) of latitudes.[6]

The commodity is trucked from the hinterland to either a river terminal or a rail terminal, at rate t per unit per mile. As noted above, we initially assume that shippers must ship to the closer latitude (this will be addressed separately as the main focus of attention in the second variant of the model). Truck transportation follows the block metric (distance between two points is measured as the sum of their vertical and horizontal displacements) and so, for given rates charged for rail and barge transportation, the hinterland will be split into blocks corresponding to demand regions: blocks nearest the river will use barge transportation. A

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[2] A somewhat similar spatial demand system is set up for Cournot competition in Anderson and Wilson (2005).

[3] Much of our work is motivated by agricultural shipments on the Mississippi to New Orleans for export. Ninety percent of corn shipments that originate upstream terminate in the New Orleans area (Boyer and Wilson, 2005).

[4] Thus, we refer to the prices paid by shippers as rates (even though these are the costs paid by the shippers), and we reserve the term "costs" for the fundamental costs.

[5] This we do in order to bring out the basic tensions of competitive rivalry in the clearest manner. The qualitative results should not change if the rail terminals are at different latitudes, though the demand expressions and the equilibrium analysis would be substantially more cumbersome.

[6] For example, $\overline{y}_i$ could be the location of a lock, and we invoke a "no-lock-jumping" assumption. Alternatively, we could use the market boundaries defined from perfectly competitive conditions between barge operators. Then the boundary, as derived below, is given as $\overline{y}_i=(\overline{b}_{i+1}-\overline{b}_i)/2t+(y_{i+1}+y_i)/2$.