JOINT PRODUCTS AND ROAD TRANSPORT RATES IN TRANSPORT MODELS

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Interregional competition and the location of economic activity have been of interest to economists since the early nineteenth century. But progress tended to be theoretical[1] until the development of the activity analysis model of production and allocation. Samuelson [12] was among the first to recognise the empirical potential of this new technique. He extended the conventional, two-region trade model to an "N" region model and showed that, for regions to maximise total gains from trade, the difference between any two regions in the price of a product must be equal to the transport costs of that product between those two regions. Samuelson's model assumed that economic activity occurred at discrete locations in space, and consequently is referred to as the point trading model.

Point trading models, and more specifically the transshipment model, have been the basis of many of the spatial studies published in the last twenty years. The data required for trans-shipment models fall into three broad categories: regional supplies, regional demands, and point-to-point per unit transfer charges.

This paper briefly examines the influence of backloading on the road transport rates used in these models, and suggests that the existing treatment of backloading is unsatisfactory. This may account, in part, for the poor predictive performance of point trading models. A technique of incorporating backloading is developed and evaluated by reference to road transport of wool in Australia.

DETERMINATION OF TRANSFER CHARGES

Haidacher [5] suggests three methods of determining point-to-point transfer charges for empirical studies. These are:

(a) the survey approach,
(b) the cost determination approach, and
(c) the statistical approach.

A survey can be expected to provide accurate estimates of existing transport charges. These existing commercial rates implicitly recognise the cost of institutional barriers, as well as being discounted for the likely availability of backloading on the return journey. However, the technique is prohibitively expensive for large models, because, if the transfer charges on all the possible linkages are to be specified, the number of linkages will be the product of the number of origins by the number of destinations. Thus a 15×15 matrix will require 225 linkages, while a 30×30 will

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[1]A notable exception was the study of Hammerberg, Parker and Bressler [6], which determined boundaries of supply areas by mapping price surfaces.

have 900 linkages. If the numbers of origins and destinations are doubled the number of linkages required must be multiplied by four. Moreover, a survey will not provide information on routes which are of interest but for which rates have not been struck or are unavailable. Consequently, the technique has been applied to small problems [11] and those for which freight schedules are available.

The cost determination approach assumes a perfectly competitive model of the road transport industry and requires knowledge of a complete set of cost/output relationships. From these, transfer charges may be calculated if values of the cost determinants, such as distance, are known.[2]

Many workers ([1], [4], [7]) have used the statistical method to determine transfer charges. This method derives functional relationships, generally by least squares regression, between transfer charges and cost determinants from a sample of transfer charges. These generalised functions are then used to estimate transfer charges on unknown routes.

If the number of possible routes in research models is large, some generalised relationship between transfer charges and the major cost determinants is required. Thus a choice must be made of either the cost determination approach or the statistical approach, or a combination of both.

Backloading, in road haulage, is loading that a truck operator may obtain to utilise the capacity made available between centre j and centre i arising from the previously provided service from i to j. The price at which the haulier can sell this service will depend on the elasticity of demand for the transport service j to i in market j. If there is no demand at any price for the transport service j to i, the haulier will have to charge the total cost of the service, from i to j and then from j to i, to the customer who has goods to be moved from i to j. Alternatively, if the elasticities of demand for the service j to i in market j were the same as for i to j in market i, the user of the service from i to j would be charged for that service only. It is therefore clear that the cost of a transport service in a competitive market depends on the elasticity of demand for the service in the reverse direction. This, together with distance travelled, is the major cost determinant in road transport charges. Despite the importance of backloading, spatial studies which derive generalised transfer costs consider that all routes in the model have identical backloading characteristics, or, more precisely, that the elasticity of demand for transport services in all markets is identical.

Thus the statistical approach usually establishes charges as some function of distance. The basic data for this function are determined from a sample of charge/distance data. These sampled charges will include varying allowances for the availability of backloading on particular routes. Consequently, all route charges derived from this function will have two serious limitations. Firstly, they will contain some unknown allowance for backloading, which is dependent upon the implicit backloading components of the sampled charges. Secondly, all routes derived from this function will be assigned identical backloading characteristics, irrespective of the actual pattern of movement along the routes. These reasons combine to cast doubt on the correctness of road transport data derived by this method in spatial models.

[2] Tramel & Seale [13] discuss a computer program which estimates point-to-point distances from geographical co-ordinants.

Workers using the cost determination approach have also made the assumption that backloading characteristics on unknown routes are identical. Basically, their approach was to determine the per mile cost of operating a fully loaded truck, and to use this cost to establish a per mile charge. One of two possible allowances for backloading is then made. Either it is assumed that backloading is freely available on all return routes at a price equal to that of the outward journey, or it is assumed (as in [10]) that backloading is completely unavailable on all routes at any worthwhile price. In that case, the charge per mile is doubled to cover the return journey.

Doubling the charge per mile where backloading is unavailable does not give a true result unless the per mile cost of running loaded and empty is equal. This assumption is not supported by facts; empty running is cheaper than loaded running, because it takes less time. Two major Australian hauling firms suggested (independently) that in hilly country the saving in time by running empty may be as much as 15 per cent. Another cause of different running costs is the different cost of vehicle tax levied on loaded and unloaded vehicles. A further difference between empty and loaded running costs occurs if drivers suspend a trailing axle when trucks are running empty. This equipment is relatively expensive and is not yet widely used, but the savings in tyre wear are estimated by operators to be 0·25¢ per tyre per mile.

Thus the cost determination approach results in the assumption of identical backloading characteristics for all routes. This assumption is invalid and will cause large discrepancies between the *actual charge* and the *calculated route charge.* This inaccurate specification of transfer charges may, to a significant extent, account for the poor predictive power of point trading models.

Wallace [14] examined the correllation between predicted and actual outcomes of nine American spatial studies. He found the best correllation to be 0·49, while the worst was 0·02. Additionally, the assumption of identical backloading characteristics on all routes would fail to explain the location of many facilities. For instance, in Victoria all wool must move from property to store for sale by way of the State-owned railway; but legislation permits woolgrowers to cart their wool to store on their own vehicles and return with other farm inputs, provided these are not for further sale. Woolgrowers used to return to their properties with empty vehicles, but now superphosphate works have been located at each Victorian selling centre, specifically to utilise this unused trucking capacity.

Therefore, backloading is a vital determinant of point-to-point road transport charges, and the bad performance of many spatial models may be attributed in large part to the assumption that all routes have identical backloading characteristics. The remainder of this paper outlines a method of incorporating backloading in transport problems. As this technique relates to jointly produced outputs, these are briefly discussed.

JOINTNESS IN PRODUCTION

Products may be produced together, either because it is technically necessary to do so or because it is economically advantageous to do so.

When the output of one product results in the production of one or more products, in proportions that are technically fixed (i.e., cannot be varied at will), the bundle of products are called pure joint products. Thus, if X and Y are joint products, an increase in the output of X always results in an increase in the output of Y, and the ratio $\Delta Y/\Delta X$ will be constant for all output levels.

Products X and Y may be referred to as common products if the output of Y, relative to the output of X, is freely variable. The important distinction between joint and common products is the degree of freedom to vary the proportions in which the outputs can be produced.

In freight haulage joint products are important, as the transport capacity on the return journey is the joint product of utilised capacity on the outward journey, i.e., the provision of a transport service from i to j produces an equal capacity from j to i.

The general haulage sector of the road transport industry is almost universally accepted as being highly competitive [9]. In addition to the usual reasons given for the industry's competitive nature, Kolsen [8] suggests that a major contributing factor is that ownership and control of the permanent way is separated from ownership and control of the vehicles moving upon it. Additionally, elements of spatial monopoly are difficult to maintain in the general haulage industry, because it is possible to move firms from one market to another at very low cost. This extreme mobility of firms is created by sub-contractors operating in the industry. A sub-contractor is an owner-driver who transports between terminals operated by a forwarding agent. A sub-contracting firm consists of the driver and his truck. Thus the firm is able to operate in, but not be committed to, spatially separated markets. This ensures that differential price ratios between spatial markets cannot be large and exist for long periods. Because of this highly competitive status, the following equality may be applied to the industry:

$$P = LRAC$$
$$P_{ij} + P_{ji} = LRAC_{ij,\, ji}$$

where P_{ij} is the price charged for the service from i to j and P_{ji} is the price for the return journey. $LRAC_{ij,\, ji}$ is the long-run average cost of providing the "bundle" of services ij and ji.

The price for which these joint products may be sold is dependent upon the demand elasticities for the products. Thus, if the elasticity of demand for transport capacity from i to j was the same as from j to i, the price would be the same in both directions, i.e., $P_{ij} = P_{ji}$. With the cost determination approach, the cost for semi-trailers operating between two markets has been found to be 40¢ per mile travelled. However, if the elasticity of the joint product in market j prevented the product from being sold at benefit to the haulier, it would be treated as waste and the truck would return empty. The cost of running empty for a truck of this type has been found to be 33¢ per mile.

Therefore, if markets i and j have identical elasticities for transport service, $P_{ij} = P_{ji}$, and this rate will be the minimum long-run rate of 40¢ per mile. A charge greater than 40¢ per mile over route ij where $P_{ij} = P_{ji}$ could not exist in the long run, as above-normal profits would be earned and new firms would enter the industry. At the other extreme, where backloading could not be obtained at a price beneficial to the haulier, the charge for the route ij would be 73¢ per mile. Again, in the long run a price greater or less than 73¢ per mile could not be charged for this route, given its backloading characteristics.

The cost incurred in utilising the joint product, the avoidable cost, is given by

$C^f_{ji} - C^e_{ji}$ where C^f_{ji} is the cost of utilising the capacity from j to i, while C^e_{ji} is the cost incurred by returning empty. In this model, the avoidable cost is 7¢ per mile.

If $P_{ji} < (C^f_{ji} - C^e_{ji})$ the haulier would return empty and P_{ij} would equal 73¢ per mile.

If $P_{ji} = (C^f_{ji} - C^e_{ji})$ the haulier would be indifferent and P_{ij} would remain 73¢ per mile.

If $P_{ji} > (C^f_{ji} - C^e_{ji})$ the haulier would accept the load and the difference $P_{ji} - (C^f_{ji} - C^e_{ji})$ would be reflected in P_{ij}, which would range between 73¢ per mile and 40¢ per mile; e.g., if the elasticity in market j allowed $P_{ji} = 9$¢ per mile, the equilibrium price of P_{ij} would be 71¢ per mile.

As backloading is important in determining point-to-point freight charges, but knowledge of backloading on specific routes is limited, how is it to be incorporated in studies of interregional competition? This may be done by classifying routes as:

primary, where $P_{ij} = P_{ji}$;

secondary, where $P_{ij} > P_{ji}$ but $P_{ji} >$ avoidable cost;

tertiary, where $P_{ij} > P_{ji}$ and $P_{ji} <$ avoidable cost;

and establishing a representative per mile charge for each route type.

EMPIRICAL APPLICATION

This technique has been used in a plant location problem involving the optimal siting of Australian wool selling centres. As the model required more than one thousand transfer charges, a survey of rates was not feasible. Of the two general methods of determining these charges, the cost determination approach was chosen.

To evaluate the influence of backloading on freights, routes were classified into the three suggested categories. Primary routes were assumed to be routes between the capital cities – Adelaide, Melbourne, Sydney and Brisbane – and between country centres and capital cities of the same State. As backloading at a price $P_{ij} = P_{ji}$ was known to be available on these routes, a charge of 40¢ per mile was used [3].

Where no significant backloading was available, routes were classified as tertiary. In the location model, these routes linked country centres, and a charge of 73¢ per mile for the dominant journey[3] was assumed.

Secondary routes occur between these two extremes, and in the study were considered to be routes from country centres to capital cities in other States. These routes are known to have backloading available at prices $P_{ij} > P_{ji}$ and $P_{ii} > (C^f_{ji} - C^e_{ji})$. A dominant charge of 56¢ per mile is assumed for these routes. This rate is the mean between primary and tertiary route charges. Additional evidence in support of this last classification is provided by Dent [2], who, in a study of existing Australian wool flows, examined actual receipts for wool movement from southern Queensland to Sydney. These rates average 0·6¢ per bale per mile, or 54¢ per mile. Under the suggested classification, the charge for this route would be 56¢ per mile.

To test the applicability of this method of incorporating backloading, wool freight charges for 19 routes were surveyed. Under the previous classification, six routes are

[3]For convenience, the dominant journey, the route along which the commodity of interest flows, is assumed to be ij.

TABLE I

Comparison of Existing and Calculated per Bale Freight Rates

(Assuming 90 bale loadings per semi-trailer)

Routes From	Routes To	Mileage	Existing Charge/Bale ($)	Calculated/Bale Charges assuming $P_{ij} = P_{ji}$ ($)	Calculated/Bale Charges assuming Backloading unavailable at a worthwhile price $P_{ij} <$ Avoidable Cost ($)	Suggested Route Classification	Calculated Charge/Bale using Suggested Route Classification ($)
Adelaide	Melbourne[a]	470	2·10	2·09	3·81	1°	2·09
Adelaide	Sydney[a]	913	4·00	4·06	7·40	1°	4·06
Adelaide	Geelong[a]	454	2·50	2·02	3·68	1°	2·02
Portland	Adelaide[a]	368	2·50	1·64	2·98	2°	2·29
Brisbane	Sydney[a]	653	2·80	2·90	5·30	1°	2·90
Brisbane	Melbourne[a]	1,092	4·50	4·85	8·86	1°	4·85
Brisbane	Newcaslte[a]	547	2·80	2·43	4·44	1°	2·43
Inverell	Brisbane[b]	263	1·50	1·17	2·13	2°	1·64
Glen Innes	Brisbane[b]	237	1·50	1·05	1·92	2°	1·48
Warialda	Brisbane[b]	261	2·00	1·16	2·12	2°	1·62
Delunga	Brisbane[b]	255	2·00	1·13	2·07	2°	1·59
Bingara	Brisbane[b]	282	2·00	1·25	2·29	2°	1·75
Barraba	Brisbane[b]	320	2·20	1·42	2·60	2°	1·99
Brisbane	Dalby[a]	136	1·35	0·60	1·10	3°	1·10
Brisbane	Roma[a]	304	2·85	1·35	2·47	3°	2·47
Brisbane	Texas[a]	191	1·80	0·85	1·55	3°	1·55
Brisbane	St. George[a]	326	3·10	1·45	2·64	3°	2·64
Brisbane	Goondiwindi[a]	228	2·15	1·01	1·85	3°	1·85
Brisbane	Dirranbandi[a]	376	3·35	1·67	3·05	3°	3·05
Sum of the squares of the differences between calculated per bale charges and existing per bale charges (dollars)				14·5739	45·5443		1·6382

[a]Charges determined from road haulage companies. [b]Charges collected from wool store receipt dockets.

primary, seven are secondary, and six are tertiary. The per mile charges for these routes were established under each of the following assumptions:

(a) All routes are assumed to have backloading freely available at a price equal to the price for the dominant route, i.e., $P_{ij} = P_{ji} = 40¢$ per mile.

(b) All routes are assumed to have backloading unavailable at any worthwhile price. In this case, $P_{ji} < (C^f_{ji} - C^e_{ji})$ and the charge for the dominant route is assumed to be 73¢ per mile.

(c) Routes are classified on the suggested basis as primary, secondary and tertiary. The assumed rates are 40¢, 56¢ and 73¢ per mile, respectively.

The sum of the squares of the deviation between existing (surveyed) per bale charges and calculated charges for each of the above assumptions was taken as a measure of the appropriateness of each assumption. These data are presented in Table I.

If the suggested classification is used, the sum of the squares of the deviation from existing charges is considerably less than the deviations observed if homogeneous backloading characteristics on all routes are assumed. On this evidence it is submitted that route charges established in this way provide a better picture of reality than charges derived on the assumption that the per mile characteristics of individual routes are identical. Consequently, the use of the suggested classification is likely to improve the poor predictive power of point trading models.

In some cases the route classification may change with a change in the direction of the wool flow. This happens because the volume of other goods transported along a specific route may be "thin", that is, wool provides the major volume moving along the route. As an illustration, consider the wool flow from i, a country centre, to j, a State capital. The dominant route (considering wool) is i to j, and the appropriate route classification is primary, as backloading from j to i is available at a price of approximately $P_{ij} = P_{ji}$. Considering the same route for other commodities, the dominant route is from j to i, and wool provides the backloading.

But now consider the hypothetical case of a selling centre in i drawing wool from j. In this instance the dominant route is from j to i. But this also is the route along which the non-wool commodities flow. Consequently, if a hypothetical selling centre were established in i, backloading to j would be scarce at any price, and so the appropriate route classification would change from primary to tertiary. A similar argument also applies to secondary routes, which change to tertiary routes if the direction of the wool flow is reversed. The routes between capital cities are primary and are not affected by the direction of the wool flow, because wool provides only a small component of their total volume of trade.

CONCLUSION

When the survey approach is used to establish point-to-point transfer charges in transport problems, backloading need not be considered explicitly, as the rates established for these routes include appropriate backloading allowances. However, the survey approach is not useful for models having numerous origins and destinations. In these cases a general method is used to establish point-to-point road transport charges. For these rates to be realistic, the effect of backloading must be considered explicitly.

A method has been outlined which allows the effect of backloading on specific route charges to be approximated. These charges are significantly better approximations of actual rates than those established by the cost determination or statistical approach. Consequently, policy decisions made on the basis of these models are likely to be more reliable than decisions based on results of models which do not consider backloading explicitly.

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