Policy, Planning, and Research
WORKING PAPERS
Transportation

Infrastructure and Urban Development Department
The World Bank
January 1990
WPS 359

A Survey of Recent Estimates of Price Elasticities of Demand for Transport

Tae H. Oum
W. G. Waters, II
and Jong Say Yong

Since transportation is a derived demand, it tends to be inelastic. Exceptions are discretionary travel and some freight shipments subject to intermodal competition.

This paper — a product of the Transportation Division, Infrastructure and Urban Development Department — forms part of an ongoing project in PPR on Pricing, Cost Recovery, and Efficient Resource Use in Transport. It assembles empirical evidence on the broad order of magnitude of the price elasticities of demand for transport on the assumption that optimal departures from marginal cost prices are set in relation to the inverse of these elasticities. Copies are available free from the World Bank, 1818 H Street NW, Washington DC 20433. Please contact Wendy Wright, room S10-055, extension 33744 (34 pages with figures, tables, and appendices, plus 22 pages of an annex).

Oum, Waters, and Jeng review 70 estimates of the price elasticity of demand for transport published in recent journal articles, estimates covering many different transport modes and market situations and employing various statistical methods and data bases.

The authors present figures separately for passenger and freight transport and include estimates of both own-price and mode choice elasticities — in the form of a range and a "most likely" estimate. They also present some elasticity estimates on demand for gasoline, together with selected cross-price elasticities (the impact on demand for one mode of transport resulting from a change in the price of another). In addition, they include a brief exposition on the different concepts of elasticity — compensated, uncompensated, price, cross-price, and mode choice — and discuss the relations between them.

The authors show that, since transportation is a derived demand, it tends to be inelastic. Exceptions are discretionary travel and some freight shipments subject to intermodal competition. Although the review is confined to estimates of price elasticities, it notes that quality variables are often more important than price, particularly in the air, motor freight, and container markets. Finally, most of the estimates relate to developed countries, reflecting the availability of data, research resources, and domicile of the researchers. The elasticity estimates are nevertheless thought to be relevant to developing countries as well. But since intermodal competition is generally less intense in developing countries, this tends to make transport demand more inelastic, although the lower income levels in such countries may partly offset this effect.

A Survey of Recent Estimates of Price Elasticities of Demand for Transport

TABLE OF CONTENTS

This paper was prepared as part of a project on Pricing, Cost Recovery and Efficient Resource Use in Transport. It was prepared by Tae H. Oum, W.G. Waters II and Jong Say Yong from the Center for Transportation Studies, University of British Columbia under the direction of Ian G. Heggie, INUTD.

A Survey of Recent Estimates of Price Elasticities of Demand for Transport

I. Introduction

There have been numerous empirical studies of the demand for transport in the past decades. With advances in computer technology, many previously inapplicable or impractical econometric methods have been applied to the field of transportation. Researchers have become more aware of pitfalls which can undermine empirical studies. In recognition of advances in the ability to estimate demand functions, this survey concentrates on the major empirical studies of own-price elasticities of demand for transport that emerged in the last ten years or so. As the title of this paper suggests, only studies which contain empirical results are included. We also omit most survey papers, but generally we include studies mentioned in these surveys. For example, the review article by Winston (1985) is not recorded in our survey, but all the demand articles cited therein are included in this review.

II. Sources of Demand Studies

With the emphasis on more recent studies, most of the studies reviewed are those which appeared in the 1980s. We have included a few studies that date back into the 1970s, primarily because of their importance in the literature. The earliest study included in this paper is the work by McFadden (1974). Our survey does not go back earlier hence empirical estimates published in the 1960's (e.g., the "abstract mode" model by Quandt and Baumol, 1966) are not included.

The majority of the studies reviewed are journal articles, for the simple reason that this is the avenue most authors use in communicating their research findings. We include a few studies not reported in academic journals. These entries generally are for modes or markets for which we did not find empirical estimates of elasticities in the published academic literature.

The literature review began with the collection of journal articles in Waters (1984, 1989). Because only articles appearing in major economics journals are included in Waters' collection,[1] we also searched most major journals pertaining to the field of transportation. Among these are Transportation Research Series A and B, Transportation, Transportation Quarterly, Transportation Journal, and Logistics and Transportation Review (a list of journals scanned is included below as Appendix 1). As noted, a few other sources were used, e.g., government reports. The search for these entries was much less extensive.

A total of 70 entries (journal articles, reports and books) were reviewed and summarized in a report appended to this paper. In view of the vast literature related to transport demand, some omissions are inevitable. Nonetheless, the articles reviewed provide a basis for identifying "typical" price elasticities of demand for transportation.

Some summary statistics about the review are reported in Table 1. The articles and studies are drawn from several countries, cover many different modes and market situations, and employ various statistical methods and data bases. The individual articles are summarized in the annotated bibliography attached to this survey as Annex A.

III. Concepts of Elasticities

The basic concept of an elasticity and its application to demand are well known. An elasticity is the percentage change in one variable in response to a percent change in another. In the case of demand, the own-price elasticity of demand is the percentage change in quantity demanded in response to a one percent change in price. The own-price elasticity of demand is expected to be negative, i.e., a price increase decreases the quantity demanded. Demand is said to be "price-elastic" if the absolute value of the own-price elasticity is greater than unity, i.e., a price change elicits a more than proportionate change in the quantity demanded. A "price-inelastic" demand has a less than

---

1 Waters' bibliography covers 40 economic journals. It includes the Journal of Transport Economics and Policy, International Journal of Transport Economics as well as some journals related to regional and urban economics.

proportionate response in the quantity demanded to a price change, i.e., an elasticity between 0 and -1.0.

Economists distinguish between two concepts of price elasticities: "ordinary" and "compensated" demand elasticities. We explain the distinction separately for consumers' demand in contrast to input demands such as freight transport demands. For a consumer demand such as the demand for leisure travel, a change in price has two effects, a substitution effect and an income effect. The substitution effect is the change in consumption in response to the price change holding real income (utility) constant. A change in price of a consumer good or service also has an income effect, i.e., a reduction in price means a consumer has more income left than before if the same quantity were consumed. This change in real income due to the price change will change consumption (it could be positive or negative depending on the relationship between income and consumption).[2/] The compensated elasticity measures only the substitution effect of a price change along a given indifference surface (Hicksian demand), whereas the ordinary demand elasticity measures the combined substitution and income effects of a price change (Marshallian demand).

The principles are the same for freight transport demands although the terminology differs. A change in the price of an input to a production process, such as freight transport, has a substitution effect as well as a scale or output effect. The substitution effect is the change in input use in response to a price change holding output constant. But a reduced price of an input increases the profit maximizing scale of output for the industry (and firms in the industry) which, in turn, increases demands for all inputs including the one experiencing the price change. As with passenger demands, a compensated elasticity measures only the substitution effect of the price change, while an ordinary elasticity measures the combined substitution and scale or output effects of a price change.

---

2 An income elasticity refers to the percentage change in quantity demanded accompanying a given percentage change in income, prices held constant. No income elasticities are reported in this study.

It is important to recognize that for measuring the ordinary price elasticities for freight demand, the freight demand system must be estimated simultaneously with the shippers' output decisions, i.e., treating output as endogenous. Ignoring the endogeneity of shippers' output decisions is equivalent to assuming that changes in freight rates do not affect output levels. This, in turn, is equivalent to ignoring the secondary effect of a freight rate change on input demand caused by the induced change in the level or scale of output. Because most of the freight demand models reviewed in this survey do not treat this secondary effect properly, the price elasticity values reported here may be biased. Since the mid-1970s, many economists have estimated neoclassical input demand systems by deriving them from the firm's or industry's cost (production) function, often specified in a translog or other flexible functional form (for example, Oum 1979b and 1979c, Friedlaender and Spady, 1980, and Spady and Friedlaender, 1978). However, most of these models are derived by minimizing the input costs (including freight transport costs) for transporting a given (exogenously determined) output, and thus yield compensated demand elasticities rather than ordinary demand elasticities. Therefore, the elasticities reported in such studies are not directly comparable with those of other studies. The freight demand study by Oum (1979c) is an exception in that he computes the ordinary price elasticities by adding the effects on demand of the changes in output scale induced by a freight rate change to the compensated price elasticities computed from the neoclassical freight demand system. Therefore, his ordinary price elasticities are comparable with those of others. Because virtually all freight demand studies report something close to ordinary demand elasticities, that is the appropriate interpretation of the results in this survey.

Passenger demand models normally are derived by maximizing, explicitly or implicitly, the utility function subject to the budget constraint. These give ordinary price elasticities, i.e., they include both income and substitution effects.[3] Because virtually all passenger demand studies report ordinary demand elasticities, that is the appropriate interpretation of the results in this survey.

The own-price elasticity is distinguished from cross-price elasticities. The latter is the percentage change in quantity demanded, say rail traffic, in response to a percentage change in the price of another service such as trucking. For substitutes, the cross-price elasticity for compensated demand is positive. If two products were unrelated to one another in the minds of consumers, the cross-price elasticity of the compensated demand would be zero, and cross-price elasticities are negative for complementary goods and services.

It is important to distinguish between the overall market elasticity of demand for transportation and the demand facing individual modes of transport. The market demand refers to the demand for transportation relative to other (non-transport) sectors of the economy. The price elasticity of demand for individual modes is related to but different from the market elasticity of demand. Under the usual aggregation condition (i.e., conditions for existence of a consistent aggregate), the linkage between mode-specific elasticities (own-price elasticity F_{ii} and cross-price elasticities F_{ij}) and the own-price elasticity for aggregate transportation demand (F) can be written as [4]:

(1) $F = \Sigma_i S_i \ (\Sigma_j \ F_{ij})$

where S_i refers to the volume share of mode i.

---

3 If one derives passenger demand by minimizing consumer's expenditure function for achieving a given utility level (or simply apply Hotelling's lemma to the expenditure function to derive the demand functions), then the resulting demand function would be a compensated one (i.e., changes along an indifference frontier).

4 In a simple two mode case, it becomes:
$F = S_1 * (F_{11} + F_{12}) + S_2 * (F_{21} + F_{22})$.

The above relationship indicates that the own-price elasticity of aggregate transport demand for a particular market is lower, in absolute value, than the weighted average of the mode-specific own-price elasticities because of the presence of positive cross-price elasticities among modes. The relationship among the concepts of price elasticities are illustrated in Figure 1. Note that, because the number of modes can differ across studies and cross-price elasticities differ as well, the own-price elasticity estimates from different studies may not be strictly comparable.

One could also focus on own- and cross-price elasticities facing individual firms. These differ from modal or market elasticities of demand. Firm elasticities vary considerably depending upon the extent and nature of competition.[5] Empirical estimates of transportation demand rarely focus on demand elasticities facing individual firms, hence we do not consider them further in this review.

There is also a distinction between short-run and long-run price elasticities. In the long run consumers (or firms) are better able to adjust to price signals than in the short run. Hence long run demand functions tend to be more elastic (less inelastic) than short run demand. Unfortunately, few studies are explicit about the time horizon of their elasticity estimates.

Concepts of demand elasticities for transportation are further complicated by mode choice (mode split, volume share) elasticities.[6] Many transportation

---

5 The elasticity of demand facing a firm depends greatly on the nature of competition between firms, e.g., Cournot quantity game, Bertrand price game, collusion, etc. A growing number of economists have looked at the price sensitivity of demand facing a firm within the framework of conjectural variations. See Appelbaum (1982) and Slade (1984). As far as we are aware, the only example of this kind applied in transport pricing is Brander and Zhang (1989) to inter-firm competition between duopoly airlines in the U.S.

6 In many of the early studies of mode choice, logit models were applied to route (or regional) aggregate market share data. Application of a logit model to aggregate data not only leads to a loss of important information about changing market size in response to a price change, it also has a serious theoretical inconsistency as analyzed by Oum (1979).

demand studies are mode choice studies, i.e., studies which predict shares of a fixed volume of traffic among modes and investigate users' mode choice behavior. These produce own-price and cross-price elasticities between modes but they differ from ordinary demand elasticities described above in that they do not take into account the effect of a transport price change on the aggregate volume of traffic. One can derive mode-split elasticities from ordinary elasticities but this entails a loss of information, and thus rarely would be a useful exercise. Because ordinary price elasticities generally are more useful than mode split elasticities, it is desirable to be able to convert mode choice elasticities to ordinary elasticities.

The relationship between mode choice (or share) elasticities and ordinary demand elasticities can be summarized by the following formula (see Taplin, 1982, and Quandt, 1968).

(2) $$F_{ij} = M_{ij} + \epsilon_j \quad \text{for all i and j.}$$

where F_{ij} is the price elasticity of the ordinary demand for mode i with respect to price of mode j, M_{ij} is the mode choice elasticity of choosing mode i with respect to price of mode j, and ϵ_j is the elasticity of demand for aggregate traffic (Q, including all modes) with respect to the price of mode j. Because information on ϵ_j's usually are not available, the following formula may be used to compute them.

(3) $$\epsilon_j = \frac{\delta Q}{\delta P_j} * \frac{P_j}{Q} = F * \frac{\delta P}{\delta P_j} * \frac{P_j}{P} < 0$$

where F is the price elasticity of aggregate transport demand ($[\delta Q/\delta P]*[P/Q]$), and $[\delta P/\delta P_j]*[P_j/P]$ is the elasticity of aggregate transport price P with respect to the price of mode j. Therefore, an explicit conversion of a mode choice elasticity to an ordinary price elasticity of demand for a mode requires information about either the elasticity of aggregate transport demand with respect to price of each mode (ϵ_j) or the price elasticity of aggregate transport demand (F) and the second term in equation (3). Unfortunately, this information is not available in the studies reviewed. As a consequence, it is virtually impossible to draw on the extensive mode choice literature to help establish likely values of ordinary demand elasticities. However, a special case of equation (2) for the expression for own-price elasticity, $F_{ii} = M_{ii} + \epsilon_i$, indicates that, in terms of absolute value, the own-price mode choice elasticity (M_{ii}) understates the ordinary own-price elasticity (F_{ii}) because ϵ_i is negative. The size of the difference, $\epsilon_i = F_{ii} - M_{ii}$, can not be determined without further information.[7] However, this tells us that the own-price elasticities for mode choice are the lower bounds for ordinary elasticities in terms of absolute values.

Taplin (1982) pointed out that it is not possible to derive ordinary elasticities unambiguously from mode split elasticities without further information. He suggested that estimates of ordinary elasticities could be constructed using equation (2) in conjunction with an assumed value for one ordinary demand elasticity, and various constraints on elasticity values based on theoretical interrelationships among a set of elasticities. This is illustrated in Appendix 3. However, the accuracy of ordinary price elasticities computed this way depends heavily upon the validity of the ordinary elasticity term chosen to initiate the computation.

Finally, we should emphasize that this review is confined to estimates of the sensitivity of transport demands to price. In many markets, particularly for higher valued freight and passenger travel, quality variables may be more important than price. Indeed, the thriving air, motor freight and container markets are testimony to the importance of service quality relative to price in many markets. This review has not looked into "quality elasticities", but this is not to suggest that they are not important.

7 Taplin (1982) notes that the sum of these "second stage elasticities," $\Sigma_j \epsilon_j$, is the price elasticity of the aggregate demand in equation (1).

IV. Estimates of Price Elasticities

The price elasticity estimates for various passenger and freight demands for transport are presented in Tables 2 and 3. Appendix 2 provides a more detailed listing of price elasticity estimates, and Annex A is an annotated bibliography of the studies reviewed in connection with this study.

The first sub-section below comments briefly on our summary of elasticity results. Subsequent sub-sections comment on the variability of estimates of transport demand elasticities across different studies, and how we arrived at a "most likely" range of price elasticities of demand for various transport markets.

A. Summary of elasticity results

Tables 2 and 3 report both own-price as well as some mode choice elasticities. As noted earlier, mode choice elasticities can be linked to ordinary demand elasticities providing sufficient information is available. Unfortunately, virtually no mode choice study reports the required information. As a result, we were unable to convert mode split elasticities to ordinary elasticities. We present mode choice elasticities in brackets in Tables 2 and 3 (and in separate columns in Appendix 2). It is important to recognize that the mode split elasticities are not directly comparable to the ordinary own-price elasticities (the mode choice own-price elasticities underestimate corresponding ordinary own-price elasticities).

Some elasticity estimates for a relevant but mode-specific market, the demand for gasoline, are presented in Table 4 below. Most of the estimates in this table are taken from the survey paper by Blum, Foos and Gaudry (1988). They surveyed a total of 21 studies.

The focus of this survey is on the own-price elasticity of demand. We did not emphasize cross-price elasticities in our review. Unlike own-price elasticities, we find almost no ability to generalize about cross-price elasticities. They are very sensitive to specific market situations and to the degree of aggregation of the data. Examining differences in cross-price elasticities across studies is likely to reflect primarily the differences in data aggregation among the studies rather than systematic properties of cross-elasticity values. Nonetheless, we selected a few cross-price elasticity estimates from studies with a relatively high degree of aggregation (thus more representative of "average" conditions). These results (from Oum, et al.) are reported for passenger and freight markets in Table 5. We reemphasize that this table draws from only a few articles and that one must be cautious in generalizing about cross-price elasticities in transport.

B. The variability of elasticity estimates

A notable feature of the elasticity estimates is the wide range of values in most cases. Many factors may have contributed to this diversity, among them are:

(i) **Some studies fail to control for the presence of intermodal competition.** As a result, the own-price elasticity estimates reflect, in part, the intensity of intermodal competition. If the prices of competitive modes change in the same direction as a mode's own-price, then the own-price elasticities are underestimated.

(ii) **Failure to recognize the presence of multicollinearity, autoregressive errors and other specification problems.** In a few cases we feel that there is a high probability of model misspecification, hence empirical estimates may not be reliable.

(iii) **Different functional forms used.** It is demonstrated in Oum (1989) that, with the same set of data, different functional forms could result in widely different elasticity estimates.

(iv) **Different definitions of variables used.** For example, some studies use real vehicle operating costs while others use the nominal values, and some studies normalize costs by income while others do not.

(v) **Different time periods and locations.** It is well-known that a long run elasticity is higher than a short-run elasticity because users have more time to adjust to price changes. In addition, data drawn from different countries may show markedly different elasticity estimates. In general, we expect that elasticity estimates for developing countries tend to be less elastic due to their less competitive market structure compared to industrially advanced countries.

(vi) **The degree of aggregation.** As more disaggregated markets are investigated, the range of elasticity estimates tend to widen because individual estimates will reflect quite unique market conditions. Aggregation "averages out" some of the underlying variabilities of price sensitivity in different markets.

The many sources of variability and differences in interpretation of elasticity estimates make it difficult to generalize about probable values for elasticities. Nonetheless, Tables 2 and 3 include our estimates of "most likely" values for own price elasticities in various markets.

C. Most likely values of price elasticities

In Tables 2 and 3, we construct a "most likely" range of elasticity estimates. It is subjective but based on a number of considerations in reviewing the many demand studies. First, some of the extreme values for elasticities were eliminated. We did not automatically eliminate references just because their results seemed out of line. Rather we reviewed the approach or types of data employed to see if that might influence the magnitudes of elasticity estimates. For example, in the case of air passenger travel, the elasticity estimates of Hensher and Louviere (1983) were omitted from consideration because the study was based on inflight interview data of a single airline for a single route. These results are not directly comparable to other studies which estimate a market demand elasticity. Some other examples with seemingly high elasticities had quality of service attributes included in their estimate of price elasticities.[8]

Where numerous studies are available, this generates a wider range of estimates but gives us more confidence in narrowing the most likely range. Also note that the distribution of elasticity estimates for a category are often concentrated within a narrow range, and this is taken into account in identifying the most likely range.

Where only one or two studies are available for a category, and where they are single estimates or only a narrow range reported, we generally postulate a wider "most likely" range than that reported in our small sample. In a few cases, particularly for specific commodity classifications, we do not venture an opinion on a most likely range for the elasticity.

Tables 2 and 3 include some mode choice elasticities. Unfortunately, it was not possible to transform mode choice elasticities into ordinary elasticities. Nonetheless, we tried to give some recognition of mode choice elasticities in constructing our "most likely" range of ordinary elasticities. Mode choice own-price elasticities are less than ordinary own-price elasticities, and occasionally this would influence our choice of an upper- or lower-bound for our most likely range.

For the most part, we were unable to categorize the various elasticity estimates as "short run" or "long run." Most studies make no reference to the

---

8 The elasticities of air passenger demand estimated by Anderson and Kraus (1981) were excluded. They estimate a "full price" elasticity, one where the monetary value of quality of service is included in the definition of price. That is, their elasticities incorporate both fare and quality elasticities, whereas our survey is confined strictly to the own-price or fare elasticity. Similarly, the freight demand elasticities estimated by Friedlaender and Spady(1980) were excluded because some quality of service attributes were included in their price elasticity estimates.

implied time horizon.[9] As a rough guide, cross-sectional data sets are thought to represent long run relationships whereas time series data (especially if monthly or quarterly data are used) reflect short run demand relationships. But this is not an unambiguous guide, and panel data sets (combined cross-section and time series data) further complicate interpreting the time dimension of elasticity estimates. For those demand categories with several elasticity estimates, we compared elasticity estimates for different data sets. The pattern is not clear. There is a tendency for cross-section data to produce more elastic (less inelastic) estimates, but there is no precise relationship. Consequently, our "most likely" range of elasticities is ambiguous concerning the implied time horizon, but we expect that the upper range of our range (in absolute values) corresponds to long run as opposed to short run elasticities.

V. Conclusion

Not surprisingly, because transportation is a derived demand, it tends to be inelastic. But there are exceptions, such as discretionary travel and some freight shipments. Our interest in this review is in own-price elasticities, i.e., the sensitivity of shippers or travelers to the price charged for transportation service. We exclude quality of service elasticities and, for the most part, cross-price elasticities from our review. Many demand studies investigate markets where there is competition from other modes. Even if the overall demand for transport by shippers or travelers is highly inelastic, the presence of competition generally causes the own-price elasticity of demand for a specific mode to be less inelastic than for the market as a whole. Therefore if one were interested in the overall or market price elasticities of demand for transport, we judge that they would be toward the inelastic end of the spectrum of empirical estimates we have surveyed.

The majority of studies are from developed countries. Presumably this reflects the availability of data, research resources, and domicile of those

---

9 This is in contrast to estimates of cost functions which almost always state explicitly whether short run or long run interpretations are involved.

doing the research. The empirical estimates of price elasticities are expected to be relevant to developing countries as well, subject to some caveats. The first general caveat is that specific values for elasticities can vary significantly from one market situation to another, therefore one must be cautious in generalizing from one situation to another whether it is in a developed or developing country. Second, a likely difference is that the degree of intermodal competition generally is much less intense in developing countries. This would tend to make transport demands more inelastic in developing countries. A third qualification is that the price elasticity of demand may differ according to income levels. One might argue that lower income groups would tend to be more price sensitive, although it is equally plausible that lower income groups have fewer transportation options thus inelastic demands. Given the diversity of market conditions in different countries for different travel or commodity markets, we do not think a broad generalization is possible.

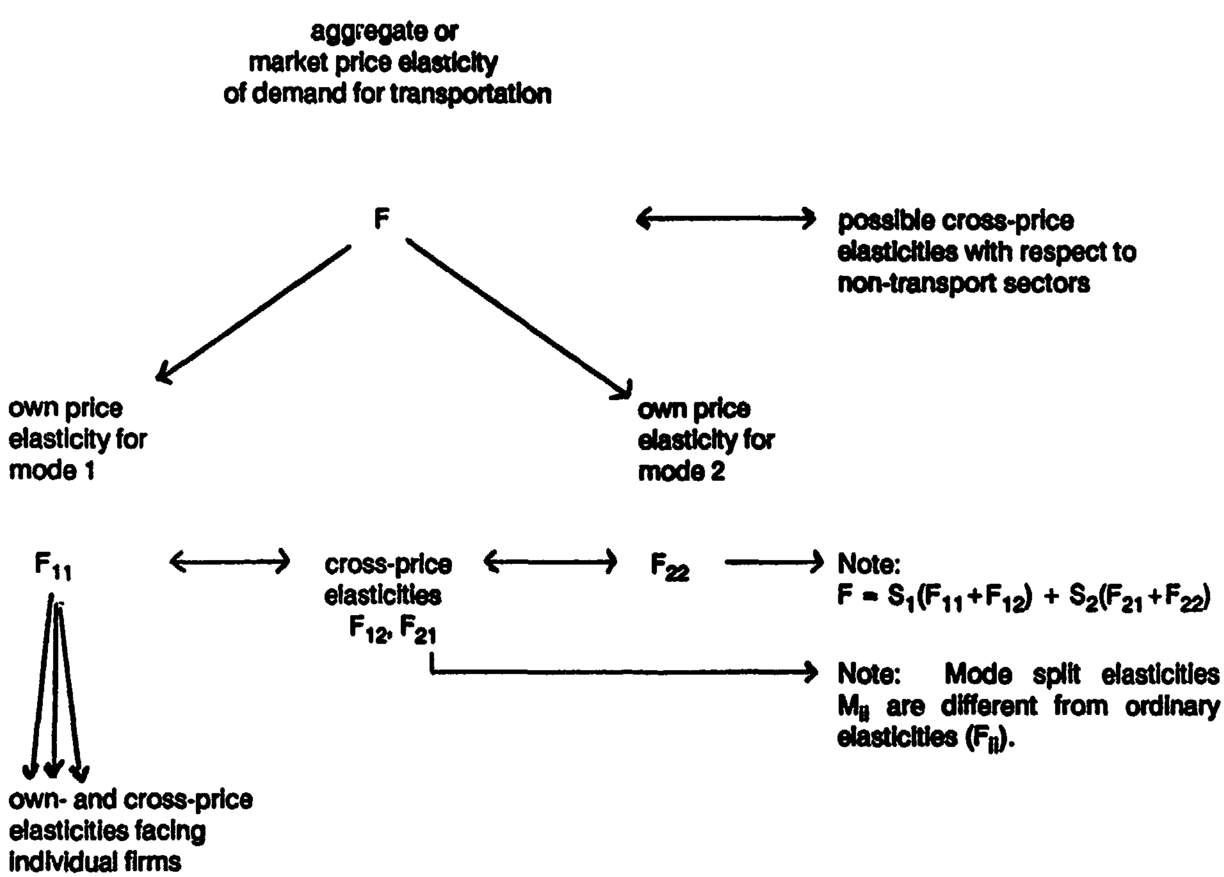

Figure 1

Illustration of the Relationship Among Price Elasticities of Demand for Aggregate Transport Market, Modes and Individual Firms

Table 1: Summary Statistics

Total Number of Studies Reviewed	70
Freight	17
Passenger	49
Others	4
Single Modal Studies	37
Multimodal Studies	27
Others	6
Air[a]	20
Auto[a]	18
Shipping[a]	5
Rail[a]	24
Truck[a]	8
Public Transit[a]	22
others[a]	3
Time Series	25
Cross Section	33
Panel Data and Pooled Time Series and Cross Section Data	3
Others (including unknown data sources)	9
United States	32
Canada	8
United Kingdom	8
Australia and New Zealand	7
Europe (excluding United Kingdom)	3
Brazil	2
India and Pakistan	2
Others[b]	8

[a]The number of studies in this classification do not sum to the total elsewhere because a single study is counted more than once in the case of multimodal studies.

[b]Including multicountry studies and studies with unknown data sources.

Table 2: Elasticities of Demand for Passenger Transport

(All elasticity figures are negative)

Mode	Range Surveyed: Market Demand Elasticities	Range Surveyed: Mode Choice Elasticities	Most Likely Range	No. of Studies[c]
Air[a]:				
Vacation	0.40–4.60	0.38	1.10–2.70	8
Non-Vacation	0.08–4.18	0.18	0.40–1.20	6
Mixed[b]	0.44–4.51	0.26–5.26	0.70–2.10	14
Rail: Intercity				
Leisure	1.40	1.20	1.40–1.60	2
Business	0.70	0.57	0.60–0.70	2
Mixed[b]	0.11–1.54	0.86–1.14	0.30–1.18	8
Rail: Intracity				
Peak	0.15	0.22–0.25	0.20–0.40	2
Off Peak	1.00	n.a.	≤ 1.00	1
All Day[b]	0.12–1.80	0.08–0.75	0.10–0.70	4
Automobile:				
Peak	0.12–0.49	0.02–2.69	0.10–0.70	9
Off Peak	0.06–0.88	0.16–0.96	0.20–1.10	6
All Day[b]	0.00–0.52	0.01–1.26	0.10–1.10	7
Bus:				
Peak	0.00	0.03–0.58	0.10–0.70	6
Off Peak	1.08–1.54	0.01–0.69	0.10–1.10	3
All Day[b]	0.10–1.62	0.03–0.70	0.10–1.30	11
Rapid Transit:				
All Day	0.05–0.86	n.a.	0.20–0.90	5
Transit System:				
Peak	0.00–0.29	0.1	0.10–0.30	4
Off Peak	0.32–1.00	n.a.	0.30–0.50	3
All Day[b]	0.01–0.96	n.a.	0.10–0.70	10
Others:				
Minibus	n.a.	0.10	-	1
Aircraft Landing	0.06–0.56	n.a.	-	1

[a]The distinction between vacation and non-vacation routes are rather arbitrary in most studies. This may partly account for the very wide range of elasticity estimates reported.

[b]This category includes studies that do not make the distinctions.

[c]The number of studies in this column do not sum to the total because some studies report more than one set of estimates.

n.a. = not available

Table 3: Elasticities of Demand for Freight Transport

(All elasticity figures are negative)

Mode	Range Surveyed	Most Likely Range	No. of Studies
Rail:			
Aggregate Commodities	0.60–1.52 (0.09–1.79)	0.40–1.20	4
Assembled Automobiles	0.65–1.08	0.70–1.10	2
Chemicals	0.39–2.25 (0.66)	0.40–0.70	3
Coal	0.02–1.04	0.10–0.40	2
Corn, Wheat, etc.	0.52–1.18	0.50–1.20	3
Fertilisers	0.02–1.04	0.10–1.00	1
Foods	0.02–2.58 (1.36)	0.30–1.00	9
Lumber, Pulp, Paper, etc.	0.05–1.97 (0.76–0.87)	0.10–0.70	7
Machinery	0.61–3.55[a]	0.60–2.30	3
Paper, Plastic and Rubber Products	0.17–1.85	0.20–1.00	4
Primary metals and Metallic Products	0.02–2.54[a] (1.57)	1.00–2.20	5
Refined Petroleum Products	0.53–0.99	0.50–1.00	3
Stone, Clay and Glass Products	0.82–1.62 (0.69)	0.80–1.70	4
Truck:			
Aggregate commodities	0.05–1.34	0.70–1.10	1
Assembled Automobiles	0.52–0.67	0.50–0.70	1
Chemicals	0.98–2.31	1.00–1.90	2
Corn, Wheat, etc.	0.73–0.99	0.70–1.00	2
Foods	0.32–1.54	0.50–1.30	3
Lumber, Wood, etc.	0.14–1.55	0.10–0.60	3
Machinery	0.04–1.23	0.10–1.20	3
Primary Metals and Metallic Products	0.18–1.36	0.30–1.10	3
Paper, Plastic and Rubber Products	1.05–2.97	1.10–3.00	2
Refined Petroleum Products	0.52–0.66	0.50–0.70	3
Stone, Clay and Glass Products	1.03–2.17[a]	1.00–2.20	2
Textiles	0.43–0.77	0.40–0.80	1

Table 3 continued ...

Mode	Range Surveyed	Most Likely Range	No. of Studies
Air:			
Aggregate Commodities	0.82–1.60	0.80–1.60	3
Shipping: Inland Waterway[a]			
Aggregate Commodities	(0.74–0.75)	-	1
Chemicals	0.75	-	1
Coal	0.28	-	1
Crude Petroleum	1.49	-	1
Grain	0.64–1.62	0.60–1.60	2
Lumber and Wood	0.60	-	1
Non-Metallic Ores	0.55	-	1
Primary Metal	0.28	-	1
Pulp and Paper	1.12	-	1
Stone, Clay and Glass Products	1.22	-	1
Shipping: Ocean[b]			
Dry Bulk Shipment[c]	0.06–0.25	-	1
Foods	0.20–0.31	-	1
Liquid Bulk Shipment	0.21	-	1
General Cargo	0.00–1.10	-	1

[a]The high elasticity estimates may reflect a low market share of aggregate freight of the mode when using the translog cost function in estimation.
[b]There have been very few empirical studies on shipping, hence the elasticity estimates reported here should be interpreted with caution.
[c]These include coal, grain, iron ore and concentrates, etc.
Note: Figures in parentheses are mode choice elasticities.

Table 4: Elasticities of Demand for Gasoline

(All elasticity figures are negative)

Country	Ranged Surveyed	Most Likely Range	No. of Studies
Austria	0.25–0.27	-	1
Canada	0.11	-	1
Israel	0.25	-	1
U.K.	0.1–0.17	-	1
U.S.	0.04–0.21	-	1
West Germany	0.25–0.93	-	1
Multicountry Studies	0.20–1.37[a]	0.20–0.50	3

[a]Included in this range is a long-run elasticity estimate of 0.32–1.37.

Table 5: Selected Estimates of Cross Elasticities

(Aggregate Data)

Authors	Modes	Cross Elasticities	Remarks
Oum (1979a)	Rail–Truck	-0.10 to +0.14	Aggregate freight transport
	Truck–Rail	-0.88 to +0.13	demand in Canada, cross elas-
	Rail–Waterway	+0.15 to +0.20	ticities reported for selected
	Waterway–Rail	+0.61 to +0.86	years between 1950–1974.
	Truck–Waterway	-0.23 to +0.03	
	Waterway–Truck	-0.12 to +0.13	
Oum and	Air–Bus	-0.02 to -0.01	Aggregate intercity passenger
Gillen (1983)	Air–Rail	+0.01 to +0.04	transport demand in Canada,
	Bus–Air	-0.12 to -0.05	cross elasticities reported
	Bus–Rail	-0.47 to -0.21	for selected years between
	Rail–Air	+0.08 to +0.51	1961–1976.
	Rail–Bus	-1.18 to -0.17	
Oum (1989)	Rail–Truck[a]	-0.18 to +0.50	Interregional freight transport
	Truck–Rail[a]	-0.62 to +0.84	demand in Canada.
	Rail–Truck[b]	-0.47 to +0.48	
	Truck–Rail[b]	-0.26 to +0.35	

[a]Aggregate commodities.

[b]Fruits, vegetables and other edible foods.

References

Anderson, J.E. and M. Kraus (1981) "Quality of Service and the Demand for Air Travel," Review of Economics and Statistics, 63(4), 533-40.

Appelbaum, Eli (1982) "The Estimation of the Degree of Oligopoly Power," J. of Econometrics 19, pp.287-299.

Blum, U.C.H., G. Foos and M.J.I. Gaudry (1988) "Aggregate Time Series Gasoline Demand Models: Review of the Literature and New Evidence for West Germany," Transportation Research A, 22, 75--88.

Brander, James A., and Anming Zhang, (1989) "Market Conduct in the Airline Industry: An Empirical Investigation," Working Paper, Faculty of Commerce and Business Administration, the University of British Columbia, Vancouver.

Friedlaender, A.F. and R.H. Spady (1980) "A Derived Demand Function for Freight Transportation," Review of Economics and Statistics, 62, 432--41.

Hensher, D.A. and Louviere, J.J. (1983) "Identifying Individual Preferences for International Air Fares: An Application of Functional Measurement Theory," Journal of Transport Economics and Policy, 17, 225--45.

McFadden, D. (1974) "The Measurement of Urban Travel Demand," Journal of Public Economics, 3, 303--28.

Oum, Tae H. (1979), "A Warning on the Use of Linear Logit Models in Transport Mode Choice Studies," Bell Journal of Economics (Spring, 1979), pp.374-388.

Oum, Tae H. (1979b), "Derived Demand for Freight Transportation and Inter-modal Competition in Canada," Journal of Transport Economics and Policy, (May, 1979), pp.149-168.

Oum, Tae H. (1979c), "A Cross-sectional Study of Freight Transport Demand and Rail-Truck Competition in Canada," Bell Journal of Economics, (Autumn, 1979), pp.463-482.

Oum, T.H. (1989) "Alternative Demand Models and Their Elasticity Estimates," Journal of Transport Economics and Policy, 23, 163--87.

Quandt, R.E. (1968), "Estimation of Modal Splits," Transportation Research, vol.2, 41-50.

Quandt, R.E. and W.J.Baumol (1966) "The Demand for Abstract Transportation Modes: Theory and Measurement," Journal of Regional Science (December), 13--26.

Slade, Margaret E. (1984) "Conjectures, Firm Characteristics and Market Structure: An Analysis of Vancouver's Gasoline Price Wars," Discussion Paper No. 84-25, Department of Economics, the University of British Columbia, Vancouver.

Spady, R.H., and A. Friedlaender (1978), "Hedonic Cost Functions for the Regulated Trucking Industry," Bell Journal of Economics, (Spring, 1978), pp. 159-79.

Taplin, J.H.E. (1982) "Inferring Ordinary Elasticities from Choice or Mode-Split Elasticities," Journal of Transport Economics and Policy, 16, 55--63.

Waters II, W.G. (1984) "A Bibliography of Articles Relevant to Transportation Appearing in Major Economics Journals: 1960--1981," Vancouver: Centre for Transportation Studies, U.B.C.

Waters II, W.G. (1989) "A Bibliography of Articles Relevant to Transportation Appearing in Major Economics Journals: Update 1982--1987," Vancouver: Centre for Transportation Studies, U.B.C.

Winston, C. (1985) "Conceptual Developments in the Economics of Transportation: An Interpretive Survey," Journal of Economic Literature, 23, 57--94.

Appendix 1
List of Journals Scanned:
(Not Including Journals listed in Waters 1984, 1989)

Journal of the Transportation Research Forum
  1980 v.21 to 1988 v.29
Logistics and Transportation Review
  1981 v.17(1) to 1989 v.25(1)
Research in Transportation Economics
  1985 v.2
  1983 v.1
Research in Urban Economics
  1981 v.1 to 1988 v.7
Transport Policy and Decision Making
  1985 1, 2, 3
  1984 3, 4
  1982 2
  1980 1, 2/3, 4
Transport Reviews
  1985 v.5(1) to 1989 v.9(2)
Transportation
  1981 v.10(1) to 1988 v.15(4)
Transportation Journal
  1982/83 v.22(1) to 1988/89 v.26(3)
Transportation Quarterly
  1985 v.39(2) to 1989 v.43(2)
Transportation Research A
  1980 v.14(1) to 1989 v.23(1)
Transportation Research B
  1980 v.14(1) to 1989 v.23(1)
Transportation Research Record
  1981 v.789 to 1988 v.1163
  Volumes not available:
    1987 v.1121-1130
    1981 v. 820- 829

Appendix 2
Complete List of Elasticity Estimates

Elasticities of Demand for Passenger Transport: All Studies

Mode	Market Demand Elasticities	Mode Choice Elasticities
Air		
Vacation	1.11,1.52,0.4-1.68-1.98,1.48-1.92, 1.23-1.84-1.93-2.75-2.95-4.05, 1.4-1.6-2.0-2.7-3.3, 2.2-2.4-2.6-4.6	0.38
Non-Vacation	1.2-1.66-1.84-2.51-3.74-3.78-4.18, 0.08-0.36-0.48,1.15,0.65,0.90	0.18
Mixed[a]	0.44-1.81,0.67-0.78-0.91-1.28, 0.76-0.84,1.39,0.53-1.00,1.12-1.28, 0.49-0.82-1.02-1.03-1.29-1.83, 1.85-2.09-2.91,0.7-1-1.5,2.82-4.51, 1.8-1.9	1.28-2.24-2.43-3.69-3.81-5.26,0.62, 0.26-0.38
Rail		
Intercity		
Leisure	1.4	1.2
Business	0.7	0.57
Mixed[a]	0.11-0.14-0.34-0.48-0.6-0.62- 0.65-0.67-0.68-0.7-0.85-0.87- 1.03-1.18,0.74-0.9,0.37-0.4, 1.08-1.54,1.19-1.5,0.16-0.3	0.32,0.86-1.14
Intracity		
Peak	0.15	0.22-0.25
Off Peak	1.0	
All Day[a]	0.12-0.23-0.44-0.49,1.8,0.3	0.08-0.29-0.44-0.57-0.75
Automobile		
Peak	0.21-0.36,0.12-0.49	0.02-0.04-0.08-0.14-0.16-0.31- 0.55-0.88,0.16,0.04,0.7,0.16-0.18, 0.16-0.46-0.59-1.16-2.03-2.69, 0.32-0.47,
Off Peak	0.14-0.29,0.88,0.15-0.45,0.06-0.09,	0.16-0.34-0.79-0.96,0.96
All Day[a]	0.0-0.09-0.22-0.52,0.06-0.1-0.23- 0.28,0.05-0.09-0.1-0.22-0.26-0.31	0.12-0.26-0.38-0.62-0.97-1.26, 0.01-0.02,0.08,0.83

Bus		
Peak	0.0	0.04,0.03,0.32,0.06,0.45–0.58
Off Peak	1.06–1.54	0.01,0.69
All Day*	0.1–0.6,0.37–0.42–0.56,0.4–0.46–0.75,0.26–0.52–0.78,0.20–0.4–0.66,0.23–0.27,1.27–1.62	0.03–0.14,0.31–0.4–0.58–0.7,0.32,0.45–0.6
Rapid Transit		
All Day	0.05,0.23–0.25,0.16–0.3,0.16-0.86,0.86	
Transit System		
Peak	0.11–0.13–0.19–0.24–0.26–0.29,0.0,0.1	0.1
Off Peak	0.36–0.39–0.41–0.44–0.49,1.0,0.32	
All Day*	0.13–0.29–0.34–0.42,0.01–0.04–0.15–0.26–0.28–0.38–0.62,0.33,0.7,0.34–0.4–0.54,0.18–0.19–0.22–0.43–0.52,0.05–0.19–0.34,0.17–0.59,0.4–0.8,0.09–0.11–0.19–0.4–0.96	
Others		
Minibus		0.1
Aircraft Landing	0.08–0.58	

*Including studies that do not make the classification.

Note: Elasticity ranges reported in the same study are joined by dashes, and commas separate estimates from different studies.

Elasticities of Demand for Freight Transport: All Studies

Mode	Demand Elasticities
Rail	
Aggregate Commodities	0.6–0.64–0.83–1.38–1.52,(0.09–0.29), (0.34–0.37–0.59–0.93–1.03–1.06–1.79), (0.25–0.35)
Apparel Products	(0.22)
Assembled Automobiles	0.92–1.08,0.65
Chemicals	0.39,0.69,2.25,(0.66)
Coal	0.02,0.14–1.04
Corn, Wheat, etc.	0.52–0.53,1.18,1.11
Fertilisers	0.02–1.04
Foods	1.23,1.04,0.39–0.48–0.8,0.02–0.27,0.29,2.58,(1.36)
Fuel Oil (except gasoline)	0.46
Furniture Products	(1.3)
Lumber, Pulp, Paper, etc.	0.54–0.56,0.05,0.36–0.67,0.58,1.97,0.08,(0.76–0.87)
Machinery (including Electrical Machinery)	2.27–3.55,0.61,(0.16–1.73)
Meat	0.02–0.27,2.58
Nonmetallic Products	1.08
Paper, Plastic and Rubber Products	1.85,1.03,0.17
Paper, Printing and Publishing	0.17
Primary Metals and Metallic Products	1.03,1.2,2.16–2.54,0.02,(1.57)
Refined Petroleum Products	0.99,0.53
Stone, Clay and Glass Products	1.68,0.82,(0.69)
Textiles	0.58,(2.03)
Tobacco Products	(0.89)
Transport Equipment	2.68

Truck	
Aggregate Commodities	0.05–0.69–0.93–1.14–1.34
Assembled Automobiles	0.52–0.67
Chemicals	0.98,1.87–2.31
Corn, Wheat, etc.	0.73,0.99
Foods	0.52,0.32–0.65–0.97–1.25–1.54,1.0
Fuel Oil (except gasoline)	1.07
Lumber, Wood, etc.	0.56,1.55,0.14
Machinery (including Electrical Machinery)	1.09–1.23,0.04–0.78
Primary Metals and Metallic Products	0.41,1.08–1.36,0.18–0.28
Nonmetallic Products	0.56
Paper, Plastic and Rubber Products	1.05,2.01–2.97
Refined Petroleum Products	0.52,0.66
Stone, Clay, and Glass Products	1.03,2.04–2.17
Textiles	0.43–0.77
Transport Equipment	0.29
Shipping	
Inland Waterway	
Aggregate	(0.74–0.75)
Chemicals	0.75
Coal	0.28
Crude Petroleum	1.49
Grain	1.48–1.62,0.64
Lumber and Wood	0.6
Non-Metallic Ores	0.55
Primary Metal	0.28
Pulp and Paper	1.12
Stone, Clay and Glass Products	1.22
Ocean	
Coal	0.06–0.24
Foods	0.2–0.31
General Cargo	0–0.5–1.1
Grain	0.02–0.06–0.27–1.64
Iron Ore and Concentrates	0.11
Liquid Bulk Shipment	0.21
Wool	0.02
Air	
Aggregate	1.32,1.47–1.60,0.82–1.03

Note: Figures in parentheses are mode choice elasticities.

Elasticities of Demand for Gasoline: All Studies

Country	Market Demand Elasticity
Austria	0.25–0.27
Canada	0.11
Israel	0.25
U.K.	0.1–0.17
U.S.	0.04–0.21
West Germany	0.25–0.93
Multicountry Studies	0.27–0.52,0.2–0.3,0.32–1.37 *

Note: *Long-run elasticities.

Appendix 3

Inferring Ordinary Price Elasticities From Mode Choice Elasticities

Taplin (1982) pointed out that it is not possible to derive ordinary elasticities unambiguously from mode split elasticities without further information. However, he suggested using equation (2) with the following theoretical constraints and an assumed number (or other estimate known to the researcher) for one of the ordinary demand elasticities, F_{ij}.

(2) $F_{ij} = M_{ij} + \epsilon_j$ for all i and j

where F_{ij} is the price elasticity of ordinary demand for mode i with respect to the price of mode j, M_{ij} is the mode choice elasticity of choosing mode i with respect to mode j, and ϵ_j is the elasticity of demand for aggregate traffic (including all modes) with respect to the price of mode j.

Constraints:

(i) the effects of a change in mode j's price cancel out when the mode choice elasticities are weighted by volume shares; i.e. one mode's gain in volume comes from the volume losses from other modes, or vice versa;

$$\Sigma_k S_k M_{kj} = 0$$

(ii) the change in the mode i's revenue caused by 1 per cent change in price of mode j is same as the change in the mode j's revenue caused by 1 per cent change in mode i's price (Hotelling-Jureen condition);

$$F_{ij} = F_{ji} (P_j X_j / P_i X_i)$$

(iii) an equiproportionate increase in prices of all goods and services and income would not change demands; i.e. the homogeneity condition of the demand function for mode i;[1]

$$\Sigma_j F_{ij} + F_{iI} = 0$$

where F_{iI} is the income elasticity of demand for mode i.

(iv) transport modes are gross substitutes;

$$F_{ij} > 0 \text{ for all j not equal to i.}$$

The price elasticities of mode choice for a binary choice model (the case of two competing modes) can be translated into ordinary price elasticities by assuming a value for one of the ordinary price elasticities and making use of condition (ii) above. Below we illustrate this using the results of Anas and Moses (1984) on bus-taxi choice analysis.

(A) Anas and Moses report own-price mode choice elasticities (for morning travel) as follows:

Mode choice	with respect to	
	price of bus	price of taxi
bus	M_{bb} = -0.026	M_{bt} =
taxi	M_{tb} =	M_{tt} = -1.307

(B) Let us assume the volume shares of bus and taxi to be 95 per cent and 5 per cent respectively, and the revenue shares to be 80 per cent and 20 per cent, respectively;

1/ This condition, based on the consumer's overall consumption of all goods and services, becomes more restrictive if it is applied only to the transportation sector. This assumes that the modal demands do not change when prices of all modes and total transport budget increase in an equal proportion, i.e., a quite restrictive assumption.

(C) Then, theoretically consistent values of the cross- price elasticities of mode choice in (A) can be computed using condition (i):

$$M_{tb} = 0.026*(0.95) / 0.05 = 0.494$$

$$M_{bt} = 1.307*(0.05) / 0.95 = 0.069$$

(D) In order to convert these mode choice elasticities to ordinary price elasticities, it is necessary to have an estimate of one of the ordinary elasticities. Let us arbitrarily assume that the ordinary own-price elasticity of bus travel (F_{bb}) is -0.30.

(E) The difference between ordinary and mode choice elasticity is: $\epsilon_b = F_{bb} - M_{bb} = -0.30 - (-0.026) = -0.274$; An application of equation (2) for F_{tb} gives $F_{tb} = M_{tb} + \epsilon_b = 0.494 - 0.274 = 0.220$;

(F) Now, we can apply condition (ii) to the above result to get the value of F_{bt}: $F_{bt} = F_{tb} (P_t X_t / P_b X_b) = 0.220*(0.20/0.80) = 0.055$;

(G) The above result is used to compute $\epsilon_t = F_{bt} - M_{bt} = 0.055 - (0.069) = -0.014$; This is then applied to compute $F_{tt} = M_{tt} + \epsilon_t = -1.307 - 0.014 = -1.321$;

Summarizing, the matrix of derived ordinary elasticities based on the assumed own-price elasticity for bus (F_{bb}) of -0.30 is:

mode choice	price of bus	price of taxi
bus	$F_{bb} = -0.30$	$F_{bt} = 0.055$
taxi	$F_{tb} = 0.220$	$F_{tt} = -1.321$

This demonstrates how ordinary price elasticities can be computed from the price elasticities for mode choice for the case of binary choice using volume and revenue shares of each mode and an assumed value of one ordinary elasticity. The other three ordinary price elasticities were uniquely determined from the information. Of course, the accuracy of the elasticity estimates computed this way depends greatly on the validity of F_{bb} (-0.30) which we chose arbitrarily. There are some cross checks on the reasonableness of the assumed elasticity. For example, initially we arbitrarily set $F_{bb} = -0.05$ instead of -0.30, but discovered that the absolute value of the own-price elasticity for the ordinary demand for taxis F_{tt} became 1.258, which was less than the absolute value of the mode split elasticity $M_{tt} = 1.307$. This is not plausible, it would mean the income effect for taxi demand is negative. This warned us that our initial assumed ordinary elasticity was inconsistent with existing information about demand embodied in the mode choice elasticities and assumed market shares.

Even for the case of three or more competing modes it is possible to determine unique values of the ordinary price elasticities from the matrix of mode choice elasticities with the information on volume and revenue shares and one ordinary demand elasticity. As before, the accuracy of the ordinary price elasticities computed depends on how accurate is the value of the one ordinary price elasticity chosen for initiating the calculation. For the sake of making this paper self contained, Taplin's (1982) example is repeated below.

Taplin's example is a mode choice study of domestic vacation travel in Australia involving three modes: air (mode 1), car (mode 2) and bus (mode 3). The data on volume shares and revenues are summarized below:

mode	trip volume share	revenue
air (mode 1)	0.2	40
car (mode 2)	0.7	60
bus (mode 3)	0.1	10

The mode split elasticity estimates (M_{ij}) are as follows:

mode	with respect to		
choice	air fare	car cost	busfare
air	-1.38	1.37	0.13
car	0.32	-0.63	0.13
bus	0.52	1.67	-1.17

(A) Let us assume the only ordinary elasticity known to us is an own-price elasticity of -1.8 with respect to costs by car (mode 2). This allows us to determine $\epsilon_2 = F_{22} - M_{22} = -1.8 - (-0.63) = -1.17$. An application of equation (2) for F_{12} and F_{32} gives $F_{12} = M_{12} + \epsilon_2 = 1.37 - 1.17 = 0.20$, and $F_{32} = M_{32} + \epsilon_2 = 1.67 - 1.17 = 0.50$. The values are uniquely determined so far.

(B) Now we choose either F_{12} or F_{32} (the results are invariant to the choice) for applying condition (ii). F_{12} is to be used for computing $F_{21} = F_{12}*(P_1\ X_1/P_2\ X_2) = 0.20*(0.40/0.60) = 0.133$. This allows us to determine $\epsilon_1 = F_{21} - M_{21} = 0.133 - (0.32) = -0.187$, which in turn allows to compute $F_{11} = M_{11} + \epsilon_1 = -1.38 - 0.187 = -1.567$, and $F_{31} = M_{31} + \epsilon_1 = 0.52 - 0.187 = 0.333$.

(C) The next step is to compute the ordinary elasticities in column 3 using the value of F_{31} and condition (ii). $F_{13} = F_{31}*(P_{33}\ X_3/P_1\ X_1) = 0.333*(10/40) = 0.083$. This allows us to determine $\epsilon_3 = F_{13} - M_{13} = 0.083 - (0.13) = -0.047$, which in turn allows to compute $F_{23} = M_{23} + \epsilon_3 = 0.13 - 0.047 = 0.083$, and $F_{33} = M_{33} + \epsilon_3 = -1.17 - 0.047 = -1.217$.

Summarizing, the matrix of derived ordinary elasticities (assuming a given value of -1.8 for F_{22}, the own-price elasticity of demand for car travel) are:

mode	price of air	price of car	price of bus
air (mode 1)	$F_{11} = -1.567$	$F_{12} = .20$	$F_{13} = .083$
car (mode 2)	$F_{21} = .133$	$F_{22} = -1.8$	$F_{23} = .083$
bus (mode 3)	$F_{31} = .333$	$F_{32} = .50$	$F_{33} = -1.217$

The accuracy of the matrix of ordinary price elasticities computed as above depends upon the accuracy of the ordinary elasticity term chosen to initiate the computation.

Annex A

AN ANNOTATED BIBLIOGRAPHY OF RECENT ESTIMATES OF PRICE ELASTICITIES OF TRANSPORT DEMANDS

Abrahams (1983)
- Single mode: Air (Passenger)
- Quarterly data 1973 to 1977. (Individual city-pairs selected from 100 most heavily traveled domestic origin-destination pairs in U.S.)
- 2SLS estimation with Cochrane-Orcutt Transformation.
- Elasticities:

	With City-Pair Dummy	Without
Transcontinental City-Pairs	-0.44	-1.81
Hawaiian City-Pairs	-1.68	-0.44
Florida Vacation City-Pairs	-0.40	-1.96
Medium-haul Western City-Pairs	-0.36	-0.48
Short-haul Western and Mid-Western City-Pairs	-0.08	NA
Short-haul Eastern City-Pairs	NA	-0.36

- Note:Elasticity N.A. due to coefficients on fare being positive.

Agarwal and Talley (1985)
- Single mode: Air (Passenger)
- Cross-section data. (Dec. 1981), 63 flight segments (i.e. service between a U.S. departure point and a foreign-country landing point).
- Log-linear demand, estimated by OLS.
- Elasticity: -0.7635 to -0.8425

Anas and Lee (1982)
- Single mode: transit (intra-city passenger)
- Intermodal competition recognized by the inclusion of auto access speed, operating costs, parking, etc.
- Direct estimation of utility functions and the market-clearing process. (A heuristic estimation method).
- U.S. Cross-section data: 1970 Census of Population and Housing for the Chicago SMSA.
- Elasticities -0.05 to -0.34
  Weighted average -0.19

Anas and Moses (1984)
- Two modes: Bus vs. Taxi (Intra-City Passenger)
- Logit and Probit models of mode choice
- Survey data, Seoul metropolitan area, Korea, 148 observations.
- Elasticities (with respect to travel cost)

	Morning	Evening
Logit estimation:		
Bus	-0.026	-0.009
Taxi	-1.307	-0.490

- Note:the authors compute the price elasticities from mode choice elasticities. Computation not shown.

Anderson and Kraus (1981)

- Single mode: Air (Passenger)
- Log-linear demand
- U.S. Monthly time-series data: 1973 to 1976
- Note: the authors originally planned to estimate the value of the time variable but were unable to obtain reliable estimates due to data problems. Instead, they assigned various values to this parameter. Also note, "price" includes value of time hence these are not fare elasticities.
- If only elasticity estimates that are statistically significant at 5% are taken into account:

	When value of time is assumed to be 0	10	30
Long haul, predominantly pleasure travel	-1.23 to -1.84	-1.93 to -2.75	-2.91 to -4.05
Long haul, predominantly business travel	-1.20 to -1.84	-1.66 to -2.50	-2.51 to -3.74
Short haul, predominantly business travel	N.A.	+0.90 to -4.18	+1.3 to -3.78
Short haul, predominantly mixed	N.A.	-0.537 to -2.09	-1.85 to -2.91

- Note: elasticity estimates N.A. because none of the estimates are significant for the value of travel time assumed.

Andrikopoulos and Terovitis (1983)

- Linear demand, single airline. (Passenger)
- Cross-section (1970-1980) and time-series (1969-1980 annual) data from Greece.
- Estimated by OLS
- Elasticities:

Cross-section (1978) with 20 city-pairs -1.854

<u>Time-Series Results</u>

Air-Ship Connection:	-0.777
Air-Bus Connection:	-0.670
Air-Bus-Rail Connection:	-1.283
Overall average	-0.910

Babcock and German (1983a)

- Single mode: Inland and coastal waterway carriers (freight)
- U.S. Annual data, 1958-80
- Linear demand model, estimated by OLS
- Elasticities:

Corn, wheat, soybeans	-0.64
Coal	-0.28
Crude Petroleum	-1.49
Non-Metallic Ores	-0.55
Lumber and Wood	-0.60
Pulp and Paper	-1.12
Chemicals	-0.75
Stone, Clay and Glass Products	-1.22
Primary Metal	-0.28

Note: Only elasticity estimates with the correct sign are reported here

- Possible misspecification for some equations

Babcock, M.W. and W. German (1983b)
- Two modes: Rail vs Truck (Freight)
- Linear regression modal split model
- Annual U.S. data, 1965-81
- Share elasticities:

Food Products	-1.36
Tobacco Products	-0.89
Textile Products	-2.03
Apparel Products	-0.22
Lumber and Wood Products	-0.76
Furniture Products	-1.30
Pulp and Paper Products	-0.87
Chemical Products	-0.66
Stone, Clay and Glass Products	-0.69
Fabricated Metal Products	-1.57
Machinery, except Electrical	-0.16
Electrical Machinery	-1.73

Bajic (1984)
- Two modes: Auto vs. Transit. (Intra-city Passenger)
- 1979 Canadian Survey data. 385 households
- Random Utility model, Logit estimation
- Elasticity of choice of Auto-mode with respect to changes in money cost of auto travel. (Parking charges plus auto operating costs)
- Elasticities:

Income	Mode-Split Elasticities
10,000	-0.14 to -0.88
20,000	-0.08 to -0.55
30,000	-0.04 to -0.31
40,000	-0.02 to -0.16

Benham (1982)
- Single mode: Bus
- U.S. Time series data (Monthly, 1976-79) and before-and-after survey.
- Linear demand model, estimated by OLS.
- Fare elasticity: -0.252 (-0.23 to -0.27)

Blum, Foos and Gaudry (1988)
- Time-series model, with AR and heteroskedasticity specification
- Monthly data, Jan. 1968 to Dec. 1983. (Germany)
- Price elasticities -0.283 to -0.307
- Concerned with gasoline demand only
- Contains a survey of 21 time series studies on gasoline demand. It consists of 5 studies on West Germany, 2 studies on Austria, 8 on U.S., 1 on Canada, 1 on Israel, 1 on U.K., 3 on multicountries

- Elasticities:

W. Germany	-0.25 to -0.93
Austria	-0.25 to -0.27
U.S.	-0.04 to -0.21
Canada	-0.11
Israel	-0.25
U.K.	-0.10 to -0.17
Multicountry	-0.27 to -0.52

Boyer (1977)

- Two modes: Rail vs. Truck (freight)
- Linear Logit, estimated by OLS and weighted least-squares
- Cross-section data, northeast U.S., no. of observations unknown
- Relative Price Sensitivities of modal split:
  - OLS: 1% change in the ratio of rail to truck rates: -0.37 to -1.03
    change of rail rates equivalent to 1% of mean truck rate: -0.59 to -1.79
  - WLS: 1% change in the ratio of rail to truck rates: -0.34 to -0.93
    change of rail rates equivalent to 1% of mean truck rate: -0.37 to -1.06

Bureau of Transport Economics, Australia (1986)

- Single mode: Shipping (freight)
- Source of data unknown
- Imputed elasticities of demand for shipping (based on elasticities of demand for commodities).

Meat	-0.20
Cereals	-0.31
Wool	-0.02
Iron and Steel	-3.00
Metals	-1.60

Cummings, Fairhurst, Labelle and Stuart (1989)

- Two modes: Bus vs. Rail (Intracity Passenger)
- U.S. Time-series data: 1980-87
- Derived fare elasticities (By comparing before and after data following fare changes).

	Range	Average for all increases
Bus	-0.20 to -0.66	-0.40
Rail	-0.16 to -0.30	-0.14
System	-0.17 to -0.59	-0.34

- Survey data: 1987
- System Fare Elasticities (Stated Preference Survey)

Market Segment	Peak	Off-Peak
Central Area	-0.26	-0.39
Radial	-0.11 to -0.13	-0.36 to -0.39
Local	-0.19 to -0.24	-0.41 to -0.44
< 2 miles	-0.29	-0.49
Overall	-0.19	-0.44
Average all day	0.33	

Doi and Allen (1986)

- Single mode: Rapid transit (Passenger)
- Linear and log-linear model
- U.S. Monthly data: 1978(1) to 1984(7)
- Fare elasticities (Dependent Variable: Ridership)
  - Linear model -0.233
  - Log-linear model -0.245
- Note: inter-model competition is recognized by the inclusion of gasoline price and bridge tolls in the regression equations.

Doganis (1985)

- Single mode: Air (Passenger)
- Studies cited (P. 176)

(1) Smith and Toms (1978)

Australian International	-1.8 to -1.9

(2) Dept. of Trade, U.K.

U.K. originating	
Inclusive tour leisure	-2.4 to -4.6
Other leisure - Western Europe	-2.2 to -2.4
Other leisure - rest of world	-2.6
Business - rest of world	-0.9

(3) British Airport Authority

U.K. resident leisure travel	
Short haul	-1.0
North America	-0.7
Middle East	-1.0
Long haul (excluding North America and Middle East)	-1.5

Fridstroöm and Thune-Larsen (1989)

- Single mode: Air (Passenger)
- Gravity model
- Norway Time Series (1972-83 annual) and Cross-Section (95 intercity links) data.

• Face Elasticities	Short and Medium-term	Very long-term
Average	-0.82	-1.63
Min	-0.49	-1.29
Max	-1.02	-1.83

Friedlaender and Spady (1980)

- Two modes: Rail vs. Truck (Freight)
- Demand function derived from shipper's cost function which is approximated by a translog function.
- U.S. Cross-section data: 96 3-digit manufacturing industries in 1972.
- Note: definition of price includes quality of service features; these are not freight rate elasticities.

- **Elasticities:**

	Rail	Truck
Food Products	-2.583	-1.001
Wood and Wood Products	-1.971	-1.547
Paper, Plastic & Rubber Products	-1.847	-1.054
Stone, Clay & Glass Products	-1.681	-1.031
Iron and Steel Products	-2.542	-1.083
Fabr. Metal Products	-2.164	-1.384
Non-electrical Machinery	-2.271	-1.085
Electrical Machinery	-3.547	-1.230

- Note:Elasticity estimates above are averaged over all regions.

Gaudry (1980)
- Two modes: Transit vs Car (intra-city passenger)
- Time series data, monthly Dec. 1956 to Dec. 1971, Montreal, Canada.
- Simultaneous Equation models of supply & demand.
- Transit Fare Elasticities

	Adults	Children
LS generalized autoregressive estimator	-0.18	-0.44
Iterated Park's SUR autoregressive estimator	-0.19	-0.43
Iterated Fair's Full Information Instrumental Variables Efficient Estimator	-0.22	-0.52

- Note: elasticities for car not available. No vehicle operating cost variable in the demand system.

Geltner and Raimundo Caramuru Barros (1984)
- Multi-modal: Bus, taxi and auto (Intra-city Passenger)
- Probabilistic Choice Models (Exact specifications unknown)
- System of demand equations according to purpose of travel
- Household survey data, 1981, Macelo, Brazil.
- Estimation method unknown
- Price share elasticities (out-of-pocket cost)

  Work travel choice based on a 10% increase in cost from existing conditions:

Bus	-0.04
Taxi	-1.88
Auto Drive	-0.16
Auto Passenger	-0.62

Gillen and Cox (1979)
- Two modes: Auto vs Transit (Passenger)
- Cross section data, 495 observations, from Metropolitan Toronto and Regional Transportation study.
- Home-based work trips
- Mode choice elasticities:

Logit	-0.46 to -1.16 to -2.03
Restricted LS	-0.16 to -0.59 to -2.69

- Note: the authors believe that the results from restricted least squares are more plausible.

Gillen, Oum and Tretheway (1988)
- Price elasticity for aircraft landing (Canada)

  -0.075 to -0.58
- Note: elasticity derived from share of landing fee and price elasticity of Air Travel (Assumed to be -1.05).

Glaister (1983)

- Single Mode: Rail (Inter-city Passenger)
- A two-stage model: Sequential multinomial logit model / OLS.
- Inter-modal competition partially controlled for using a "motorway dummy".
- U.K. time series data. 13 four-weekly periods in each of the six years 1972 to 1977.
- Overall elasticities of total trips with respect to a uniform increase in all fares

High Wycombe / London	-0.77 to -0.90
Bedford / London	-0.74

- Note: Primary concern is choice between ticket types.

Goodwin and Williams (1985)

- A review of British studies of demand analysis associated with a conference held in Apr. 1984.
- Aggregate studies:
- Fare Elasticities

Bus	-0.1 to -0.6
Rail (London)	-0.12 to -0.23
Rail (Glasgow)	-0.44 to -0.49

- Model and data unknown.

Grayson (1981)

- Multi-modal: Auto, Air, Bus, Rail (Inter-city Passenger)
- Logit model
- U.S. Survey data: National Travel Survey, 1977.
  1658 observations
- Elasticities (with respect to cost)

Auto	-0.076
Air	-0.618
Bus	-0.321
Rail	-0.315

- Note: type of elasticities unknown

Guria (1988)

- Single mode: Rail (freight)
- Inter-modal competition not recognized.
- New Zealand data. 101 sets of observations each covering a 4-week period, from Apr. 1, 1977 to Jan. 5, 1985.
- Log-linear demand function, estimated by OLS.
- Elasticities:

	when dependent variable is	
	TK	T
Coal	-1.04	-0.14
Dairy Products	+0.10	+0.10
Fertilizers	-1.04	-0.02
Meat	-0.02	-0.27
Milled Timber	-0.05	-0.05
Pulp & Paper	-0.67	-0.36

TK ≡ Net tonne - km of freight carried by rail
T ≡ tonnes of freight carried by rail

Haitovsky, Solomon and Silman (1987)

- Single mode: Air (Passenger)
- Log-linear demand function
- Pooled time series (1970-80, annual) and cross-section data (vacation travel to Israel from 12 origin countries)
- Estimated by Variance Component Method
- Elasticity: -1.11
- Note:the price variable (air fare) is normalized by income

Hamberger and Chatterjee (1987)

- Single mode: Bus (intra-city)
- Inter-modal competition partially recognized by dummies
- Linear Ridership equation, estimated by OLS
- U.S. Time Series data: Quarterly, 1979I to 1984III (Knoxville, Tennessee).
- Elasticity: (Ridership with respect to fare).
  -0.522 ± 0.257

Hauser, Beaulieu and Baumel (1985)

- Single mode: Inland Waterway (freight)
- Interregional linear Programming Model
  - U.S. 1980 cross section data
- Elasticities: -1.48 to -1.62

Hensher (1985)

- Single mode: Auto use in the household sector.
- Survey data, Sydney (Australia) Metropolitan area, 1436 observations.
- Simultaneous equation model, estimated by 3SLS
- Elasticities:

Fuel cost per km.	-0.217 to -0.516
km-dependent costs (cost of maintenance, body, engine and mechanical repairs, and tyres).	-0.003 to -0.067

- Note: the paper presents long run & short run elasticities of 1,2 and 3 vehicle households.

Hensher and Louviere (1983)

- Single mode: Air (Passenger), single airline (identity unknown)
- Inflight survey data, single route, 176 observations (multiple countries)
- Price share elasticities:

Fare	Elasticities
$1000	-3.81 to -5.26
750	-2.43 to -3.69
500	-1.28 to -2.24

Hensher and Smith (1986)

- Single Mode: Auto (Passenger)
- System of simultaneous equations
- 3 estimation methods: OLS, 2SLS, 3SLS
- Australian Survey data: 1434 observations

- Elasticities:
  (i) Annual household vehicle km with respect to fuel cost per km incurred by the household
  Short-run OLS -0.237 2SLS-0.092 3SLS-0.099
  Long-run OLS -0.311 2SLS-0.218 3SLS-0.260
  (ii) Annual household vehicle km with respect to km dependent costs (maintenance, body, engine, etc.)
  Short-run OLS -0.045 2SLS-0.051 3SLS-0.046

Ippolito (1981)
- Single mode: Air (Passenger)
- Log-linear demand function, allow for inter-modal competition by dummy
- Simultaneous equation model
- Data Source unknown
- Fare elasticity -0.525 to -1.00

Johnson and Hensher (1982)
- Two modes: Car vs train (Passenger)
- Multinomial Probit model
- Panel Data. Suburbs of Sydney, Australia, 1971-73, 163 observations
- Elasticities of Probability of Choice of
  Car -0.119 to -0.255 to -0.383 to -0.622 to -0.971 to -1.26
  Train -0.084 to -0.29 to -0.44 to -0.574 to -0.751
- Elasticity measures obtained from 7 models

Jones and Nichols (1983)
- Single Mode: Rail (Inter-city Passenger)
- Multiplicative demand function. Estimated in log-linear form by OLS.
- U.K. time Series data, 4-week ticket sales, 1970-1976.
- Between London and:

	Elasticities	Controlled for Inter-modal Competition
Bath	-0.14	No
Birmingham	-0.67	No
Bristol	-0.70	Yes
Cardiff	-0.85	Yes
Carlisle	-0.34	No
Edinburgh	-0.60	Yes
Glasgow	-1.18	Yes
Leeds	-0.62	No
Leicester	-0.67	No
Liverpool	-0.85	Yes
Manchester	-0.65	Yes
Newcastle	-1.03	No
Norwich	-0.60	No
Nottingham	-0.68	No
Preston	-0.11	No
Swansea	-0.87	Yes
Swindon	-0.48	Yes

- Inter-modal competition partially controlled for using a dummy for some routes.

Kroes and Sheldon (1985)

- Single mode: Rail (Intercity Passenger)
- The following elasticities are cited from a project for British Rail conducted by Steer Davies & Gleave Ltd. using Stated Preference Techniques.
- Elasticities

Fare Worsening	-1.50
Fare Improvement	-1.19

Kroes and Sheldon (1988)

- Single mode: Rail (Inter-city Passenger)
- U.K. Interview data, approximately 500 observations
- Estimation method: MONANOVA
-

Trip purpose	Elasticities
Business	-0.7
Optional	-1.4

Kyte, Stoner and Cryer (1988)

- ARIMA model
- U.S. Monthly data Jan. 1973 to June 1982
- Single mode: Transit (Inter-city Passenger)
- Travel cost by auto is included as independent variable
- Elasticities:

Transit system	-0.29 to -0.34	(average fare)
City Sectors	-0.13 to -0.32	(average fare)
City Sectors	-0.15 to -0.42	(cash fare)

Levin (1978)

- Two modes: Rail vs. Truck (freight)
- Multinomial Logit Model
- U.S. Cross-section data: 42 commodity groups reported in the 1972 Census of Transportation
- Elasticities:

  Rail -0.25 to -0.35
- Note: the figures above are average elasticities

Lewis and Widup (1982)

- Two modes: Rail vs. Truck (Freight)
- A translog demand model for shipments of assembled automobiles.
- Simultaneous Equation model estimated by FIML.
- Annual U.S. data 1955 to 1975.
- Elasticities:

Truck	-0.52 to -0.67
Rail	-0.92 to -1.06

Madan and Groenhout (1987)

- Two modes: Highway vs. Transit (Intra-city Passenger)
- Probabilistic Choice Model, allowing for correlations of utilities between modes.
- Australian Survey data, 1981 Sydney Regional Travel Survey, Sample size unknown.
- Elasticities (aggregate demand)

Highway	-0.038	(Vehicle operating cost)
Transit	-0.102	(Transit fare)

- Note:Aggregate demand elasticities are a probability-weighted average of individual elasticities.

Mannering and Winston (1985)
- Single mode: Auto
- A discrete/continuous model of vehicle ownership and utilization
- U.S. Cross-section data: 1978 National Interim Energy Consumption Survey and 1979 Household Transportation Panel Survey
- Elasticities: (vehicle utilization)

Single-vehicle households		
	Short Run	-0.228
	Long Run	-0.279
Two-vehicle households		
	Short Run	-0.059
	Long Run	-0.099

McCarthy (1982)
- Multimodel: Car, bus, rapid transit (Intra-city Passenger)
- Multinomial logit model
- Concerned mainly with the stability of disaggregate models by comparing estimates before and after the rapid transit system in Bay Area, San Francisco
- U.S. Survey data, Pre-rapid transit, 133 observations; Post-rapid transit, 1973-74, 161 observations; 1974, 176 observations
- Elasticities: (Weighted aggregate measures, out of pocket cost normalized by wage)

Pre-rapid transit		
	Auto	-0.055
	Bus	-0.368
Post-rapid transit (1973-74)		
	Auto	-0.063 to -0.073
	Bus	-0.372 to -0.417
	Transit	-0.343 to -0.38
Post-rapid transit (1975)		
	Auto	-0.074 to -0.088
	Bus	-0.381 to -0.562
	Transit	-0.397 to -0.539.

McCarthy (1986)
- Single mode: Auto (Passenger)
- U.S. Survey data, 287 observations
- Two-equation model (Ownership and Usage)
- 3SLS estimation
- Elasticities: -0.149 to -0.446

McFadden (1974)
- Multimodal: Auto, Bus & Rapid Transit (Passenger)
- Conditional logit model
- Survey data: San Francisco Bay Area

- Elasticities: (Work trips)

			Modal Split
Pre-Rapid Transit			
	Auto	-0.32	75%
	Bus	-0.45	25%
Post-Rapid Transit			
	Auto	-0.47	66%
	Bus	-0.58	20%
	Rapid Transit	-0.86	14%

McGeehan (1984)
- Single mode: Rail (Inter-city Passenger)
- Linear demand function
- Single Equation OLS estimation
- Quarterly data 1970 to 1982, Ireland
- Elasticities -0.37 to -0.40

Modak and Bhanushali (1985)
- Single mode: Bus (Intra-city Passenger)
- Linear demand equation
- India Cross section data: 1980-81, 176 routes; 1981-82, 184 routes; 1982-83, 193 routes
- Fare elasticities:

	Range	Mean
1980 (after a 13.59% rise in fare)	-0.23 to -0.88	-0.48
1981 (after a 3.08% rise in fare)	+2.69 to -0.99	0.75
1982 (after a 26.97% rise in fare)	-0.21 to -0.78	0.40

- Note:Inter-modal competition not recognized. High probability of misspecification of demand equations

Morrison and Winston (1983)
- Multimodal: Auto, bus, rail and air (Inter-city Passenger)
- Cross section data: U.S. Census of Transportation National Travel Survey, 1977
- Random Utility model, estimated by MLE
- Two specifications: H.H. trips and person trips.
- Modal choice elasticities:

Auto	-0.83	-0.83
Bus	-0.45	-0.60
Rail	-0.86	-1.14
Air	-0.26	-0.38

Morrison and Winston (1985)
- Multimodal: Auto, bus, rail and air (Inter-city Passenger)
- Nested logit model
- U.S. 1977 Census of Transportation National Travel Survey (1893 household vacation trips, 3623 travellers, 607 city pairs)
- Modal choice elasticities

	Vacation Trips	Business Travellers
Auto	-0.955	-0.699
Bus	-0.694	-0.315
Rail	-1.20	-0.572
Air	-0.378	-0.181

Oum (1979a)

- Multi-modal: Rail, Truck & Waterway (Freight)
- Revenue share models, in translog functional form
- Canadian Time series data, annual 1945-74
- Mode choice elasticities

Rail	-0.093 to -0.291
Truck	+1.112 to -0.162
Waterway	-0.738 to -0.750

Oum (1979b)

- Two modes: Rail vs. Truck (Freight)
- Canadian CFTM data base (1970), 8 commodity groups
- Translog demand model, estimated by nonlinear least squares
- Ordinary elasticities of demand
  (Assume Unit elasticity of demand for the commodity and the proportional change in the commodity's price with respect to a change in the price of freight mode is 0.1)

	Rail	Truck
Fruits, Vegetables and edible foods	-1.037	-0.521
Lumber (including flooring)	-0.581	-0.563
Chemicals	-0.688	-0.982
Fuel Oil (except gasoline)	-0.459	-1.07
Refined Petroleum Products	-0.988	-0.513
Metallic Products	-1.198	-0.410
Nonmetallic Products	-1.079	-0.560

Oum (1989)

- Two modes: Rail vs Truck (freight)
- Canadian CFTM data base, 1979, Commodity 14 (fruits, vegetables and edible foods) and aggregate commodities.
- A comparison of Translog, Log-linear, Linear, Box-Cox Transformation and Logit models.
- Elasticities (Ordinary Demand)

	Aggregate		Commodity 14	
	Rail	Truck	Rail	Truck
Translog	-0.598	-0.692	-0.796	-0.652
Log-linear	-1.517	-1.341	-0.795	-1.542
Linear	-0.638	-0.048	-0.391	-0.318
Box-Cox	-1.384	-1.140	-0.795	-1.248
Logit	-0.83	-0.928	-0.484	-0.970

Oum and Gillen (1983)

- Multi-modes: Air, Bus and Rail (Inter-city Passenger)
- Structural analysis--demand equations derived from utility maximization.
- Estimated by Nonlinear least squares
- Canadian Quarterly data, 1961-76.

- Elasticities:

Air	-1.116 to -1.277
Bus	-1.275 to -1.615
Rail	-1.060 to -1.536

Oum, Gillen and Noble (1986)
- Single mode: Air (Passenger)
- Cross-section data (1978), 200 intra-U.S. routes
- Log-linear aggregate demand model, (estimated by OLS)
- Price elasticities

Vacation Routes	-1.52
Non-vacation Routes	-1.15

Pucher and Rothenberg (1979)
- A survey of the available empirical evidence on the elasticity of travel demand.
- Consists of 8 studies on gasoline demand, 3 studies on urban travel demand and 9 studies on transit fare elasticities.
- Elasticities:

(i)	Gasoline:	-0.2 to -0.3 (short run)	
		-0.32 to -1.37 (long run)	
(ii)	Auto:	Work trips	-0.12 to -0.49
		Shopping	-0.88
	Transit:	Work trips	-0.10
		Shopping	-0.32
	Bus:	Work trips	0
	Rail:	Work trips	-0.30
(iii)	Fare elasticities		
	System	-0.09 to -0.11 to -0.19 to -0.40 to -0.96	
	Bus	-0.31 to -0.4 to -0.58 to -0.70	
	Rail	-1.8 (noncaptive traffic)	
	Subway	-0.16 to -0.86	

Saad, Austen, and Taylor (1985)
- single mode: Australian export/import shipping
- yearly aggregate time-series data for Australia: 1971-82.
- log-linear model applied separately to export/import of each commodity and to each region of the world
- Elasticities:

Dry bulk cargo:	coal	-0.06, -0.24;
	iron ore	-0.11
	grains	-0.02, -0.06, -1.64
Liquid bulk cargo:		-0.21
General cargo:		0, -0.50, -1.107

Southworth (1981)
- two modes: Auto vs transit (Passenger)
- Survey data: 3795 observations, West Yorkshire, England
- Multinomial logit models
- Auto mode choice elasticities (Monetary travel cost)

Modal Choice Model

Social/Recreational	-0.164 to -0.341
Work	-0.162 to -0.179
Shopping	-0.788 to -0.965

Straszheim (1978)

- Single mode: Air (Passenger)
- International air travel.
- Log-linear demand equations, corrected for autocorrelation.
- Time-series data: 1952-73
- Elasticities:

First class	-0.649
Economy Fare	-1.481
Peak period economy fare	-1.922

Swait and Ben-Akiva (1987)

- Multimodal: bus, auto, rail, walk (Passenger)
  intra-city travel for work trips
- Survey data, 1977 Sao Paulo, Brazil Origin/Destination survey, 1725 observations
- Two models: Multinomial Logit Model and Parametrized Logit Captivity Model
- Elasticities:

	Multinomial Logit Model	Parametrized Logit Captivity Model
Bus	-0.14	-0.03
Auto	-0.02	-0.01
Rail	-0.25	-0.22

- Note:The above are estimated arc elasticities for uniform 100% increase in travel cost.

Talley and Eckroade (1984)

- Single mode: Air (Passenger)
- Log-linear demand equations
- U.S. Cross-section data, no. of observations unknown.
- Elasticities -2.828 to -4.506 (with respect to fare)

Talley and Schwarz-Miller (1988)

- Single mode: Air (Passenger and freight)
- Cross-section data: 22 U.S. air-passenger-cargo carriers for the year 1983.
- Log-linear demand function, estimated by 2SLS.
- Elasticities:

Air Cargo price elasticity	-1.318
Air Passenger price elasticity	-1.389

Taplin (1980)

- Single mode: Air (Passenger)
- A summary of results of 8 previous studies
- Fare elasticities (Overseas leisure travel)
  -1.4 - 1.6 - 2.0 - 2.7 - 3.3

Thobani (1984)

- Multi-modal: Car, taxi, rickshaw, minibus, walking and bus
- Nested Logit model
- Survey data: 330 observations (Karachi, Pakistan)
- Mode choice elasticities

Minibus	-0.10
Bus	-0.06

- Note:The above are elasticities computed on the basis of a 10% change in the cost of travel. Only elasticities of demand for minibus and bus are reported.

Tye and Leonard (1983)

- Single mode: Rail (Freight) (U.S.)
- Elasticity measures quoted from:

  Verified statement of William E. Wecker, Ex Parte No. 347 (sub-No. 1), before the ICC, 11 May, 1981. Appendix B. p. 4.

Commodities	Elasticities
Automobiles	-0.65
Corn, etc.	-0.53
Wheat, etc.	-0.52
Coal	-0.02
Food	-1.23
Lumber	-0.54
Pulp	-0.56
Chemicals	-0.39
Primary metals	-1.03

Wang, Maling and McCarthy (1981)

- Single mode: Air (Freight)
- Box-Cox transformation used
- U.S. Annual data 1950-77
- Elasticities

Passenger/Cargo Carriers	-2.33 to -2.50
All-Cargo carriers	-0.42 to -0.84
Aggregate model	-1.47 to -1.60

Wang and Skinner (1984)

- Single mode: Urban transit
- Monthly data for 7 U.S. Transit Authorities
- Linear & log-linear demand functions, estimated by OLS
- Elasticities (Dependent variable is ridership)

Albany, N.Y. (1973: 1 to 1980: 12)	-0.62
Atlanta, G.A. (1970: 1 to 1979: 12)	-0.042
Baltimore, M.D. (1973: 1 to 1981: 1)	-0.38
Des Moines, IO (1976: 9 to 1980: 12)	-0.28
Jacksonville, FLA (1976: 3 to 1980: 3)	-0.26
Miami, FL (1973: 1 to 1980: 12)	-0.009
New York (Surface transit) (1972: 1 to 1980: 12)	-0.15
New York (Rapid Transit) (1972: 1 to 1980: 10)	-0.05

White (1981)

- Single mode: Public transit
- U.K. Before and after survey of fare increases in 1976
- Fare elasticities (Bus)

Morpeth, England		
	Peak period	0.00
	Off peak	-1.00
	All day average	-0.70
Sheffield-Doncaster, England		
	Long distance	-0.80
	Medium distance	-0.40

- Fare elasticities (Urban railways)

London		
	Peak period	-0.15
	Off peak	-1.0

- Note: the above elasticity estimates fail to take into account the presence of inter-modal competition.

White (1984)

- Single mode: Auto (Passenger)
- U.K. Before and after survey of toll charges
- Elasticities

Auto (Southampton, England)		
	peak period	-0.21 to -0.36
	off peak	-0.14 to -0.29

Wilson, Wilson and Koo (1988)

- Two modes: Rail vs. Truck (Freight)
- U.S. Monthly data, July 1973 to June 1983
- Transport of wheat (hard red spring and durum) from North Dakota to the main terminal markets of Minneapolis and Duluth
- Estimated by Autoregressive 3SLS
- Elasticities:

Rail	-1.18
Truck	-0.73

Winston (1981)

- Two modes: Rail vs. Truck (freight)
- Disaggregate mode choice model, estimated by maximum likelihood
- U.S. cross-section data
- Elasticities:

Commodity Groups	Rail	Private	Common
Unregulated agriculture	-1.11	-0.99	--
Regulated agriculture	-0.29	-0.27	-0.32
Textiles and fabricated textiles	-0.56	-0.43	-0.77
Chemicals	-2.25	-2.31	-1.87
Leather, rubber and plastic product	-1.09	-2.01	-2.97
Stone, clay and glass products	-0.82	-2.04	-2.17
Primary and fabricated metals	-0.019	-0.18	-0.28
Machinery incl. electrical machinery	-0.61	-0.78	-0.04
Transport equipment	-2.68	-2.96	-2.32
Paper, printing and publishing	-0.17	-0.29	--
Petroleum and petroleum products	-0.53	-0.66	--
Lumber, wood and furniture	-0.08	-0.14	--

- Note:Both intra- and inter-modal competition are taken into account.

BIBLIOGRAPHY

Abrahams, M. (1983) "A Service Quality Model of Air Travel Demand: An Empirical Study", Transportation Research, 17A(5), 385-93.

Agarwal, V. and W. Talley (1985) "The Demand for International Air Passenger Service Provided by U.S. Air Carriers", International Journal of Transport Economics, 12(1), 63-70.

Anas, A. and G.Y. Lee (1982) "The Potential for a Value Capture Policy to Finance Rapid Transit Projects in Chicago's Southwest Side: An Empirical Simulation Analysis", Research in Urban Economics, 2, 171-202.

Anas, A. and L.N. Moses (1984) "Qualitative Choice and the Blending of Discrete Alternatives," Review of Economics and Statistics, 66(4), 547-55.

Anderson, J.E. and M. Kraus (1981) "Quality of Service and the Demand for Air Travel", Review of Economics and Statistics, 63(4), 533-40.

Andrikopoulos, A.A. and T. Terovitis (1983) "An Abstract Mode Model: A Cross-Section and Time Series Investigation", International Journal of Transport Economics, 10(3), 563-76.

Babcock, M.W. and W. German (1983a) "Forecast of Water Carrier Demand to 1985", Transportation Research Forum, 24(1), 249-57.

Babcock, M.W. and W. German (1983b) "1985 Forecast: Rail Share of Intercity Manufacturers Freight Markets", Transportation Research Forum, 24(1), 614-20.

Bajic, B. (1984) "Choice of Travel Mode for Work Trips: Some Findings for Metropolitan Toronto", International Journal of Transport Economics, 11(1), 78-96.

Benham, J.L. (1982) "Analysis of a Fare Increase By Use of Time-Series and Before-and-After Data", Transportation Research Record, 877, 84-90.

Blum, U.C.H., G. Foos, and M.J.I. Gaudry (1988) "Aggregate Time Series Gasoline Demand Models: Review of the Literature and New Evidence for West Germany", Transportation Research, 22A(2), 75-88.

Boyer, K.D. (1977) "Minimum Rate Regulation, Modal Split Sensitivities, and the Railroad Problem", Journal of Political Economy, 85(3), 493-512.

Bureau of Transport Economics, Australia (1986) A Study of Liner Shipping Services in and out of Australia, Vol.2, Canberra: Australian Government Publishing Service.

Cummings, C.P., M. Fairhurst, S. Labelle, and D. Stuart, (1989) "Market Segmentation of Transit Fare Elasticities", Transportation Quarterly, 43(3), 407-20.

Doi, M. and W.B. Allen (1986) "A Time Series Analysis of Monthly Ridership for an Urban Rail Rapid Transit Line", Transportation, 13(3), 257-69.

Doganis, R. (1985) Flying Off Course: The Economics of International Airlines, U.K.: George Allen & Unwin.

Fridstrøm, L. and H. Thune-Larsen (1989) "An Econometric Air Travel Demand Models for the Entire Conventional Domestic Network: The Case of Norway", Transportation Research, 23B(3), 213-24.

Friedlaender, A.F. and R.H. Spady (1980) "A Derived Demand Function for Freight Transportation", Review of Economics and Statistics, 62, 432-41.

Gaudry, M.J.I. (1980) "A Study of Aggregate Bi-Modal Urban Travel Supply, Demand and Network Behavior Using Simultaneous Equation With Autoregressive Residuals", Transportation Research, 14B(1-2), 29-58.

Geltner, D. and Raimundo Caramuru Barros (1984) "Travel Behavior and Policy Analysis in a Medium-size Brazilian City", Transport Policy and Decision Making, 2, 425-50.5.

Gillen, D.W. and D.J. Cox (1979) "Assumed versus Estimated Functional Form in Disaggregate Mode Choice Models", Regional Science and Urban Economics, 9, 185-195.

Gillen, D.W., T.H. Oum and M.W. Tretheway (1988) "Airport Pricing Policies: An Application to Canadian Airports", Journal of Transport Research Forum, 1, 28-34.

Glaister, G. (1983) "Some Characteristics of Rail Commuter Demand", Journal of Transport Economics and Policy, 17(2), 115-32.

Goodwin, P.B. and H.C.W.L. Williams (1985) "Public Transport Demand Models and Elasticity Measures: An Overview of Recent British Experience", Transportation Research, 19B(3), 253-8.

Grayson, A. (1981) "Disaggregate Model of Mode Choice in Intercity Travel," Transportation Research Record, 835, 36-42.

Guria, J.C. (1988) "Effects of the Recent Road Transport Deregulation on Rail Freight Demands in New Zealand", International Journal of Transport Economics, 15(2), 169-87.

Haitovsky, Y., I. Salomon and A. Silman (1987) "The Economic Impact of Charter Flights on Tourism to Israel: An Econometric Approach", Journal of Transport Economics and Policy, 21(2), 111-34.

Hamberger, C.G. and A. Chatterjee (1987) "Effects of Fare and Other Factors on Express Bus Ridership in a Medium-sized Urban Area," Transportation Research Record, 1108, 53-9.

Hauser, R.J., J. Beaulieu and C.P. Baumel (1985) "Impacts of Inland Waterway User Fees on Grain Transportation and Implied Barge Rate Elasticities", Logistics and Transportation Review, 21(1), 37-55.

Hensher, D.A. (1985) "An Econometric Model of Vehicle Use in the Household Sector", Transportation Research, 19B (4), 303-14.

Hensher, D.A. and J.J. Louviere (1983) "Identifying Individual Preferences for International Air Fares: An Application of Functional Measurement Theory", Journal of Transport Economics and Policy, 17(3), 225-45.

Hensher, D.A. and N.C. Smith (1986) "A Structural Model of the Use of Automobiles by Households: A Case Study of Urban Australia," Transport Review, 6(1), 87-111.

Ippolito, R.A. (1981) "Estimating Airline Demand With Quality of Service Variables", Journal of Transport Economics and Policy, 15(1), 7-16.

Johnson L. and D. Hensher (1982) "Application of Multinomial Probit to a Two-period Panel Data Set", Transportation Research, 16A (5-6), 457-64.

Jones, I.S. and A.J. Nichols (1983) "The Demand for Inter-City Rail Travel in the United Kingdom", Journal of Transport Economics and Policy, 17(2), 133-53.

Kroes, E.P. and R.J. Sheldon (1985), "Stated Preference Techniques In Measuring Travel Elasticities", in G.R.M. Jansen, P. Nijkamp and C.J. Ruijgrok (eds.), Transportation and Mobility in an Era of Transition, Ams. : North Holland.

Kroes, E.P. and R.J. Sheldon (1988) "Stated Preference Method: An Introduction", Journal of Transport Economics and Policy, 22(1), 11-25.

Kyte, M., J. Stoner and J. Cryer (1988) "A Time-Series Analysis of Public Transit Ridership in Portland, Oregon, 1971-82", Transportation Research, 22A(5), 345-59.

Levin, R.C. (1978) "Allocation in Surface Freight Transportation: Does Rate Regulation Matter?", Bell Journal of Economics, 9(1), 18-45.

Lewis, K.A. and D.P. Widup (1982) "Deregulation and Rail-Truck Competition: Evidence From a Translog Transport Demand Model for Assembled Automobiles", Journal of Transport Economics and Policy, 16(2), 139-49.

Madan, D.B. and R. Groenhout (1987) "Modelling Travel Mode Choices For the Sydney Work Trip", Journal of Transport Economics and Policy, 21(2), 135-49.

Mannering, F. and C. Winston (1985) "A Dynamic Empirical Analysis of Household Vehicle Ownership and Utilization," Rand Journal of Economics, 16(2), 215-36.

McCarthy, P.S. (1982) "Further Evidence on the Temporal Stability of Disaggregate Travel Demand Models", Transportation Research, 16B(4), 263-78.

McCarthy, P.S. (1986) "Shared Fleet Arrangements: Implications for Vehicle Demand Using a Simultaneous Equation Approach", International Journal of Transport Economics, 13(1), 87-103.

McFadden, D.(1974) "The Measurement of Urban Travel Demand", Journal of Public Economics, 3, 303-28.

McGeehan, H. (1984) "Forecasting the Demand for Inter-Urban Railway Demand Travel in the Republic of Ireland", Journal of Transport Economics and Policy, 18(3), 275-91.

Modak, S.K. and V.G. Bhanushali (1985) "Demand Elasticities for Public Bus Transport in Bombay," Transportation Research Forum, 26, 175-83.

Morrison, S.A. and C. Winston (1983) "The Demand for Intercity Passenger Transportation: The Impact on the Bus Industry in a Changing Environment", Transportation Research Forum, 24(1), 526-34.

Morrison, S.A. and C. Winston (1985) "An Econometric Analysis of the Demand for Intercity Passenger Transportation," Research in Transportation Economics, 2, 213-37.

Oum, T.H. (1979a) "Derived Demand for Freight Transport and Inter-modal competition in Canada", Journal of Transport Economics and Policy, 13(2), 149-68.

Oum, T.H. (1979b) "A Cross-Sectional Study of Freight Transport Demand and Rail-Truck Competition in Canada", Bell Journal of Economics, 10, 463-82.

Oum, T.H. (1989) "Alternative Demand Models and Their Elasticity Estimates", Journal of Transport Economics and Policy, 23(2), 163-87.

Oum, T.H. and D.W. Gillen (1983) "The Structure of Intercity Travel Demand in Canada: Theory, Tests and Empirical Results", Transportation Research, 17B(3), 175-91.

Oum, T.H., D.W. Gillen and S.E. Noble (1986) "Demand for Fareclasses and Pricing in Airline Markets", Logistics and Transportation Review, 22(3), 195-222.

Pucher, J. and J. Rothenberg (1979) "Potential of Pricing Solutions for Urban Transportation Problems: An Empirical Assessment", Transportation Research Record, 731, 19-28.

Saad, M., S. Austen and S. Taylor (1985) "Demand for Australia's International Sea Freight Task", Forum Papers of the 10th Australian Transport Research Forum, May 1985, Vol. 2, Melbourne.

Southworth, F. (1981) "Calibration of Multinomial Logit Model of Mode and Destination Choice", Transportation Research, 15A(4), 315-26.

Straszheim, M.R.(1978) "Airline Demand Functions in the North Atlantic and Their Pricing Implications", Journal of Transport Economics and Policy, 12(2), 179-95.

Swait, J. and M. Ben-Akiva (1987) "Empirical Test of a Constrained Choice Discrete Model: Mode Choice in Sao Paulo, Brazil", Transportation Research, 21B(2), 103-116.

Talley, W.K. and W.R.Eckroade (1984) "Airline Passenger Demand in Monopoly Flight Segments of a Single Airline", Transportation Journal, 24(2), 73-79.

Talley, W.K. and Schwarz-Miller (1988) "The Demand for Air Services Provided by Air Passenger-Cargo Carriers in a Deregulated Environment", International Journal of Transport Economics, 15(2), 159-68.

Taplin, J.H.E.(1980) "A Coherence Approach to Estimates of Price Elasticities in the Vacation Travel Market", Journal of Transport Economics and Policy, 14(1), 19-35.

Thobani, M. (1984) "A Nested Logit Model of Travel Mode to Work and Auto Ownership," Journal of Urban Economics, 15, 287-301.

Tye, W.B. and H.B. Leonard (1983) "On the Problems of Applying Ramsey Pricing to the Railroad Industry with Uncertain Demand Elasticities", Transportation Research, 17A(6),439-50.

Wang, G.H.K., W. Maling and E. McCarthy (1981) "Functional Forms and Aggregate U.S. Domestic Air Cargo Demand: 1950-1977", Transportation Research, 15A(3), 249-56.

Wang, G.H.K. and D. Skinner (1984) "The Impact of Fare and Gasoline Price Changes On Monthly Transit Ridership: Empirical Evidence From Seven U.S. Transit Authorities", Transportation Research, 18B(1), 29-41.

White, P.R.(1981) "Recent Developments in the Pricing of Local Public Transportation Services", Transport Reviews, 1(2), 127-50.

White, P.R.(1984) "Man and His Transport Behavior: Part 4a: User Response to Price Changes: Application of the 'threshold concept'", Transport Reviews, 4(4), 367-86.

Wilson, W.W., W.W. Wilson and W.W. Koo (1988) "Modal Competition in Grain Transport", Journal of Transport Economics and Policy, 23(3), 319-37.

Winston, C. (1981) "A Disaggregate Model of the Demand for Intercity Freight Transportation", Econometrica, 49(4), 981-1006.

PPR Working Paper Series

	Title	Author	Date	Contact for paper
WPS335	Macroeconomic Adjustment and the Labor Market in Four Latin American Countries	Ramon E. Lopez Luis A. Riveros	December 1989	L. Riveros 61762
WPS336	Complementary Approaches to Financing Health Services in Africa	Germano Mwabu		
WPS337	Projecting Mortality for All Countries	Rodolfo A. Bulatao Eduard Bos Patience W. Stephens My T. Vu	December 1989	S. Ainsworth 31091
WPS338	Supply and Use of Essential Drugs in Sub-Saharan Africa: Issues and Possible Solutions	S. D. Foster		
WPS339	Private Investment and Macro-economic Adjustment: An Overview	Luis Serven Andres Solimano	December 1989	E. Khine 61763
WPS340	Prudential Regulation and Banking Supervision: Building an Institutional Framework for Banks	Vincent P. Polizatto	January 1990	WDR Office 31393
WPS341	Cost-of-Living Differences between Urban and Rural Areas of Indonesia	Martin Ravallion Dominique van de Walle	December 1989	C. Spooner 30464
WPS342	Human Capital and Endogenous Growth in a Large Scale Life-Cycle Model	Patricio Arrau	December 1989	S. King-Watson 33730
WPS343	Policy Determinants of Growth: Survey of Theory and Evidence	William R. Easterly Deborah L. Wetzel	December 1989	R. Luz 61588
WPS344	Policy Distortions, Size of Government, and Growth	William Easterly	December 1989	R. Luz 61588
WPS345	Private Transfers and Public Policy in Developing Countries: A Case Study for Peru	Donald Cox Emmanuel Jimenez	December 1989	A. Bhalla 60359
WPS346	India's Growing Conflict between Trade and Transport: Issues and Options	Hans Jurgen Peters	January 1990	T. Lim 34894
WPS347	Housing Finance in Developing Countries: A Transaction Cost Approach	Robert M. Buckley	December 1989	WDR Office 31393

PPR Working Paper Series

	Title	Author	Date	Contact for paper
WPS348	Recent Trends and Prospects for Agricultural Commodity Exports in Sub-Saharan Africa	Takamasa Akiyama Donald F. Larson	December 1989	D. Gustafson 33714
WPS349	A Short-run Econometric Analysis of the Indonesian Monetary System	Sadiq Ahmed Basant K. Kapur		
WPS350	Legal Process and Economic Development: A Case Study of Indonesia	Cheryl W. Gray	December 1989	B. Dhomun 33765
WPS351	The Savings and Loan Problem in the U.S.	Stanley C. Silverberg		
WPS352	Voluntary Export Restraints and Resource Allocation in Exporting Countries	Jaime de Melo L. Alan Winters		
WPS353	On the Theory of Tariff Reforms	Arvind Panagariya		
WPS354	Commodity Prices, Macroeconomic News, and Business Cycles	Dhaneshwar Ghura		
WPS355	Evolution of Credit Terms: An Empirical Study of Commercial Bank Lending to Developing Countries	Sule Ozler		
WPS356	A Framework for Analyzing Financial Performance of the Transport Sector	Ian G. Heggie Michael Quick		
WPS357	Application of Flexible Functional Forms to Substitutability among Metals in U.S. Industries	Ying Qian		
WPS358	FY89 Sector Review: Population, Health, and Nutrition	Population, Health, and Nutrition Division, Population and Human Resources Department		
WPS359	A Survey of Recent Estimates of Price Elasticities of Demand for Transport	Tae H. Oum W. G. Waters, II Jong Say Yong	January 1990	W. Wright 33744
WPS360	Compounding Financial Repression with Rigid Urban Regulations: Lessons of the Korea Housing Market	Bertrand Renaud		
WPS361	Housing and Labor Market Distortions in Poland: Linkages and Policy Implications	Stephen K. Mayo James I. Stein		