A REVIEW OF NEW DEMAND ELASTICITIES WITH SPECIAL REFERENCE TO SHORT AND LONG RUN EFFECTS OF PRICE CHANGES

By P. B. Goodwin*

1. INTRODUCTION

Demand elasticities are, in general, rather crude and approximate measures of aggregate responses in a market. They do, however, have the great attractions of being empirically estimable, reasonably easily understood, tested by experience, and directly usable for policy assessment.

Empirical knowledge of the size and variability of travel demand elasticities has had an important effect on thinking about transport policy. Low elasticities imply relatively ineffective levers for influencing demand (and correspondingly effective ones for influencing revenue), and circumscribe the sorts of policies which will be taken seriously. Zero elasticities, implied by the absence of certain relationships in traffic forecasting models, shift the attention of policy-makers away from such aspects of behaviour, in favour of those whose sensitivity to price and other influences is quantified.

For a number of reasons, there is currently a need to reassess this relationship. In part this derives from a recognition that in many countries increased capacity cannot easily cater for the forecast rates of traffic growth, and the tools of demand management therefore have greater importance. Among these tools, use of the price mechanism is particularly important because of its contribution to generating funds for public or private expenditure, and helping markets to operate more efficiently by ensuring that the external costs of pollution and congestion are met by those who cause them.

Therefore it is important for policy-making to be informed by the best available knowledge about the sensitivity of travel demand to the prices operating on it.

During the 1980s, some important developments were taking place in the understanding of travel demand — not, primarily, generated by policy interests, but in the context of empirical and theoretical studies that emphasised the broad range of behavioural responses that existed, and the complex dynamic processes of adaptation that were implied by these responses. The papers edited by Jones (1990) summarise these developments. At the same time, a very large number of elasticity studies were being carried out, with very little consistency in method or assumptions.

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The question arose, did these empirical studies simply reinforce what was already known from previous work, or were new insights available, reflecting either the new policy interests or the new research interests, or both?

Two earlier Working Papers, by Oum, Waters and Yong (1990) and by Goodwin (1991) set out independently to review available evidence since the late 1970s on transport demand elasticities, especially own-price elasticities estimated empirically from cross-section or time-series data. When the authors became aware of each other's work, they found to their surprise that out of a total of some 150 cited references, the two reviews only had a handful of references in common.

On examination, part of the reason for the discrepancy lay in the different coverage and research strategies involved in the two studies (respectively a North American compared with a European base; formal search of academic journals compared with 'chaining'; a broad coverage of all modes compared with a narrower focus on cars and public transport).

However, in the opinion of the author there is another reason, with important consequences for exercises of this nature. In the field of transport demand analysis, there have developed two quite different publication cultures. The first consists of the traditional academic route of refereed papers in a set of established journals, together with (hard-back) books also primarily aimed at an academic market. The second consists of reports, either as part of a series or one-off, printed by Government agencies (local, national and international), by transport operators, or by the consultants or academics who have carried out the studies. Typically the review procedures before publication are also different - anonymous peer review in the first case, client/contractor discussion in the second - and for that reason the former can carry more weight within the academic tradition, while the latter are often more overtly directed at practical application and correspondingly influential among policy-makers and operators. Both are, however, unambiguously in the public domain, and the experience of carrying out the reviews is a salutary lesson that comprehensive literature surveys must cover both forms of publication.

Two very influential examples of the second stream of work were the review of public transport elasticities edited by Webster and Bly (1980), and of petrol price elasticities by the Commission of the European Communities (1980). The present paper is intended to bring those two sources up to date by including references since 1980, and a few earlier ones which had escaped notice. In addition, the scope has been widened a little in relation to the effect of public transport accessibility on car ownership where the literature surveyed uncovered some useful extra references.

As an overview, it is worth noting that there appears to have been some drift upwards in elasticities estimated in the current period. The unweighted mean value of 50 quoted bus fare elasticities is -0.41, compared with the -0.3 earlier taken as orthodox. The unweighted mean value of 120 elasticities of petrol consumption with respect to fuel price is -0.48, compared with earlier values of -0.1 to -0.4.

However, by far the most important tendency in the new studies has been the use of estimation procedures explicitly distinguishing between short term and long term effects. This was hardly ever done for public transport, but is now more common, and for fuel it is on its way to becoming standard.

Overall, there is a reasonably clear pattern for long term elasticities to be between 50 per cent higher and three times higher than the short term.
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TABLE 1
Summary of Evidence from Studies of Elasticity of Petrol Consumption With Respect to Price

<table>
<thead>
<tr>
<th></th>
<th>Explicit</th>
<th></th>
<th>Ambiguous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Short term</td>
<td>Long term</td>
<td></td>
</tr>
<tr>
<td>Time-series</td>
<td>-0.27</td>
<td>-0.71</td>
<td>-0.53</td>
</tr>
<tr>
<td></td>
<td>(0.18, 51)</td>
<td>(0.41, 45)</td>
<td>(0.47, 8)</td>
</tr>
<tr>
<td>Cross-section</td>
<td>-0.28</td>
<td>-0.84</td>
<td>-0.18</td>
</tr>
<tr>
<td></td>
<td>(0.13, 6 )</td>
<td>(0.18, 8 )</td>
<td>(0.10, 5 )</td>
</tr>
</tbody>
</table>

Figures in brackets are one standard deviation, and the number of quoted elasticities in the average. From 13 studies: Ben Akiva et al. (1986); Bland (1984); Bonsall and Champernowne (1976); Commission of the European Communities (1980); Donelly (1985); Drollas (1984, 1987); Goodwin (1987a); Mackett (1984); Thomson (1972); Vaes (1982); Wabe (1987); Zudak and Koshal (1982). Not included is Hensher and Young (1991) which provides a synthesis of a number of studies and recommends a ‘five-year’ fuel elasticity for road passenger vehicles of -0.66, which would be consistent with a long term equilibrium figure of -0.7 or -0.8 as suggested here.

Some caveats should be mentioned. Apart from a very few studies which were omitted due to incomprehensibility or absurdity, this review, fairly uncritically, takes all results as of equal merit. This gives greater emphasis to those studies (often, but by no means always, the better ones) which give a larger number of detailed estimates for different market segments or estimation procedures. It also gives greater weight to those studies whose authors helpfully present their results in the form of elasticities rather than leaving them as dimensioned coefficients.

2. CAR COSTS

Effect of Petrol Price on Petrol Consumption
The average of 120 estimates of petrol price elasticity is -0.48. It may be disaggregated as follows.

Each quoted elasticity has been divided into one of six categories, namely cross-section or time-series, subdivided into explicit short term, explicit long term, and ambiguous. For the time-series results short term and long term are defined by the model parameters. For cross-section results, ‘short’ and ‘long’ term results are based on the original authors’ own judgement on the nature of the behavioural change and variables allowed in the models. Models with no explicit consideration of time-scale are treated as ambiguous. The results are shown in Table 1.
The time-series results are mostly from annual, quarterly or monthly data over a time period of 5-15 years. The cross-section results are typically from 'instantaneous' surveys actually spread over 1-6 months, or from annual sales/consumption data. It seems reasonable in both cases to say that 'short term' refers to a period less than one year long.

The long term in both cases ought to be a real final equilibrium, but in practice models do not work that way. Time-series analysis often seems to be able to detect lags of the order of half as long as the series (that is, about 5 years in these cases), and the cross-section models used typically do not allow for effects on patterns of building, industrial location and so on.

**Effect of Petrol Price on Traffic Levels**

It should be expected that traffic levels would be proportional to petrol consumption in the short run, but not in the longer run as people can trade down (or up) the size and efficiency of cars they buy. There are not enough results available to test this expectation as completely as above, but a summary is shown in Table 2.

Dix & Goodwin (1982) suggested that in the short run elasticities of traffic levels and of petrol consumption with respect to petrol price should be equal to each other, and low, but over time they would diverge as the long run petrol consumption elasticity grew faster than the traffic elasticity. The behavioural basis for them both to increase over time is that changes in trip rates, car ownership, destination choice, and location decisions take some time to implement. The basis for expecting fuel consumption elasticities to grow faster is that some changes, especially changes in vehicle size and efficiency, have an effect on consumption while preserving mobility.

The picture that emerges fairly clearly is that the longer term elasticities are in the order of twice as high as the shorter term ones. However, both short and long term effects of petrol price changes on traffic levels are considerably less than their effects on petrol consumption. This implies that even in the short run there are behavioural adaptations that affect petrol consumption more than traffic; changes in driving styles and speed may be suggested, though it has not previously been thought that this effect would be big enough to explain the difference. There is also the possibility that there is a preference to modify the least energy-efficient journeys.

Supporting evidence that the longer term effects may be substantial is available from a few studies which have directly estimated the effects of petrol price on the car stock itself. Hensher et al. (1987), using four years of panel data, estimated that the elasticity of fleet size and type with respect to fuel cost was -0.15 to -0.41, Mackett (1985) gave a figure of -0.01, Tanner (1981, 1983) gave figures ranging from -0.2 to -0.4, Berkovek (1985) and Berkovek and Rust (1985) gave results from a cross-section model implying a mid-point elasticity of fleet size with respect to fuel price of -0.1. A central value is of the order of -0.2.

We can put these results together with the much better established estimates for the effects of car purchase costs on car ownership; Harbour (1987) reviewed 93 estimates, which had a mean of -0.89, with most results in the range -0.4 to -1.6. To a first approximation, the elasticities of car ownership with respect to purchase cost and petrol
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TABLE 2

Summary of Evidence from Studies of Elasticity of Traffic Levels with respect to Petrol Price

<table>
<thead>
<tr>
<th></th>
<th>Explicit</th>
<th>Ambiguous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Short</td>
<td>Long</td>
</tr>
<tr>
<td>Time-series</td>
<td>-0.16</td>
<td>-0.46</td>
</tr>
<tr>
<td></td>
<td>(0.08 ,4)</td>
<td>(0.40, 5)</td>
</tr>
<tr>
<td>Cross-section</td>
<td>—</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>(0.06, 2)</td>
<td>(n.a., 1)</td>
</tr>
</tbody>
</table>

The elasticities in this table are from: Bland (1984); Bonsall and Champernowne (1976); Hensher and Smith (1986a); Horowitz (1982); Lewis (1978); Mackett (1984); Mannering (1986); Ryder (1982); Tanner (1981); Uri (1982); Vaes (1982).

cost ought to be approximately in the ratio of the two expenditures, which would support a fuel figure of around -0.4, though this is larger than the empirical results noted above, perhaps due to misperception of fuel costs. Mogridge (1983) suggested an overall long run constancy of expenditure on motoring, hence an interaction between responses to fuel price changes and to car purchase costs, giving an elasticity with respect to total motoring costs of -1, which is also rather less sensitive than implied in Harbour’s review.

To summarise these results, for a sustained real 10 per cent increase in fuel price, we have:

- in the short run, a decrease in traffic of 1.5 per cent or thereabouts, and a decrease in fuel consumption of 3 per cent or thereabouts, the difference being possibly due to more careful driving and greater sensitivity on energy-inefficient journeys.

- in the longer run, a decrease in traffic of 3 per cent to 5 per cent, split between a reduction in car ownership and a decrease in car use (neither being more than 3 per cent on its own), and a decrease in petrol consumption of 7 per cent or more, the extra reduction being achieved by smaller or more efficient vehicles, but damped by downward pressure on the price of new and second-hand vehicles.

The policy implication would seem to be that petrol price manipulation is a more effective lever to achieve objectives of fuel conservation than it is for control of congestion (though in the longer run the effects, even here, are larger than has traditionally been assumed).
TABLE 3

Bus Fare Elasticities Related to Time Period

<table>
<thead>
<tr>
<th>Source</th>
<th>Time period</th>
<th>Average Elasticity</th>
<th>S.D.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before and after</td>
<td>around 6 months</td>
<td>-0.21</td>
<td>0.12</td>
<td>3</td>
</tr>
<tr>
<td>Explicit short</td>
<td>0-6 months</td>
<td>-0.28</td>
<td>0.13</td>
<td>8</td>
</tr>
<tr>
<td>Unlagged time-series</td>
<td>0-12 months</td>
<td>-0.37</td>
<td>0.18</td>
<td>24</td>
</tr>
<tr>
<td>Explicit 'long'</td>
<td>4+ years</td>
<td>-0.55</td>
<td>0.20</td>
<td>8</td>
</tr>
<tr>
<td>Equilibrium</td>
<td>5-30</td>
<td>-0.65</td>
<td>0.18</td>
<td>7</td>
</tr>
</tbody>
</table>

The studies used for this table were: Blase (1985); Cervero (1985); Doi and Allen (1986); Fairhurst et al. (1987); Goodwin (1973, 1975, 1987b); Greater London Council (1977); Grimshaw (1984); Hallam (1978); Mackett (1984); MacKenzie and Goodwin (1986); Meurs et al. (1990); National Bus Company (1984); Oldfield (1979); Ryder (1982); Smith (1982); Studemund and Connor (1982); Tyson (1984); Wang and Skinner (1984); Zahavi and McLean (1983).

3. PUBLIC TRANSPORT COSTS

Bus

The overall average of 50 elasticities found was -0.41. In nearly all cases, it was possible to classify them according to a scheme related to the time period, accepting in some cases their authors’ judgement rather than explicit model specification. The results are shown in Table 3.

Given the power from previous work of a static elasticity of -0.3, usually estimated from unlagged time series data, it would make sense to consider this as a reasonable figure for the effects within the first year (though the current figure for that particular class of approach is rather higher, at -0.37). Then the effect after four years or so would more sensibly be described as medium term, and is given as -0.55, creeping up to -0.65 over a decade or more. Some studies have found higher values (up to -0.98), but others lower (down to -0.45), and there is not yet sufficient pattern apparent to distinguish the causes for this.

Table 3 does not include the results of Gilbert and Jalilian (1991), who estimate a bus fare elasticity in London of -0.8 in the short run and -1.2 to -1.3 in the long run - a rare study to have found bus elasticities of greater than 1, which if valid has profound policy and operating implications. They used considerably more advanced econometric methods than have usually been applied to bus statistics, albeit with some data inadequacies, and the results certainly merit further verification. It is interesting to observe that while the absolute level is higher than the other studies, the relativity between short and long term elasticities is closely consistent. Off-peak elasticities remain typically about twice as high as in the peak.

Thus, in the short term, bus demand remains, as traditionally thought, inelastic.
enough to make revenue raising by fare increases an effective policy, but demand increases by fare reductions (for example to assist congestion) rather limited. But in the longer run the effectiveness of the first policy is reduced, and of the second is increased.

**Underground Railway**

Estimates of underground railway fare elasticity are sparse. The most influential have to be those of London Transport; Goulcher (1990) estimated a first-year morning peak trip elasticity of around –0.4, with a long run value of –0.6. Gilbert and Jalilian (1991) estimated a short run elasticity of –0.4, and a long run figure of –0.7 to –1.0. It should be remembered that these figures include a substantial transfer effect between tube and bus; in circumstances where both modes changed their prices together, the overall elasticity is lower; earlier work by Fairhurst *et al.* (1987) had given a one-year effect of –0.2 and a longer term effect of –0.4.

**Rail**

The overall average of 92 quoted values is –0.79 (standard deviation 0.32). However, there is considerable overlap in coverage with several studies referring to similar London-based intercity or commuting movements. This applies to studies by Fowkes *et al.* (1985), Glaister (1983), Hughes (1980), Jones and Nichols (1983), Kroes and Sheldon (1985), Mackett (1985), Oldfield and Taylor (1981), and Owen and Phillips (1987). Godward (1984) and Bamford (1984) both refer to the West Midlands, Hensher and Bullock (1979), and Hensher and Smith (1986b) to Australia, and Webster and Bly (1980) cite 10 references with elasticities ranging from –0.13 to –0.81.

Owen and Phillips (1987) used a formulation enabling explicit estimation of short and long term elasticities. Their short term figure of –0.69 (average of twenty different flows, ranging from –0.4 to –0.76) compares well with an average of –0.65 for 38 other estimates using unlagged time-series or short term before-and-after studies, and their long term figure of –1.08 (varying from –0.61 to –1.38) compares with some but not all of Mackett’s estimates, drawn from a long term land-use/transport interaction model.

Given the rather high average elasticities, it seems clear that some market segments must be very sensitive indeed to fare changes. BR’s own figure is –0.9 for the provincial sector. Glaister gave –1.1 for some London commuters if season ticket charges only are changed. Hughes gave –1.01 for reduced fare tickets. Jones *et al.* (1983) gave figures up to –1.2. Mackett’s modelling suggested –1.5 for commuting journeys to inner (not central) London, and –1.1 to other destinations. Indeed Owen and Phillips’ long term result says that this whole market sector is highly elastic.

Each of these high figures is itself an average of different times of day, specific origin-destination pairs, sub-sections of the market, and so on. In the nature of averages, this must imply the existence of people for whom the response to fare changes is very large indeed - certainly enough to justify (selective) price reductions as a way of raising revenue, and to invalidate the effectiveness of price increases for those sectors.

**Effect of Petrol Prices on Public Transport Demand**

Five results from three studies give an average cross-elasticity of public transport demand with respect to petrol prices of +0.34. (Range +0.08 to +0.8). These are Bland (1984), Doi and Allen (1986), and Wang and Skinner (1984).
4. ACCESSIBILITY AND CAR OWNERSHIP

Eleven studies have found a significant effect of some measure of accessibility on car ownership, and especially effects of public transport service levels or costs. Bates and Roberts (1979, 1981), and Copley and Lowe (1981), give results which broadly support an elasticity of car ownership with respect to public transport service level of about -0.1. Jones and Tanner (1979) associate a variation in car ownership of ±25 per cent with variations in public transport accessibility. Mackett gives an elasticity with respect to bus fare only of +0.04 (consistent with a service-level elasticity also of the order of -0.1). Daly and Zachary (1977) suggested that free public transport would lead to a 3 per cent fall in car ownership and 10 per cent fall in car availability, for commuting only.

Some studies have given higher values: Button, Pearman and Fowkes’ (1980) results imply that the elasticity of car ownership with respect to bus generalised cost is about the same as with respect to income (certainly considerably greater than 0.1, though elasticities are not directly estimated). Zahavi (1982) suggests an elasticity of car ownership with respect to the size of the road network of -0.38. Results from Daor and Hathaway (1973), Fairhurst (1975), Goodwin (1988), Koenig (1980) and McCarthy (1985) all support the existence of significant effects.

The elasticity of car ownership with respect to public transport generalised costs is not likely to be less than +0.1, or more than about +0.3, implying a rather small figure of less than +0.1 for fares alone. Putting this together with the results for the increase in long term elasticities for both car use and public transport use considered separately, it may be that modal shifts are more feasible than is often assumed (though still less than the very high cross-elasticities implied by some of the early generation of disaggregate mode choice models).

5. DISCUSSION AND CONCLUSIONS

In general, for many years price elasticities were known to be low - certainly far below the level at which revenue would be lost through fare or petrol price increases. They were also implicitly held to be rather narrow in scope, as may be seen by considering the sorts of transport models thought to be able to comprehend the most important behavioural responses to price changes, with overall trip rates and car ownership both unaffected by travel costs. The issue of the time-scale within which people respond to price changes has not formed a part of those studies which use unlagged time-series analysis or inference from models calibrated on cross-section data.

The pattern which emerges from this review supports Oum, Waters and Yong’s conclusion that

"...competition between modes, routes or firms gives rise to a wide range of price elasticities, generally much more elastic than conventional wisdom would suggest..."

It is not clear whether the ‘conventional wisdom’ was correct in its day, the elasticities themselves having changed, perhaps because of the greater range of behavioural possibilities open in an increasingly complex transport system, or whether some history of methodological bias led to an underestimate of the sensitivity of travel demand. There is some reason for suspecting the latter.
Consider the indications - which surely must now be taken very seriously indeed, since empirical observation, behavioural theory, and common sense all point in the same direction - that long term elasticities are higher than short term ones. This unobjectionable proposition has three very profound implications.

First, it implies that behavioural response to cost changes is a response that takes place over time. It follows that, in an era when price stability is absent, observations recorded at a specific point in time cannot be analysed on the assumption that the observed demand is in equilibrium with the observed price. Unlagged time-series analysis, and models calibrated from cross-section data, inherently make the assumption of observed equilibrium; by failing to consider the history of their observation, they are subject to a specification bias, whose character is determined by that history. Once we accept the existence of time-dependent responses, even if only as a research hypothesis, it is necessary to require elasticity estimation to have an explicit time-dependent specification.

Secondly, it makes sense that the range of responses open to people is greater in the longer run than they can make immediately. For this reason, some of the responses deemed unnecessary for consideration in the past are now appearing to be of possible importance. In particular, car use costs may not only marginally influence the day-to-day pattern of travel, but also car ownership, vehicle type and location decisions; and public transport fares may have a considerably bigger effect on the public transport market than traditionally assumed, especially over a period of some years — and, possibly, on traffic levels as well.

Thirdly, all this means that policy opportunities may also be wider, albeit demanding analysis in which questions relating to time-scale — horizon, duration, delays, and sequence of implementation — become increasingly important. The results do support the view that pricing (in particular petrol price and public transport fares, but also by extension other prices) has a powerful cumulative effect on the pattern of travel demand.

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A version of this bibliography with brief summaries of most of the citations is available:

*An Annotated Bibliography on Demand Elasticities*

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