FARE EVASION AS A RESULT OF EXPECTED UTILITY MAXIMISATION

Some Empirical Support

By Peter Kooreman*

1. INTRODUCTION

Fare evasion is a phenomenon that is inherent in virtually any public transport system. Although systems exist where it is physically impossible to enter the vehicles without having a valid farecard, many public transport systems are not so safeguarded and can be used, more or less easily, without a farecard. Especially in metropolitan public transport systems with a high degree of utilisation, a completely secure system would slow down the inflow of passengers and hence reduce the capacity of the system. This is one of the reasons why many cities opt for a system which allows access without having a farecard, combined with random inspection of passengers and fining of free riders.

In such cases, the transport company is confronted with the problem of determining the optimal inspection policy. In Polinsky and Shavell (1979), a framework is developed for analysing the trade-off between the probability and magnitude of fines, assuming that individuals maximise expected utility. In that model, all individuals are identical and only differ with respect to the gain they may obtain from free riding. In the case of fare evasion, where the gain of evading (that is, the price of a farecard) is equal for all passengers, this would imply that either passengers would all buy a farecard or would all not buy a farecard. Clearly, this is at variance with casual observation. Possible explanations for the diversity in observed behaviour are that passengers are heterogeneous with respect to their degree of risk aversion or that they do not correctly perceive the parameters of the transport environment, in particular the inspection probability. In Boyd et al. (1989) a fare evasion model is presented with risk-neutral expected utility maximising passengers, allowing the perception of the inspection probability to be different from the actual probability. For some specific functional forms the optimal inspection level is determined. Both the papers by Polinsky and Shavell and by Boyd et al. contain numerical examples, but no empirical work.

The present paper reports the results of an attempt to confront the theory of fare evasion with empirical data. Although the data set is limited, we find support for the hypothesis that passengers behave as expected utility maximisers.

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In section 2, some testable implications are derived from a model of fare evasion. It becomes evident that the assumptions needed for deriving the implications are rather weak. The empirical data and evidence are presented in Section 3. Section 4 presents some conclusions.

2. PASSENGER BEHAVIOUR

A passenger in a public transport system with self-service fare collection has two options: buying a farecard at price \( k \) or not buying a farecard. All passengers are inspected with probability \( p \). If a passenger does not have a farecard, he has to pay a fine \( f(k) \). As a working hypothesis we assume that passengers behave as expected utility maximisers.\(^1\)

Let \( U_k \) denote the utility of buying a farecard, \( U_0 \) the utility of not buying a farecard and not being fined, and \( U_f \) the utility of not buying a farecard and being fined. The inspection probability as perceived by the passenger is denoted by \( p_x \). We assume \( \partial U_f / \partial k < 0 \) and \( U_f / \partial f < 0 \) and \( p_x / \partial p > 0 \). A farecard will be bought if

\[
U_k = p_x U_f + (1 - p_x) U_0
\]

or

\[
r = \frac{U_k - U_0}{U_f - U_0} \leq p_x
\]

and it will not be bought if \( r > p_x \). \( r \) may be referred to as the reservation inspection probability. Given that \( p_x \) enters equation (1) linearly, it may also be interpreted as the mean of a distribution function describing a passenger’s perception of possible values for \( p \). The smaller the value of \( r \), the more risk-averse a passenger. From the assumptions on the derivatives of \( U_k \) and \( U_f \) and from equation (2) it follows that \( r / \partial k > 0 \) and \( r / \partial f < 0 \).

To formalise the notion of risk aversion heterogeneity, we use \( U(\cdot; \alpha) \) for the utility functions, where \( \alpha \) is a parameter which measures a passenger’s risk aversion and which varies randomly across passengers. Then the probability that a passenger buys a farecard equals

\[
q = P[r(\alpha) < p_x] = \int_{r(\alpha) < p_x} f(\alpha) d\alpha.
\]

where \( f(\cdot) \) is the probability density function of \( \alpha \). From equation (3) and the assumptions \( \partial r / \partial k > 0 \), \( r / \partial f < 0 \) and \( p_x / \partial p > 0 \), it follows that the fare evasion rate \( 1 - q \) is decreasing in \( p \), increasing in \( k \) and decreasing in \( f \). The higher the value of \( f \) and the lower the value of \( k \), the faster \( q \) approaches to unity if \( p \) increases.

The assumptions necessary to derive these implications are rather weak. It is not assumed that passengers have a correct perception of the parameters of the transport

\(^1\) Boyd et al. (1989) assume that some passengers are always honest, irrespective of the inspection level. This is certainly plausible, but it is empirically indistinguishable from passengers having a high degree of risk aversion.
environment, in particular the inspection probability. Instead, we make the much weaker assumption that a higher inspection probability leads to a higher perceived inspection probability. Moreover, the utility of being fined may also incorporate possible non-pecuniary costs of being fined (such as the embarrassment of not being able to show a farecard or a possible loss of time). It is only assumed that the utility of being fined is a decreasing function of the monetary fine.

If there are no non-pecuniary costs, and if passengers correctly perceive $p$, $k$ and $f$, equation (2) may be specified in the following terms:

$$ r = \frac{U(y-k)-U(y)}{U(y-f)-U(y)} \leq p $$  \hspace{1cm} (2')

Here $y$ is the passenger’s initial wealth and $U(.)$ is an increasing and differentiable utility function. For a risk-neutral passenger, the first equality in (2') collapses to $r=k/f$; for a risk-averse passenger $0 \leq r < k/f$; whereas for a risk-loving passenger $k/f < r \leq 1$.

As a further specification, the following example should be considered:

$$ U(y; \alpha) = \begin{cases} 
-e^{-\alpha y} & \text{if } \alpha > 0 \\
y & \text{if } \alpha = 0 \\
e^{\alpha y} & \text{if } \alpha < 0
\end{cases} $$

where $\alpha$ equals the passenger’s (absolute) risk aversion $[-U''(y)/U'(y)]$. For this specification we have

$$ r(\alpha) = \frac{e^{\alpha k} - 1}{e^{\alpha f} - 1} $$

It is easily checked that $\partial r(\alpha)/\partial \alpha \leq 0$ and that $\lim_{\alpha \to 0} r(\alpha) = k/f$, $\lim_{\alpha \to \infty} r(\alpha) = 0$, and $\lim_{\alpha \to \infty} r(\alpha) = 1$.

From these properties it follows that, for all $0 \leq p \leq 1$, there exists exactly one $\alpha$ which solves the equation $r(\alpha) = p$. The solution can be denoted by $\alpha^* = r^{-1}(p)$. Then

$$ q(p) = P[r(\alpha) < p] = P(\alpha > \alpha^*) = 1 - F(\alpha^*) $$

where $F(.)$ is the cumulative distribution function corresponding to $f(.)$.

3. SOME EMPIRICAL SUPPORT

Table 1 gives some data on seven public transport systems in cities in Europe and Canada. Although the sources of the data are obviously heterogeneous from a geographical point of view, the transport systems in the seven cities are quite similar. Tickets are collected by self-service systems and there are no substantial physical obstacles for entering the vehicles without having a farecard.

The table shows quite marked variation in fare evasion rates, inspection probabilities and fine/fare ratios across cities. The Vancouver observation ($f/k=1$ and $q=0$) provides support for the fact that indirect costs of being fined are not negligible. If these costs were absent, we would have $q=0$. 

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TABLE 1

Data on Seven Public Transport Systems

<table>
<thead>
<tr>
<th>City</th>
<th>Fare Evasion Rate $(100 \times (1 - q))$</th>
<th>Inspection Rate $(100 \times p)$</th>
<th>Fine/Fare Ratio $(f/k)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bern</td>
<td>1.0</td>
<td>5.0</td>
<td>33.3</td>
</tr>
<tr>
<td>Cologne</td>
<td>3.0</td>
<td>1.4</td>
<td>13.3</td>
</tr>
<tr>
<td>Geneva</td>
<td>1.1</td>
<td>2.5</td>
<td>40.0</td>
</tr>
<tr>
<td>The Hague</td>
<td>9.9</td>
<td>1.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Milan</td>
<td>8.0</td>
<td>1.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Munich</td>
<td>1.4</td>
<td>3.0</td>
<td>26.6</td>
</tr>
<tr>
<td>Vancouver</td>
<td>0.5</td>
<td>43.3</td>
<td>1.0</td>
</tr>
</tbody>
</table>


To see whether the data are consistent with the predictions of the model in section 2, we ran the following regressions ($t$-values in parentheses):

\[
\log[100 \times (1-\eta)] = 2.97 - 0.45 \log(f/k) - 0.99 \log(100 \times p) \quad R^2=0.960 \\
(6.0) \quad (-3.1) \quad (-6.8)
\]

\[
\log((1-\eta)/\eta) = -5.61 - 0.52 \log(f/k) - 0.92 \log[p/(1-p)] \quad R^2=0.910 \\
(-12.8) \quad (-3.2) \quad (-6.3)
\]

The second specification ensures that predicted $\eta$'s always lie within the unit interval and that $\eta$ approaches 0 or 1 if $p$ equals 0 or 1. To circumvent the problem of international comparison of absolute fare and fine amounts, we have used the fine/fare ratio rather than including the fine and fare amounts separately. Despite the small number of observations, the results clearly support the predictions of the model. The coefficients have the expected signs and are significant at the 5 per cent level. Figure 1 visualises the relationship between $\eta$ and $p$ as implied by equation (5), for $f/k=3$ and for $f/k=40$, respectively.

The fare evasion elasticity with respect to the inspection rate is about $-1$, whereas the elasticity with respect to the fine/fare ratio is almost $-0.5$. It should be stressed, however, that the fare evasion elasticities may be different across the seven cities.

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2 The results do not differ much, as $\eta$ is at least 0.900.
4. CONCLUDING REMARKS

In this paper we have confronted the theory of fare evasion behaviour with data from seven public transport systems. The results indicate that the hypothesis that passengers behave as expected utility maximisers is an appropriate description of observed behaviour.

Collection of multiple observations on each city, possibly on the basis of experiments, will be necessary to obtain reliable estimates of all elasticities of interest. The availability of such estimates is a prerequisite for evaluating the optimality of inspection policies along the lines as set forth in Boyd et al. (1989).

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REFERENCES


