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A Panel data approach to evaluate the Passenger Satisfaction of a Public Transport Service

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Abstract

In the present work we analyze the passenger satisfaction of a public transport service by means of a panel data approach. Improving the quality and efficiency of public transport is important if we are to change the daily transport habits of the public. The congestion in urban areas and its immediate and wider consequences on the climate are pushing central and local governments to instigate sustainable transport policies. These policies require an ever more personalised attention to the desires of the customer, to know and quantify the most influential variables on their decision to travel in public transport. The quality of a public transport system is covered by many factors, such as considerations relative to comfort and safety within the vehicle, the time taken to cover the routes and the convenience and existence of any supporting infrastructure. The techniques that we have used to analyse the panel data are: fixed effects and random effects.

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1. Introduction

The issue of quality in the public services is strongly felt both in the literature, where it continues to be a topic of research particularly developed, both by insiders, who see it as the central node in the business organization (Hensher et al. , 2003; Zeithaml and Bitner , 2002; Bateson and Hoffman , 2000).

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The starting point is the definition of the concept of quality. From a historical point of view, the origin dates back to the advent of the Industrial Revolution. The meaning attributed to it has undergone several changes over time, in line with changes and developments in the environmental reality and context. The range of definitions used is very wide, so that it goes from "conformity to specifications or requirements", passing through the "suitability", until you get to the wide sphere of "customer satisfaction" (Negro, 1995, Franceschini, 2001). It must also make a clear distinction between the quality of services and the quality of goods. The main differences are: intangibility, contextuality and heterogeneity.

The service is, by its nature, an immaterial reality, an activity, a service and can not be concretely shown before purchase (Normann, 1985). The goods, on the contrary, have perfectly identifiable and measurable physical characteristics. For services, therefore, you can not easily determine what factors are to be observed, what action to perform, tests and inspections to be carried out before the sale to ensure quality.

The second element concerns the inseparability between the time of production and the delivery of the service. The quality is manifested while the service is produced /consumed. The client, therefore, is an integral part of the process of consumption and, necessarily, also that of assessment. It would not be possible, in fact, consider the quality if not the very moment in which the service is provided. Quite different is the situation in the case of goods which can be built, tested, sold and used in completely different places and by completely different people. The third characteristic of the service is linked to the incidence of the human factor. The service is a two-dimensional relationship between supplier and consumer, based on an exchange not only economic but also informative and emotional. The quality of services, significantly more than that of the goods, and is strongly influenced by the context.

As part of the approaches that put the consumer in a central location, such as ultimate judge of quality, are very common techniques that provide for the collection of customer feedback about the various features of the service through appropriate scales at which to apply specific techniques graduation (Edwards, 1957).

Generally, we use customer satisfaction surveys where the survey instrument is characterized by a questionnaire items, that is, statements about the characteristics investigated, and verbal scales that respondents adopt to provide their opinion on the issues that affect the quality of the service. In particular, the present work deals with the main elements that serve to characterize the quality evaluation, and provides a practical reflection of its operations through a case study on the evaluation of the passenger satisfaction of a local public transport (LPT).

Improving the quality and efficiency of public transport is important if we are to change the daily transport habits of the public. The congestion in urban areas and its immediate and wider consequences on the climate are pushing central and local governments to instigate sustainable transport policies.

These policies require an ever more personalised attention to the desires of the customer, to know and quantify the most influential variables on their decision to travel in public transport. The quality of a public transport system is covered by many factors, such as considerations relative to comfort and safety within the vehicle, the time taken to cover the routes and the convenience and existence of any supporting infrastructure.

For our study we have used data gathered by means of the questionnaire and to analyse the passenger satisfaction of the public service we have used a panel data approach, where the entities or levels are the urban areas. The behaviour of these entities (in particular, eight of them) has been observed over a three year period of time (2010-2012).

The techniques that we have used to analyse the panel data are: fixed effects and random effects (Wooldridge, 2009,2010; Stock and Watson, 2012).

The paper is organized as followed: in section 2, the panel data approach (fixed effects, random effect and fixed vs random effects) is shown. In section 3, the case study will be shown.

2. The Panel Data

A way to check the effects of the omitted variables, without being really observed, requires a particular type of data, called panel data (or longitudinal data), where each entity is observed across two or more periods of time.

By studying the variations of the dependent variable over time, the panel data eliminate the effect of omitted variables, which, despite being different entities, do not vary over time. These entities may have been corporations, individuals, countries, etc..

Why do we use panel data? (Hsiao, 1985)

Benefits:

- They allow to identify the effects that are not identified in the cross-section data. (Ben-Porath,1973).
- The panel allows you to study the dynamics: while the cross-section allows you to estimate what proportion of the population is unemployed in a unit of time, the panel data show how this share varies over time;

- The panel data contain more information, more variability and therefore less collinearity among the variables and produce estimates more efficient, more precise parameters.
- They allow you to control the effect of individual heterogeneity: i.e variables constant over time (individual heterogeneity) not observed (for which no data are available). (Baltagi and Levin, 1992; Baltagi, 2008).

Limits:

- Difficulty in the sample design and data collection.
- Distortion of the measurement errors.
- Problem of selection, no answers nor dissensions
- Limited dimension of time series.

2.1. The fixed effects (FE)

The fixed effects (FE) explore the relationship between predictor and outcome variables within an entity (country, person, company, etc.). Each entity has its own individual characteristics that may or may not influence the predictor variables (for example being a male or female could influence the opinion toward certain issue or the political system of a particular country could have some effect on trade or GDP or the business practices of a company may influence its stock price).

When using FE we assume that something within the individual may impact or bias the predictor or outcome variables and we need to control for this. This is the rationale behind the assumption of the correlation between entity's error term and predictor variables. FE remove the effect of those time-invariant characteristics from the predictor variables so we can assess the predictors' net effect. Another important assumption of the FE model is that those time-invariant characteristics are unique to the individual and should not be correlated with other individual characteristics.

Each entity is different, therefore the entity's error term and the constant (which captures individual characteristics) should not be correlated with the others (Stock and Watson, 2003).

The fixed effect model is:

$$Y_i = \beta_{i0} + \beta_1 x_{i1} + \beta_2 x_{i2} + \dots + \beta_j x_{ij} + \dots + \beta_k x_{ik} + \varepsilon_i \quad (1)$$

where:

β_{i0} is the unknown intercept for each entity (n entity-specific intercepts).

Y_i is it the dependent variables.

x_{ij} represents of j-th independent variable.

β_j is j-th coefficient to be estimated.

ε_i is the error term.

To estimate the parameters of the model, it is a common practice to use the estimator *within* B. In fact, we have to apply the classic linear model where both the dependent variable and the matrix of regressors are expressed in deviation of the individual averages calculated with respect to time. The estimator B takes the name *within estimator* because it take into account the individual effects through this processing done, but it deletes them from the model using for each individual the information resulting from temporal variations (variation in groups).

The constant β_{i0} is equal to the difference between the average individual of the dependent variable and the mean of the regressors individual weighted by estimator *within*. The constants β_{i0} with $i = 1, 2, \dots, N$ capture the effect of those variables that vary between individuals, but remain unchanged over time.

Besides the within estimator, it is possible to use the estimator dummy variables (LSVD), where, the researcher can consider the β_{i0} as equivalent to introduce a separate dummy variables for each group. It is precisely because we have controlled for (all) group characteristics that we are willing to assume independence of the observation.

Unfortunately, this implies that we cannot include group-level covariates among the predictors, as they would be collinear with dummies. The within and LSVD estimators produce the same numeric value.

2.2. The random effects

The rationale behind random effects model is that, unlike the fixed effects model, the variation across entities is assumed to be random and uncorrelated with the predictor or independent variables included in the model:

“...the crucial distinction between fixed and random effects is whether the unobserved individual effect embodies elements that are correlated with the regressors in the model, not whether these effects are stochastic or not” (Green, 2008, p.183). An advantage of random effects is that you can include time invariant variables (i.e. gender). In the fixed effect model these variables are absorbed by the intercept.

The random effect model is:

$$Y_i = \gamma_{i0} + \gamma_1 x_{i1} + \gamma_2 x_{i2} + \dots + \gamma_j x_{ij} + \dots + \gamma_k x_{ik} + \delta_i + \varepsilon_i \quad (2)$$

where δ_i is the vector of the individual effects.

The model (2) can be rewritten as:

$$Y_i = \gamma_{i0} + \gamma_1 x_{i1} + \gamma_2 x_{i2} + \dots + \gamma_j x_{ij} + \dots + \gamma_k x_{ik} + \phi_i \quad (3)$$

Let's $\phi_i = \delta_i + \varepsilon_i$ the error of the random effect model, we can immediately note that this error is composed of a component that varies among the individuals-entities (but constant over time), and another one that varies stochastically among individuals-entities and across time.

Random effects assume that the entity's error term is not correlated with the predictors. The RE allows to generalize the inferences beyond the sample used in the model.

2.3. Fixed vs random effects

The generally accepted way of choosing between fixed and random effects is running a Hausman H-test (Hausman, 1978). Statistically, fixed effects are always a reasonable thing to do with panel data (they always give consistent results) but they may not be the most efficient model to run. Random effects will give you better P-values as they are a more efficient estimator, so you should run random effects if it is statistically justifiable to do so.

The Hausman H-test checks a more efficient model against a less efficient but consistent model to make sure that the more efficient model also gives consistent. The Hausman H-test tests probes the null hypothesis that the coefficients estimated by the efficient random effects estimator are the same as the ones estimated by the consistent fixed effects estimator. If the null hypothesis is accepted (Prob H larger than .05 under the Chi-square distribution with g degree of freedom, where g is rank of the matrix $[Var(B_{fixed}) - Var(B_{random})]$, that is g=k if all those variance are independent) then it is safe to use random effects. If a significant P-value is found, however, fixed effects should be considered.

Table 1. Hausman H-test

	Random Effects	Fixed Effects
$H_0: Cov(x_{it}, \delta_i) = 0$	Consistent and Efficient	Consistent and Inefficient
$H_1: Cov(x_{it}, \delta_i) \neq 0$	Inconsistent	Consistent

3. The case study

In this study, we consider a panel data to evaluate the passenger satisfaction of a public transport service of a small-medium large city of the south of Italy. The response variable is the overall passenger satisfaction. The predictors variables are: access to the vehicles, staff, status of the vehicles, security and punctuality.

The information on these aspects of the quality are selected by means of a questionnaire, where the interviewed subjects (selected by means of a random procedure and according to some control variables such as gender, age, job

and education) were asked to express their level of satisfaction on a scale 1 (unsatisfactory at all) – 10 (full satisfaction).

In particular, the variable:

- access to the vehicles, epitomizes aspects about the availability of tickets purchase.
- staff, epitomizes aspects about the kindness of the staff.
- status of vehicles, epitomizes aspects about cleanness and reduction of environmental impact .
- security, epitomizes aspects about the safety of the travel.
- punctuality, epitomizes aspects about the respect of service times.

Later, from the opinions expressed by the users, we have infer some synthesis measures for different urban areas which make up ultimately our entities.

The behavior of these entities (i.e eight urban areas), has been observed over a three- year period of time (2010-2012). The output of the fixed effects is shown in table 2 and table 3:

Table 2. Fixed effects (within) regression

Overall PS	Coef	Std. Err.	t	P > t	95% IC	
Access vehicles	0.1999	0.3035	0.66	0.524	-0.4682	0.8677
Staff	-0.3127	0.3329	-0.94	0.368	-1.0454	0.4201
Status of the vehicles	0.3671	0.3633	1.01	0.334	-0.4325	1.1667
Security	-0.3524	0.3562	-0.99	0.344	-1.1365	0.4316
Punctuality	0.7510	0.1756	4.28	0.001	0.3645	1.1375
Constant	3.2418	2.3792	1.36	0.200	-1.9948	8.4784

Table 3. Principal index

Index	Value
F test	4.37
P.value	0.0196
R^2_{within}	0.6649
$R^2_{between}$	0.4594
$R^2_{overall}$	0.5879

The fixed effects model, in table 3, shows a significant overall model (P-value = 0.0196), with only one statistically significant variable: the punctuality.

The output of the random effects is shown in table 4 and table 5:

Table 4. Random effects GLS regression

Overall PS	Coef	Std. Err.	z	P > z	95% IC	
Access vehicles	0.2164	0.2279	0.95	0.342	-0.2303	0.6631
Staff	-0.3833	0.1907	-2.01	0.045	-0.7572	- 0.0094
Status of the vehicles	0.5299	0.2673	1.98	0.047	0.0059	1.0538
Security	-0.3094	0.2549	-1.21	0.225	-0.8090	0.1903
Punctuality	0.6786	0.1283	5.29	0.000	0.4267	0.9302
Constant	2.6879	1.6724	1.61	0.108	-0.5899	5.9657

Table 5. Principal index

Index	Value
Wald test	29.85
P.value (Wald)	0.0000
R^2_{within}	0.6444
$R^2_{between}$	0.5703
$R^2_{overall}$	0.6178

In the random effects model we have three variables statistically significant: Staff, Status of the vehicles and Punctuality. In this case, the interpretation of the coefficients is tricky since they include both the within-entity and between-entity effects. The coefficient B_j relative to the regressor X_j represents the average effect of X_j over Y when X_j changes across time and between aree urbane by one unit, keeping constant the values of the other regressors in the model.

To see if there are random effects we have carried out the Breusch-Pagan Lagrange Multiplier (LM) test. The null hypothesis is that individual-specific or time-specific error variance components are zero. If the null hypothesis is not rejected, the pooled OLS is preferred; otherwise, the random effect model is better. In our case study the test shows the presence of the random effects (P-value = 0.04).

In table 6 we compare the coefficients of the fixed and random effects model:

Table 6. Comparison between the coefficients random and fixed effects model

Index	Coeff. FE	Coeff. RE
Access vehicles	0.1999	0.2164
Staff	-0.3127	-0.3833
Status of the vehicles	0.3671	0.5299
Security	-0.3524	-0.3094
Punctuality	0.7510	0.6786
Constant	3.2418	2.6879

As evidenced in Table 6, the coefficients of the variables remain relatively constant when changing from random effects to fixed effects. The Hausman H-test reveals that the random effects estimator is more appropriate (P-value = 0.8374, well above the critical value of 0.05). As the matter of fact, under H_0 the RE is the best (the estimation GLS is BLUE), while, under H_1 , the statistics properties of the estimator GLS of the RE are not met. As a result, under H_0 the estimates will be statistically similar and, therefore, the random model-GLS, which is more efficient, will be chosen.

Moreover, in examining the signs of each of the independent variables that are statistically significant in the random and fixed effects regression, the regression output signs agree, in most cases, with the expected signs.

4. Discussion

In the present work we have analyzed the passenger satisfaction of a public transport service by means of a panel data approach, where the behaviour of the entities has been observed over a three- year period of time (2010-2012). The techniques that we have used for analyze the panel date are: fixed effects and random effects. The choice between fixed and random effects was performed running Hausman H-test.

In particular, the choice of dealing with individual effects as fixed or random enough delicate. The fixed effects should be used to estimate the specific effects of the sample (i.e, an exhaustive sample countries, a sample of companies in a particular industry in which the selected sample is representative of the characteristics of the industry). By contrast, the random effects should be used for random samples and to make inference on the population.

With a reference to our case study the choice could be cast on the fixed effects model, as our entity can not really be thought of as random draws from a population. In fact, the inferences that we have drawn are conditioned to the individuals included in the sample as opposed to a random model where the individual characteristics become a component of the population and the inferences are then related to the same population.

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