The Impact of Integrated Tariff Systems on Public Transport Demand: Evidence from Italy

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Abstract

The increasing problems of pollution and traffic congestion require the definition of a model of sustainable mobility – in particular, in large urban areas. An indirect control on these negative externalities associated with private transport may be pursued by means of policies aimed at improving quality and accessibility of public transit networks. To that end, one popular option is the design of an Integrated Tariff System (ITS): the crucial question remains whether such a policy can be effective in raising the number of public transport users. In this study, we use a twelve-year panel of 69 Italian public transit providers (with or without ITS) and estimate alternative specifications of the demand function. Results show that the impact due to ITS introduction is, on average, moderate. Results also highlight the importance of taking into account the specific features of ITS, such as its validity over an extended network, the availability of a single ticket option, and the application of zonal pricing schemes.

1. Introduction

Growing concerns about pollution and traffic congestion represent a challenge that calls for the definition of a model of sustainable mobility – a particularly urgent need in the centres of large urban agglomerates. On the one hand, one can try to control the congestion and the other private transport externalities directly, by internalising the associated costs through the introduction of payment mechanisms for users (for example, parking fees or road pricing schemes). On the other hand, it is possible to exert an indirect control of such externalities, by promoting policies aimed at improving the quality and accessibility of the public transport network. In that regard, the provision of an integrated and high-quality transport system can represent a valid tool. The term integration may refer to *informative integration*, where users have easy access to information about the different networks, timetables and tariffs, *physical integration* among different networks (infrastructures and network designs that make it easier for users to change the modality of transport), and *tariff integration*, the effectiveness of which is clearly greater when the other two forms of integration are in place.

In this paper, we will consider the above aspects jointly, as an Integrated Tariff System (ITS). An ITS allows passengers to utilize several transport modalities (e.g., intercity and urban buses, subway, local railway, ferry boats, etc.) by buying one ticket only, which can be used in either a short time period (e.g., two hours, daily ticket) or can have a seasonal validity (e.g., weekly, monthly or yearly). As such, the integrated travel card allows users to consider the whole public transit system within a specific area (urban, metropolitan, or even regional), as if it were organized by a sole firm offering a single service. ITS have been introduced in many countries and are the subject of explorative studies promoted by the European Commission (NEA, 2003) and by governments (e.g., for Scotland, see the Scottish Executive Social Research, 2004, while for the U.K., see

the TRL report, 2004). Notwithstanding this increasing interest, academic research, both at the theoretical (Cassone and Marchese, 2005; Marchese, 2006) and empirical level is rather limited. As pointed out by the Scottish Transport Research Planning Group: "*No conclusive evidence was found that integrated ticketing leads directly to patronage or revenue increases, partly because integrated schemes have apparently not been studied or introduced in isolation. However, the many presumed benefits are thought to constitute a reasonable case for introduction*" (Scottish Executive Social Research, 2004, p. 48). A similar view can be found in the TRL Report: "*Results of studies of the effects of pre-paid ticketing systems (travelcards or season tickets) show no consistent pattern: in some cases elasticities are greater for pre-paid tickets than for cash fares, but in other cases the opposite is found*" (TRL, 2004, p. 18).

The present work contributes to this literature by providing fresh empirical evidence on the impact of the introduction of ITS on patronage. By carrying out an econometric analysis on a panel of 69 Italian local public transport (LPT) companies observed from the period 1991-2002, we study the determinants of LPT demand by discussing, also, the effects of various qualitative features of the service (i.e., average speed, frequency and density), with the ultimate goal of evaluating the shifts in LPT demand due to the provision of an ITS. From a methodological point of view, the analysis relies on the estimation of dynamic panel models. To be more specific, the outcomes arising from a fixed-effects model (in which the lagged output variable is affected by an endogeneity problem), are compared with those resulting from the estimation of GMM models (Arellano and Bond, 1991; Blundell and Bond, 1998). Moreover, we estimate the CORRECTED Least Square Dummy Variables (LSDV) model, first introduced by Kiviet (1995) and subsequently implemented by Bruno (2005), that foresees a correction of the bias implicit in the fixed-effects model and, as compared to the generalized method of

moments (GMM) specification, is more appropriate in the case of samples, which are limited in the cross-sectional dimension.

The remainder of the paper is organized as follows. Section 2 presents a selected review of the empirical literature on transport demand and of the very few studies focused on the impact of pre-paid and integrated tickets on patronage. Section 3 describes the data and the construction of the variables used in the demand model. Section 4 presents the empirical methodology and discusses the main results of our estimations. Section 5 concludes.

2. Literature review

There are an impressive number of papers that have investigated the demand for LPT service. A recent comprehensive review is contained in the TRL report (2004). As a general result, nowadays it is widely accepted that studies on public transport demand that consider tariffs as the main variable in the process of consumer choice are not very useful. The bus passenger demand is a typical consumer good for which, in addition to price, qualitative factors, such as, for instance, frequency, commercial speed, network coverage, and the possibility of interconnections with nodes of other transport networks (e.g., railways, airports), are very important and must be taken into account.

For example, Dargay and Hanly (2002) included among the regressors a variable, "bus-kilometers," which is the total number of kilometres covered by the vehicles in the rolling stock. The elasticity of the demand, with respect to this variable, was higher than the price elasticity, underlying the importance of qualitative aspects of the service. Turning to the traditional estimates of demand elasticities, with respect to the price and to income, the literature shows a short-run price elasticity ranging from -0.3 and -0.8 and a long-run elasticity that is often above 1 (Gilbert and Jalilian, 1991) in absolute

value. The income elasticity is, in general, low (Asensio *et al.*, 2003) and, in some studies, after the inclusion of a variable to check for the use of private cars (which is correlated to income level), it is found to be negative. Thus, there is some evidence consistent with the fact that bus passenger transport can be considered as an inferior good. Dargay and Hanly (2002) also provided a useful review of the results that have appeared in the empirical literature. To summarize:

- The price elasticity is higher in the peak hours, and lower during the other periods of the day (Oum *et al.*, 1992);

- The price elasticity is higher for single tickets, compared to multi-ride tickets, and both are higher, compared to an 'average' elasticity, suggesting that single tickets and multi-ride tickets are substitute goods (De Rus, 1990; Dargay and Pekkarinen, 1997);

- The price elasticity for suburban service is higher, compared to that measured for urban service (Nijkamp and Pepping, 1998).

To the best of our knowledge, there are only three studies that investigated, either directly or indirectly, the impact of ITS on bus passenger demand. Fitzroy and Smith (1999) analysed the impact of the introduction of discounted, integrated, season tickets, using a sample of four Swiss towns, observed from 1971 to 1996. The results from a pooled estimation (including city dummies among the regressors), and from a seemingly unrelated regression (SUR) system, show a positive and significant impact of the season-ticket dummy variables on LPT demand. This effect is different across towns, with the most powerful impact arising in Geneva (15%-16%). Moreover, the extension of season ticket validity to all LPT companies in the city of Bern (inter-

operator transferability) significantly affected the demand, implying an increase ranging from 14% to 26% (pooled and SUR estimation, respectively).[1]

While the former study provided relevant information concerning the introduction of ITS only indirectly, the study by Matas (2004) focused directly on this topic. In 1987, the regional government of Madrid created an integrated fare system for the whole LPT network, based on a travel card. By collecting data for bus and underground trips in the Madrid region for the years 1979-2001, Matas estimated a two-equations system, by applying the SUR method, in order to take into account the possible correlation in the errors across the two types of service. The results showed that the introduction of travel cards led to a growth in bus and underground patronage of 3.4% and 5.3% in the short run, and 7% and 15% in the long run, respectively. Finally, Dargay and Pekkarinen (1997) evaluated the effects of integrated ticket policies on bus use in Finland, but the focus of their observation was to estimate the fare elasticities on the demand for bus cards and on the travel demand with these cards. Both demands were found to be highly sensitive to price and income.

For the sake of completeness, we report also the results of the already cited study by the NEA (2003), which contains some anecdotical evidence on the impact of integrated tariffs. It is shown that the introduction of ITS on a set of European cities induced an increase in transport demand ranging from 4% (Manchester) to 33% (Paris). However, the analysis does not make use of econometric techniques, and relies on a summary index of integration, which includes informative integration, network integration, and tariff integration. Regarding the Italian evidence, it is shown that the introduction of a new integrated fare system in Rome (Metrobus) had the effect of raising public transport patronage by more than 6% in two years.

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[1] In a previous study (Fitzroy and Smith, 1994) the authors analysed only the demand for public transport in Zurich, and found similar evidence on the impact of integrated season tickets.

In the present work, we analyse the evolution of LPT demand for 69 Italian operators, observed for 12 years. Differently from Matas (2004), and Fitzroy and Smith (1999), we do not have time-series data for one region, or a small number of towns only, so panel data econometric techniques can be easily applied. Moreover, the paper mainly focuses on tariff integration and tries to directly evaluate the impact of the different ITS features that have been introduced on public transport patronage (e.g., exclusivity of the integrated ticket, extension of tariff integration outside the municipal boundaries, the possibility of buying a single-trip (or short time validity) integrated ticket rather than being obliged to buy seasonal tickets).

3. Data and variables

In respect to other European countries, the adoption of ITS in Italy was slow to occur. Apart from initial experiences in Lombardy and in the Bozen Province in the second half of the 1970s, the majority of operators began to introduce some forms of tariff integration only during the 1990s. In 2002, 42% of urban transport systems in Italy were fully or partially integrated, with larger percentages recorded in Northern Italy and in large- and medium-sized towns. Such percentages are continually growing over time. As described in detail in Piacenza and Carpani (2003), ITS characteristics vary from case to case. For example, there are still geographical limitations of validity within some provinces or regions, and the integrated ticket can sometimes represent an alternative to buying separate tickets, issued by individual LPT operators. In an empirical investigation, such differences can be exploited in order to evaluate separately the effects of different types of tariff integration on public transport patronage.

Our data-base consists of 69 LPT companies, observed from 1991 to 2002. We gathered information from the annual directories of ASSTRA – the nationwide association of

publicly-owned LPT operators in Italy – and directly from questionnaires sent to firms, in order to circumvent the problem of missing technical data and to obtain further information on ITS. The geographical localization of our sample firms fits closely with the national distribution of LPT demand: 60% of companies are located in Northern Italy, 17% in Central Italy and the remaining 23% in Southern Italy. There are 38 mixed firms that provide both urban and intercity service, while 21 and 10 operators specialize in urban and intercity service, respectively. As for the introduction of integrated tariffs, 25 operators (of which 9 urban-type, 2 intercity-type and 14 mixed-type firms) are involved in some form of ITS.

The dependent variable used in the estimation of the demand model (see section 4) is the total number of transported passengers per year (Y). This variable has been preferable to other demand indicators such as passenger-kms (which also includes aspects related to the supply of the service) and traffic revenues (which are affected by the pricing policy).

The public transport tariff (P) has been measured in terms of average price, using a proxy, i.e., by dividing total revenues from ticket sales (deflated by a consumer price index, base year 2000) by the total number of passengers. Unfortunately, given the wide selection of ticket types offered, we were not able to disaggregate data by the type of tariff (e.g., number of passengers that use single tickets, seasonal tickets, intercity tickets), so our empirical strategy is the estimation of a single equation describing the demand of an 'average' LPT service.

In our study, service quality is captured via three indicators usually considered in the literature on LPT demand: average commercial speed (SP), route density (RD), and service frequency (FR). The average speed of LPT vehicles is inversely related to in-vehicle travel time, and has been obtained by dividing the total yearly kilometres

covered by all vehicles in the rolling stock by the total number of service hours. The frequency, which is a proxy for waiting time costs, is measured as the ratio of total yearly vehicle-kilometres to the network length. Finally, route density has been computed by dividing the network length by square kilometres of served area; a high value of this variable means that users can easily have access to the LPT network and, consequently, face lower walking time costs.

LPT demand also depends on the socio-economic and demographic characteristics of the served area. Disposable real income affects transport demand both directly (a higher income level should reflect an increase in working activities and therefore stimulate mobility) and indirectly (through the increased probability to buy and/or use private cars at higher income levels, thereby reducing LPT demand). Real income (I) has been measured as the deflated (using the gross domestic product (GDP) deflator index) per-capita income at the provincial level. As for the other socio-economic and demographic regressors that are often included in LPT demand estimation, we constructed the following variables for the territorial area covered by each firm:[2]

- general occupation rate (OCC_G), measured by the number of employed people within the total working age population (15-64 years);

- occupation rate in the agricultural sector (OCC_{AG}), computed as the ratio of employed people in agriculture to the total number of workers;

- elderly and female population rate (respectively, POP_{OLD} and POP_{FEM}), measured by the ratios of people older than 64 years and of women to the total population, respectively.

Apart from occupation rate in the agricultural sector, all the other proxies are expected to exert a positive effect on LPT demand. However, since they are highly correlated

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[2] The information on per-capita income levels and other socio-economic and demographic characteristics has been gathered from the directories of ISTAT (the Italian National Institute of Statistics) and from data processed by the Istituto Guglielmo Tagliacarne (Foundation of the Italian Chambers of Commerce).

with the income indicator (especially the occupational variables) and, their within-standard deviation is very limited (see table 1), we ultimately decided to exclude them from the regressions analysis presented below.[3]

[TABLE 1 HERE]

Since the key issue of this study is the investigation of the impact exerted by integrated tariffs, we constructed also a dummy variable assuming value 1 when the introduction of integrated tariffs is observed (D_{INTRO}), and, most importantly, four other dummies accounting for the presence of specific features of ITS, namely:

-   extension of the integration validity outside the urban area and/or a specific single route (D_{EXT});

-   supply of a single integrated ticket (including the daily ticket) together with the classical seasonal ticket (weekly or more), which allows for more flexibility, to the benefit of occasional users (D_{SING});

-   flexible territorial validity, according to the number of purchased "zones," e.g., urban centre, within a ring of 10 km from the centre, within a ring of 20 km, etc. (D_{ZONE});

-   exclusivity of the integrated ticket (D_{EXCLU}), that is, the unavailability of alternative, less expensive, tickets, which are valid only on a subset of transport modalities (e.g., subway-only, bus-only, urban-only, etc.).

Descriptive statistics are shown in table 1.

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[3] The results relative to our key variables, with the inclusion of such additional characteristics in the model, are virtually unchanged and are available upon request.

4. Demand estimation

4.1. Model specification

To assess the impact of ITS on LPT patronage, a demand function model for public transit service provided by the 69 companies in our sample must be specified and then estimated. As remarked in Oum (1989), one of the most striking features of the transportation literature is the wide variety of demand models proposed, which is mostly linked to the choice of aggregation level of the data and to the choice of functional form. Indeed, differences in types of data and in functional specifications are likely to affect empirical results with relevant policy implications, such as elasticity values and traffic forecasts.

As for the type of data, the choice between *aggregate* – where the basic unit of observation is the aggregate volume of a particular mode in a market – and *disaggregate* modeling approach – where the basic unit of observation is an individual decision maker's distinct choice – largely depends on the goal of the study and the cost of collecting the data. When the purpose of the analysis is to forecast the average behaviour of an aggregate group of individuals (e.g., the residents in a given metropolitan area), for instance in response to some changes in LPT policy (e.g., introduction of ITS), then the use of aggregate data is more natural and even preferable, although it introduces certain restrictive theoretical assumptions about consumer behaviour.[4] As Winston (1985) underlines in a survey paper highlighting the advantages and disadvantages of the two approaches, a disaggregate model requires an extensive data-base. Data are often difficult to obtain, due to the confidentiality of private information, and even when their collection is feasible, the process could be very expensive. Therefore, following the previous studies by Fitzroy and Smith (1999) and

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[4] See Berechman (1993, chapter 2) and Gagnepain and Ivaldi (2002, appendix).

Matas (2004), we have decided to rely on the estimation of an aggregate demand function, which allows us to provide an approximation of the underlying factors behind the observed changes in public transport demand and of the corresponding elasticities.

The functional forms most prevalently used to estimate aggregate transport demand models are the *linear* and *log-linear* specifications. The linear function has been used extensively in early studies (e.g., Bates, 1982; Benham, 1982) because it is simple to estimate and the empirical results can be easily interpreted. It presents the advantage that each demand elasticity depends on the value of the variable, but for many variables the assumption of a linear effect may not be realistic. On the other hand, the log-linear (or *double-log*) model specifies the logarithm of traffic volume as a linear function of the logarithms of potential determinants, such as prices and quality attributes. Since it is capable of modeling nonlinear effects, and the coefficients themselves directly represent the demand elasticities with respect to the different explanatory variables, the log-linear specification is currently the most widely used form in transport demand analysis (e.g., for public transit systems, Fitzroy and Smith, 1994 and 1999; Gagnepain and Ivaldi, 2002; Matas, 2004). The main drawback of this model is that each elasticity is invariant across all data points, and is not dependent on its location along the demand curve. However, the assumption of constant elasticity has been tested by the estimation of both a linear and a log-linear model. The procedure used to compare the different functional forms is based on the respective likelihood values, according to the Box-Cox (1964) metric.[5] The selection indicated the double-log as the specification best fitting the data, so we chose to adopt this model in our econometric analysis.

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[5] Both linear and log-linear specifications are nested in the more general Box-Cox (1964) model, with λ transformation of the dependent and independent variables, where the transformation for the variable x is defined as follows: $x = (x^{\lambda} -1)/\lambda$. Indeed, the linear and log-linear forms can be obtained by setting the value of the Box-Cox parameter λ equal to one and zero, respectively. For more details on this issue, see Oum (1989) and Benfratello *et al.* (2008).

As for the determinants to be included in the demand function, we follow the classical guidelines and assume that the aggregate consumption of local public transport, *Y*, depends on transit fare level, *P*, with other variables representing service attributes denoted by *Z*, and a vector *S* of socio-economic characteristics of served population (Berechman, 1993). Thus, we can write the general expression for the demand function as follows:

$$Y_{it} = D(P_{it}, Z_{it}, S_{it})$$ [1]

with $i = 1, \ldots, 69$ denoting the firm, and $t = 1991, \ldots, 2002$ being the year observed. According to the variables selection described above (section 3), the vector *Z* includes: average commercial speed (*SP*), route density (*RD*), service frequency (*FR*), the dummy capturing the impact of the ITS introduction (D_{INTRO}, in the BASIC MODEL) or, alternatively, the set of dummies reflecting the presence of specific features of tariff integration – namely, extension (D_{EXT}), single ticket option (D_{SING}), flexible territorial validity (D_{ZONE}) and exclusivity (D_{EXCLU}). The latter are introduced both in isolation (EXTENDED MODEL 1) and in interaction with a set of *service-specific* dummies (EXTENDED MODEL 2), in order to account for differentiated impact according to the type of service provided – namely, urban (D_{URB}), intercity (D_{INT}) and mixed (D_{MIX}). As for the socio-economic characteristics, in the final specification of [1] the vector *S* reduces only to a real income indicator (*I*), measured by the deflated per-capita provincial income. A lagged value of the dependent variable (Y_{t-1}) is included to capture potential lags in the adjustment of LPT demand to changes in the right-hand side determinants.

Given the adopted log-linear form, the demand equation to be estimated for the BASIC MODEL, according to the procedures discussed in the next section, is the following:[6]

$$\ln Y_{it} = \alpha + \beta_1 \ln Y_{i,t-1} + \beta_2 \ln P_{it} + \beta_3 \ln SP_{it} + \beta_4 \ln RD_{it} + \beta_5 \ln FR_{it} + \beta_6 \ln I_{it} + \delta D_{INTRO} + \varepsilon_{it} \quad [2]$$

where ε_{it} is an error term including a random noise and unobservable effects which are firm-specific but may be fixed over time.

4.2. Econometric analysis

4.2.1. Methodological issues

As already mentioned, one distinction of our study, with respect to the previous literature on LPT demand, is the possibility of exploiting the advantages of econometric techniques developed for the estimation of dynamic panel data.

First, let us review briefly some of the main econometric concerns that need to be addressed when estimating model [2], under the assumption that the error term is composed by a random noise (u_{it}) and a firm-specific unobservable effect (γ_i).

$$\varepsilon_{it} = \gamma_i + u_{it} \quad [3]$$

γ_i captures the heterogeneity of the sample and may be correlated with the observable variables used as regressors, making OLS estimates biased and inconsistent. In our dynamic model, the problem in applying OLS is immediate, since the lag of the demand is endogenous to the fixed-effects in the error term. Suppose, for example, that a firm faces a reduction (or an increase) of passengers due to some specific environmental factors that are not modeled (e.g., downward trend in population, factors affecting the quality or the cost of alternative modes of transports, etc.). This fixed-effect is

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[6] In the EXTENDED MODEL 1, δD_{INTRO} is substituted with $\sum_{r} \delta_r D_r$, while in the EXTENDED MODEL 2 it is replaced with $\sum_{r} \sum_{s} \delta_{rs} D_r D_s$, where $r = SING, EXT, ZONE, EXCLU$ and $s = URB, INT, MIX$.

positively correlated with the lagged variable, thus the downward (or upward) trend in demand due to the fixed-effect will, instead, inflate the OLS coefficient for the lagged variable (Roodman, 2006).

With panel data, unobserved heterogeneity bias can be handled by introducing firm-specific dummy variables, leading to the LSDV (or fixed-effect) estimator. However, LSDV does not eliminate *dynamic* panel bias.[7]

One way to deal with the problem is provided by the DIFFERENCE GMM (Arellano and Bond, 1991), which removes the fixed-effects by transforming the data and estimating equation [2] in *differences*. In the model in difference, the lagged dependent variable remains endogenous, but deeper lags are orthogonal to the error and thus can be used as instruments (as long as the error term u_{it} is serially uncorrelated).

An alternative approach is given by the SYSTEM GMM, which can greatly increase the efficiency of the estimates, as shown in Blundell and Bond (1998). Instead of transforming the regressors to remove the fixed-effects, the SYSTEM GMM transforms (by taking differences) the instruments to make them exogenous to the fixed-effects. This methodology requires the additional assumption that changes in any instrumenting variable are uncorrelated with the fixed-effect, and it is particularly suitable for estimating processes that can be considered closed to a random walk.

Both DIFFERENCE and SYSTEM GMM are valid tools, when the database has a large number of cross-sectional units ($N \rightarrow \infty$) with respect to a short time extension (T), otherwise the number of instruments, which grows prolifically in the time dimension, would increase too much, leading to a problem of over-identification. In fact, finite samples may lack adequate information to estimate the variance matrix of the moments, which is quadratic in the instruments. Over-identification is quite difficult to detect,

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[7] Actually, the bias of LSDV has an opposite sign, with respect to the bias of OLS, and thus the range between these two estimates obtained for the lagged variable coefficient provides a useful check on results from theoretically superior estimators (Bond, 2002).

since the unique tool is represented by the Sargan test, whose reliability weakens as the number of instruments grows. One minimum (but insufficient) caution is to have a number of instruments lower than the cross-sectional dimension; however, as shown by Windmeijer (2005), in finite samples, the bias is present to some extent, even when instruments are few.[8]

For balanced finite sample panel data, there exists another way to obtain unbiased estimates of a dynamic model: perform the LSDV estimator and then correct the results for the bias (CORRECTED LSDV), which can be predicted to a high degree of precision (Kiviet, 1995 and 1999; Bun and Kiviet, 2003). Judson and Owen (1999) run Monte Carlo simulations – with N ranging from 20 to 100 and T from 10 to 30 – providing evidence that a CORRECTED LSDV estimator consistently outperforms GMM models. This procedure, which seems to have been quite unexploited so far, has been extended to unbalanced panel data, in a study by Bruno (2005), who also implemented it as a new STATA routine. The statistical significance of CORRECTED LSDV estimated coefficients is tested by resorting to a bootstrap procedure for the computation of standard errors.

In table 2, we compare the results of alternative panel data estimators applied to our basic model, where integrated tariff is represented by a single dummy variable, without details about its characteristics. Both DIFFERENCE and SYSTEM GMM estimators fail to pass the Sargan test, highlighting that the problem of over-identification is serious. We can note, as compared to the other estimators, that coefficients obtained from the CORRECTED LSDV procedure have some relevant differences in the magnitude, even if the sign of significant coefficients are all confirmed. Moreover, the difference in the lagged variable tends to attenuate the long-run impact in a more credible range (the

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[8] Windmeijer (2005) runs a simulation for a panel with $N = 100$ and $T = 8$, showing that reducing the number of instruments from 28 to 13 decreased the average bias by 40%, but did not eliminate it completely.

coefficient in SYSTEM GMM would imply that the long-run effect is approximately 40 times the short-run effect, while results from CORRECTED LSDV reduce this multiplicative impact to about 5). One can argue that LSDV and CORRECTED LSDV estimates are rather similar, but, again, the difference in the coefficient of the lagged variable is such that the bias correction has a huge impact on long-run elasticity estimates.[9] Therefore, the next section will focus on the parameter results obtained from the CORRECTED LSDV procedure.

[TABLE 2 HERE]

4.2.2. Estimation results

We estimate three models, to account for alternative treatments of information regarding the type of integrated tariffs (see table 3). In line with the evidence from the wide literature on LPT demand estimation, short-run price (*P*) elasticity is about -0.18, with long run elasticity around -1. Thus, reducing prices is hardly an effective policy to induce users to choose public transport, and it is also hardly feasible from a financial point of view, given that it would produce a serious decline in revenues, at least in the short run. Income (*I*) is not significant in our regressions, indicating that public transport cannot be considered as an inferior good; this result is probably driven by the existence of several big cities in our sample, cities where the problem of congestion is serious and hinders private mobility. Another idiosyncrasy of Italy is given by the characteristic geographical density of relatively low-scale and interconnected cities, which has led to the definition of the Pianura Padana as a "megalopolis," where traffic is increasing in an exponential way, such that there are 20 million inhabitants covering, on average, 20 kilometres every day. In such a congested context, the development of high-quality

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[9] More precisely, the confidence intervals at the 95% degree, for the coefficients reported in columns 2 and 5, are not overlapping only in the case of the Y_{t-1} variable.

public transport can be considered as a valid alternative to private modes, independent of the level of income.

We consider quality, by trying to assess separately the impact of three supply characteristics which reflect a better experience for LPT users, from different points of view. Although there may be some correlation problems among covariates, it is important to control for all these factors to distinguish between qualitative aspects, which require modifications in the supply level (thus having a huge impact on costs), and the eventual user preference for integrated tariff policies, which is, indeed, the focus of our work. In particular, commercial speed (*SP*) directly impacts travel time and can be promoted by the regulatory authority through the introduction of reserved bus lanes or by developing modes of transport that represent a valid alternative to road transport (e.g, subway, railways). An increase in service frequency (*FR*), which means an increase of the supply over a given network, can capture several aspects from the user's perspective (a reduction of the waiting time, an increase in the timetable flexibility, a reduction of crowding). Finally, the density of the service (*RD*) requires the extension of the public network by the introduction of new routes, and can impact demand, since it improves the accessibility of LPT services.

The coefficient relative to commercial speed is positive, as expected, but small and not significantly different from zero. At first glance, this result appears to be counterintuitive, suggesting that factors impacting travel time do not have any effect on public transport use. However, it must be pointed out that our sample is heterogeneous in terms of supplied trips, since it includes urban, intercity and mixed type services. As discussed in Small and Verhoef (2007, p. 8), "*travel time has the largest effect on choice for trips of moderate distance, being less important for both short and long trips.*" In order to tackle this issue, we have run a set of regressions revealing that speed

actually exerts a significant impact only for mixed service, which is typically associated with moderate distance trips.[10]

Route density and service frequency are highly significant and their elasticities are very similar, suggesting that the consumers value both equally. Incidentally, this evidence is coherent with the theoretical analysis by Kraus (2008), which implies that if a public transit agency minimizes costs (the sum of user crowding costs and the costs that the network authority incurs for providing bus service), then the elasticities with respect to route density and service frequency have to coincide.[11]

[TABLE 3 HERE]

4.2.2.1. Impact of integrated tariff systems

The role of ITS was first investigated by including in the model a dummy accounting for the introduction of any form of tariff integration (BASIC MODEL). The evidence of a positive impact on LPT demand could not be rejected, considering a 10% level of significance. In particular, our results indicate that the introduction of an ITS can increase the number of passenger-trips by 2.19% in the short-run and by 12.04% in the long-run (see table 4).[12] Even if this result may appear mild, it must be noted that it simply reflects the introduction of a different price policy over a given LPT network, with given quality attributes and keeping constant the average price for passenger-trips.

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[10] Specifically, we have run a set of regressions in which SP: 1] has been included as the only qualitative variable; 2] has been interacted with the three types of service ($SP \cdot D_{URB}$, $SP \cdot D_{INT}$, $SP \cdot D_{MIX}$); 3] has been included in its interacted form jointly with FR and RD. In case 1] the coefficient on SP remains not significantly different from zero. In case 2] only $SP \cdot D_{MIX}$ is statistically significant, while speed does not affect the demand for urban (i.e., short trips) and intercity (i.e., long trips) services. The latter evidence is confirmed also in case 3], although the introduction of FR and RD variables reduces the significance of the impact exerted by $SP \cdot D_{MIX}$. These results are consistent with the discussion in Small and Verhoef (2007), who also underline that route density and service frequency are the relevant aspects for public transit users.

[11] Kraus (2008) has shown that, for a cost-minimizing public transit network, the assessment of local economies of scale is the same along all the possible margins for adjusting capacity. Thus, a regulatory authority seeking to reach the optimal service size should be indifferent between increasing the frequency or the density. We are grateful to Richard Arnott for this remark.

[12] To compute the percentage impact on Y of each dummy variable D we adopted the formula in Kennedy (1981): $E_{Y,D} = 100\{\exp[\delta - \mathrm{Var}(\delta)/2] - 1\}$, where δ and $\mathrm{Var}(\delta)$ are the estimated coefficient and related variance for the dummy.

Thus, the estimated overall impact of ITS on LPT demand arises irrespective of eventual quantity discount policies, such as season tickets, which are often associated with integrated tariffs. Moreover, this evidence does not take into account the characteristics of ITS, the design of which can be very heterogeneous (as described in section 3) and can seriously affect its effectiveness. Therefore, in EXTENDED MODEL 1 we included all four ITS features – i.e., single ticket option, extension, flexible territorial (zonal) validity, and exclusivity – as separate regressors. Results in table 3 show that D_{SING}, D_{EXT} and D_{ZONE} exhibit a positive sign, but only the latter is statistically significant, while D_{EXCLU}, albeit not significant, has a negative impact. However, keeping in mind that the desirability (in terms of promotion of LPT demand) of specific ITS characteristics can vary according to the type of LPT service provided – i.e., urban, intercity or mixed – we estimated EXTENDED MODEL 2, where each type of LPT service has been interacted with each observed ITS characteristic.[13]

[TABLE 4 HERE]

Results from EXTENDED MODEL 2 highlight the impact of three specific characteristics of ITS. In particular, within the urban LPT networks it seems important to give the users the opportunity to choose an integrated ticket for a single trip. This is coherent with the possibility of having, in urban centres, several occasional users moving within the city for a very specific reason (e.g., a particular event, a one-day tourist visit, etc.), while intercity travelling may be more correlated with usual commuters, who are more keen to buy seasonal tickets. The estimated effect of urban integrated tariffs, allowing for single tickets, is around 7% in the short-run and is over 26% in the long-run. Moreover, the introduction of zonal pricing shows a positive impact of a similar magnitude on LPT

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[13] Over the total of 828 observations, we have 196 cases of the presence of integrated tariffs. When creating sub-samples, it appeared that some pairwise combinations were not present in the sample, specifically, $D_{SING}D_{INT}$, $D_{ZONE}D_{INT}$, $D_{EXCLU}D_{INT}$.

demand, since such pricing better discriminates according to users' needs: for example, by increasing the option of short distance/less expensive trips (e.g., by offering different travelcards to be used in the historical centres only rather than throughout the whole network). When considering mixed networks, as expected, the most important characteristic of the integration appears to be the extension of the integration outside the urban area, which can induce an immediate shift of demand of 5%, and can, in the long-run, produce an increase of passenger-trips of around 25%. This result is also coherent with Marchese (2006), who emphasized the major role of integrated tariffs as the extension of the network increases.

Although the estimation of the extended models provides more detailed information on the impact of ITS, it is worthwhile to note here the issue of possible correlation between tariff integration and discount policies. While we are reasonably confident that the latter are, to a large extent, captured by the average price data in the case of the BASIC MODEL, more caution should be taken in interpreting the point estimates obtained from EXTENDED MODEL 2. In fact, the specific characteristics of integration are likely to go along with changes in the price structure – especially the single ticket option and zonal pricing – and the attraction of new users may be more due to a differential rather than to an average price effect. In any case, while the quantitative impact of these characteristics may reflect – at least to some extent – a price effect too, the above results provide important indications on the most suitable ITS design for each type of LPT network.[14]

5. Concluding remarks

The increase of mobility needs associated with economic development raises continual concerns about pollution and traffic congestion, inducing policy makers to adopt

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[14] We thank an anonymous referee for having raised this critical issue.

measures to control the use of private transport modes. Solutions such as parking fees or road pricing, aimed at internalising the social costs of private transport, as well as the introduction of limited traffic zones, have become popular. The focus on negative incentives to private transport has sometimes overshadowed complementary policies, aimed at improving the public transport service, thus trying to capture users' preferences directly. In this paper, we focus on this second type of measures by investigating how much qualitative factors can affect public transport demand.

Our findings show that the introduction of Integrated Tariff Systems (ITS) exerted a positive impact on passenger demand for a sample of 69 Italian LPT operators observed over the 1991-2002 period. On average, the estimated effects of integrated tariffs on patronage are 2% in the short-run and 12% in the long-run. Moreover, focusing attention on the specific characteristics of ITS, both the provision of a single, integrated ticket in addition to the usual season ticket, as well as the introduction of zonal pricing schemes, have a significant impact, in the case of urban public transit demand. In a similar vein, for mixed-type operators providing both urban and intercity service, the extension of the area of validity of the integrated ticket has proven to be the most important ITS feature.

Such results, which have been tested under different panel data estimators (LSDV, DIFFERENCE and SYSTEM GMM, CORRECTED LSDV), highlight that not only a shift towards integration but also the specific ITS features which are implemented should be properly taken into account by local authorities, in order to increase the demand for collective transport. As compared to other public interventions aimed at directly reducing private car circulation, the adoption of ITS implies a much more structural change, in the sense that, in contrast to simple monetary (dis)incentives, it can modify consumer behaviour permanently, in favour of the public transport modality. Of course,

these positive effects are more likely to emerge the higher the quality of the LPT service is, in terms of network density, frequency, inter-modal coordination, and whether parallel policies aimed at facilitating the circulation of buses, such as reserved lanes or preferential traffic-light arrangements, are put forward.

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Table 1. Summary statistics for the variables of the demand analysis

| Variable | Mean | Standard deviation | | | Min | Max |
		Overall	*Between*	*Within*		
Y	49,973,860	144,853,900	144,754,000	17,538,000	306,456	1,085,808,000
P (€)	0.53	0.26	0.25	0.08	0.08	1.60
SP	24	9	9	2	10	50
RD	1.37	1.94	1.93	0.14	0.09	16.83
FR	14,211	15,865	15,857	1,896	811	99,064
I (€)	18,074	4,275	4,180	1,017	9,657	28,678
OCC_G	0.55	0.09	0.08	0.03	0.33	0.87
OCC_{AG}	0.06	0.05	0.05	0.01	0.00	0.22
POP_{OLD}	0.18	0.04	0.04	0.01	0.10	0.25
POP_{FEM}	0.52	0.01	0.01	0.00	0.51	0.54
D_{INTRO}	0.24	0.43	0.34	0.26	0.00	1.00
D_{EXT}	0.14	0.34	0.27	0.21	0.00	1.00
D_{SING}	0.15	0.36	0.29	0.21	0.00	1.00
D_{ZONE}	0.08	0.26	0.21	0.14	0.00	1.00
D_{EXCLU}	0.10	0.30	0.24	0.17	0.00	1.00

Table 2. Estimates of model [2] from alternative panel data approaches

Regressor [a]	LSDV		DIFFERENCE GMM		SYSTEM GMM		CORRECTED LSDV [b]	
	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Y_{t-1}	0.659	(0.000)	0.601	(0.000)	0.976	(0.000)	0.818	(0.000)
P	-0.209	(0.000)	-0.360	(0.000)	-0.055	(0.000)	-0.177	(0.000)
SP	0.024	(0.435)	0.029	(0.508)	0.069	(0.000)	0.029	(0.427)
RD	0.127	(0.000)	0.080	(0.038)	0.001	(0.803)	0.112	(0.000)
FR	0.127	(0.000)	0.058	(0.074)	0.015	(0.083)	0.114	(0.000)
I	-0.060	(0.217)	0.069	(0.226)	-0.002	(0.770)	0.055	(0.298)
D_{INTRO}	0.020	(0.056)	-0.008	(0.579)	0.044	(0.000)	0.022	(0.081)
Constant	4. 794	(0.000)	-	-	-	-	-	-
Nr. observations	759		690		759		759	
R^2 *Within*	0.703		-		-		-	
R^2 *Between*	0.967		-		-		-	
R^2 *Overall*	0.965		-		-		-	
AR(1) test	-		-5.74	(0.000)	-7.63	(0.000)	-	
AR(2) test	-		0.43	(0.665)	-0.10	(0.922)	-	
Sargan test	-		110.66 [c]	(0.000)	116.69 [d]	(0.000)	-	
Nr. instruments	-		61		71		-	

[a] The dependent variable Y is the total number of transported passengers.
[b] Bootstrapped standard errors are based on 200 replications. Coefficients from the Blundell-Bond (1998) approach are used as initial parameter estimates.
[c] Statistical distribution: $\chi^2_{(54)}$.
[d] Statistical distribution: $\chi^2_{(64)}$.

Table 3. Estimates of model [2] from alternative specifications of ITS effects

Regressor [a]	BASIC MODEL		EXTENDED MODEL 1		EXTENDED MODEL 2	
	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Y_{t-1}	0.818	(0.000)	0.804	(0.000)	0.802	(0.000)
P	-0.177	(0.000)	-0.184	(0.000)	-0.188	(0.000)
SP	0.029	(0.427)	0.017	(0.636)	0.019	(0.607)
RD	0.112	(0.000)	0.113	(0.000)	0.097	(0.001)
FR	0.114	(0.000)	0.118	(0.000)	0.112	(0.000)
I	0.055	(0.298)	0.040	(0.459)	0.040	(0.459)
D_{INTRO}	0.022	(0.081)	-	-	-	-
D_{SING}	-	-	0.008	(0.594)	-	-
$D_{SING}D_{URB}$	-	-	-	-	0.066	(0.021)
$D_{SING}D_{MIX}$	-	-	-	-	-0.029	(0.194)
D_{EXT}	-	-	0.011	(0.558)	-	-
$D_{EXT}D_{URB}$	-	-	-	-	0.006	(0.807)
$D_{EXT}D_{INT}$	-	-	-	-	0.062	(0.185)
$D_{EXT}D_{MIX}$	-	-	-	-	0.050	(0.053)
D_{ZONE}	-	-	0.049	(0.064)	-	-
$D_{ZONE}D_{URB}$	-	-	-	-	0.065	(0.062)
$D_{ZONE}D_{MIX}$	-	-	-	-	0.001	(0.982)
D_{EXCLU}	-	-	-0.010	(0.662)	-	-
$D_{EXCLU}D_{URB}$	-	-	-	-	-0.045	(0.192)
$D_{EXCLU}D_{MIX}$	-	-	-	-	0.003	(0.932)

[a] The dependent variable Y is the total number of transported passengers.

Table 4. Impact of ITS: short-run and long-run elasticities

	BASIC MODEL		EXTENDED MODEL 2	
	Short-run	Long-run	Short-run	Long-run
D_{INTRO}	2.19%	12.04%	-	-
$D_{SING} D_{URB}$	-	-	6.75%	34.08%
$D_{ZONE} D_{URB}$			6.66%	33.64%
$D_{EXT} D_{MIX}$	-	-	5.05%	25.51%