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Behavioural implications of non-linear effects on urban freight transport policies: The case of retailers and transport providers in Rome

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ABSTRACT

Cities import goods and freight transport is essential. However, it also generates social costs. Ensuring efficient urban freight transport is important although difficult. Policy makers intervene by defining and implementing policy measures that try to foster market efficiency in an environmentally sustainable way. General-purpose policies have often backfired when insufficient attention was paid to specific stakeholders' preferences. This paper investigates the impact the number of loading and unloading bays, the probability of finding them free and entrance fees have on retailers' and transport providers' utilities. Willingness to pay measures are used to test and quantify possible non-linear attribute variation effects. The main findings underline both the substantial difference in retailers' and transport providers' utility while evidencing the presence of non-negligible non-linear effects. Unfortunately the research results obtained are at odds with the recently introduced changes of the regulatory framework governing the Limited Traffic Zone in the city of Rome that is the case study considered in the paper.

1. Introduction

Cities import goods. Freight transport is essential but it also generates social costs. Ensuring efficient urban freight transport[1] is a fundamental and daunting task for local policy makers. In fact, while it is common to witness an articulated and pervasive deployment of detailed policies, these often engender undesired and unforeseen effects. This occurrence is prevalently linked to the: (1) complexity of the regulatory framework; (2) heterogeneity of contractual relationships and distribution of relative power among the agents involved; (3) contrasting stakeholders' interests; (4) absence of a well determined assignment of property rights that favours the insurgence of external costs (e.g. congestion, visual intrusion, noise, atmospheric pollution).

Freight modelling often adopts an aggregate stance with limited attention paid to agent-level considerations (e.g. Gruber et al., 2013; Liedtke and Schepperle, 2004; Roorda et al., 2010; Wisetjindawat et al., 2005). On the contrary, a micro level of analysis is necessary to investigate the behavioural implications these policies entail (Hensher and Figliozzi, 2007). Models adopting a behavioural approach explicitly consider stakeholders' utility maximization efforts thus providing richer model specifications capable of capturing important decision-maker's motivations and warranting a better understanding of policy effects. Freight demand is commonly considered, even with noticeable exceptions (Hesse and Rodrigue, 2004), derived rather than direct. In fact, there is always some agent's profit maximization intent, linked to an underlining market, at the base of freight demand. Analysing freight related choices within a well-defined theoretical framework helps understanding and forecasting.

The most important agent-types in urban freight are: retailers, transport providers and own-account. Only a limited number of papers have overtly considered their specific stated preferences and behaviour (e.g. De Oliveira et al., 2012; Domínguez et al., 2012; Gatta and Marcucci, 2013a, 2014; Hensher and Puckett, 2005; Holguín-Veras et al., 2007, 2008; Marcucci and Gatta, 2013; Marcucci et al., 2007, 2013b, 2015; Puckett et al., 2007) notwithstanding their *a priori* bearing (Ogden, 1992). The gap between the theoretical acknowledgment and the practical investigation of agent-specific characteristics can be explained via the lack of appropriate data due to the high cost of acquiring

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[1] According to Dablanc (2009) urban freight transport can be defined as: " . . . a segment of freight transport which takes place in an urban environment. Specifically, urban freight is the transport of goods by or for commercial entities (as opposed to households) taking place in an urban area and serving this area."

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them (Marcucci et al., 2013a). A complementary contribution of this paper is the definition and employment of an elicitation method representing a good compromise between cost minimization and data quality.

Effective policies capable of producing the desired results need reliable knowledge of the most likely response the intervention will produce. These will, in turn, depend on the: (1) regulatory regime; (2) contractual relationships; (3) commercial habits; (4) role played along the supply chain and, possibly, also other specific *status quo* elements. Agents' preference heterogeneity[2], role, characteristics, level of involvement are particularly pronounced in this sector. Urban freight transport policies are likely to have highly differentiated effects among stakeholders and this often implies a low level of result transferability (Stathopoulos et al., 2012). Furthermore, non-linear attribute effects are seldom investigated (Gatta and Marcucci, 2013b; Marcucci and Gatta, 2014; Nijkamp et al., 2004; Rich et al., 2009; Masiero and Hensher, 2009; Danielis and Marcucci, 2007; Rotaris et al., 2012). The linearity assumption implies a constant marginal contribution to the utility that should be tested rather than assumed. This represents the focus of this paper.

The results described are based on data acquired thanks to a project funded by Volvo Research Foundation (2009) focusing on *ex ante* policy evaluation for freight transport policies. The Limited Traffic Zone in the city centre of Rome is the case study investigated. The data collected explicitly differentiate among transport providers and retailers. Policy preferences were elicited through a Stated Ranking Exercise. Respondents were asked to rank alternative options including the *status quo* situation (Marcucci et al., 2012).

The paper reports the results of different Multinomial Logit (MNL) model specifications aimed at: (1) investigating the non-linear effects of policy intervention on both retailers' and transport providers' utility functions; (2) individuating potential biases when linearity is assumed; (3) comparing policy effects for the two agents considered.

Policy makers are keen to know, before a policy is implemented, the likely reactions so to gauge how much of the objectives set will be achieved. The reactions to a policy are strictly linked to the variation it provokes in each agent's profit function that can be approximated by willingness to pay (WTP) measures for its implementation given the articulated implications it might have. WTP is used to compare respondents' preferences under different assumptions with respect to the effects of given policies. Testing the commonly held assumption that attributes have linearly undifferentiated effects, the paper provides estimates of the possible biases this assumption might produce for the different agent types considered[3]. It consolidates and extends recent results (Marcucci and Gatta, 2014) that tested and measured non-linear effects in this research field for retailers alone adopting only a specific form of non-linear effects.

The paper is structured as follows. Section 2 illustrates the methodology adopted while section 3 describes the survey instrument developed and the data acquired. Section 4 reports and discusses the econometric results and policy implications. Section 5 concludes and illustrates future research endeavours.

2. Methodology

Discrete choice models describe, explain and predict choices between two or more discrete alternatives[4]. In particular, MNL models are estimated using different specifications: (1) the deterministic part of utility is, first, specified as linear-in-the-attributes; (2) non-linearity is, then, tested by using, one at a time, three different mathematical transformations[5] (i.e. piecewise linear, logarithmic and power series) for all attributes[6]; (3) the best fitting model is obtained combining the most appropriate specification for each attribute.

Model 1 adopts a linear specification and attributes are normalised by dividing each level by its own minimum. The deterministic part of the utility, in the case of a single attribute, can be written as:

$$V_{i,q} = \beta_k x_{k,i,q} \tag{1}$$

where $x_{k,i,q}$ is the value of the attribute for alternative i faced by respondent q and β_k is its marginal contribution to the utility. In fact:

$$\frac{\partial V_{i,q}}{\partial x_{k,i,q}} = \beta_k \tag{2}$$

Model 2 refers to the piecewise linear specification. In this case, effects coding is used and the *status quo* level is taken as a reference. The deterministic part of the utility, in the case of a three-level attribute, can be written as follows:

$$V_{i,q} = \beta_{k_2} x_{k_2,i,q} + \beta_{k_3} x_{k_3,i,q} \tag{3}$$

where $x_{k2,i,q}$ and $x_{k3,i,q}$ are two auxiliary variables taking the values 1, 0 or −1. Assuming the first level as reference, $x_{k2,i,q}$ is equal to: 1 when the respondent faces level 2; −1 in the case of level 1; 0 otherwise. Similar considerations apply for $x_{k3,i,q}$. The marginal contribution to utility is thus:

$$\frac{\partial V_{i,q}}{\partial x_{k,i,q}} = \begin{cases} -\beta_{k_2} - \beta_{k_3}, \text{if } x_{k,i,q} = x_{k_1,i,q} \\ \beta_{k_2} \text{if } x_{k,i,q} = x_{k_2,i,q} \\ \beta_{k_3}, \text{if } x_{k,i,q} = x_{k_3,i,q} \end{cases} \tag{4}$$

Model 3 is based on the logarithmic transformation of the variables. The deterministic part of the utility is expressed as:

$$V_{i,q} = \beta_k \log(x_{k,i,q}) \tag{5}$$

This hypothesis is consistent with standard microeconomic theory assuming a decreasing marginal contribution to utility which is calculated as follows:

$$\frac{\partial V_{i,q}}{\partial x_{k,i,q}} = \beta_k \frac{1}{x_{k,i,q}} \tag{6}$$

Model 4 adopts a power series transformation. In particular, a second degree transformation for the attributes is specified as follows:

$$V_{i,q} = \beta_{k_1} x_{k,i,q} + \beta_{k_2} x_{k,i,q}^2 \tag{7}$$

[2] Heterogeneity can be investigated by using advanced modelling techniques (e.g. Marcucci and Gatta, 2012; Fabrizi et al., 2012; Felici and Gatta, 2008).

[3] It is also important to note that differences in attribute evaluation might depend on the specific type of good which can be characterised as specific versus generic where specific goods are made for a single customer while generic goods are produced irrespective of which final customer will buy them. These issues have been discussed in Massiani et al., 2009.

[4] For a detailed discussion of the methodological framework and possible applications of discrete choice models see, for example, Ben-Akiva and Lerman, (1985); Hensher et al., (2005); Train, (2005); Marcucci (2005); Gatta (2006); Marcucci and Gatta (2012).

[5] Non-linear effects on utility function can be also tested via self-stated attribute cut-off. Please refers to Marcucci and Gatta (2011) for a detailed description and application.

[6] Only the best fitting models are reported and commented.

Table 1
Attribute levels and ranges used in the stated ranking experiment.

Attribute	Levels and range of attribute (*status quo* in bold)
Loading/unloading bays	**Level 1: 400** Level 2: 800 Level 3: 1200
Probability of free l/u bays	**Level 1: 10%** Level 2: 20% Level 3: 30%
Entrance fee	Level 1: 200€ Level 2: 400€ **Level 3: 600€** Level 4: 800€ Level 5: 1000€

The marginal contribution to the utility is now computed as reported in Eq. (8).

$$\frac{\partial V_{i,q}}{\partial x_{k,i,q}} = \beta_{k_1} + 2\beta_{k_2} x_{k,i,q} \quad (8)$$

Model 5 is a combination of the previous attribute specifications. In more detail, the model is based on the mixture that assures the best fit of the data.

3. Survey instrument and data description

This paper uses data acquired in Rome's Limited Traffic Zone between March and December 2009. This area in the city centre of Rome, first implemented in the late eighties, covers a 5 km^2. Retailers and transport providers pay an access fee. Enforcement is performed through cameras and optical character recognition software. The system operates during daytime with a yearly entrance fee of 565€ per number plate when the survey was conducted[7].

Great attention was paid to questionnaire development. Attributes included in the questionnaire were defined, selected, developed and customized through a long, t`ime-consuming and fruitful stakeholders involvement. A Stated Ranking Exercise format was finally chosen after extensive consultations since it was considered the most appropriate response format to elicit agents' preferences for alternative urban freight policies. Questionnaire implementation involved different phases among which the most important were: (1) advancement from stakeholder consultation to final attribute selection criteria; (2) attribute definition; (3) levels and ranges selection; (4) progressive design differentiation by agent-type (Stathopoulos et al., 2011).

Attribute selection was performed considering: (1) literature survey; (2) similar studies previously performed in Rome; (3) focus groups with experts.

A literature review focused on papers adopting an agent-based perspective provided a set of eligible attributes with potentially conflicting policy instruments/characteristics[8].

Previous studies in Rome (STA, 2001; Filippi and Campagna, 2008; Comi et al., 2008) together with expert and stakeholder focus groups guided the attribute selection process. Shared support by all the stakeholders involved was the criterion used to select the attributes subsequently validated via a pilot test with real operators (Marcucci et al., 2012). The attributes finally included are: (1) number of loading/unloading bays; (2) probability of finding loading/unloading bays free; (3) entrance fee. Attributes, number of levels, and ranges are reported in Table 1. Attributes are all characterized by, at least, three levels. This allows testing for non-linear effects that represent the core of this paper.

The lowest and highest levels of attribute ranges were defined in line with stakeholders' opinions and comments so to achieve realism and properly mirror plausible policy changes. The lowest attribute level for loading/unloading bays and probability of finding them free coincides with the *status quo* situation. Only improvements were considered with respect to the *status quo*. A wide and symmetric range of variation was used for entrance fee.

According to the response format chosen, the respondents were asked to rank two policy options plus the *status quo* alternative presented. Table 2 reports an example of a ranking task.

Table 2
Example of a ranking task.

	Policy 1	Policy 2	*Status quo*
Loading/unloading bays (LUB):	1200	800	400
Probability of free l/u bays (PLUBF):	10%	20%	10%
Entrance fee (EF):	1000€	400€	600€
Policy ranking	☐	☐	☐

In total, 252 interviews were performed and 156 used in this paper with 90 retailers and 66 transport providers. The total number of observations used for data analysis are 1624 for retailers and 1164 for transport providers.

4. Econometric results and policy implications

This section reports the results of the models estimated for both retailers and transport providers.

Table 3 shows the results for retailers. Model 1 provides interesting results and shows a satisfactory fit to the data (adj. pseudo-R^2 = 0.142)[9]. All the coefficients are statistically significant and with the expected sign. In particular, an increase in either the number of loading and unloading bays or in the probability of finding them free has a positive impact on retailers' utility. On the contrary, an increase in entrance fee has a negative one. The model also includes two alternative-specific constants[10] for the unlabelled hypothetical cases whose coefficients are both positive implying a negative evaluation of the *status quo*. The normalization adopted in the linear specification implies the estimated coefficients of the attributes considered represent the impact the base level has on utility. Therefore, an entrance fee of 200€ has an impact of −0.6996, while utility increases by 0.2533 and 0.3472 when loading/unloading bays are equal to 400 and the probability of free loading/unloading bays is equal to 10%, respectively. All those coefficients express the constant marginal contribution to the utility.

Model 2 is characterized by a statistically significant and improved fit (adj. pseudo-R^2 = 0.155). All coefficients are statistically significant and in line with model 1. The piecewise linear transformation tested for loading/unloading bays does not improve the model thus suggesting its linear impact. The non-linear effect of the remaining two attributes is evident. In fact, as it

[7] Nowadays, Euro3 and more fuel-efficient vehicles only can enter. Entrance fees have, on average, been quadrupled while keeping all else equal. Entrance fee is based on the emission characteristics, with reductions for more fuel-efficient vehicles and increases for more polluting ones. Electric vehicles' entrance is free and subject to no time restrictions.

[8] Night-time deliveries, for instance, were considered efficiency enhancing by carriers but viewed as a mere increase in costs by retailers and thus excluded.

[9] The pseudo-R^2 refers to the likelihood ratio Mc Fadden R^2.

[10] The inclusion of the alternative-specific constants in the model not only substantially increased the model fit but also favoured a more realistic interpretation of the parameters.

Table 3
Retailers: econometric results.

Coefficients	Model 1 linear	Model 2 piece-wise	Model 3 logarithmic	Model 4 power	Model 5 best specification
Alternative-specific constant					
Alternative 1	0.8244***	1.0054***	0.7712***	0.7564***	1.0054***
Alternative 2	0.6578***	0.7541***	0.6216***	0.6147***	0.7541***
Loading/unloading bays					
Linear	0.2533***	0.2499***	0.2520***	0.1830***	0.2499***
Level 2					
Level 3					
Logarithmic					
Power					
Probability to find l/u bays free					
Linear	0.3472***			1.5096***	
Level 2		0.2048***			0.2048***
Level 3		0.2740***			0.2740***
Logarithmic			0.6467***		
Power				−0.3006***	
Entrance fee					
Linear	−0.6996***		−0.6967***	0.2236	
Level 1		1.0781***			1.0781***
Level 2		0.9650***			0.9650***
Level 4		−0.8037***			−0.8037***
Level 5		−1.5552***			−1.5552
Logarithmic					
Power				−0.1597***	
No. of estimated parameters	5	9	5	7	9
Log-likelihood	−1126.935	−1107.896	−1124.068	−1116.267	−1107.896
Pseudo-R^2	0.145	0.160	0.147	0.153	0.160
Adjusted pseudo-R^2	0.142	0.155	0.144	0.149	0.155
No. of observations	1624	1624	1624	1624	1624

*** Significance level at 1%.

is for the probability of finding loading/unloading bays free, the relatively high value of the level2-coefficient with respect to level3 indicates a decreasing marginal impact on utility which is consistent with the “proportionate effect theory” (Tapley et al., 2006) postulating economic agents are less sensitive to a given change in an attribute at higher absolute values of that attribute. The adoption of the effects coding for entrance fee produced interesting results. The presence of five levels and their symmetricity with respect to the *status quo* (i.e. 600€) allows testing “prospect theory” (Kahneman and Tversky, 1979). In line with this theory, initial variations, in both directions, from the *status quo* have larger effects with respect to subsequent ones. Moreover, positive variations are valued less than negative ones, testified by both inner and outer variations.

Model 3 refers to the logarithmic specification. In this case, only the transformation of the probability of finding loading/unloading bays free significantly improves model’s fit, implying a decreasing marginal contribution to utility for this attribute. The remaining attributes are specified as linear and their coefficients, in terms of sign and absolute value, do not vary significantly when compared with the estimates obtained in model 1.

Model 4, based on power series transformations, improves the log-likelihood function with respect to model 1. Also in this case, it is preferable to specify the loading/unloading bays attribute as linear. The second degree transformation applied to the other two attributes reveals a decreasing marginal contribution to utility.

In general, the log-likelihood ratio tests performed show that all the non-linear models fit the data better with respect to the linear model. Model 5, the best specification, is exactly the same as model 2 suggesting loading/unloading bays should be considered having a linear effect, while both the probability of finding loading/

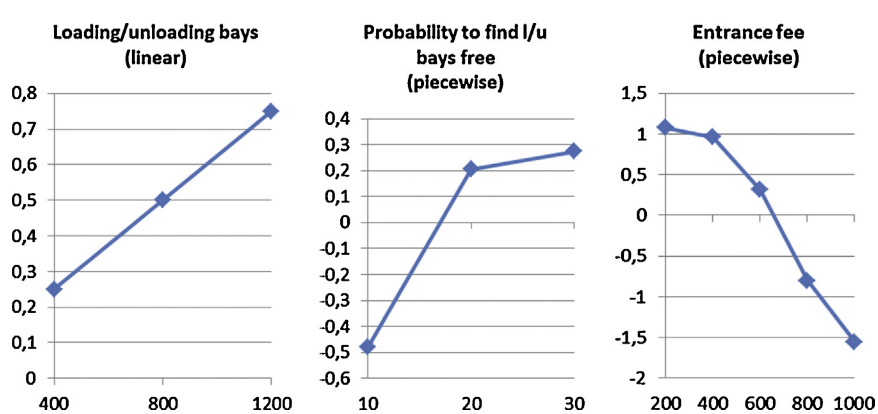

Fig. 1. Retailers: attributes’ contribution to utility function.

Table 4
Transport providers: econometric results.

Coefficients	Model 6 linear	Model 7 piece-wise	Model 8 logarithmic	Model 9 power	Model 10 best specification
Alternative-specific constant					
Alternative 1	0.6860***	1.0413***	0.6009***	0.9743***	1.0648***
Alternative 2	0.7086***	0.9718***	0.6549***	0.9699***	0.9758***
Loading/unloading bays					
Linear	0.5577***			0.4443***	
Level 2		0.2376***			
Level 3		0.4906***			
Logarithmic			1.0340***		1.1171***
Power					
Probability to find l/u bays free					
Linear	0.4347***	0.6125***	0.4595***	0.3739***	0.5741***
Level 2					
Level 3					
Logarithmic					
Power					
Entrance fee					
Linear	−1.1700***		−1.1749***	0.2870	0.2032
Level 1		2.2195***			
Level 2		1.5861***			
Level 4		−1.1306***			
Level 5		−3.2595***			
Logarithmic					
Power				−0.2599***	−0.2613***
No. of estimated parameters	5	9	5	6	6
Log-likelihood	−690.626	−661.100	−687.434	−667.516	−662.842
Pseudo-R^2	0.254	0.286	0.258	0.279	0.285
Adjusted pseudo-R^2	0.251	0.281	0.255	0.276	0.281
No. of observations	1164	1164	1164	1164	1164

*** Significance level at 1%.

unloading bays free and entrance fee should be transformed according to the piecewise linear approach (Fig. 1).

Table 4 shows the results for transport providers. Model 6 fits the data well (adj. pseudo-R^2 = 0.251). The goodness of fit is higher with respect to the equivalent retailers' case. The coefficients are all statistically significant and the interpretation of the sign is consistent with theory. Similar considerations also apply in this case.

Model 7 provides a statistically significant better fit (adj. pseudo-R^2 = 0.281). The piecewise linear transformation seems appropriate for loading/unloading bays and entrance fee whereas it does not seem suitable for the probability of finding loading/unloading bays free. Also in this case, the non-linear effect is clear and stronger for entrance fee.

In model 8, the logarithmic transformation is used only for loading/unloading bays. The values of the coefficients related to the other two attributes are similar to those estimated in model 6.

Model 9 suggests the second degree transformation is suitable only for entrance fee indicating a decreasing marginal contribution to utility.

All non-linear models have higher explanatory power with respect to their linear counterparts. The best non-linear specification, model 10, adopts: (1) a logarithmic transformation for loading/unloading bays; (2) power series transformation for entrance fee; (3) linear specification for probability of finding loading/unloading bays free (Fig. 2).

In order to analyse the impact of different estimation methods, define and measure the potential biases for policy implementation the paper uses WTP for comparison purposes so to avoid scale problems. The WTP to move from the reference level of an attribute

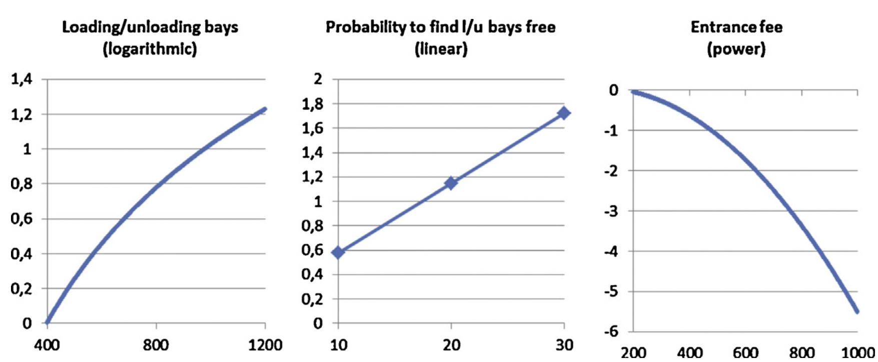

Fig. 2. Transport providers: attributes' contribution to utility.

Table 5
WTP comparison between linear and best non-linear model specification.

Policy intervention	Linear specification	Best non-linear specification	Potential bias absolute and %
Retailers			
Loading/unloading bays			
From 400 to 800	73€	45€	+28€ (+62%)
From 400 to 1200	146€	90€	+56€ (+62%)
Probability to find l/u bays free			
From 10% to 20%	99€	122€	−23€ (−19%)
From 10% to 30%	198€	135€	+63€ (+47%)
Transport providers			
Loading/unloading bays			
From 400 to 800	95€	103€	−8€ (−8%)
From 400 to 1200	190€	156€	+34€ (+22%)
Probability to find l/u bays free			
From 10% to 20%	75€	78€	−3€ (−4%)
From 10% to 30%	150€	147€	+3€ (+2%)

to a different one represents the difference in the corresponding valuations (Collins et al., 2012)

Table 5 reports the WTP estimates[11] for given policy changes according to both linear and best non-linear specification. Looking at both model specifications indicates that the two agent-types have opposite sensitivities. In fact, transport providers are more interested in the number of loading/unloading bays, while retailers are more concerned about the probability of finding them free. This suggests the adoption of a light intervention policy based more on regulation rather than infrastructure modification with a reduced impact on public finance. In more detail, transport providers are willing to pay 190€ to obtain 800 additional loading/unloading bays (while retailers 146€), and 150€ to get 20 additional units of probability of finding loading/unloading bays free (while retailers 198€).

Furthermore, the results show the strong policy impacts that adopting either a linear or non-linear assumption might have. In fact, comparing the results of the two model specifications, one observes substantial differences for both loading/unloading bays and probability of finding them free. In particular, linear models tend to overestimate WTPs associated with the highest attribute levels while underestimate WTP linked to the intermediate levels, with the exception of loading/unloading bays for retailers.

It is interesting to note that the bias for the agent-types is different with WTP for retailers showing a higher bias. Transport providers, on the other hand, seem not so affected by this phenomenon. A possible explanation of this last point is that the model assuming a linear specification of the attributes already provided a relatively high model fit. From a simulation perspective, one has to underline that the bias introduced would be the greatest should local decision makers decide to implement a strong intervention policy where both loading/unloading bays and probability of finding them free are brought to the highest levels considered in our experiment. In particular, neglecting non-linear effects produces significant WTP overestimations (+156€). These considerations are only tentative given the small sample considered but still, in our opinion, represent a warning for policy makers. The cautionary view proposed in this paper is, unfortunately, not shared by local decision makers in Rome. In fact, a regulatory change was recently introduced almost quadruplicating, on average, the entrance fee to the Limited Traffic Zone without providing any compensatory measures for the higher costs stakeholders have to incur (Rome Mobility Agency, 2015). It is no surprise that a strong upheaval against this measure emerged and this could also have potential implications for the next political elections (Marcucci et al., 2005).

5. Concluding remarks

This paper tests the non-linear effects of level variation for the attributes considered in a urban freight policy for the Limited Traffic Zone in Rome.

The research focused on retailers' and transport providers' preferences eliciting them via a Stated Ranking Exercise. The results obtained indicate that, for the sample interviewed, non-linear effects are more relevant for retailers with respect to transport providers. The bias introduced if non-linear effects are neglected increases with the distance the variation has with respect to the *status quo*.

The paper contributes to the literature by underlining the potential impact of a phenomenon not usually considered relevant. The analysis is performed at an agent-specific level. Whereas in this case the non-linear effects alone are considered, previous research from the authors indicates that heterogeneity in preferences can be present also within single agent category.

Future research will aim at: (1) increasing the number of respondents, (2) widening the type of policy instruments evaluated, (3) include other relevant stakeholders (i.e. citizens).

Unfortunately, notwithstanding the detailed and cautionary suggestions provided, local decision makers in Rome have recently modified the regulatory framework by substantially increase the entrance fee in the Limited Traffic Zone without any compensatory measures. The decision taken does not bode well for the future. The upheaval it has provoked suggests that this policy intervention was considered as yet another form of additional taxation. This is not in line with the consultative approach adopted in other large cities with similar problems (e.g. Lindholm and Browne, 2013).

Acknowledgments

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[11] Please refers to Gatta et al. (2014) for an in-depth discussion on WTP confidence intervals.

complex large urban area of Rome" (Grant#SP-2007-50) and the Italian Ministry of Education, University and Research for funding the project "Methods and models for estimating the effectiveness of strategies for urban distribution of goods".

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