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WORKING PAPER SERIES

Who's afraid of power lines?
Merging survey and GIS data to account for spatial heterogeneity

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Who’s afraid of power lines? Merging survey and GIS data to account for spatial heterogeneity

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Abstract

The study offers a comprehensive assessment of the externalities produced by High Voltage Transmission Lines as perceived by residents in the infrastructure corridors. A GIS approach has been experimented in the sampling design of a CV survey in order to obtain additional information about the local context within which impacts are perceived and to take into account the spatial specificity of the external effects. We estimate, by means of a double-bounded logit model, the marginal damage from human health, landscape and environmental effects. We differentiate the analyses with separate bid designs for households in close proximity to the lines, affected by a depreciation of their real estate property values, and for all other respondents affected by generic forms of damage linked to visual encumbrance. A significant explanatory contribution in the modelled utility functions of resident households is given by the implementation of GIS-based variables, such as the proximity to power lines, built as a distance decay indicator, and local context features such as density of power lines, presence of other linear infrastructures, and local environmental amenity.

Keywords: *High Voltage Transmission Lines; Contingent valuation; GIS; externalities; linear infrastructures.*

JEL Classification: *C21, D62, H5, O13, O22, Q4.*

1. Introduction

Being able to estimate the unpriced impacts caused by the generation and transport of energy is increasingly recognized as a key factor in the design of efficient energy policies, both in public and in private energy industries (Pearce, 2001). The internalization of health, environmental and occupational externalities is the basic criterion, typically inspired by a welfare economics perspective driving the rationalization of decisional processes in the evaluation of investments in the energy sector. The availability of information, in the form of monetary estimates of different typologies of externality, is the binding constraint in making this economic approach operational. An appreciable number of empirical studies on the externalities associated with infrastructures has been developed in recent years, and results of *ad hoc* monetary valuations are gradually being accumulated and organized by independent research programmes (European Commission, 1995, 1998; CSERGE, 1999).

Only seldom, however, the results are suitable for benefit transfer or for systematic generalizations. In addition, wide areas still remain uncovered, or with poor and outdated data. Monetary evaluations of the external costs of electricity transport facilities such as High Voltage Transmission Lines are relatively scarce. The available results have been mostly obtained by hedonic pricing in North-America (Kinnard, 1967; Colwell and Foley, 1969; Colwell, 1990; Kroll and Priestley, 1992; Kung and Seagle, 1992; Delaney and Timmons, 1992 for the United States; and Des Rosiers, 2002 in Canada). In the European context, two studies focus on real estate impacts in the UK (Gallimore and Jayne, 1999; Sims and Dent, 2005). The only stated preferences analyses are due to Atkinson *et al.* (2004) who, by means a choice modelling experiment, obtained (negative) willingness to pay estimates for different types of transmission towers; and to Tempesta and Marazzi (2005) and Rosato *et al.* (2004) who estimate with contingent valuation studies the damage to the aesthetic quality of landscapes in Italy.

This paper offers a first large scale Contingent Valuation study of the externalities caused by High Voltage Transmission Lines (HVTLs) in a European region – namely, in Piedmont, Italy. The purpose is not only to provide monetary estimates of the external costs involved, but also to offer decision-makers an implementable decision support tool. Potential applications include the location choices involved in designing or renewing the infrastructure networks, and the calculation of reference values for the arrangement and negotiation of compensative measures at the local level. The results of our research can also constitute an informational basis for the implementation of software based tools, such as *EcoSense* (Krewitt *et al.,* 1995), designed for ex-ante simulations and scenario analysis.

The contingent valuation approach infers monetary values environmental changes by simulating market mechanisms and estimating the willingness to pay (WTP) of citizens for specific amenities or disamenities. In our case it is aimed at estimating general individual measures of WTP for an environmental change concerning a hypothetical scenario of removal of the power line contiguous to the respondent dwelling. The elicitation is based on the double-bounded dichotomous choice format (Hanemann *et al.,* 1991), which allows us to define a relationship between WTP and other observable explanatory variables affecting the deterministic component of the respondents' utility function.

Our reference population are the residents in the corridors around HVTLs. Since the hypothetical scenario matches the actual residential location of respondents, our analysis can include further information about the spatial and environmental structure of the interaction between households and the power line. The link between preferences and environmental and other micro-spatial characteristics is built by making use of the geographical information system (GIS) to map and collect quantitative variables that are then tested as explanatory variables of the WTPs. We use distance-based approaches (Bateman, 2002) to include, among the set of explanatory variables, the proximity of respondents to the infrastructure being valued, the impact of the simultaneous presence of other local infrastructures on the residents' perception of the disamenity caused by the HVTL, and quantitative indicators of environmental quality. One of the paper's objectives is to verify whether the perceived externalities are sensitive to these micro-spatial features, which we call *local context variables* (LCV). This is an aspect that in our study turns out to play an important role and that has received little attention in the existing literature. In addition, the combination of contingent valuation surveys with spatial analyses represents an innovative approach that may prove useful in the general context of the valuation of linear infrastructures.

In the first section we illustrate the structure of the case study; in section 2 we present the econometric models, while section 3 reports the variables and the results of the estimated models. Section 4 concludes.

2. Experiment design

The study area is the Piedmont Region, in North-Western Italy. The experiment involved a large sample of residents in proximity of the actual HVTLs of the entire regional network (see §2.1). As a consequence of the experimental design, the households being interviewed are well informed and familiar with the infrastructure. The exclusion from the sample of non-resident and tourist preferences responds to the intention of obtaining estimates utilizable as a reference point in the arrangement of compensative policies.

The target of the contingent valuation consists in the bundle of environmental, human health and landscape externalities produced by HVTLs. The spatial context in which the externalities of linear infrastructures are perceived is conventionally identified by means of corridors. Socioeconomic and ecosystemic impacts are more intense in these areas (Geneletti, 2002). The choice of the corridor width plays an important role in the experiment design. A review of the existing empirical studies, summarized in Table 1, shows widths of the HVTL corridor varying between 122 meters and 5 Km. A corridor, however, includes sub-areas among which the impacts of power lines vary sensibly depending on the shape and size of the towers, the orographic trim, climatic conditions and the presence of vegetation. In view of the high variability of the territory crossed by HVTLs in our case, we consider a corridor of 1200 meters. The maximum distance between interviewed households and power lines is hence 600 meters.[1]

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[1] Rosato *et al.* (2004), in their CV study on HVTLs, define a corridor of 1200 meters as "the corridor interested by direct impacts of visual encumbrance and health risk" (our translation).

Table 1. Previous monetary valuations of HVTL externaliites

Author	Technique	Corridor width	Results
Kinnard (1967)	Interviews to owners	4 categories. The more distant houses are at 61m (200 feet)	Low reduction in real estate values (around 3%)
Clarke and Treadway (1972)	Hedonic price	-	Significant reduction for residential houses but not for commercial activities
Boyer *et al*. (1978)	Interviews to owners	1 mile	Real estate value reduction around 16% and 29% depending on the distance from the HVTL
Colwell and Foley (1979)	Hedonic price	122m (400feet)	No effects for houses within 60m, reduction only for houses within 15m.
Colwell (1990)	Hedonic price	122 m (400feet)	Reduction in real estate values related to the proximity of houses to the HVTLs
Kung and Seagle (1992)	Hedonic price	-	No effect with statistical support, about 72% of the owners declare the HVTL has not influence on real estate values
Delaney and Timmons (1992)	Hedonic price	-	Reduction up to 10% depending on the distance from the HVTL
Hamilton and Schwann (1995)	Hedonic price	200m	Reduction between 1.1% for house at 200 meters from the lines and 6.3% for those at 100 meters
Callanan and Hargreaves (1995)	Hedonic price	300 m	In proximity of a tower (≤ 10 meters) the reduction can reach 27.3% of the real estate value.
Bond and Hopkins (2000)	Hedonic price	400 m	The effects on the real estate values are not significant in statistical terms
Des Rosiers (2002)	Hedonic price	488 m	Reduction up to 20% for houses very close to HVTLs
Haider *et al.* (2001)	Hedonic price	3000 m	Average reduction of 4 - 6.2% for properties within 1km from HVTLs. Little evidence of impact on property values at distance >500m.
Rosato *et al.* (2004)	Contingent Valuation	1500 m	Average WTP around 530 € per household. No statistical relation between distance and WTP.
Atkinson *et al.* *(*2004)	Choice Experiments	500m-5 km	Compare 5 different structures for HVTL and estimate household WTPs for each tower design: between 1.85£ and 2.03£
Tempesta and Marazzi (2005)	Contingent Valuation	-	Median WTA around 200€, median WTP around 80 € per person. Do not investigate the relationship between WTP/WTA and proximity to the HVTLs

We overlaid the 1200 meters corridors around the HVTLs on the official regional cartography[2] and on existing geographical analyses of the Piedmont region providing a zoning in sub-regional macro-areas (Clementi *et al*., 1996). These macro-areas are sample strata (Figure 1) that have an appreciable degree of internal homogeneity from the point of view of settlement and landscape typologies, vegetation, and orography.

Considering the lines with a tension of 132kV, 220kV and 380kV, the HVTLs' network crosses 786 municipalities and involves a target population of 2.613.904 inhabitants living within the corridor of the infrastructure. The number of interviews was divided among the macro-areas on the basis of the size of the resident population in the HVTL corridor. The total number of interviews for macro-area was then allocated among municipalities, using a density index of power lines.[3]

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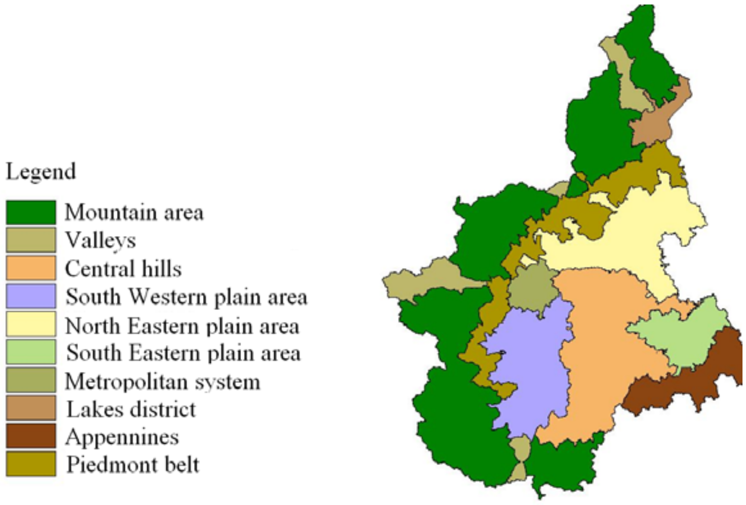
[2] The set of Technical Regional maps, at a scale 1:10000.

[3] The density index of power lines was defined as the dimensionless ratio between the corridor area and the municipal area.

Figure1. Map of sample strata



2.1. The survey dataset

We contacted approximately 5000 households by sending them a presentation letter on University of Turin headed paper, announcing them that they had been selected for participation in a survey promoted by the Piedmont Region, and that they would have been subsequently interviewed by telephone. We collected a total of 1459 complete interviews. People stating a zero WTP were asked to explain the reason: through their answers we distinguished and excluded protest responses (more likely associated with the denial of the valuation scenario or with a protest strategic behaviour) from the 'true' zeros. The final dataset consists of 1194 valid observations, divided into subsamples for three discretely different levels of damage (see §2.3).

Table 2. Descriptive statistics

Variable name	Mean	St./Dev.	Variable Description	Type
Vector 2	9.1%	-	Cases in the intermediate damage subsample	Dummy
Environmental	6.0%	-	Environmental externalities ranked as most relevant	Dummy
Health	52.6%	-	Human health externalities ranked as most relevant	Dummy
Visual	22.3%	-	Dummy for landscape and visual encumbrance ranked as most relevant	Dummy
Income:	€ 22,799.91	€ 17,441	Yearly income	Count
Children	28.5%	-	Presence of children (younger than 14)	Dummy
Age	52.8	15.864	Age	Count
Gender:		-		
Women	64.1%	-	Female	Dummy
Men	35.9%	-		
Family size	2,936	1.119	Number household components	Count
Years edu	9.87	4.305	Number of years of education	Count
Education	46.7%		High school or higher degree	Dummy
Proximity	7.62E-05	1.32E-05	Inverse of the square distance to the HVTL	Cardinal
in meters	324.57	220.241	Euclidean distance to the infrastructure	Cardinal
Line Density	0.392	0.194	Ratio between infrastructure length and area of the NUTS4 unit	Cardinal
LogRail	7.398	7.600	Distance from the next railway (logged)	Cardinal
in meters	3,000.80	3141.424	Distance from the next railway	Cardinal
LogRoads	6.999	7.090	Distance from the next highroad (logged)	Cardinal
in meters	2,150.045	2,494.487	Distance from the next highroad	Cardinal
Protection	72.6%	-	Presence of local environmental ties	Dummy

Table 2 reports descriptive statistics for the respondents' characteristics. The average age of respondents is 52 years. Women represent 64% of the sample. The mean of years of schooling is 9.87 and 46.7% of the respondents has a high school or more advanced degree. Families are on average composed by 2,936 people and children are present in 28.5% of them. The average household income is € 22,800 per year. The local context variables give us indications on the spatial context the respondents live in: their houses are on average at a distance of 324 meters from the power lines and at 3 km and 2.1 km respectively from rails and highways. The percentage of municipalities' areas covered by the HVTLs corridors is on average 39.2%, and in 72% of the cities in which the interviews were collected there is at least one area protected by law for its environmental or cultural relevance.

2.2. The CV scenario

The contingent valuation approach, as other stated-preference valuation methods, employs a simulated environmental change to estimate welfare impacts. In the dichotomous choice format, the elicitation of WTPs is based on the (stated) acceptance or rejection of a bid to access this hypothetical scenario.

The scenario proposed in the survey uses a referendum format: it envisages a regional program for the modernization and rationalization of the power lines network, involving the removal of some portions of the infrastructure. Carrying out this program requires a contribution by citizens, presented in the form of the payment of a *lump-sum* tax. The hypothetical market thus assumes the form of a local political market:

"…Suppose that your municipality, in order to decide whether to demolish a 5 Km portion of HVTL, is asking the opinion of citizens through a referendum. If you vote NO, the portion of power line will not be removed. If you vote YES, the line will be removed, but all the citizens will have to contribute the payment of a lump-sum tax. If the amount of the tax were X Euro, would you vote Yes or No?"

The length of the portion to be removed, 5 km, reflects the scale of the decision (set at the municipal level), and corresponds to the mean value of the length of HVTLs crossing municipalities in the region. Households were asked to reveal the damage they perceive due to the HVTL in their own specific context: the valuation is not referred to an abstract and standardized scenario, but to the real environment in which the respondent-infrastructure interaction takes place. Being the respondents well endowed in terms of first-hand information on the scenario, the implementation of visual and other informative supports useless, if not during the interview was assumed to be counterproductive.[4]

The estimated willingness to pay aims at reflecting the perceived value of the overall impact deriving from all relevant externalities connected with the presence of HVTLs. To this purpose, a section of the questionnaire is dedicated to acquiring an individual description of the components of damage (e.g. perception of risk for human health, visual encumbrance, other external effects for landowners) and their ranking.

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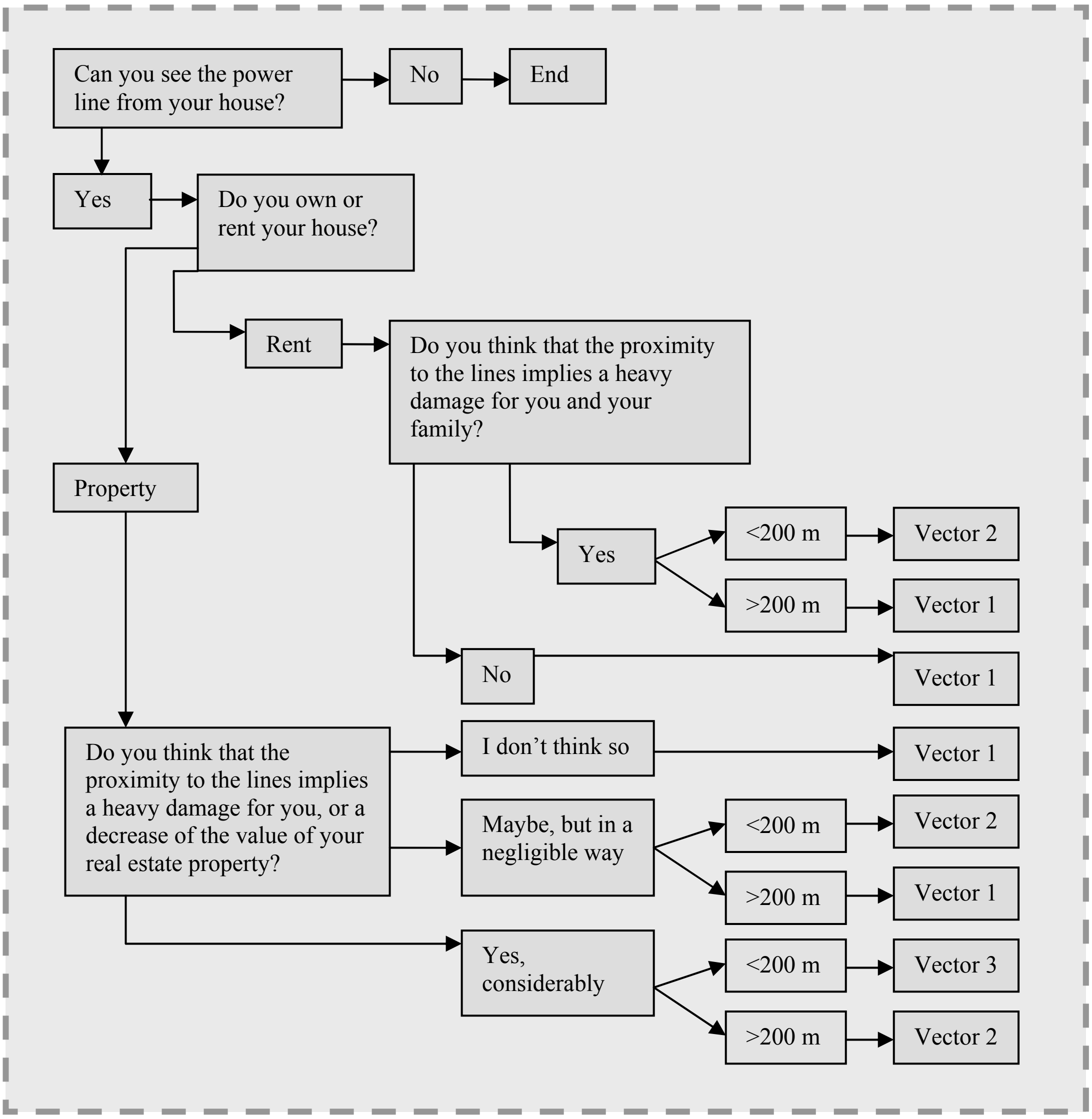
[4] In the contingent valuation literature there is evidence that the effect of providing informational supports on WTP values depends on the level of prior information (Tkac, 1998), improving the study design only if the information given is truly new for the respondent (Hoehn and Randall, 2002) and the level of involvement in the good being evaluated is low (Ajzen *et al.*, 1996).

Figure 2. Price vectors auto-selection criterion



2.3 Pre-test and different typologies of damage

The bid vectors were defined through a process involving an exploratory pre-test. *Open-ended* elicitation questions were employed in the pre-test on a sample of 100 respondents, in order to obtain preliminary indications on the maximum WTP values. Most respondents living in close proximity to the lines indicated WTP values between 10,000 and 20,000 €, explained by negative impacts of the infrastructure on real estate property values. All other respondents, who mainly reported forms of nuisance linked to visual encumbrance or perceived environmental damage, expressed a much lower WTP. This information led us to infer that these different forms of impact arising at different distances from the lines were so qualitatively dissimilar as to require a separate treatment. We therefore predisposed three separate vectors of bid values. The first part of the questionnaire contains a few questions aimed at providing information on the type of individually perceived damage in order to assign the appropriate bid vector to the respondent. Typology and intensity of the perceived impacts, proximity to the lines, and depreciation of the house are used as assignment criteria (the flowchart in Figure 2 illustrates the algorithm for the selection of the bid vector). In this way, the respondent herself selects the bid vector. Vector 1 is associated with a diffused and ordinary perception of damage. The others two vectors are used in case of intermediate (vector 2) and heavy damage (vector 3), linked to the presence of real estate depreciations and/or the perception on the part of the respondent of a serious burden imposed by the infrastructure.

3. The model

Our elicitation question has a dichotomous choice format. Respondents who vote 'yes' at the simulated referendum are asked a follow-up question, with a second bid value increased by 50%. Respondents voting 'no' at the first request are proposed to answer again the same question with a lower bid value, reduced by 50%. Each respondent is first assigned one of the bid vectors (depending on her answers to the introductory part of the questionnaire). Within such vector, the bid chosen as the initial value is systematically varied across respondents. The assignment of the initial bid value depends on the answers given by respondents to the questions related to intensity and type of perceived damage in the introductory part of the questionnaire (Figure 1). The assumption that the two bid questions share the same latent distribution of individual willingness to pay allows us to define interval data coded by sequenced responses (Yes-Yes, Yes-No, No-Yes, No-No). This format draws on the seminal work by Bishop and Heberlein (1979), extended by Hanemann (1984), who proposed the *single bounded* model as theoretically consistent with the random utility framework. The *double bounded* model, based on the implementation of the follow-up question, was subsequently introduced (Hanemann *et al.,* 1991) as a way to improve the process. The *double bounded* format has been demonstrated to be more efficient in capturing and using information (Scarpa and Bateman, 2000) without imposing an excessive cognitive burden on the respondent, and complies with the recommendations of the NOAA panel (Arrow *et al.*, 1993).

We define the indirect utility $V(y,q)$ as the maximum utility attainable by the interviewed given income *m* and environmental quality *q*. The WTP in order to get quality q_0 when facing quality q_1 is implicitly defined by the condition

$$V(y-WTP,q_1)=V(y,q_0).$$

The willingness to pay, in this framework, measures the compensative surplus – the amount of income that the respondents would be willing to pay in order to obtain the environmental change proposed by the hypothetical scenario, keeping their initial level of welfare unchanged.

If the individual is offered to pay a sum (a bid) B in order to replace q_1 with q_0, she will accept the bid if $B \le WTP$.

The WTP is specified as:

$$WTP = \beta' z + \varepsilon$$

where *z* is a vector of variables measuring individual and environmental characteristics, β is a vector of parameters to be estimated as the maximum and ε is a random variable with logistic distribution, with mean zero and variance σ^2, accounting for unobserved variables. The probability that a bid B is accepted is therefore

$$\text{Prob}\left(WTP \ge B\right) = 1 - F\left(\frac{\beta' z - B}{\sigma}\right),$$

where F is the standardized distribution. In the double bounded format, we add a follow-up question, assuming that the nuisance component shares the same distribution for the two questions. We can express the acceptance or refusal probabilities when two bids are submitted. If for example B_1 is accepted but B_2 refused (with $B_2 > B_1$), the probability is:

$$P^{yn} = \text{Prob}\,(B_1 \leq WTP \leq B_2) = F\left(\frac{\beta' z - B_2}{\sigma}\right) - F\left(\frac{\beta' z - B_1}{\sigma}\right).$$

If B_1 is refused and B_2 accepted (in this case $B_1 > B_2$), the probability is

$$P^{ny} = \text{Prob}\,(B_1 \leq WTP \leq B_2) = F\left(\frac{\beta' z - B_1}{\sigma}\right) - F\left(\frac{\beta' z - B_2}{\sigma}\right).$$

If both are accepted (with $B_2 > B_1$), the probability is

$$P^{yy} = \text{Prob}\,(WTP > B_2) = 1 - F\left(\frac{\beta' z - B_2}{\sigma}\right),$$

and if both are refused (with $B_2 < B_1$)

$$P^{nn} = \text{Prob}\,(WTP > B_2) = F\left(\frac{\beta' z - B_2}{\sigma}\right).$$

In the likelihood function employed to estimate the parameters of the WTP function, dummy indicators are included to index the four possible combinations of answers. Given our assumptions, the log likelihood function of the sample is:

$$Ln(\theta) = \sum_{i=1}^{N} \left\{ d_i^{yy} \ln P^{yy} + d_i^{yn} \ln P^{yn} + d_i^{ny} \ln P^{ny} + d_i^{nn} \ln P^{nn} \right\}$$

with d_i^{yy}, d_i^{yn}, d_i^{ny}, d_i^{nn} being the dummies for each combination of responses.

Table 3 shows the frequencies of each combination of answers to the initial and the follow-up bid questions. As in many contingent valuation exercises, the majority of the sample gave a 'Yes-Yes' or 'No-No' answer (30.52% and 36.7% of the interviews respectively), while fewer respondents answered 'Yes-No' and 'No-Yes' (respectively 21.4% and 11.4%).

Table 3. Number of observations for each combination of answers

	Ordinary damage	**Intermediate damage**	**Heavy damage**
Yes-Yes	311	33	30
Yes-No	218	31	12
No-Yes	116	14	12
No-No	374	20	23
Number of cases	1019	98	77

3.2. Basic models

The three basic models, for ordinary, intermediate and heavy damage, include the bid amounts and a constant. In Table 4 we present unconditional estimates of mean WTP based on the double-bounded solution proposed by Hanemann et al. (1991). Because WTP estimates are to be considered as nonlinear functions of parameters, we employ a Krinsky-Robb procedure to obtain the confidence intervals for WTP estimates for the three levels of impact (Krinsky and Robb, 1986; Park *et al.*, 1991).

3.3. Extended model

As evidenced by the pre-test, a few households denounce a severe depreciation of their property as a consequence of an extreme proximity to the infrastructure, a damage that is of a different nature with respect to the one suffered by the large majority of other interviewed households. We therefore further investigate the latter separately. This is done through an extended model, for whose estimation we use only the 1116 observations obtained with the ordinary and the intermediate damage vectors, merged together (although a dummy variable allows us to identify the two kinds of respondents). Starting from the basic model we insert sequentially three groups of variables (*perception variables*, *socio-demographic variables* and *local context variables*) selected from the information collected with the survey and with the data geo-referentiation. The *perception variables* group identifies the type of impact ranked as most important by the respondent, among a set composed by environmental, human health risk, and visual impacts. Three dummy variables have been coded to disentangle the effects of these impact typologies on responses.

Socio-demographic variables include the annual gross income of the household, a dummy that identifies a high education level (high school or a more advanced degree), and an indicator for the presence of children in the family.

Local context variables explain responses heterogeneity through the features of the valuation context. In particular:

- the distance between the nearest power line and the house of the respondent. The variable is built as the inverse of the square distance, in order to model the fact that the perception of damage decreases rapidly with increasing distance from HVTLs;
- the density of power lines that crosses the municipality area, a continuous variable equal to the ratio between the area enclosed by the HVTLs corridor and the total municipal area;
- the proximity of the house to other linear infrastructures, in particular roads and railways. These variables are expressed as the natural logarithm of the Euclidian distances;
- the presence of protected areas, classified as valuable areas through legislative acts or ties: SIC, SIR, ZPS[5], parks, tie 1497/39 – a geo-referenced indicator used to investigate the interaction between environmental and landscape quality and the perception of damages from HVTLs. The variable included in the model is a dummy for the presence of at least one tie in the municipality of respondent.

4. Results

From the three basic models, estimating unconditional mean values of willingness to pay, it emerges that the households subject to what we called 'ordinary' impacts from the HVTL (landscape degradation, visual encumbrance) have a mean WTP of € 189 for getting rid of the prospected 5 km of lines in their proximity. The estimated WTP for respondents subject to an intermediate level of impact (a varying mix of visual encumbrance, perceived health risks, perceived environmental and ecological risks) is of € 576. Markedly higher, € 3753, is the WTP of the subsample suffering depreciation of real estate ownerships as a consequence of the extreme proximity to the power lines.

The interval of the WTPs is € 178-200 in the case of ordinary damage, € 512-626 for intermediate damage, and € 2,758-4,748 for heavy damage.

The estimates of mean and confidence intervals of willingness to pay obtained with the basic models for the three levels of damage are reported in Table 4. Table 5 reports the estimates of the complete and of the reduced models**.**

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[5] SIC areas are defined, in the Italian law, as sites of communitarian interest, SIR as sites of regional interest, and ZPS are special protection sites. The Law N.1497 of 1939 establishes the nature of the constraints applying to activities in those areas, and still is the main legislation targeted to protect landscape amenities.

Table 4. The basic models

	Coefficient	**Standard Error**	**Asy-t.**	**P [| Z | > z]**	**E(WTP) (Dev.St.)**
Ordinary damage					
Constant	1.026	0.075	13.644	0.000	**€ 189**[6]
Bid	- 0.005	0.000	- 21.556	0.000	(€11)
Intermediate damage					
Constant	1.997	0.287	6.943	0.000	**€569**
Bid	- 0.003	0.000	- 8.048	0.000	(€57)
Heavy damage					
Constant	0.849	0.238	3.564	0.000	**€3.753**
Bid	-0.000	0.403D-04	- 5.604	0.000	(€995)

Table 5. The extended model

	Model 1	**Model 2**	**Model 3**	**Model 4**
Variables	**Coeff.** [Asy-t.]	**Coeff.** [Asy-t.]	**Coeff.** [Asy-t.]	**Coeff.** [Asy-t.]
Constant	0.953 [3.279]**	0.067 [0.466]	-0.615 [-3.697]***	-1.078 [-2.160]**
Bid	-0.005 [-22.966]***	-0.005 -23.01***	-0.005 [- 23.11]***	-0.005 [-23.15]***
Vector 2	1.826 [8.235]***	1.877 [7.513]***	1.756 [7.707]***	1.773 [7.705]***
Environmental	-	0.718 [2.670]***	0.515 [1.851]**	0.568 [2.029]**
Health	-	1.220 [7.477]***	1.034 [6.140]***	1.059 [6.207]***
Visual	-	0.962 [5.229]***	0.644 [3.380]***	0.672 [3.487]***
Income	-	-	0.025 [6.472]***	0.024 [6.147]***
Children	-	-	0.319 [2.405]**	0.343 [2.553]**
Education	-	-	0.603 [4.890]***	0.6104 [4.904]***
Proximity	-	-	-	0.901 [2.029]***
Line Density	-	-	-	0.862 [2.782]***
LogRail	-	-	-	0.086 [1.766]*
LogRoads	-	-	-	-0.103 [-2.126]**
Protection	-	-	-	0.213 [1.607]
Sample size	1116	1116	1116	1116
Log-likelihood	1539.943	1509.912	1455.252	1441.637
Goodness of fit				
LR Test				
Model 4 vs. Model 1	196.614***			
Model 4 vs. Model 2		136.552***		
Model 4 vs. Model 3			27.235***	

,,*** Coefficients different from zero with an error probability of 10%, 5%, .1%*

The insertion in the model of the perception variables, identifying the type of impact considered as prevalent by the respondent between environmental impact, human health risk, and impact on the landscape, allows us to recognise the relative weight of the different motives of public aversion to power lines. The component of damage about which the

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[6] The WTPs are per household.

respondents turn out to be most concerned is 'human health risks' (54.5%). For 21.6% of the respondents the visual impacts on landscape quality are the most relevant, whereas only 6% considers ecosystem impact as the most serious form of damage. A 17% of the sample declares not to suffer any damage from the infrastructure. The three dummy variables identifying the perception, socio-demographic and local context variables are highly significant. Households for whom the mostly severely perceived impacts are health risks are willing to pay, *ceteris paribus*, € 188 more than people associating no impacts to the presence of the power line (conditional WTPs assessed at the mean value of the other covariates). The respondents signalling the impacts on landscape as the most relevant show an increase in WTP of € 119, while € 101 is the marginal WTP of individuals declaring to be mainly worried about the impacts on ecosystems.

Among socio-demographic variables, the variable 'income' is, as expected, statistically significant and with a positive coefficient. Households declaring an annual gross income of € 7500 are willing to pay € 35. WTPs grow linearly with income: 130€ for a family income of € 30,000, € 305 for an income of € 70,000, up to € 436 for families with an income higher than € 100,000 per year.

A high level of education also has a positive and statistically significant coefficient: Respondents with an high education degree are willing to pay, *ceteris paribus*, € 108 more. Furthermore, the presence of children in the family implies higher WTP: people appear to be more willing to pay in order to protect their children from the potential health risks. Parents of either gender are willing to pay more (around € 60 more) than their childless counterparts, a result in accordance with both the economic literature concerning the valuation of environmental improvements (Dupont, 2004), and studies on environmental attitudes in sociology and psychology (Bord and O'Connor, 1997; Stern *et al.*, 1993).

Spatial proximity variables (to HVTL, roads, railways or other infrastructures), based on transformations of distance measures, are implemented in the model in the form of spatial weights.[7] An important issue in using LCVs linked to spatial data stems from the absence of a consolidate and standardized methodology for their coding. In the words of Bavaud (1998: p. 1):

> [...] for there is no such thing as "true", "universal" spatial weights, optimal in all situations: good candidates must reflect the properties of the particular phenomenon, properties which are bound to differ from field to field. On the other hand, this difficulty should not impede a more systematic investigation of models for spatial weights, starting with the question 'which classes of models yield specified families of spatial weights, and what are the properties of the latter?

The proximity to the power line is coded by a distance decay transformation, using a positive, decreasing function of the square of the Euclidean distance (1/*distance*^2). The variable presents a positive coefficient (0.9010) and a high statistical significance (P value 0.0089). The perception of damage decreases rapidly with increasing distance from HVTLs (Figure 3): the WTP is € 711 higher for respondents living at 15 meters from the line, € 400 at 20 meters, € 100 at 40 meters, € 45 at 60 meters, and less than € 10 at 120 meters from the line. The WTP tends to vanish for the households living on the border of our corridor (600 meters distance from the power lines).

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[7] We are using spatial weights in order to code single characteristics of the households' locations, rather than to deal with spatial autocorrelation or spatial dependence as in the case of SAR or spatial lag models (Anselin, 1988).

These results contribute to the as yet inconclusive evidence on the dimension of the externalities imposed by HVTLs and on the shape of the relationship between perceived damage and distance from the infrastructure emerging from the literature. Kroll and Priestley (1992) in their survey assert that on average the existing valuation studies do not find a significant decrease in property values linked to the presence of HTVLs. In a few CV studies (e.g. Rosato *et al.,* 2004) the distance from the power lines does not appear to influence the willingness to pay. Other researches find a linkage between the intensity of the damage and the distance from the lines: according to Colwell and Foley (1979), for instance, there is a depreciation effect for houses within 60 meters from the power line, particularly significant for those situated within 15 meters. A group of applications of the hedonic pricing method identify distance as a relevant explanatory variable, and offer mixed evidence of a linear relationship between proximity and depreciation (Colwell, 1990; Delaney and Timmons, 1992; Hamilton Schwann, 1995; Boyer, 1978). In Sims and Dent (2005) the negative impacts diminish gradually and disappear for houses situated at 250 meters, whereas living within 100 meters from HVTLs causes a decrease in the property value between 6% and 17% with respect to a property with the same features situated far from the line. Overall the estimated depreciation varies sensibly: it can generally be included between 2% and 10% (Hamilton and Schwann, 1995), although it can reach values between 16% and 29% for houses near the towers (Boyer, 1978; Bond and Hopkins, 2000; Des Rosiers, 2002).

Our study, based on a large sample of households directly affected by the externalities to be evaluated, tells that the impacts of high voltage power lines are perceived as significant by people living in the affected corridors, and appear to depend on the distance. Table 6 reports the frequency of respondents reporting no impact *versus* distance between dwelling and HVTL. The proximity variable (based on the inverse-squared distance) in our model points out that the impact of the infrastructure follows a nonlinear path, offering support to the idea of Sims and Dent (2005) that, after a certain distance, the overall perception of the lines vanishes and the infrastructure becomes part of the landscape. WTP values conditional on distance from HVTLs rapidly shrink in the range of the first 50-60 meters, and then asymptotically converge to zero. The issue of the proximity of the infrastructure has relevant implications. From the operational point of view, the possibility of estimating WTPs conditional on distance offers a valuable informational support for the design of compensation policies (a first, straightforward indication being that compensation policies ought to acknowledge the distinct situations of a first 0-60 meters corridor and of a second, 60-600 meters corridor).

Table 6. Frequency of respondents reporting no impact vs. distance from dwelling (measured by GIS)

Distance	**Frequency**
0-50 meters	15 (6.9%)
50-200 meters	69 (31.8%)
200-1000 meters	132(60.8%)

As to the other local context variables, a higher density of power lines in proximity of the respondents' houses induces, *ceteris paribus*, a higher willingness to pay to get rid of the proposed portion of infrastructure; the variable is statistically significant (0.0054) and presents a positive coefficient (0.8624). The WTP increases of € 15 if 10% of the municipal territory is occupied by power line corridors, of € 45 if the corridors occupy 30% of the municipal area, € 76 if the corridors occupy 70% of the territory, up to € 150 when the entire municipal area is interested by the presence of the power line. The density of power lines imposes an increasing marginal damage.

Among the other infrastructures in the immediacy of the respondents' premises (highways, railways, roads, airports and brownfields), only the variables referred to roads and railways, constructed as the log-natural of the Euclidean distance from the houses, are statistically significant. The influence of the simultaneous presence of other infrastructures on the WTPs to remove the power line is not univocally explained by our model. The coefficients do not all have the same sign: positive for railways and highways, negative for roads. On the one hand, the positive sign of the railways and highways coefficient is interpretable as a substitution effect: externalities associated with the presence of a railway or highway in proximity of the house are likely to outweigh those associated with HVTLs, thus reducing the relative perception of the negative impacts from the latter. On the other hand, the negative sign of the roads coefficient could be thought of as signalling a complementarity effect by which the respondents increase their WTP to remove the HVTLs in order to eliminate at least one of two comparable sources of externalities affecting their houses. In general the difficulty in identifying a univocal interpretation could derive from the fact that aspects not observable through a distance measure contribute to the formation of perceptions. The house orientation with respect to the infrastructure, for example, may be a relevant element in determining the perception of impact, and the number of observations, in our sample, relative to houses simultaneously exposed to multiple infrastructures may not be sufficiently high to average out this effect. The tested models synthesise and stylize phenomena so as to bring them to levels of complexity treatable through statistical inference. Our estimates should be meant as the most plausible configuration of the perceived damage under ordinary conditions. Interaction effects between multiple infrastructures generate complex situations that require *ad hoc* investigations.

The presence of protection programmes and ties in the municipality of the respondent, used as a proxy of high environmental and landscape quality, is significant at the 90% level and presents a positive coefficient (0.21). The damage caused by HVTLs appears to induce WTPs € 38 higher in municipalities with environmental ties and protected areas, which we may reasonably think of as those recognised of high environmental and landscape value.

4.1 Goodness of fit

In order to combine statistical and descriptive ways of comparing the basic model with the models with an incremental number of covariates we employ the 'sequential classification procedure', an extension of the standard classification approach used to calculate the percentage of fully, correctly, classified cases (FCCC) (Kanninen and Khawaja, 1995).[8]

In addition, a sequence of likelihood ratio (LR) tests are applied in order to check whether adding to the base model each group of variables significantly improves the likelihood maximization process. Results of the LR tests (Table 5) confirm the validity of the introduction of the LCV in the model, rejecting the null hypothesis with a probability above 99%. The Kanninen and Khawaja's procedure confirms the results of LR tests (Table 7), showing an increase in the explanatory power of the model with LCV.

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[8] Alternative methods, based on statistical structural tests, have been proposed to assess the goodness of fit of double bounded logit models (Herriges, 1999; Harpman and Welsh, 1999). Kanninen and Khawaja's procedure in our view is the one offering the most straightforward representation of the level of explanatory power of models, even if by a descriptive approach.

Table 7. The 'sequential classification procedure'

	ICCY	ICCN	ICCT	ICCC	FCCY	FCCN	FCCT	FCCC
Model 1	353	315	668	**59.80%**	226	235	461	**41.27%**
Model 2 [a]	341	369	710	**63.56%**	212	289	501	**44.85%**
Model 3 [b]	380	362	742	**66.42%**	240	278	518	**46.37%**
Model 4[c]	382	373	755	**67.59%**	247	285	532	**47.62%**

a Basic model + perception variables

b Basic model +perception variables +socio-demographic variables

c Basic model + perception variables + socio-demographic variables + Local Context Variables

5. Conclusions

We have developed an analytical model and a methodological approach for a comprehensive monetary valuation of the externalities imposed by high voltage transmission lines. Our exercise offers decision makers both ready-made estimates conveying indications for location choices and compensation policies, and a replicable example of a methodology for the evaluation of policy alternatives. Our results can be summarised as follows.

The perceived external costs of infrastructures such as high voltage power lines critically depend, in a nonlinear way, on the distance between residential houses and the infrastructures themselves. Pooling together, in valuation surveys, respondents subject only to the impact on landscape with respondents perceiving human health risks and with respondents whose real estate property has suffered a severe depreciation as a consequence of the infrastructure produces misleading results: WTPs that differ an order of magnitude would be averaged in a measure that no longer conveys much in terms of operational indications.

People are the more discontent not only the closer the power lines have been built to their homes, but also the more they are concerned about magnetic field related health risks and the more educated they are. The presence of children in the household also increases individual willingness to pay.

Finally, the interactions between people and the infrastructures existing on a given territory are defined in a spatial and geographical context, so that spatial features (landscape shape and value, prevailing land uses, presence of other infrastructures and so on) may be a relevant source of heterogeneity in public preferences, especially when linear infrastructures run across wide areas and differentiated environmental and landscape structures.

These are some of the aspects that contribute to explain the social costs of important infrastructures that are typically not addressed in existing approaches for the estimation of the WTP for reducing externalities, causing these approaches to yield biased estimates. Herein we present a new approach that merges contingent valuation with a GIS spatial analysis. Our results show that geo-referenced CV survey data allow the analyst to provide a more comprehensive valuation of the various forms of external costs involved. This in turn may become a useful support for decision-makers facing questions relative to planning and choosing the location of infrastructure networks, or negotiating compensative measures. Particularly when the construction of new facilities encounters opposition by the population, more accurate measures of WTPs may prove valuable instruments for more articulate procedures of conflict management.

A spatial approach to environmental valuation draws attention to the general problem of choosing the "right" scale for statistical inference. It also raises the issue of the correspondence between the spatial viewpoint of the valuation exercise and the scale of the policies that will be informed by its results. If WTP estimates are required, say, to internalise the social cost of infrastructures in a regional level cost-benefit analysis, the valuation study should be designed accordingly: WTPs estimated, say, on a municipal level sample would adopt the viewpoint of one part to inform policies impacting on the whole region. Conversely, a mean value of WTP calculated with a standard indirect utility function (omitting socio-demographic and context variables), and hence distant from the situation of specific households, would be a biased reference point for calculating compensative measures.

Taking this point of view also re-opens room for studying the econometric models for the analysis of Contingent Valuation data best suited to deal with the problem of the distribution of impacts in a spatial framework.

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