Exploring the accuracy of road-noise benefits transfer

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Background

- W/o market failures no need for intervention - individuals' decision would maximize social welfare
- Noise is an environmental pollutant which, e.g., causes disturbance and has negative health effects
  - More than 20% of the population within the EU being exposed to higher noise levels than are deemed acceptable (EC, 1996)
  - A main polluter is the transport sector where road traffic is the main contributor
  - Pollution is expected to increase due to urbanization and increased traffic volumes
  - Obvious market failure – Externality
- To address problem:
  - Legislation, physical investments, etc. ⇒ Benefit-cost analysis (BCA)
  - Pricing based on the short-run marginal cost principle (Andersson and Ögren, JTEP, 2013)

Preference elicitation

- No easily available market prices for noise abatement ⇒ non-market valuation techniques need to be used to estimate benefit measures
  - Stated preferences (SP): Hypothetical market is created in which respondents are asked to state their preferences
    - Contingent valuation, Choice experiments, etc.
    - Flexible
    - Framing effects, strategic and hypothetical bias, etc.
  - Revealed preferences (RP): Observed market decisions are used to elicit individual preferences
    - Hedonic pricing (HP), Travel cost method, etc.
    - Actual decisions
    - Assumes that analyst is informed about individuals' decision alternatives

Original WTP values not available?

- Often original willingness to pay (WTP) values, i.e. values for a specific good and population, are not available
- Instead we have to rely on benefits transfers
- Benefits transfer (BT): The use of values borrowed from study cites (cases) at policy sites (cases).
  - Policy site (case): Where values are to be transferred
  - Study site (case): Where original data were collected
- "Benefit transfer is one of the most common methods for conducting [BCA] at the [US EPA]." (Kaul et al., JEEM, 2013)
  - BT also used for transport noise in Sweden (ASEK)

Objectives

The objectives of the study are to:

1. Estimate marginal WTP for road noise using the hedonic regression technique
2. Examining how stable estimates are between regions, i.e. exploring the accuracy of the use of benefits transfers
3. (To be extended with analysis for railway noise)

Benefits transfers (BT)

- Advantages:
  - If BT valid, no need for original studies
  - "Quick": Values already available
  - "Cheap": No need to conduct a new (and often costly) valuation study (RP or SP)
  - $\Rightarrow$ cost-effective
  - If original studies not possible, BT might be the answer
- Weaknesses:
  - Values are used for other settings than where they were derived
  - May introduce further inaccuracy
    - Potential inaccuracy in elicited values from RP and SP studies may be increased by inaccuracy in BT
  - Empirical findings suggest transfer errors are "almost inevitable"
- Crucial stage: When estimates/models are selected and the effects at the policy site are determined

Naïve (unadjusted) WTP transfer

- Estimate from study cite (S) used unadjusted for policy site (P):

$$\text{WTP}_S = \text{WTP}_P$$

- Typically the mean or median
- The virtue is the "simplicity and ease"
- Fails to capture important differences between S and P
  - Socio-economic and demographic characteristics
  - Physical characteristics of site
  - Proposed change in provision of good
  - Difference in the "market" conditions
  - Temporal changes (changes in valuation over time)

WTP transfer with adjustment

- WTP_S adjusted to take into account differences between S and P
- Assuming income is an (the most) important factor that influences WTP, a widely used formula is:

$$\text{WTP}_P = \text{WTP}_S \left(\frac{Y_P}{Y_S} \right)^e$$

where Y_i is income and e is the income elasticity of WTP

- We assume that $e = 1$ (Nellthorp et al., TR, 2007) $\Rightarrow$

$$\text{WTP}_P = \text{WTP}_S \left(\frac{Y_P}{Y_S} \right)$$

WTP function transfer

- The WTP function transfer (BTF) can be seen as an extension of the adjustment approach: Multiple adjustments
- Assume linear function:

$$\widehat{\text{WTP}}_P = f(\beta_s, X_P) = \beta_{0S} + \beta_{1S}X_{1P} + \beta_{2S}X_{2P} + \ldots + \beta_{nS}X_{nP}$$

- Hypothesis is that explanatory variables are of the same categories in the two sites
- (Related: *Meta-analysis*, regression analysis is used to examine how values obtained in different studies may have been affected by different characteristics (population, elicitation method, etc).)

Transfer error

- The standard measure of the error of BT, Transfer error (TE):

$$\text{TE} = \frac{\text{transferred estimate} - \text{own-study estimate}}{\text{own-study estimate}} \times 100$$

- For instance, let transferred and own-study estimate equal 1,430 and 1,300, respectively, then

$$\text{TE} = \frac{\text{1,430-1,300}}{\text{1,300}} \times 100 = \frac{1.1x - x}{x} \times 100 = 10$$

"Review of BT and TER"

Kaul et al. (JEEM, 2013):

- Results are mixed but suggest that BFT overall performs best
  - Median TE 39 and 33 w/ and w/o outliers (mean 172 and 42 w/ and w/o outliers)
  - Study type influences TE
    - Contingent valuation generates lower TE than other methods (HP excluded from analysis due to only one study)
- Only one BT study based on HP found – Eshet et al. (ERE, 2004)
  - Waste transfer stations in Israel
  - Examines BFT approach
  - TE: $\approx 20 - 30\%$
- Franck et al. (JEEP, 2014): HP study based on two markets in Belgium $\rightarrow$ TE $\approx$ 10 % (Not in Kaul et al.)

Aircraft noise values – a meta-analysis

- Schipper et al. (JATM, 1998) conducted a meta-analysis to examine differences in estimates for aircraft noise
- They found that several factors can explain differences in estimates:
  - Time of original study
  - Population examined
  - Price level of property market
  - Functional form of the hedonic price function
- Conclusion: Findings problematic from a BT perspective

Setup this study

- Only one good (bad), i.e. road-noise
- Data from the same point in time
- Only data from Sweden, but several different local markets
- Only hedonic regression technique used
- Same functional form used in all markets
- $\Rightarrow$ "Study/design issues" should not influence TE, only "market differences"

Hedonic regression:

- Let **Z** be a good, and Q, **A** and **G** its attributes (where **A** and **G** are vectors), i.e.

$$\mathbf{Z} = [Q, \mathbf{A}, \mathbf{G}]$$

- The price of the good is a function of its attributes:

$$P = P(Q, \mathbf{A}, \mathbf{G})$$

- The implicit price of a single attribute is given by:

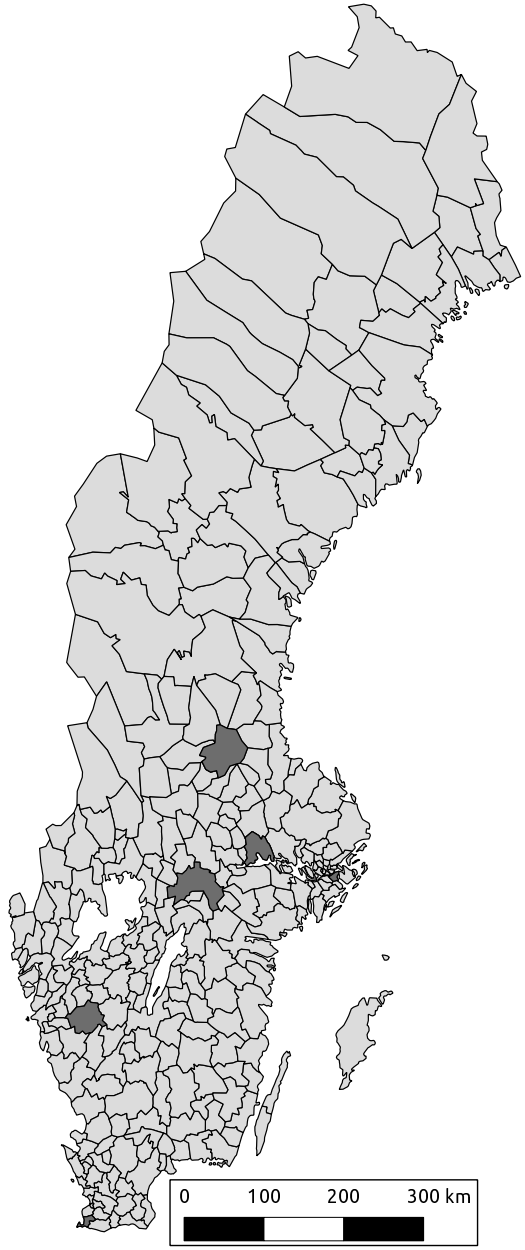
$$\pi = \frac{\partial P}{\partial Q}$$

- Eliciting the "true WTP" in HP studies itself a challenge. Here, however, it is assumed that the primary study at the policy site provides the "true value"
  - We are interested in the effect from transferring values from a study cite to the policy cite

Sources

- National land survey of Sweden
  - Sale prices of properties
  - Property attributes
  - Geographical coordinates
  - All sales 2002-2012
- Swedish Transport Administration: Traffic data
- Lantmäteriet: Map data

Selected areas



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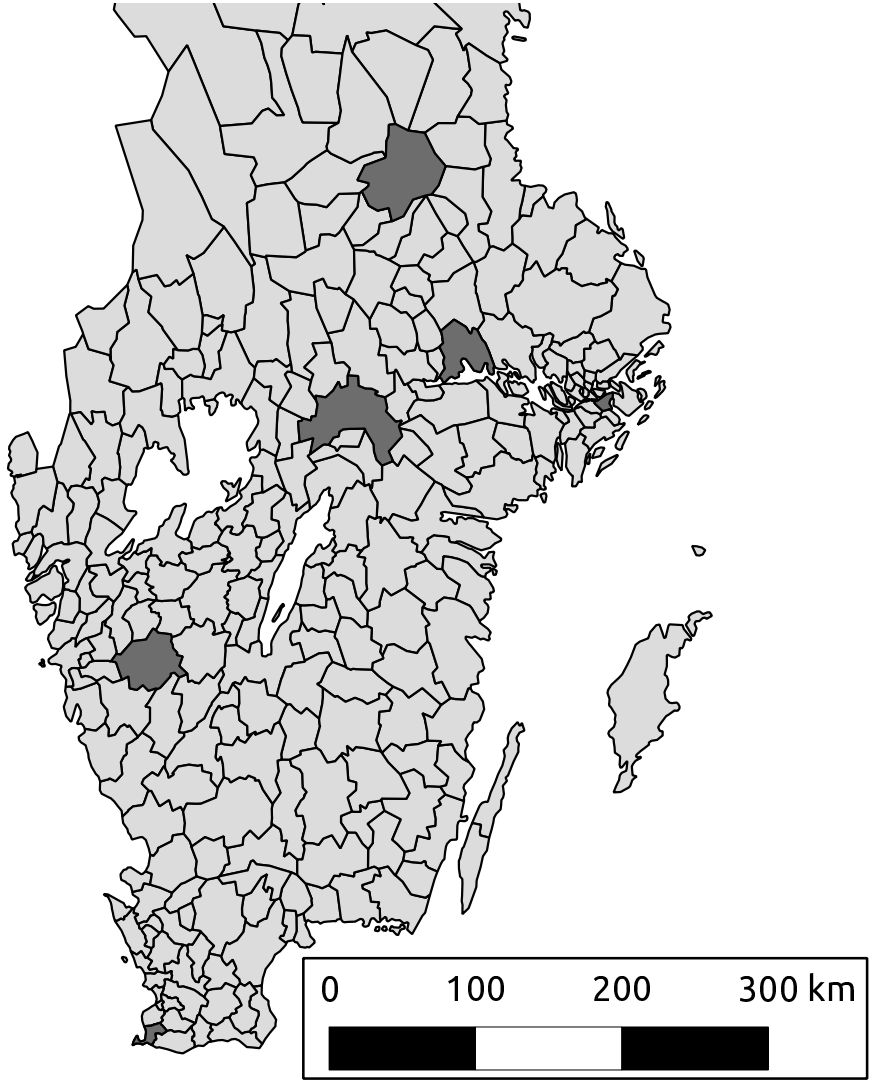


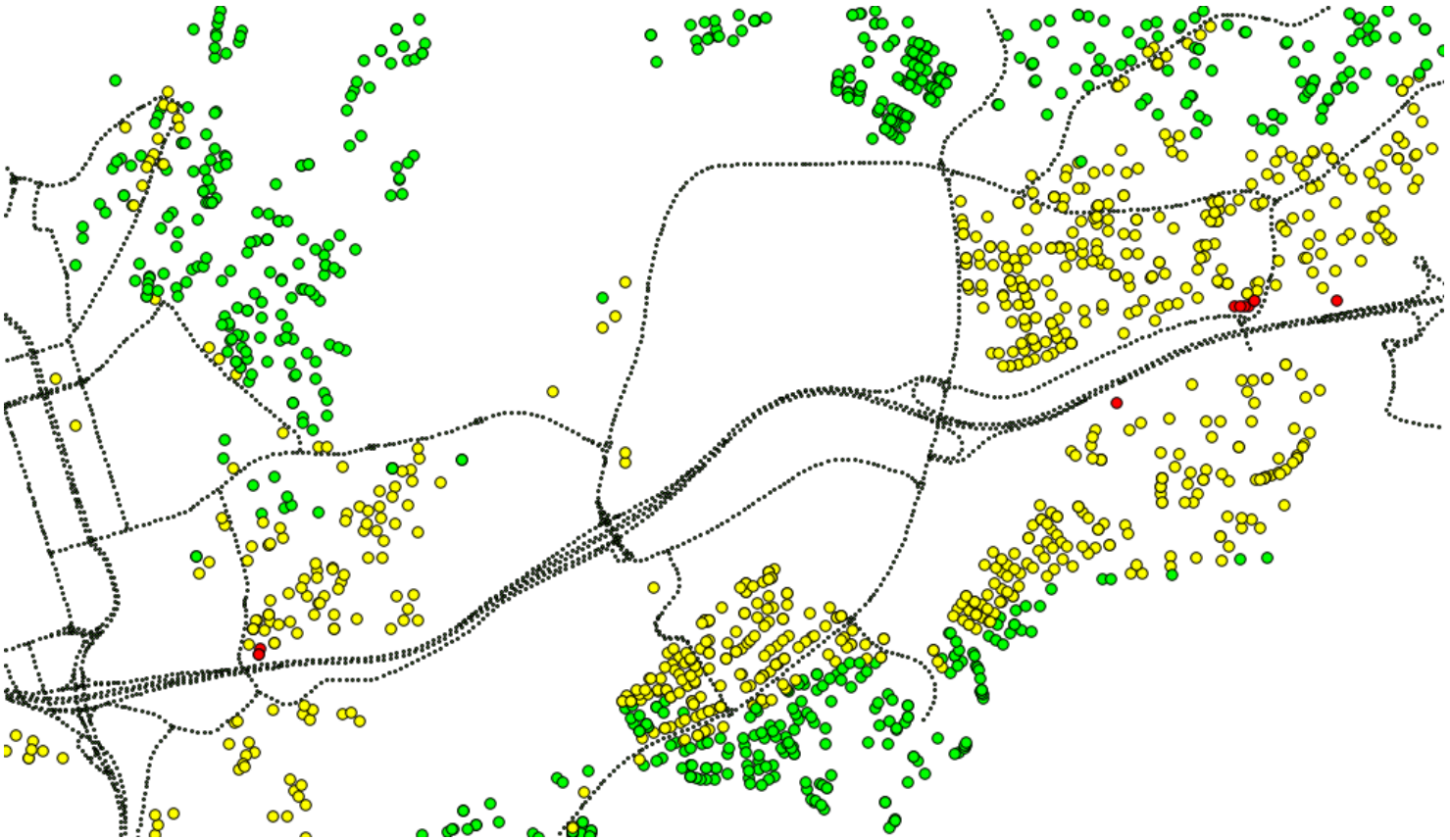
Selected areas: Comments

- Selected areas not chosen to examine BT per se
- Areas chosen based on:
  - Availability of significant road-noise emission source
  - Road-noise main traffic-noise sources
  - Sufficient number of property transactions to conduct HP study
  - Enough coverage of different regions to examine regional differences in WTP
- Last bullet:
  - Actual test of BT
  - As shown above, the requirement of enough number of transactions restricts the regions that can be examined

Explanatory variables

- Structural variables (property attributes):
  - Property area, living space, subsidiary space, and age
  - Quality index
  - House type: Detached (r.g.), Terraced, and Linked
- Geographical attributes:
  - 3 distance based variables – "Road", "Railway", "Dist. station"
  - Neighborhood information used as "fixed effect"
- Noise indicator: Road noise
  - 24 hour A-weighted equivalent sound pressure level ($L_{\mathrm{AEq,24h}}$)
  - Transformed to "Peace and quiet" ($Q = 75 - L_{\mathrm{AEq,24h}}$)

Example noise calculations – Borås



Green $<$ 45 dB, Yellow 45-60 dB, Red $>$ 60 dB

Hedonic regression:

- Dominating price function used in the literature is the semi-log, hence we use it for easy comparison
- Price equation:

$$\ln P_i = \beta_0 + \beta_1 Q_i + \sum_{n=1}^{N} \gamma_n f(a_{ni}) + \sum_{h=1}^{H} \lambda_h f(g_{hi}) + \varepsilon_i$$

- Implicit price of "peace and quiet":

$$\pi_i = \beta_1 \bar{P}$$

- Annualized implicit price:

$$\pi_i' = (0.0311 + 0.0075)\pi_i$$

  - (In regression annualized price used as dependent variable.)

Noise sensitivity depreciation index

- The noise sensitivity depreciation index often used as a measure of WTP to reduce noise exposure

$$\text{NSDI} = \left| \frac{\partial P}{\partial L} \frac{100}{P} \right|$$

- Since, many (most) hedonic noise studies have used a semi-logarithmic functional form which gives a constant NSDI:

$$\text{NSDI} = \beta \cdot 100$$

- All variables in the regressions divided by 100 $\Rightarrow$ coefficients can be interpreted as NSDI, and its equivalents
- "Road NSDI" in the range 0.08-2.3 with 0.55 average (Bateman et al., 2001)

Hedonic regression estimates (selection)

	Umeå	Västerås	Nacka	Borås	Vellinge	Örebro	Falun
Peace 'n' quiet	0.470***	0.206***	0.303***	0.255***	0.183*	0.413***	0.693***
	(0.085)	(0.047)	(0.060)	(0.092)	(0.109)	(0.073)	(0.124)
Living space	0.361***	0.393***	0.377***	0.425***	0.313***	0.441***	0.401***
	(0.013)	(0.010)	(0.012)	(0.014)	(0.015)	(0.014)	(0.019)
Subsidiary space	0.006	0.061***	0.101***	0.019	0.051***	0.027**	-0.039**
	(0.011)	(0.009)	(0.014)	(0.013)	(0.019)	(0.012)	(0.017)
Standard	1.884***	1.709***	1.101***	1.940***	1.286***	1.671***	2.777***
	(0.111)	(0.089)	(0.117)	(0.113)	(0.146)	(0.111)	(0.183)
Property area	0.002***	0.005***	0.007***	0.002***	0.010***	0.003***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Dist. station	-0.003***	-0.009***	-0.004	-0.003***	0.007***	-0.003***	-0.004***
	(0.000)	(0.000)	(0.002)	(0.000)	(0.001)	(0.000)	(0.000)
Dist. railway	-0.002***	0.003***	0.000	-0.001**	0.006***	-0.002***	0.001**
	(0.000)	(0.000)	(0.002)	(0.000)	(0.001)	(0.000)	(0.001)
Dist. road	0.009	0.006	0.038***	0.023***	-0.018*	-0.007	0.012
	(0.007)	(0.005)	(0.006)	(0.008)	(0.009)	(0.007)	(0.012)
Linked	-8.136***	-14.444***	-22.149***	-11.575***	-6.123***	-13.535***	-12.784***
	(1.478)	(1.115)	(1.705)	(2.337)	(1.556)	(1.516)	(2.472)
Terraced	-18.926***	-21.728***	-25.698***	-17.963***	-17.624***	-11.203***	-14.280***
	(1.447)	(1.032)	(1.598)	(1.908)	(3.237)	(2.719)	(3.598)
N	2 996	4 402	2 528	3 445	1 791	3 109	1 885
R^2	0.765	0.671	0.718	0.616	0.633	0.735	0.718
Mean MWTP	371	187	581	162	256	317	402
Lower CI	241	103	355	48	-44	207	261
Upper CI	503	272	807	277	557	427	543

note: *** p<0.01, ** p<0.05, * p<0.1

Transfer error – Naïve transfer

	Transfer from							
Transfer to	Umeå	Västerås	Nacka	Borås	Vellinge	Örebro	Falun	Mean
Umeå	0	-49.54	56.39	-56.19	-31.02	-14.71	8.23	-14.47
Västerås	98.19	0	209.94	-13.18	36.71	69.03	114.50	85.87
Nacka	-36.06	-67.74	0	-71.99	-55.89	-45.46	-30.79	-51.32
Borås	128.28	15.18	257.00	0	57.46	94.69	147.07	116.61
Vellinge	44.97	-26.85	126.72	-36.49	0	23.64	56.90	31.48
Örebro	17.25	-40.84	83.37	-48.64	-19.12	0	26.90	3.15
Falun	-7.60	-53.38	44.49	-59.53	-36.27	-21.20	0	-22.25
Mean	40.84	-37.20	129.65	-47.67	-8.02	17.67	53.80	

(Reminder: $\mathrm{TE} = \left(\frac{\mathrm{WTP}_T}{\mathrm{WTP}_O} - 1\right) \times 100$

Transfer error – Income adjustment

	Transfer from							
Transfer to	Umeå	Västerås	Nacka	Borås	Vellinge	Örebro	Falun	Mean
Umeå	0	-52.52	10.17	-55.87	-46.80	-13.81	4.76	-25.68
Västerås	110.62	0	132.04	-7.06	12.05	81.54	120.65	74.97
Nacka	-9.23	-56.90	0	-59.95	-51.71	-21.76	-4.91	-34.08
Borås	126.62	7.60	149.66	0	20.56	95.33	137.41	89.53
Vellinge	87.97	-10.75	107.08	-17.05	0	62.02	96.92	54.37
Örebro	16.02	-44.92	27.81	-48.80	-38.28	0	21.54	-11.11
Falun	-4.55	-54.68	5.16	-57.88	-49.22	-17.73	0	-29.82
Mean	54.58	-35.36	71.99	-41.10	-25.57	30.93	62.73	

Transfer error – BT Function

	Transfer from							
Transfer to	Umeå	Västerås	Nacka	Borås	Vellinge	Örebro	Falun	Mean
Umeå	0	-63.26	19.49	-61.54	-2.31	-21.98	4.35	-20.87
Västerås	140.94	0	161.44	-11.10	-0.58	79.69	130.19	83.43
Nacka	-9.89	-54.45	0	-66.49	-72.73	-32.57	-11.38	-41.25
Borås	171.58	5.91	210.88	0	33.71	105.78	151.83	113.28
Vellinge	83.48	39.65	134.20	-29.73	0	31.26	133.57	65.41
Örebro	34.66	-46.51	56.91	-50.23	-17.13	0	31.63	1.55
Falun	-0.28	-61.78	22.35	-62.28	-14.39	-23.16	0	-23.26
Mean	70.08	-30.07	100.88	-46.89	-12.24	23.17	73.36	

Discussion and conclusions (I)

- Hedonic regression analysis provides results in line with expectations
  - HP regression: Variables have correct signs and are stat. sign.
  - NSDI in the range 0.18-0.69 (Literature: 0.08-2.3 with 0.55 average)
- Variation in the size of TE between "transferred from and to", and between BT methods
  - Naïve BT in most cases produces non-negligible TE ($> 40\%$)
  - Income adjustment and BTF can reduce TE, but not systematically

Discussion and conclusions (II)

- The relatively large TE in many cases ⇒ approach of benefits transfer problematic
  - Practical point of view: Some degree of imprecision "does not matter" (How much transfer error is acceptable?)
  - "[A] transfer can be no more reliable than the original estimates upon which it is based." (Pearce et la., 2006, p. 256)
- However, results suggest that BT based on first step of HP regression problematic ⇒ estimate demand function
  - Andersson, Swärdh, Timmins, and Ögren, "to be continued..."