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Paradoxes of rationality in road safety policy

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Rationality is an ideal for public policy

- Herbert Simon:
 - “One kind of optimism, or supposed optimism, argues that if we think hard enough, are rational enough, we can solve all our problems”
 - Does this apply to public policy designed to improve road safety?
- Key characteristics of a rational road safety policy:
 - It is evidence-based, i.e. based on the best available knowledge about the effects of safety measures
 - It seeks to maximise the benefits of road safety measures within a given budget
 - It is preference-based, i.e. based on the willingness of the population to pay for improved road safety



Rational road safety policy

- Policy in which the use of road safety measures is based on cost-benefit analyses
 - The monetary valuation of road safety applied in cost-benefit analyses is based on willingness-to-pay
 - Resource allocation is based on a goal of maximising the benefits of funds spent on road safety measures
 - A policy based on these principles will improve road safety at the lowest possible cost to society based on respect for individual preferences with respect to the provision of road safety
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What is a paradox of rationality?

- A paradox of rationality occurs whenever conflicting choices can both be defended as rational, i.e. when faced with options A and B:
 - Choice of A can be defended as better than choice of B
 - While also:
 - Choice of B can be defended as better than choice of A
 - Appeal to rationality does then not resolve the dilemma and the normative guidance provided by the standard of rationality breaks down
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Paradoxes that will be discussed

1. The dependence of choices on irrelevant alternatives
 2. Preference reversal as a result of preference aggregation
 3. Preference reversal as a result of preference intensity
 4. Preference reversal as a result of non-linear utility
 5. Ex post reversal of an ex ante potential Pareto improvement
 6. Conflicts between individual and collective rationality
 7. Interactions influencing marginal cost-effectiveness
 8. Games of resource allocation responsive to competing standards of rationality
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Some preliminaries and tools of analysis

- It will be assumed that individual preferences can be represented by means of a VonNeumann-Morgenstern utility function
 - It will be assumed that preferences for the provision of safety can be represented in terms of a continuous (individual) demand function
 - It will be assumed that the marginal utility of money is monotonically declining
 - It will be assumed that individual utility depends on income and health state
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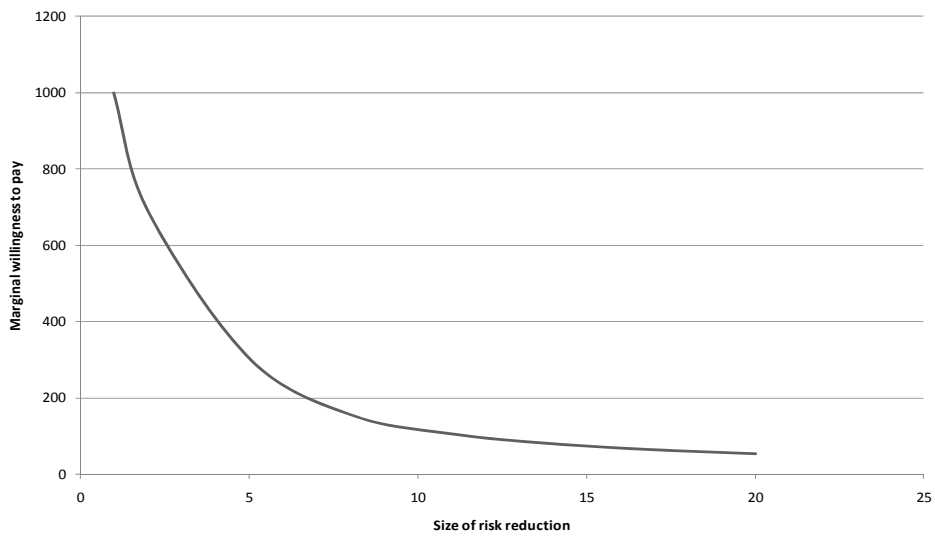


Willingness to pay for safety

Initial risk (per 100,000)	Risk reduction	Willingness to pay (WTP)	Marginal WTP	Value of a statistical life
20×10^{-5}	1×10^{-5}	1000	1000	100,000,000
20×10^{-5}	2×10^{-5}	1693	693	84,657,359
20×10^{-5}	5×10^{-5}	2609	305	52,188,758
20×10^{-5}	8×10^{-5}	3079	157	38,493,019
20×10^{-5}	11×10^{-5}	3398	106	30,889,957
20×10^{-5}	14×10^{-5}	3639	80	25,993,267
20×10^{-5}	17×10^{-5}	3833	65	22,548,314
20×10^{-5}	20×10^{-5}	3996	54	19,978,661



Demand function for improved safety





Dependence on irrelevant alternatives

Characteristics	Option A	Option B
Initial risk	20×10^{-5}	20×10^{-5}
Risk reduction	2×10^{-5}	8×10^{-5}
Size of population	1,000,000	250,000
Fatalities prevented	20	20
Monetary value	1693 million	770 million



Discussion of the paradox

- Options A and B are identical with respect to initial risk and the number of lives saved
- They differ with respect to risk reduction and the size of the population that benefits from it
- From an ethical point of view, it can be argued that all lives are equally valuable and equally entitled to protection from preventable risks
- In that case, the options are equal and no preference for one of the options can be rationally justified
- In the example option A would be preferred *ceteris paribus* since the economic benefits are greatest



Irrelevant alternatives, continued

- However, the ceteris paribus clause does not apply, since any number of combinations of the size of the risk reduction, the size of the population, the income of the population, the shape of the demand function, etc, etc, can produce options that are:
 - Identical in terms of the number of lives saved
 - Different in terms of the monetary valuation of the lives saved
- Hence, choice between these options depend on background characteristics that determine WTP and vary arbitrarily from one case to another
- Choices are therefore dependent on irrelevant alternatives



Preference reversal upon preference aggregation

Characteristics	Option A	Option B
Initial risk	20×10^{-5}	20×10^{-5}
Risk reduction	1×10^{-5}	11×10^{-5}
Size of population	1,000,000	250,000
Fatalities prevented	10	27.5
Monetary value	1000 million	849 million



Discussion of the paradox

- Option B reduces risk much more than option A ($11 > 1$)
 - Option B results in a lower final level of risk than option A ($9 < 19$)
 - Option B saves nearly 2.8 times as many lives as option A ($27.5 > 10$)
 - Willingness to pay for option B is almost 3.4 times greater than willingness to pay for option A ($3398 > 1000$)

 - All these arguments favour option B over option A

 - Still, *ceteris paribus*, option A would be chosen
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Preferences are reversed

- When individual WTP is aggregated to form the value of a statistical life, preferences are completely reversed
 - All else equal: the higher the WTP, the lower the VOSL
 - Hence, choices made on the basis of VOSL will systematically be exactly the opposite of what individuals prefer

 - The root of the problem is the non-linearity and sub-proportionality of the individual demand function with respect to the size of the risk reduction
 - The demand function is, however, consistent with VNM-utility
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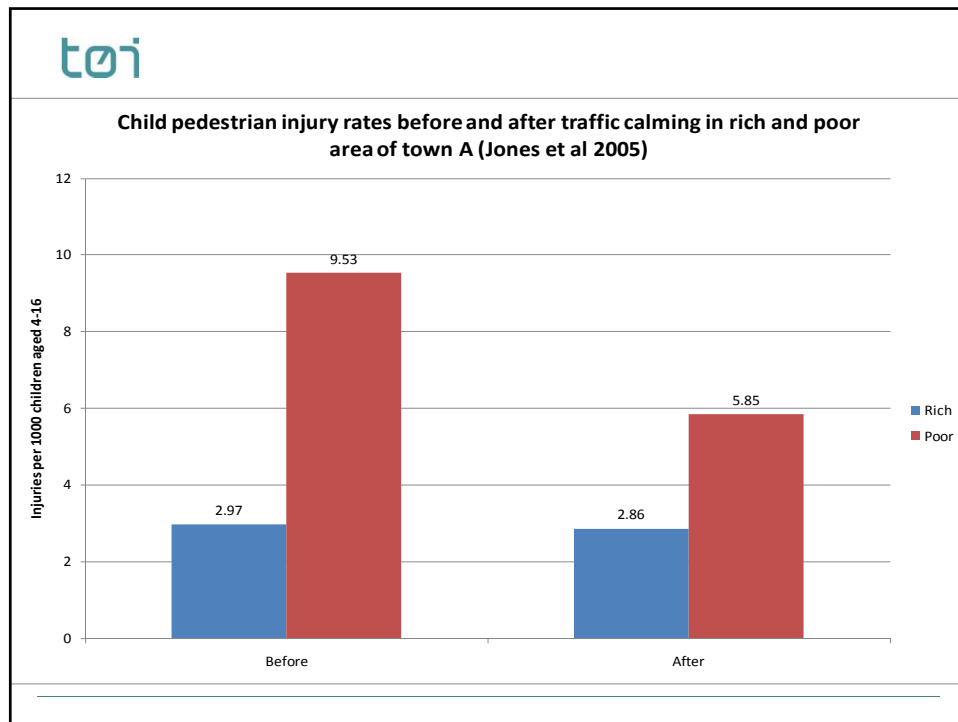
The intensity of preferences

	Option A	Option B
Number of rich individuals	100	100
Number of poor individuals	900	900
Income per rich individual	500	500
Income per poor individual	50	50
Willingness-to-pay per rich individual	5	15
Willingness-to-pay per poor individual	2	1
Total willingness-to-pay - rich	500	1500
Total willingness-to-pay - poor	1800	900
Total willingness-to-pay - both groups	2300	2400
Share of income paid by the rich	0.01	0.03
Share of income paid by the poor	0.04	0.02
Relative aggregated willingness-to-pay - rich	1	3
Relative aggregated willingness-to-pay - poor	36	18
Total relative aggregated willingness-to-pay	37	21



Discussion of the paradox

- The intensity of preference can be measured in terms of:
 - The share of income an individual is willing to spend on a good
 - The difference in utility associated with the provision of a good
- The intensity of preference is one of the background characteristics that influences willingness to pay
- To account for intensity of preference, it is necessary to assign weights to WTP, i.e. one unit of money does not represent the same value irrespective of the factors that determine willingness to pay
- Weighting by the marginal utility of money is an attractive option to account for the different value of a given sum of money for the rich and the poor



Utility functions assumed

Utility conditional on death = $u(\text{death}, w) = \ln(w + 1)$

Utility conditional on survival = $u(\text{survival}, w) = 5 + 5 \ln(w + 1)$

W is income

Denote survival by 1 and death by 0

Utility maximisation implies a willingness to pay m to reduce the risk of death from p to p - r:

$$(1 - p)U(1, w) + pU(0, w) = (1 - p + r)U(1, w - m) + (p - r)U(0, w - m)$$



Willingness to pay in towns A and B

Town	Group	Risk before	Risk after	Mean WTP
A	Rich	2.97	2.86	950
A	Poor	9.53	5.85	7845
B	Rich	2.10	1.93	1900
B	Poor	6.05	5.25	1725



Funding and compensation

- If the schemes are to be funded by money raised locally, the poor area of town A will be favoured (since mean WTP is higher)
- However, the rich area of town B will be favoured, even if the risk reduction is considerably smaller for the rich than for the poor
- If, in town A, the poor are required to compensate the rich for not having safety improved, the required compensation (950) is smaller than WTP (7845), and the transfer is thus feasible
- Likewise the rich can compensate the poor in town B

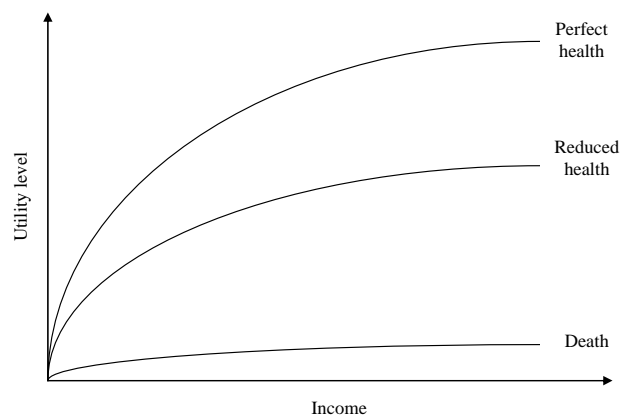
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Compensation continued

- The poor cannot, however, compensate the rich in town B in case the safety schemes are introduced in the poor area, but the rich demand compensation for not having safety improved in the rich area
- In general, the rich will be favoured since they are willing to pay more for safety schemes providing a certain safety benefit than the poor
- Schemes that require the poor to compensate the rich will rarely be feasible

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Utility functions that depend on health status





Utility ex ante and ex post

- Utility in perfect health = $5 + 5 \cdot \ln(w + 1)$
- Utility in reduced health = $3 + 5 \cdot \ln(w + 1)$
- Current utility level = $0.994 \cdot (5 + 5 \cdot \ln(200000 + 1)) + 0.006 \cdot (3 + 5 \cdot \ln(200000 + 1)) = 66.0184$
- New utility level = $0.995 \cdot (5 + 5 \cdot \ln(200000 + 1)) + 0.005 \cdot (3 + 5 \cdot \ln(200000 + 1)) = 66.0204$
- WTP for reduction of risk of reduced health = 480
- Utility when health is reduced = 64.0304
- Compensation needed to restore original level of utility = 97650



Individual and collective rationality

- Individual rationality: choices based on impacts that influence personal utility only
- Collective rationality: choices that make at least one person better off without making anyone worse off (Pareto-optimality)
- Potential Pareto improvement: choices in which gainers can compensate losers (in utility terms) and still be better off
- This criterion is generally regarded as being fulfilled if benefits are greater than costs
- Social dilemmas: conflicts between individual and collective rationality



A case of a social dilemma

Table 10: Societal versus user perspective on studded tyres.

Amounts in million NOK (1 NOK = 0.12 EURO)		
Item	Gains (favourable impacts)	Losses (adverse impacts)
Gains and losses to road users		
Accidents	132.5	
Travel time	53.1	
Additional trips made	5.0	
Costs of studded tyres		95.2
Fuel consumption		44.0
Total impacts	190.6	139.2
Gains and losses external to road users		
Accidents	61.4	
Road wear		46.4
Air pollution		180.0
Total impacts	61.4	226.4
Gains and losses for society as a whole		
Total impacts	252.0	365.6



The combined effect of measures

- Suppose there are 100 accidents:
 - Measure A reduces them by 40 (residual = 60 = remaining accidents)
 - Measure B reduces them by 30 (residual = 70)
- The combined effect (model 1) is then 1 – the product of the residuals:
 - $1 - ((1 - E_1) \cdot (1 - E_2)) = 1 - (0.6 \cdot 0.7) = 1 - 0.42 = 0.58 = 58$ accidents prevented
 - This is smaller than the sum of the first order effects (40 + 30 = 70)
- There is even support for a more conservative model:
 - $0.58^{0.6} = 0.72 = 28$ accidents prevented
 - This means that measures that are cost-effective according to first order effects may be cost-ineffective if combined in a programme



The safety programme paradox

Measure	First order effects of measures			Measures as a programme		
	Benefits	Costs	BC-ratio	Benefits	Costs	BC-ratio
A	20	16	1.25	14.1	16	0.88
B	15	12	1.25	10.6	12	0.88
C	10	8	1.25	7.0	8	0.88
D	5	4	1.25	3.5	4	0.88
All	50	40	1.25	35.2	40	0.88



Mechanisms of resource allocation

- Ideal: resources are allocated in proportion to the pool of cost-effective measures, so that funding exactly matches the cost of implementing these measures
- Incremental: last year's budget is taken as basis and a small increase proposed
- By negotiation: stakeholders negotiate and agree on both the size of the budget and the main outlines of policy priorities
- In practice, the latter two mechanisms are used – this is in a sense rational, but undermines cost-effectiveness



The game of vote trading

	Issues				
Voters	1	2	3	4	5
1	+10	-8	-3	-7	-4
2	-9	+20	-13	-1	-8
3	-6	-7	+15	-9	-5
4	-2	-1	-7	+30	-3
5	-2	-3	-2	-7	+10
Benefits	10	20	15	30	10
Costs	19	19	25	24	20
BC-ratio	0.53	1.05	0.60	1.25	0.50



Solution to the game

- Voters 1, 3 and 5 will form a coalition to ensure passage of issues 1, 3 and 5
- These are all cost-ineffective
- The cost-effective programmes 2 and 4 will not be implemented

- There is evidence supporting the existence of such a resource allocation mechanism in Norway
- It operates first at the regional level, then at the local level



An example at the local level

Municipality	Contribution to funding (%)	Cars per kilometre of road	Relative benefits of roundabout	Efficient selection for conversion	Municipal benefits to cost	Game equilibrium selection	Municipal benefits to cost
1001	47.06	285.8	3.75	8	3.19	3	1.19
1002	8.23	133.4	1.75	4	4.25	1	1.06
1003	6.17	90.4	1.19	2	1.92	1	0.96
1004	5.64	42.8	0.56	0	0.00	2	1.00
1014	7.67	73.4	0.96	0	0.00	1	0.63
1017	3.55	77.3	1.01	1	1.43	1	1.43
1018	6.26	162.6	2.13	5	8.52	1	1.70
1021	1.31	21.4	0.28	0	0.00	1	1.07
1026	0.51	30.9	0.41	0	0.00	1	3.98
1027	0.96	14.8	0.19	0	0.00	1	1.01
1029	2.61	36.6	0.48	0	0.00	1	0.92
1032	4.50	50.6	0.66	0	0.00	1	0.74
1034	0.97	22.2	0.29	0	0.00	1	1.50
1037	3.40	27.1	0.35	0	0.00	2	1.04
1046	1.16	12.4	0.16	0	0.00	2	1.40
Total	100	76.2	1.00	20		20	



Reflections and final remarks

- Is there something wrong about using rationality as an ideal for public policy?
- No, but it has to be recognised that it is not the only relevant ideal – at least not as long as rationality is interpreted as economic efficiency based on cost-benefit analysis
- Other ideals for public policy include:
 - Equity or fairness – this may justify departures from economic efficiency
 - Democratic legitimacy – this supports the use of consultation and negotiation seeking consensus – which again may imply departures from economic efficiency

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Further reflections and remarks

- Are the paradoxes of rationality that have been discussed attributable to a fundamental vagueness of the criterion of rationality?
 - No, economic rationality as defined in terms of cost-benefit analysis is a perfectly clear and – indeed – mathematically precise ideal
 - Except for uncertainty due to incomplete or imperfect knowledge, it is always clear what the most cost-effective solution to a problem is
 - But then why do choice of a cost-effective solution sometimes strike us as paradoxical or at least counter-intuitive?
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Final reflections and remarks

- Choices are always made within a context consisting of background characteristics that shape preferences and expectations
 - In that sense, any choice depends on irrelevant alternatives, in the sense that is influenced by contextual factors that are unique to each choice
 - This may give some choices an appearance of being paradoxical, although they are not so in a stringent sense
 - In some cases there are competing standards of rationality that pull in different directions
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