On Using Standard Values of Time in Project Appraisal: Income Equity vs. Preference Equity

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Background & Motivation

- Urban highways suffer delays of six billion hours annually due to traffic congestion
  - Transportation improvements are needed
  - But how much should we invest in them?

- The “Value of Time”
  - The amount that users are willing to pay for a (marginal) reduction in travel time
  - Needed to evaluate transportation improvements
Consider a proposal to expand a highway

- Cost: $10 million to construct
- Benefit: Reduces travel times by one-million hours
  - Assume that the expansion will only last one year so we don’t need to worry about annuity values

Is this project worthwhile if:

- the value of time is $20 per hour?
- the value of time is $4 per hour?
Our Research by Example

- Recurring Empirical Finding
  - Value of time estimates increase with income

- Now consider two proposed improvements
  - One affects the Rich, whose value of time is $20
  - The other affects the Poor, whose value of time is $4
  - Each project costs $10 million and will reduce travel times by one-million hours
  - Which project will be approved?
Our Research by Example

- Suppose instead that the **average** value of time, $12 per hour, is used to evaluate both projects
  - This is called a “standard” or “equity” value of time
  - It is commonly used in the U.K., U.S., Chile, and several countries in the E.U.
  - Which project will be approved?

- Now suppose each project is financed by tax payments amounting to $10 per hour saved
  - e.g. a $10 million bond paid by increased sales taxes
  - Would the Poor want their project approved?
Key Findings and Contributions

- We show that the “Equity Value” approach:
  - Will indeed treat all income groups equally when appraising time-saving projects
  - But will give more weight to those who gain the least (utility) from faster travel
  - And could result in a misallocation of resources
Key Findings and Contributions

- We develop an alternative appraisal scheme that
  - Still uses a single value of time
  - Allows project benefits to increase for those who gain more (utility) from travel-time savings
  - Averages the effects of income on project benefits, thus giving equal treatment to all income groups
  - Can be employed with basic discrete-choice analysis
  - Generalizes existing solutions in the literature
  - Applies to the appraisal of non-transport projects such as pollution abatement
Takeaway Points

- Using “standard” or “equity” values of time to repair income equality can lead to preference inequality
  - They might not be as “equitable” as hoped for

- Income inequality can instead be addressed by fairly simple adjustments to existing methods for estimating the value of time
  - Details are in the Appendix to this presentation
Appendix
Value of Time

- **Individual’s Utility Function** \((u)\)
  \[ u = u(x, T_W, \{T_k\}) \]

- **Lagrangian Function** \((L)\)
  \[ L = u(x, T_W, \{T_k\}) + \lambda \cdot [Y + wT_W - x] + \mu \cdot [\overline{T} - T_W - \sum_k T_k] + \sum_k \theta_k \cdot [T_k - \overline{T}_k] \]

**Abbreviations**
- \(x\) = composite good
- \(T_W\) = time spent at work
- \(\{T_k\}\) = set of times spent on \(K\) activities
- \(Y\) = unearned income
- \(w\) = wage rate
- \(\overline{T}\) = total time available
- \(T_k\) = time spent on \(k\)
- \(\overline{T}_k\) = minimum time required for \(k\)
Value of Time

- Indirect Utility Function \((U)\)
  \[U = U(Y, w, \bar{T}, \{T_k\})\]

- Value of Time \((V)\)
  Consider a travel activity, \(t\), which requires a minimum travel time of \(\bar{T}_t\)
  \[V \equiv \frac{dY}{d\bar{T}_t}\bigg|_{dU=0} = -\frac{\partial U/\partial \bar{T}_t}{\partial U/\partial Y} = \frac{\theta_t}{\lambda} \quad \left(= \frac{\mu}{\lambda} - \frac{\partial u/\partial T_t}{\lambda}\right)\]
  \(V\) is the willingness to pay for a marginal reduction in the minimum required travel time \((-d\bar{T}_t)\)
Analytical Framework

- **Social Welfare Function** ($W$)
  \[ W = W[U_1(Y_1, w_1, \bar{T}_1, \{\bar{T}_{k_1}\}) \ldots U_n(Y_n, w_n, \bar{T}_n, \{\bar{T}_{k_n}\})] \]

- **Welfare Gain from a Time-Saving Transportation Improvement**
  \[ dW = \sum_i \frac{\partial W}{\partial U_i} \frac{\partial U_i}{\partial \bar{T}_{ti}} d\bar{T}_{ti} = -\sum_i \frac{\partial W}{\partial U_i} \theta_{ti} d\bar{T}_{ti} \]
  
  Welfare Gain

  Social Weight

  Time Savings

  Marginal Utility of Travel-Time Savings
  \[ (= -\partial U_i / \partial \bar{T}_{ti}) \]
Analytical Framework

- Some Notation

\[ S_i \equiv \frac{\partial W}{\partial U_i} \]  
Social weight assigned to \( i \)'s welfare gain

\[ \theta_i \equiv \theta_{ti} \]  
\( i \)'s marginal utility from lower travel time

\[ \lambda_i = \frac{\partial U_i}{\partial Y_i} \]  
Increase in \( i \)'s maximum attainable utility when income increases, referred to as the “marginal utility of income”

\[ dTS_i \equiv -d\bar{T}_{ti} \]  
Travel time savings from a transportation improvement (minimum travel time reduction)
Analytical Framework

- **Simpler statement of the Welfare Gain**
  \[ dW = \sum_i s_i \theta_i dTS_i = \sum_i s_i \lambda_i V_i dTS_i \]

- **Monetary Benefit of an Improvement (\(dB\))**
  - Define \(\lambda_W\) as a scale factor that converts the welfare gain to a monetary value (c.f. \(V_i = \theta_i / \lambda_i\))
  \[ dB \equiv \frac{dW}{\lambda_W} = \frac{1}{\lambda_W} \sum_i s_i \lambda_i V_i dTS_i \]
Value of Time in Project Appraisal

- How should we use value-of-time estimates to appraise transportation improvements?
  - What are the social weights implicitly assigned to each user’s travel-time savings?

- The “Harberger Approach”
  - The benefits accruing to each user “are added without regard to the individuals to whom they accrue” (Harberger, 1971; Small & Rosen, 1981)

\[ dB = \sum_i V_i dT_i \]
Value of Time in Project Appraisal

- The “Standard-Value Approach”
  - Each user is assigned the same value of time
    - e.g. income-averaged value in the U.K.
    - e.g. evaluated at median income in the U.S.
  - Motivated by equity concerns and/or simplicity
    - Sometimes called an “Equity Value” of time

- Letting $V$ denote a single, standard value of time equally assigned to all users:

$$dB_s = V \sum_i dTS_i$$
The Harberger Approach

- **Implied Social Weights**
  \[
  dB = \frac{1}{\lambda_w} \sum_i s_i \lambda_i V_i dTS_i \rightarrow dB = \sum_i V_i dT_i
  \]

  - Implies: \( s_i = \frac{\lambda_W}{\lambda_i} \)

  - Let’s call this the “Harberger Weight”: \( h_i \equiv \frac{\lambda_W}{\lambda_i} \)

- **Equity Concern** (Galvez & Jara-Diaz, 1998)
  - Empirically, \( \lambda_i \) tends to increase with income
  - And we see that \( h_i \propto \frac{1}{\lambda_i} \)
The Harberger Approach

- More weight will be assigned to groups with higher incomes
  - To the extent that the marginal utility of income decreases with income

- Should transportation policy be used to repair income inequality?
  - The Harberger Approach is consistent with how choices in markets are actually made
  - On the other hand, equity concerns are legitimate policy concerns
The Standard-Value Approach

- **Implied Social Weights**
  - We interpret the social weights implied by the Standard-Value Approach as “equity-adjusted” Harberger weights.
  - Let $e_i$ denote an equity adjustment such that $s_i = h_i e_i$.
  - Which $e_i$ converts $dB = \sum_i V_i dT_i$ to $dB_S = V \sum_i dT_i$?

  - A natural candidate is: $e_i \equiv \frac{V}{V_i}$

  - Which implies: $s_i = h_i e_i = \frac{V \lambda w}{\theta_i}$

  - And: $dB_S = V \sum_i dT_i$
The Standard-Value Approach

- A Different Type of Equity Concern
  \[ dB_S = V \sum_i dT_i \] implies \( s_i \propto \frac{1}{\theta_i} \)

- Those who gain the least utility from travel-time savings are assigned the largest weights
  - Correcting the income inequity introduces a travel-time-preference inequity
  - Could also lead to a misallocation of resources, recalling the example of “poor” commuters who prefer slower travel to higher taxes
User Payments

- What are the implied social weights when transportation improvements are financed by user payments such as taxes or road tolls?

  
  "Social Marginal Utility of Money":
  \[ \lambda_W = \sum_i s_i \lambda_i \pi_i \quad \text{share of total payments} \]

  Implied Monetary Benefit:
  \[ dB = \frac{dW}{\lambda_W} = \frac{\sum_i s_i \theta_i dTS_i}{\sum_i s_i \lambda_i \pi_i} \]
User Payments

- Applying Harberger weights:
  \[ s_i = h_i = \frac{\lambda W}{\lambda_i} \] implies \[ dB = \sum_i V_i dTS_i \]

- Applying equity-adjusted Harberger weights:
  \[ s_i = h_i e_i = \frac{V \lambda W}{\theta_i} \] implies
  \[ dB_S = \left[ \sum_i \frac{\pi_i}{V_i} \right]^{-1} \sum_i dTS_i = V_{HM} \sum_i dTS_i \]
  - \( V_{HM} \) is a weighted harmonic mean value of time
  - It is standard value of time, but not one that is ever used in practice!
User Payments

- Then which weights are consistent with the Standard Value Approach that is actually used?

Let: 

\[ dB = \frac{\sum_i s_T \theta_i dTS_i}{\sum_i s_M \lambda_i \pi_i} \]

Different weights applied to welfare gains and user payments

- where: 

\[ s_T = h_i e_i = \frac{V \lambda W}{\theta_i} \] (equity-adjusted weights)

- and: 

\[ s_M = h_i = \frac{\lambda W}{\lambda_i} \] (Harberger weights)

Then: 

\[ dB = dB_S = V \sum_i dTS_i \]

Noting: 

\[ s_T \propto \frac{1}{\theta_i} \]
User Payments

- When considering projects financed by user payments, the Standard-Value Approach
  - Still assigns the largest weights to those who gain the least utility from travel-time savings
  - Requires the application of unequal weights on
    - The welfare gains of a project
    - The social costs of financing the project

- There is no micro-foundational justification for this application of unequal social weights
User Payments

- More on micro-foundational support for the Standard-Value Approach

  - Galvez & Jara-Diaz (1998); Mackie et al. (2001):
    - \( dB_s = V_\theta \sum_i dTS_i \) where \( V_\theta \equiv \frac{\theta}{\lambda_i} \)
    - Requires the (heroic) assumption that \( \theta_i = \theta \) \( \forall i \)

- We demonstrate that the Standard-Value Approach can be derived without relying on that assumption
  - But implies a weighting scheme where \( s_i \propto \frac{1}{\theta_i} \)
An Alternative Approach

- The forced tradeoff between income inequity and time-preference inequity is caused by:
  - Attempting to correct income inequity through the value of time
  - Instead of focusing on the culprit: the diminishing marginal utility of income

- If an equity adjustment is desired, we propose
  - \( e'_i \equiv \frac{\lambda_i}{\bar{\lambda}} \)
  - where \( \bar{\lambda} \) is an average marginal utility of income
An Alternative Approach

- Applying our proposed equity adjustment:
  \[ s_i = h_i e'_i = \frac{\lambda w_i}{\lambda} \] implying \[ dB = \frac{\sum_i \theta_i dTS_i}{\lambda} \]

- Gives equal weight to all income levels
- Allows more weight for those who gain more utility from time savings
- Estimable with ordinary travel-demand models
- Generalizes existing approaches in the literature
Comparison with Existing Approaches

- Galvez & Jara-Diaz (1998); Mackie et al. (2001)

Recall: \[ dB = \frac{\sum_i s_i \theta_i dTS_i}{\sum_i s_i \lambda_i \pi_i} \]

Applying our equity adjustment: \[ dB = \frac{\sum_i \theta_i dTS_i}{\sum_i \lambda_i \pi_i} \]

(A “neutral approach” to appraisal where \( s_i = 1 \ \forall \ i \))

If \( \lambda_i \) and \( \pi_i \) are (linearly) independent, then:

\[ dB = \frac{\sum_i \theta_i dTS_i}{\bar{\lambda}} \]
Comparison with Existing Approaches

- Fowkes (2010)

  \[ dB_K \equiv V_K \sum_i dTS_i \]

  \[ V_K \equiv \sum_i \frac{\lambda_i}{\lambda} \frac{V_{iK_i}}{\sum_i K_i} \]

  where \( K_i \) is distance travelled

- Applying our equity adjustment:
  \[ dB = \frac{\sum_i \theta_i dTS_i}{\lambda} \]