Does labor supply modeling affect findings of transport policy analyses?

Georg Hirte and Stefan Tscharaktschiew
TU Dresden, Institute of Transport & Economics

Advancing Metropolitan Modeling for the Analysis of Urban Sustainability Policies, Riverside, CA

January 16th, 2015

Labor supply in transport economics policy analysis

Urban/transport economists model labor supply in different ways:

1. **No decision on labor supply**
   - Leisure fixed (McDonald 2009, Wrede 2009)
   - Leisure depends on commuting time $\longrightarrow$ leisure as residual (Brueckner 2005, Rhee et al. 2014)
   - Labor supply depends on commuting time $\longrightarrow$ labor supply as residual (Lucas & Rossi-Hansberg, 2002)
2. **Endogenous labor supply**
   1. Endogenous working hours but exogenous workdays (Anas & Kim 1996, Anas & Xu, 1999, De Palma & Lindsay 2004)
   2. Endogenous workdays but exogenous working hours (Verhoef 2005, Arnott 2007, Tscharaktschiew & Hirte 2010a)

Endogenous working hours

Anas (2002)	
Anas and Kim (1996)	Olwert and Guldmann (2012)
Anas and Rhee (2006)	Parry and Bento (2002)
Anas and Xu (1999)	Van Ommeren and Fosgerau (2009)
De Borger and Wuyts (2011a)	Verhoef and Nijkamp (2002)
De Palma and Lindsey (2004)	West and Williams (2007)
Fujishima (2011)	White (1988)
Hotchkiss and White (1993)	White (1977)
Spatial model (incorporating location decisions of households and/or firms)	

Endogenous working days

Arnott (2007)	Lin and Prince (2009)
Berg (2007)	Parry and Bento (2001)
Calthrop (2001)	Parry and Small (2005)
De Borger and Van Dender (2003)	Parry (2011)
De Borger and Wuyts (2009)	Tscharaktschiew (2014)
De Borger and Wuyts (2011b)	Tscharaktschiew and Hirte (2010)
Fosgerau and Pilegaard (2007)	Tscharaktschiew and Hirte (2012)
Hirte and Tscharaktschiew (2013a)	Van Dender (2003)
Hirte and Tscharaktschiew (2013b)	Verhoef (2005)
Spatial model (incorporating location decisions of households and/or firms)	

Labor or leisure as residual

Leisure as residual (sum of leisure + commuting time is fixed, labor fixed)	
Anas and Hiramatsu (2012)	De Lara et al. (2013)
Anas and Hiramatsu (2013)	De Salvo (1977)
Anas and Liu (2013)	Kono et al. (2013)
Anas and Rhee (2007)	Kwon (2005)
Arnott et al. (2008)	Martin (2001)
Bento et al. (2006)	McDonald (2009)
Brock and Wrede (2005)	Parry (1995)
Borck and Wrede (2008)	Parry and Small (2009)
Borck and Wrede (2009)	Parry and Timilsina (2010)
Brueckner (2005)	Ross and Zenou (2009)
Brueckner (2007)	Sullivan (1983a,b)
Brueckner et al. (2002)	Rhee, Yu, Hirte (2014)
Calthrop et al. (2000)	Wrede (2001)
De Borger and Wouters (1998)	Wrede (2009)
Labor as residual (sum of labor + commuting time is fixed, no leisure)	
Lucas and Rossi-Hansberg (2002)	Rossi-Hansberg (2014)
Spatial model (incorporating location decisions of households and/or firms)	

Why labor supply modeling might matter?

Question

Are the effects of transportation policies robust to the modeling of labor supply?

1. **Labor supply** is a decision variable of workers
   (in particular in the medium or long run; wage tax distortions)
2. **Fixed costs per day or week**: child care, commuting (Cogan 1981).
   $\rightarrow$ VOT of an additional hour on a workday
   $>$ VOT of an hour that implies to add another workday
3. **No. of workdays determines the number of commuting trips:**
   - **Tax distortions of travel related taxes** depend on the number of trips (e.g. congestion toll, cordon toll, fuel taxes, emission tax, miles tax, parking fees)
   - **Congestion** depends among others on the number of trips

Which labor supply modeling fits empirics?

1. **Differentiating working**
   - **Hours per week and weeks**
     (Hanoch 1980, Blank 1988, Triest 1990, Heckman 1993)
   - **Hours per day and days**
     (Hammermesh 1996)
   - **Days per week, hours per day, weeks per year**
     (Dechter 2013)
   - **Participation vs. hours worked or workdays**
     (Heckman 1993, Blundell & MaCurdy 1999, Kleven & Kreiner 2006; Dechter 2013)
2. **Inhomogeneity of leisure**
   - **Leisure on workdays and leisure on leisure days**
     (Hanoch 1975, Oi 1976, Dechter 2013)
3. **Empirical research in transportation**:
   - Gutiérrez-i-Puigarnau & van Ommeren (2010)

Research Question

Question

Are the effects of transportation policies robust to the modeling of labor supply?

In particular, we

1. Suggest a **hybrid labor supply approach**:
   decision on workdays per year and daily workhours
2. **Derive and compare the VOTs** of the different approaches:
   'workhours'; 'workdays'; hybrid approach
3. **Derive welfare changes and optimal policies in an urban model**
4. **Run simulations** of several policies (congestion toll, cordon toll, miles tax, land-use type regulation, infrastructure expansion) to identify sign and size of various effects (e.g. welfare)

Findings

- **Approach chosen matters** for signs and magnitude of welfare effects of tax instruments
- **Hybrid approach is less sensitive**
- **Days approach** approximates hybrid approach with homogeneous leisure
- **Hours approach** approximates hybrid approach with inhomogeneous leisure and labor tax recycling

Theoretical Background

General Setting

- City with 2 zones
- Mixed zones: working, living, shopping
- RUM approach (Anas & Xu 1999)
- Monetary + time costs of travelling (endogenous)

Inhomogeneous hybrid approach

A household derives utility u from consumption (shopping) z, housing q, and leisure

$$u = u(z, q, \mathcal{L}_1, \mathcal{L}_2)$$

- z = consumption (shopping)
- q = housing
- $\mathcal{L}_1 = \ell D$ = leisure on workdays
  (ℓ leisure hours per day, D workdays)
- $\mathcal{L}_2 = lL$ = leisure on leisure days
  (l leisure hours per leisure day, L leisure days).

Constraints

$$
\begin{aligned}
\left(w^n h - c\right) D + \mathcal{I} - \left(p + c^z\right) z - r^q q &= 0 && [\text{budget, } \lambda] \\
E - D - L &= 0 && [\text{days, } \gamma] \\
eD - \left(h + t\right) D - \ell D - \beta t^z z &= 0 && [\text{hours on workday, } \mu] \\
eL - lL - \left(1 - \beta\right) t^z z &= 0 && [\text{hours on leisure day, } \rho]
\end{aligned}
$$

- E endowment of days per year,
- e daily time endowment,
- β share of shopping on workdays,
- t^z shopping trip time
- c monetary travel costs

VOTs in different approaches

	$u(z, q, ...)$	VOTh: $\frac{\mu}{\lambda}$	VOTl: $\frac{\rho}{\lambda}$
Hybrid_i	$\mathcal{L}_1, \mathcal{L}_2$	w^n	$w^n - \frac{w^n t + c}{e}$
Hybrid_h	$\mathcal{L}$	w^n	$w^n - \frac{w^n t + c}{e - \bar{\ell}}$
Hours_i	$\mathcal{L}_1, \mathcal{L}_2$	w^n	$\frac{\rho}{\lambda}$
Hours_h	$\mathcal{L}$	w^n	w^n
Days_i	$\mathcal{L}_1, \mathcal{L}_2$	$\frac{u_{\mathcal{L}_1}}{\lambda} = \frac{\mu}{\lambda}$	$\frac{w^n \bar{h} - c}{e} + \frac{\mu}{\lambda}\frac{e - \bar{h} - t}{e}$
Days_h	$\mathcal{L}$	$\frac{w^n \bar{h} - c}{\bar{h} + t}$	$\frac{w^n \bar{h} - c}{\bar{h} + t}$

- $VOTL = \frac{\gamma}{\lambda} = e\frac{\rho}{\lambda}$
- **Full consumer price (**LS-tax recycling, inhomogeneous leisure)

$$P = p + c^z + \left\{ \beta \frac{\mu}{\lambda} + (1 - \beta) \frac{\rho}{\gamma} \right\} t^z \tag{1}$$

Closing the model

- Probability for residence-working location (i, j) (MNL: Small & Rosen 1981)

$$\Psi_{ij} = \frac{\exp\left(\Lambda V_{ij}\right)}{\sum_a \sum_b \exp\left(\Lambda V_{ab}\right)} \tag{2}$$

- Local output - representative firm (CRS); inputs labor and land

$$X_i = f\left(L_i, Q_i\right) \tag{3}$$

- Government budget ($s_i A_i$ = share of land used for infrastructure)

$$\tau^w T^w + \sum_i \tau_i^t T_i^t + \tau^{ls} N = \sum_i r_i s_i A_i \tag{4}$$

- Land market clearing

$$\left(1 - s_i\right) A_i = Q_i + N \sum_j \Psi ij q_{ij} \tag{5}$$

- Local labor and good markets clearing

Welfare

Welfare = expected value of maximized utilities
(Small & Rosen 1981, Anas & Rhee 2006)

$$W = E\left[\max\left(V_{ij} + \varepsilon_{ij}\right)\right] = \frac{1}{\Lambda} \ln \sum_i \sum_j \exp\left(\Lambda V_{ij}\right) \tag{6}$$

Marginal welfare change w.r.t. congestion toll τ_k^t in zone k,

$$\frac{1}{\lambda}\frac{dW}{d\tau_k^t} = \underbrace{\left(MEC^t - \tau_k^t \frac{Adj^t}{-dF/d\tau_k^t}\right)\left(-\frac{dF}{d\tau_k^t}\right)}_{\text{Pigouvian term}} + \underbrace{TI^t}_{\text{tax interaction}} + \underbrace{RE^t}_{\text{redistribution}} \tag{7}$$

Definitions

$$MEC^t \equiv \frac{N}{\lambda} \sum_i \sum_j \Psi_{ij} \lambda_{ij} D_{ij} \frac{dt_{ij} / d\tau_k^t}{dF / d\tau_k^t}$$

$$\frac{dF}{d\tau_k^t} = N \sum_i \sum_j \left(\Psi_{ij} \frac{dD_{ij}}{d\tau_k^t} + D_{ij} \frac{d\Psi_{ij}}{d\tau_k^t} \right) + N \sum_j \sum_{j \neq i} \left(\Psi_{ji} \frac{dD_{ji}}{d\tau_k^t} + D_{ji} \frac{d\Psi_{ji}}{d\tau_k^t} \right)$$

$$\begin{aligned} TI^t \equiv & \ \tau^w N \sum_i \sum_j \left(\Psi_{ij} w_j h_{ij} \frac{dD_{ij}}{d\tau_k^t} + \Psi_{ij} w_j D_{ij} \frac{dh_{ij}}{d\tau_k^t} + w_j h_{ij} D_{ij} \frac{d\Psi_{ij}}{d\tau_k^t} \right) \\ & + N \sum_{i \neq k} \tau_i^t \left[\sum_j \left(\Psi_{ij} \frac{dD_{ij}}{d\tau_k^t} + D_{ij} \frac{d\Psi_{ij}}{d\tau_k^t} \right) + N \sum_{j \neq i} \left(\Psi_{ji} \frac{dD_{ji}}{d\tau^k} + D_{ji} \frac{d\Psi_{ji}}{d\tau^k} \right) \right. \end{aligned}$$

$$RE^t \equiv MEC^t \frac{dF}{d\tau_k^t} \left(\phi^E - 1 \right) + Y^t \left(\phi^Y - 1 \right) - N \sum_i \sum_j \Psi_{ij} \delta^k D_{ij} \left(\phi^T - 1 \right)$$

Relocation and workdays

Remark

In a **workhours** *approach the welfare effects of Pigouvian congestion tolls are only determined by relocation and changes in daily working hours.*

Remark

With prohibiting spatial relocation costs (no relocation) the Pigouvian term is zero (no Pigouvian toll) in the **workhours approach**. *Congestion tolls only affect the tax interaction effects.*

Hence, in non-spatial approaches workdays and workhours approach will differ strongly.

Optimal congestion toll

The **optimal congestion toll** in zone k :

$$\left(\tau_k^t\right)^* = \underbrace{\frac{MEC^t}{Adj^t}\left(-\frac{dF}{d\tau_i^t}\right)}_{(+)} + \underbrace{\frac{TI^t}{Adj^t}}_{(-)} + \underbrace{\frac{RE^t}{Adj^t}}_{(?)}. \tag{8}$$

No clear result $\longrightarrow$ simulations

Spatial CGE Policy Analyses - Benchmark

- Anas & Rhee (2006)
- BPR congestion function
- CD utility, CES subutility, CD production
- Balance of payment (absentee landlords, transportation costs)
- Calibration to 'average' U.S. MSA
  - 500,000 households
  - Average commuting time 31 minutes per one-way trip
  - 31 hours total annual time delay
  - 22 cpm average marginal external costs
- 180 simulations (5 policies, 36 simulations each)

Results (1a): Labor, travel, Pigouvian tolls

Pigouvian congestion toll - 1a	Benchm	Hours	Hybrid	Days
Time allocation				
(1) Workdays per year	263	0	−1	−1
(3) Hours on a workday spent working/leisure	8.3/5.8/	0/0	+0.1/0	0/+0.1
(6) Total labor supply [hours/year]	2187	+6	−2	−6
(7) Total leisure demand [hours/year]	2164	+3	+12	+17
(8) Total commuting time on workdays	272	−6	−8	−7
(9) Total shopping time [hours/year]	417	−3	−3	−4
Travel/Transport/Traffic				
(10) Travel time delay [hours/year]	31	−5	−5	−5
(11) MECC [$-cents/mile]	22	−3	−4	−3
(12) Total travel time [hours/year]	689	−9	−10	−11
Pigouvian congestion toll				
(19) Congestion toll [$/trip] city–city	0.0	1.54	1.51	1.50
(20) Congestion toll [$/trip] city–sub	0.0	0.16	0.15	0.14
(21) Congestion toll [$/trip] sub–city	0.0	7.33	7.22	7.35
(22) Congestion toll [$/trip] sub–sub	0.0	2.13	2.09	2.04

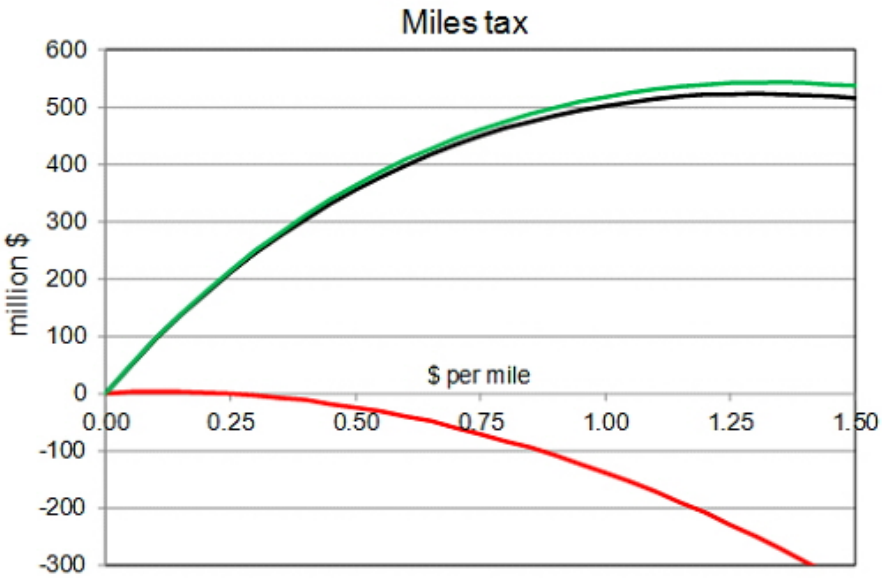
Results (1a): city, tax, location

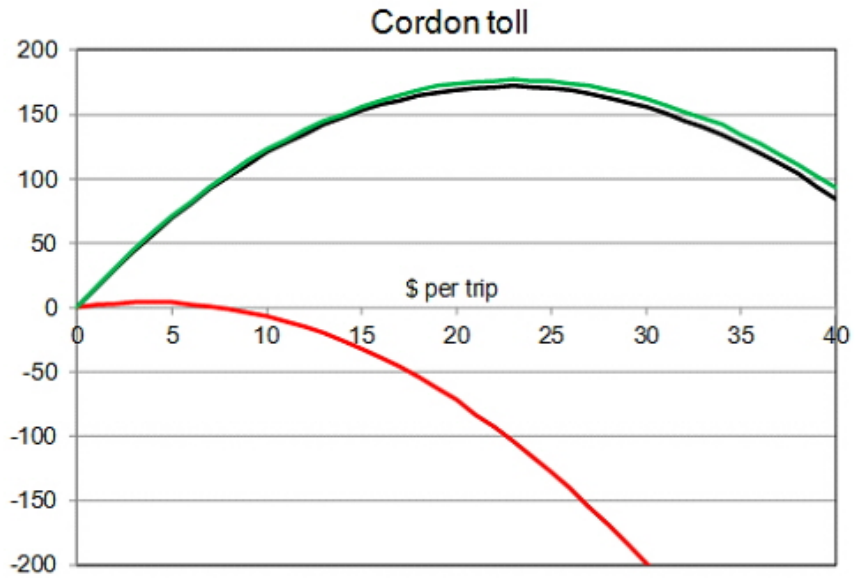
Pigouvian congestion toll - 1a	Benchm	Hours	Hybrid	Days
Households				
(23) Gross income [$]	61,071	−460	−632	−1,136
(24) Consumption [trips]	472	0	−1	−2
(25) Av. housing [sqr feet]	7778	−55	−58	−77
Urban Economy				
(27) Urban GDP [bill $/year]	29.1	−0.2	−0.3	−0.5
(28) EV [million $/year]	–	+43	+16	−17
(29) Rent city/suburb	5.95/2.22	+0.12/−0.05	+0.09/−0.05	+0.08/−0
(30) Wage rate city/sub [$/hour]	22.81/19.65	−0.05/−0.39	−0.04/−0.36	−0.04/−0
Government				
(31) Labor tax rev [mill $/year]	8171	−65	−87	−155
(32) LS tax rev. [mill $/year]	–974	−817	−804	−791
(33) Congest toll rev. [mill $/year]	0	+897	+880	+890
(34) Infrastr costs [mill $/year]	7197	+15	−13	−56
Location				
(35) Households – city	168,687	+3,745	+3,687	+2,882
(37) Jobs – city	268,099	−6,356	−6,313	−4,971

Results: tax policies - Equivalent Variations

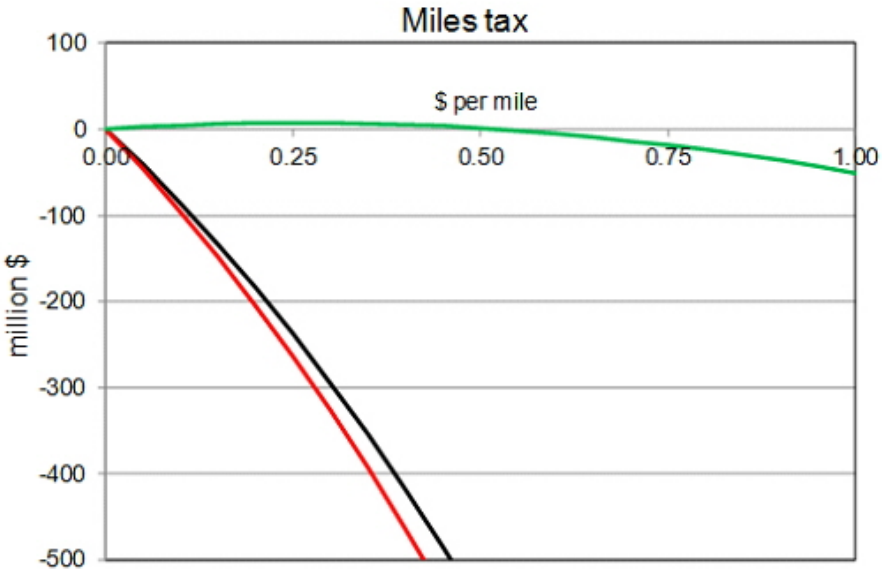
				Inhomogeneous				Homogeneous			
	Policy	**Recycl**	**Land**	no.	**h**	**hyb**	**D**	no	**h**	**hyb**	**D**
1	Pigou	LS	Mix	1a	43	16	-17	6a	30	-107	-109
2	Pigou	LS	Abs	1b	56	26	-17	6b	76	-140	-155
3	Pigou	LS	Urb	1c	17	4	-10	6c	2	-15	-16
4	Pigou	Labor	Mix	1d	202	199	13	6d	177	20	4
5	Pigou	Labor	Abs	1e	217	215	16	6e	325	63	24
6	Pigou	Labor	Urb	1f	127	122	5	6f	15	1	-1
13	Miles	LS	Mix	3a	4	-4	-6	8a	3	-41	-46
14	Miles	LS	Abs	3b	6	-2	-5	8b	5	-33	-40
15	Miles	LS	Urb	3c	1	-3	-6	8c	1	-40	-45
16	Miles	Labor	Mix	3d	50	49	2	8d	53	3	0
17	Miles	Labor	Abs	3e	47	46	3	8e	58	7	3
18	Miles	Labor	Urb	3f	46	45	1	8f	32	-1	-2
19	Cordon	LS	Mix	4a	9	-11	-27	9a	3	-122	-143
20	Cordon	LS	Abs	4b	12	-7	-27	9b	14	-91	-121
21	Cordon	LS	Urb	4c	2	-12	-24	9c	1	-126	-149
22	Cordon	Labor	Mix	4d	123	121	-7	9d	128	3	-19
23	Cordon	Labor	Abs	4e	115	111	-7	9e	140	12	-12
24	Cordon	Labor	Urb	4f	113	109	-8	9f	81	-18	-31

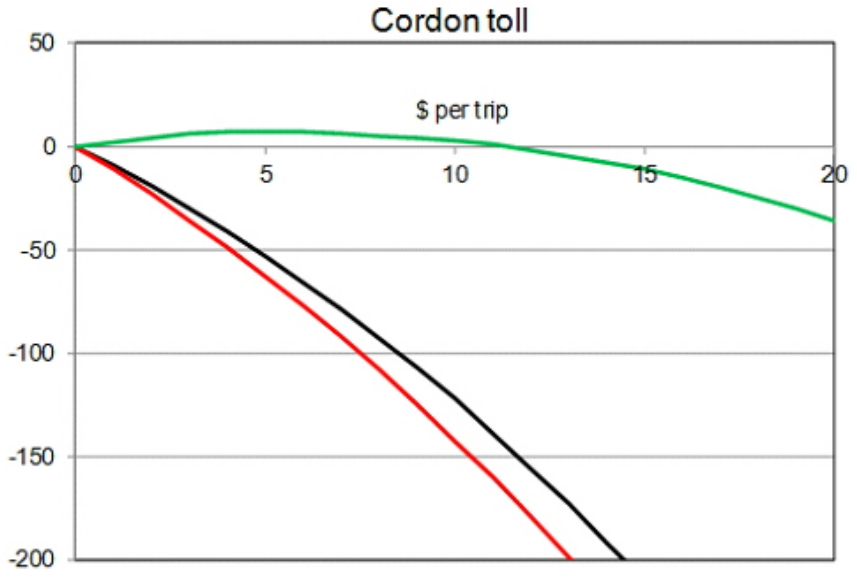
Inhomogeneous leisure – labor tax recycling





Homogeneous leisure – lump-sum tax recycling





Findings

1. **In 50% of the simulations the welfare sign varies across approaches**
2. **Labor tax recycling** provides higher benefits than **lump sum tax recycling** (reason: tax recycling effects)
3. With **homogeneous leisure** + labor tax recycling: EV in hybrid and workhours are very similar
4. With **inhomogeneous leisure** + lump sum tax: EV in hybrid and workdays are very similar
5. **No differences w.r.t to planning or capacity expansion**

Findings (contd.)

- **Planning instruments: LUR**
  - LUR and road capacity expansion: all approaches are similar (no direct effect of policy on the VOT)
  - With land-use type regulation the land market distortion effect does not depend directly on labor supply

$$\frac{1}{\lambda}\frac{dW}{d\zeta_k} = MEC_{\zeta k}\left(-\frac{dF}{d\zeta_k}\right) + TI_{\zeta k} + N\sum_i \left(r_i^q - r_i^Q\right)(1-s_i)\,A_i + RE_{\zeta k}.$$

- **Congestion:** all approaches provide very similar results concerning congestion
- **Land use:** stronger resorting with workhours and hybrid approach.

Conclusions

- **Labor supply approaches matters w.r.t. to welfare** (sign + magnitude) of economic instruments
- It does hardly matter w.r.t. congestion or commuting levels
- **Recommendations**:
  1. **General: Hybrid approach should be preferred**
  2. **Planning instruments + economic instruments** (inhomogeneity + LS tax recycling): approach doesn't matter
  3. **Economic instruments + homogeneity + LS/wage tax recycling** Workdays is good approximation to hybrid; workhours not
  4. **Economic instruments + inhomogeneity + wage tax recycling** Workhours is a good approximation to hybrid; workdays not
- There is a need for empiric research and better data

Thanks for your attention!

Value of times (VOTs) - inhomogeneous hybrid approach

- **VOTh (hour on a workday)**

$$\frac{\mu}{\lambda} = w^n \tag{9}$$

- **VOTL (leisure day)**

$$\frac{\gamma}{\lambda} = e\frac{\rho}{\gamma} = w^n\left(e - t\right) - c \tag{10}$$

- **VOTl (hour on leisure day)**

$$\frac{\rho}{\gamma} = \frac{\gamma}{\lambda}\frac{1}{e} = w^n - \frac{w^n t + c}{e} \tag{11}$$

- **Full consumer price (**LS-tax recycling, inhomogeneous leisure)

$$P = p + c^z + \left\{\beta\frac{\mu}{\lambda} + \left(1 - \beta\right)\frac{\rho}{\gamma}\right\} t^z \tag{12}$$

Results: land use + road capacity expansion: EV

				Inhomogeneous				Homogeneous			
	Policy	**Tax**	**Land**	no	*h*	hyb	*D*	no	*h*	hyb	*D*
7	Road	LS	Mix	2a	-499	-476	-633	7a	-521	-494	-507
8	Road	LS	Abs	2b	-420	-384	-589	7b	-368	-350	-385
9	Road	LS	Urb	2c	-732	-730	-748	7c	-808	-764	-755
10	Road	Lab	Mix	2d	-706	-709	-669	7d	-757	-699	-715
11	Road	Lab	Abs	2e	-580	-571	-620	7e	-552	-494	-535
12	Road	Lab	Urb	2f	-1038	-1047	-785	7f	-1139	-1079	-107
25	LUR	LS	Mix	5a	-16	-6	-74	10a	-54	-12	-57
26	LUR	LS	Abs	5b	8	20	-38	10b	30	63	-9
27	LUR	LS	Urb	5c	-206	-207	-195	10c	-201	-202	-198
28	LUR	Lab	Mix	5d	-121	-125	-91	10d	-104	-125	-102
29	LUR	Lab	Abs	5e	-61	-46	-65	10e	-66	-44	-69
30	LUR	Lab	Urb	5f	-647	-660	-242	10f	-667	-670	-533