Transportation Capital and its Effects on the U.S. Economy: A General Equilibrium Approach

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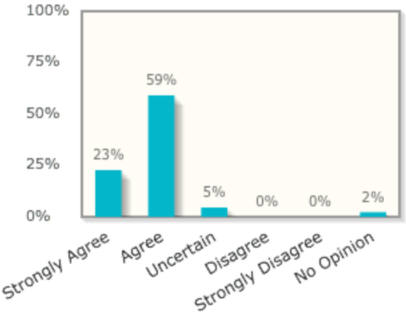
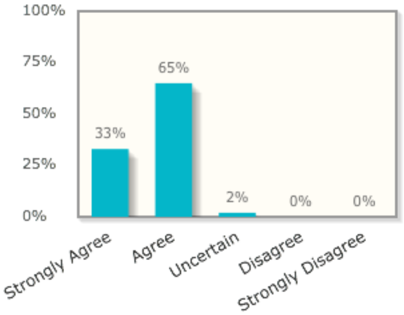
Motivation

Question A: Because the US has underspent on new projects, maintenance, or both, the federal government has an opportunity to increase average incomes by spending more on roads, railways, bridges and airports.

Responses



Responses weighted by each expert's confidence



Also asked in 2013 and 2017, with similar results.

Bridging a Gap

- In the last recession, many macroeconomists treated transportation infrastructure spending a "G"
- Big macro literature on government spending and transfer multipliers (Leeper, Traum and Walker, 2015)
- Big micro literature on effects of transportation capital (Melo, Graham, and Brage-Ardano, 2013)
- Less connecting the two: Barro (1991), Leeper, Walker, Wang (2010)

Goal

- Build a macro model that features government investment in infrastructure, taking micro transportation estimates seriously
- Lessons:
  - Welfare and GDP are potentially significantly different in this context (compared to "T" or "G")
  - Even if long-run multipliers are above one *and long-run flow utility gains*, transportation infrastructure spending can reduce utility, especially with construction-related congestion
  - Japan's low government investment multiplier can be reconciled with higher US investment multiplier
  - Slow infrastructure spending announced long in advance may be better than rapid spending
  - Efficient transportation spending is important (not discussed here)

Literature

- Output elasticity of transportation capital: Aschauer (1989), Munnell (1990), Melo et al. (2013)
- Transportation capital's effects on commuting: Cervero (2002), Duranton and Turner (2011), Hall (2016)
- Macro models of transportation: Fernald (1999), Fajgelbaum and Schaal (2017)

Model Overview

1. Households

2. Government

3. Firms

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Model Overview

1. Households
   - Provide labor, save, consume, pay taxes
2. Government
   - Taxes, determines government non-transportation expenditures, transfers, and transportation expenditures
3. Firms
   - Take in labor and capital and produce goods
4. Standard competitive equilibrium: government decisions taken as given.

Households

- Standard period utility over consumption c and labor L with two adjustments: commuting loss of time (ω_t) and shopping loss of time (ξ_t):

$$U(c_t, L_t) = \frac{c_t^{1-\sigma}}{1-\sigma} - \psi \frac{\epsilon}{1+\epsilon} \left(L_t (1 + \omega_t) + \xi_t c_t \right)^{\frac{1+\epsilon}{\epsilon}}$$

- With period budget constraint over consumption, denoting investment i, various taxes τ^H, τ^G, and τ^T, investment income rK, transfers T, and profits remitted to the household π:

$$c_t + i_t = w_t L_t (1 - \tau_t^H - \tau_t^G - \tau_t^T) + (1 - \tau_t^K) r_t K_t + T_t + \pi_t$$

Household FOC's & Capital LOM

- Household's intratemporal tradeoffs slightly perturbed:

$$\frac{1}{c_t^{\sigma}} - \xi_t \psi (L_t(1+\omega_t) + \xi_t c_t)^{\frac{1}{\epsilon}} = \lambda_t$$

$$(1+\omega_t)\psi(L(1+\omega_t) + \xi_t c_t)^{\frac{1}{\epsilon}} = \lambda_t w_t (1 - \tau_t^H - \tau_t^G - \tau_t^T)$$

- Result: shopping wedge is tax on labor and capital, commuting wedge is tax on labor

- Macroeconomist's view: wedges $\omega \approx 0.11$ and $\xi c/L \approx 0.27$ are big!

- Physical (non-transportation) capital LOM with adjustment costs:

$$K_{t+1} = (1-\delta)K_t + i_t - \frac{\kappa}{2}\left(\frac{i_t}{K_t} - \delta\right)^2 K_t$$

Firms

- Perfectly competitive firm with productivity A, chosen inputs to production structural and equipment capital K, labor hours L, and unchosen input to production transportation capital K^T, with output elasticities α, $1-\alpha$, λ_K

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} (K_t^T)^{\lambda_K}$$

- Note that for the firm, production is CRS (not for a social planner)

- We can absorb the unchosen input into the TFP term:

$$A_t^* = A_t (K_t^T)^{\lambda_K}$$

- After that, firms are standard: capital affects productivity

$$Y_t = A_t^* K_t^{\alpha} L_t^{1-\alpha}$$

Government

- Government spends money on one of three things, financing each with a labor income tax:
  - Non-transportation government expenditures G (τ^G)
  - Lump-sum transfers to households T (τ)
  - Transportation capital K^T (τ^T)
- G and T are standard:

$$G_t + T_t = \tau_t^G w_t L_t + \tau_t^H w_t L_t + \tau_t^K r_t K_t$$

Transportation Capital

- Transportation capital is raised from labor income tax

$$i_t^T = \tau_t^T w_t L_t$$

- Transportation capital is nonstandard: average depreciation rate δ_{1,K^T} and marginal depreciation rate δ_{2,K^T}:

$$K_{t+1}^T = (1 - \delta_{1,K^T}) K_t^T - \delta_{2,K^T} (K_t^T - \overline{K^T}) + \sum_{j=0}^{\overline{T}} \phi_j i_{t-j}^T$$

- Gets at increasing costs of infrastructure **or** decreasing efficiency & potential congestion, time-to-build

- Other than taxes, transportation infrastructure has three important elasticities that impact the real economy:

$$\Delta \log A_t^* = \lambda_K \tilde{K}^T$$

$$\Delta \log \xi_t = \gamma_\xi \tilde{K}^T$$

$$\Delta \log \omega_t = \gamma_\omega \tilde{K}^T$$

Model Summary

- Basic NCG model adjusted to have transportation capital
- Increased transportation capital:
  - Increases labor income tax rates
  - Increases firm productivity (constant returns)
  - Decreases labor wedge (commuting)
  - Decreases consumption wedge (shopping)
- Transportation capital dynamics may display congestion, time-to-build
- Transportation capital has flexible cost function, absorbs any decreasing returns

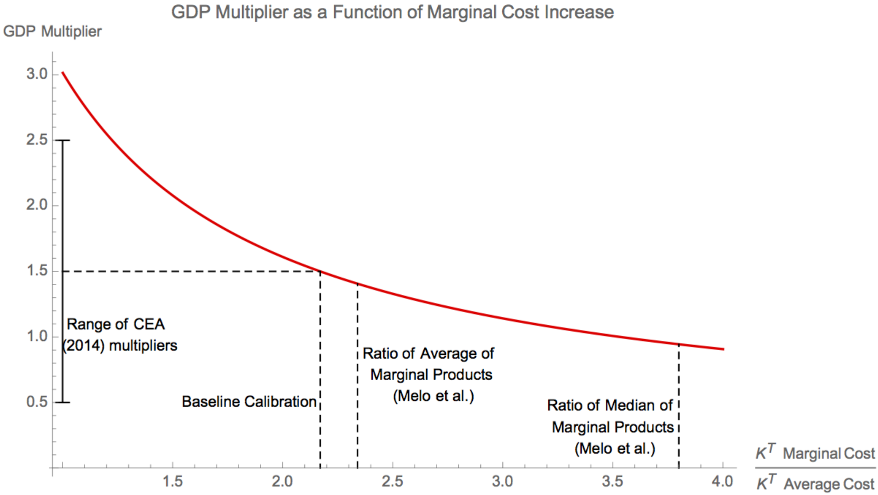
Calibration

- Calibrate to the U.S. economy in 2016: some direct, some jointly.
- Omit most calibration discussion for time ▸ Joint calibration moments ▸ Joint calibration parameters ▸ Directly-calibrated parameters
- Seven important parameters & moments (prime denotes a 5% increase in infrastructure)
  - λ^K: 0.038, Melo et al. (2013), U.S. Median
  - $\{\phi_0, \phi_1, \phi_2\}$: $\{-0.5, 0.5, 1\}$, Al-Kaisy & Hall (2003)
  - γ_ξ: $(\xi' - \xi)c = -4$, close to Duranton & Turner (2009)
  - γ_ω: $(\omega' - \omega)L = -0.5$, close to Duranton & Turner (2009)
  - δ_{2,K^T}: $\frac{Y' - Y}{w'L'(\tau^T)' - wL(\tau^T)} = 1.5$, CEA (2015)

Calibration-II

- $\delta_{2,K^T} = 0.114$ in calibration
- Seems high!
- Functional forms load diminishing returns on increasing costs
- Ratio of physical elasticity to monetary elasticity informative
  - 2.17 in our model
  - 2.34 taking average ratio in Melo et al.
  - 3.8 taking median ratio in Melo et al.

Robustness: Marginal depreciation rate



Long-Run Results

Baseline & Counterfactual Static Results

Variable	Baseline	$K^T \uparrow 5\%$	Difference
Labor hours	1,510	1,512	2
Investment	9,499	9,537	38
Gov. transportation spending	2,259	2,504	245
Consumption	63,227	63,311	84
Gov. non-transportation spending	15,358	15,358	0
GDP	90,342	90,710	368
Equivalent variation	·	139	139

Numbers annually, in dollars per working age capita and hours per working age capita.

Measure equivalent variation using baseline BC multiplier λ:

$$EV = \frac{U' - U}{\lambda} \tag{1}$$

Static Results

- Why is general equilibrium so important?
- We can break down GDP changes into direct changes due to productivity and endogenous responses:

$$\frac{dY}{Y} = \frac{dA}{A} + \alpha \frac{dK}{K} + (1 - \alpha) \frac{dL}{L}$$

- Decomposing,
  - A: 25%
  - K: 47%
  - L: 28%
- Result: output multiplier determines $\frac{dY}{Y}$ and output elasticity determines $\frac{dA}{A}$, so endogenous responses must make up 75% of GDP increase!

Static Results

- Totally differentiate the utility function, to get five sources of utility gains

$$du = \frac{dc}{c} - \psi \left(L(1+\tau^W) + \xi_{sc} c \right)^{\frac{1}{\epsilon}}$$

$$\cdot((1+\tau^W)dL + Ld\tau^W + \xi_{sc}dc + cd\xi_{sc})$$

1. Change in consumption: +\$98
2. Change in labor: -\$62
3. Change in commuting wedge: +\$13
4. Change in consumption travel time: -\$14
5. Change in consumption travel wedge: +\$104
6. Total: +\$139

Japan

- Japan has displayed much lower infrastructure GDP multipliers (Doi and Ihori, 2009)
- $\lambda_K = 0.038$ says strongly diminishing returns! Lower L and lower TFP, combined with higher K^T gives low marginal productivity.
- Re-calibrate parts of our model to Japan: $\left(\frac{i^T}{Y} = 0.07,\ \tau^k = 0.55\right)$
- Spending dramatically higher, per-capita capital stock 44% higher
- Long-run GDP Multiplier of 0.96, or 0.41 if δ fit to $\delta = \delta_0 e^{\rho} K^T$
- Welfare *losses* of \$0.09 per dollar spent, or \$0.64 per dollar spent

Summary of long-run results

1. Long-run flow welfare gains fairly robust to changes in wedges, productivity, or costs (not shown) ▸ Robustness

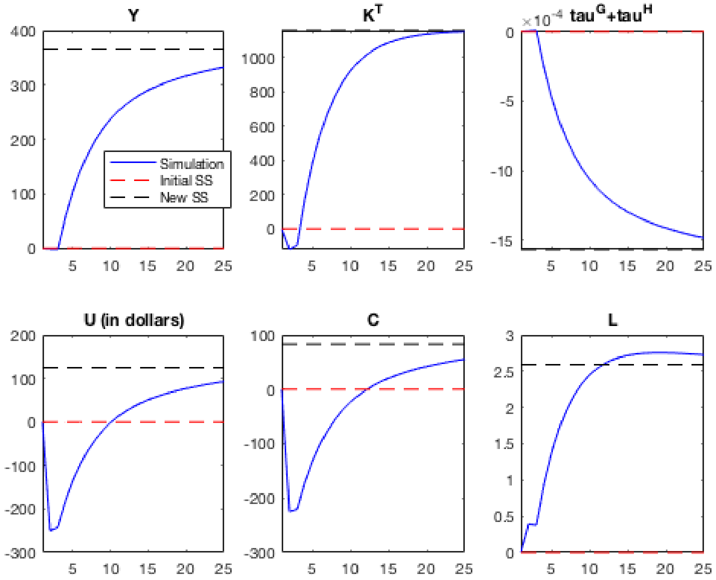
2. Much of increase in GDP comes from GE modeling: partial equilibrium would miss.

3. Because labor and investment increase, welfare and GDP split (more than G or T).

4. Diminishing returns (increasing cost per effective unit) appear present in estimates, can explain Japan's low multiplier

- Move to dynamic results...

Dynamic Results



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Dynamic Results

- Welfare gains move from \$139 yearly gain (\$2,388 NPV) to a $\sim$\$1 average yearly loss (-\$16 NPV)
- Significant portion due to costly-time-to-build: \$19 gain (\$369 NPV) without costly aspect
- Bigger losses due to transition path itself
- Tax smoothing relatively unimportant (but could be with low interest rates)
- **Smaller** loss when transportation infrastructure building is delayed

Conclusion

- Transportation is important for macro (large wedges)
- Macro is important for transportation (necessarily large GE effects)
- Utility and GDP gains can (more) easily diverge with transportation infrastructure
- Positive long-run impact on flow utility not a guarantee of positive NPV EV
- Slow infrastructure spending announced long in advance may be better than rapid spending

Joint Calibration

Calibrating Moments

Description	Equation	Source
Labor hours	L=1510	ATUS
GDP	Y=90342	NIPA
Transfers as frac. of GDP	$\frac{wL\tau^H}{Y} = 0.12$	NIPA
Wasted time shopping	$\bar{\xi}c = 402$	ATUS
Change in times wasted	$(\xi' - \xi)c = -4$	See
shopping and commuting	$(\omega' - \omega)L = -0.5$	text
Gov. exp. as a frac. of GDP	$\frac{wL\tau^G}{Y} = 0.17$	NIPA
Trans. as a frac. of GDP	$\frac{i_t^T}{Y} = 0.025$	CBO (2015)
Transportation multiplier	$\frac{Y'-Y}{(wL\tau^T)'-wL(\tau^T)} = 1.5$	CEA (2014)

Table: This table depicts our 9 equations for 9 parameters: ψ, $\bar{A}$, τ^H, δ_{1,K^T}, δ_{2,K^T}, $\bar{\xi}$, γ_ξ, γ_ω, τ^G.

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Direct Calibration

Direct Calibration

Parameter	Symbol	Value	Source
IES	σ	1.38	SW 2007
Labor supply elasticity	ϵ	0.75	C 2011
Capital's output share	α	0.283	GR 2007
K depreciation	δ	0.064	GR 2007
Commuting wedge	$\overline{\omega}$	0.11	ATUS
Capital tax rate	τ^K	0.29	GR 2007
Cap. adjustment costs	κ	8	CCD 2005
Trans. Elas. of A	λ_K	0.038	MGR 2013
Discount rate	β	0.95	GR 2007
Time-to-bulid	$\{\phi_0, \phi_1, \phi_2\}$	$\{-0.5, 0.5, 1\}$	AK 2003

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Joint Calibration

Joint Calibration

Parameter	Symbol	Value	Source
Expenditure tax	τ^G	0.237	$G(X, \Theta)$
Shopping wedge	$\bar{\xi}$	0.006	$G(X, \Theta)$
Baseline K^T depreciation	δ_{1,K^T}	0.097	$G(X, \Theta)$
Marginal K^T depreciation	δ_{2,K^T}	0.114	$G(X, \Theta)$
Baseline TFP	$\bar{A}$	16.35	$G(X, \Theta)$
Disutility of labor	ψ	$1.98 \cdot 10^{-10}$	$G(X, \Theta)$
Transfer tax rate	τ^H	0.05	$G(X, \Theta)$
Trans. Elas. of ξ	γ_ξ	-0.24	$G(X, \Theta)$
Trans. Elas. of ω	γ_ω	-0.08	$G(X, \Theta)$

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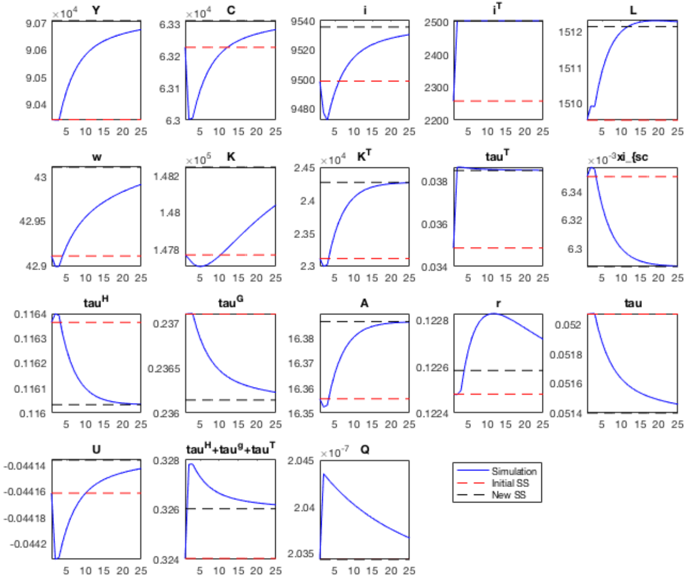
Full Dynamics



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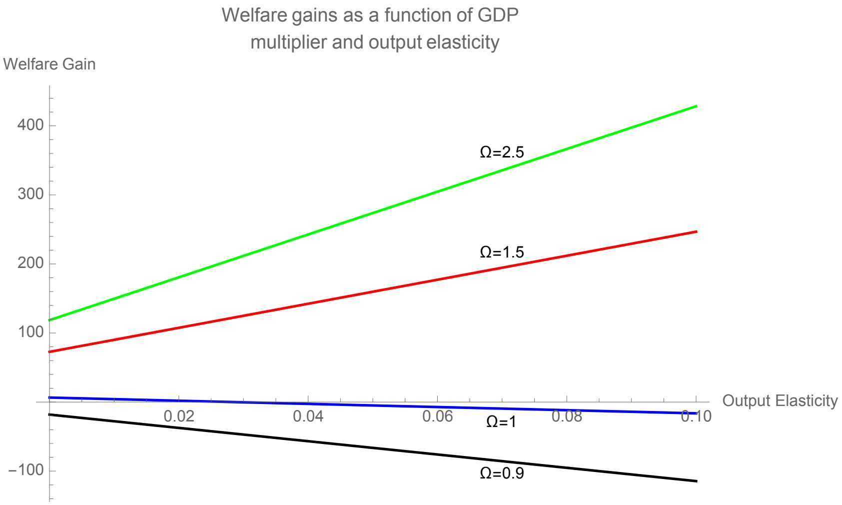
Robustness: Ω and λ_K



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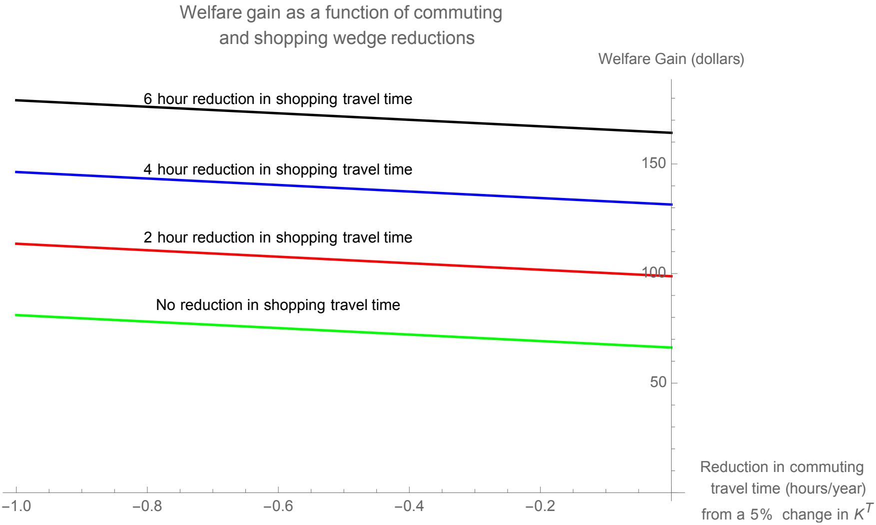
Robustness: ω and ξ



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