The Macroeconomic Consequences of Infrastructure Investment

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Overview

Introduction

- Public capital can play an important role in increasing long-run output and standards of living
- More recently, government infrastructure spending is also considered in policy discussions regarding short-run stimulus
- Government infrastructure spending provides two benefits:
  - Keynesian demand stimulus in the short run
  - and neoclassical supply stimulus in the long run
- **This paper:** examines the macroeconomic theory and empirical evidence on the benefits of infrastructure spending, both in the long run and the short run

Introduction

main findings

- Infrastructure investment may not be the most powerful short-run stimulus
- However public capital and infrastructure spending in particular have significant positive effects on long-run output and productivity
- The long-run government investment multipliers depend critically on
  - the production function elasticity of output to public capital
  - where the economy begins relative to the socially optimal level of public capital
- The aggregate production function elasticity of output to public capital is probably between 0.065 and 0.12
- The short-run government investment multiplier is higher under ZLB

Government Investment in Dynamic Macroeconomic Models

- The short-run and long-run effects of government investment and public capital in both
  - a stylized neoclassical model
  - and a medium scale New Keynesian model

A Stylized Neoclassical Model

- The social planner chooses sequences C_t, N_t, I_t, Y_t, and K_t to maximize

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln C_t - \nu \frac{N_t^{1+\phi}}{1+\phi} + \Gamma\left(G_t^C\right) \right] \tag{1}$$

- Resource constraint:

$$C_t + I_t + G_t^C + G_t^I \leq Y_t \tag{2}$$

- Production function:

$$Y_t = A_t K_{t-1}^{\alpha} N_t^{1-\alpha} \left(K_{t-1}^G\right)^{\theta_G} \tag{3}$$

  - θ_G is the elasticity of output to public capital

A Stylized Neoclassical Model

- Low of motion for public and private capital:

$$K_t^G = G_t^I + (1 - \delta_G) K_{t-1}^G \tag{4}$$

$$K_t = I_t + (1 - \delta) K_{t-1} \tag{5}$$

- Government budget constraint:

$$G_t^C + G_t^I = T_t \tag{6}$$

- For now the two types of government spending are taken as exogenous processes

A Medium-Scale New Keynesian Model

- Following mainly Gali et al. (2007) model with some extensions
- A fraction $(1-\lambda)$ of households have access to capital markets with the following budget constraint:

$$P_t(C_t + I_t) + R_t^{-1} B_{t+1} = W_t P_t N_t + R_t^k P_t K_t + B_t + D_t - P_t T_t \quad (7)$$

- Fraction λ of them do not own any assets nor have any liabilities: rule-of-thumb households

$$P_t C_t^r = W_t P_t N_t^r - P_t T_t \quad (8)$$

- A continuum of monopolistically competitive firms producing differentiated intermediate goods

$$X_{tj} = A_t (u_{tj} K_{t-1,j})^{\alpha} N_{tj}^{1-\alpha} \left(K_{t-1}^G \right)^{\theta_G} \quad (9)$$

- Each firm resets its price with probability $(1-\theta_P)$ each period

A Medium-Scale New Keynesian Model

- Final goods firm

$$Y_t = \left(\int_0^1 X_t(j)^{\frac{\varepsilon_p - 1}{\epsilon_p}} dj \right)^{\frac{\varepsilon_p}{\varepsilon_p - 1}} \tag{10}$$

- Monetary policy:

$$r_t = r + \phi_\pi \pi_t \tag{11}$$

- Fiscal policy:
  - $$P_t T_t + R_t^{-1} B_{t+1} = B_t + P_t G_t \tag{12}$$
  - define $g_t \equiv (G_t - G)/Y$, $t_t \equiv (T_t - T)/Y$, and $b_t \equiv ((B_t/P_{t-1}) - (B/P))/Y$
  - $$t_t = \phi_b b_t + \phi_g g_t \tag{13}$$
  - $$g_t^i = \rho_g g_{t-1} + \varepsilon_t \qquad i = C, I \tag{14}$$

A Medium-Scale New Keynesian Model

- A fictitious labor union sets wages to maximize the weighted utility across the two types of households. The union can only reoptimize the wages with probability $1 - \theta_w$
- Investment adjustment cost

$$K_t = (1 - \delta(u))K_{t-1} + I_t \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] \tag{15}$$

where

$$\delta(u) = \delta_0 + \delta_1(u-1) + \delta_2(u-1)^2 \tag{16}$$

and

$$S\left(\frac{I_t}{I_{t-1}}\right) = \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \tag{17}$$

- Aggregate production function:

$$s_t \cdot Y_t = A_t \left(u_t \cdot K_{t-1}\right)^{\alpha} \left(N_t^d\right)^{1-\alpha} \left(K_{t-1}^G\right)^{\theta_G} \tag{18}$$

Calibration Of The Models

Parameter	Value	Description
Parameters in both models		
β	0.99	Subjective discount factor
ν	1	Weight on disutility of labor
ϕ	0.25	Inverse of the Frisch elasticity of labor supply
α	0.36	Exponent on private capital in production function
θ_G	0.05	Exponent on government capital in production function
δ	0.015	Depreciation rate of private capital
δ_G	0.01	Depreciation rate of public capital
gy	0.175	Steady-state share of total govt spending to GDP
giy	0.035	Steady-state share of govt investment to GDP
ρ_G	0.95	Autoregressive coefficient on appropriations process

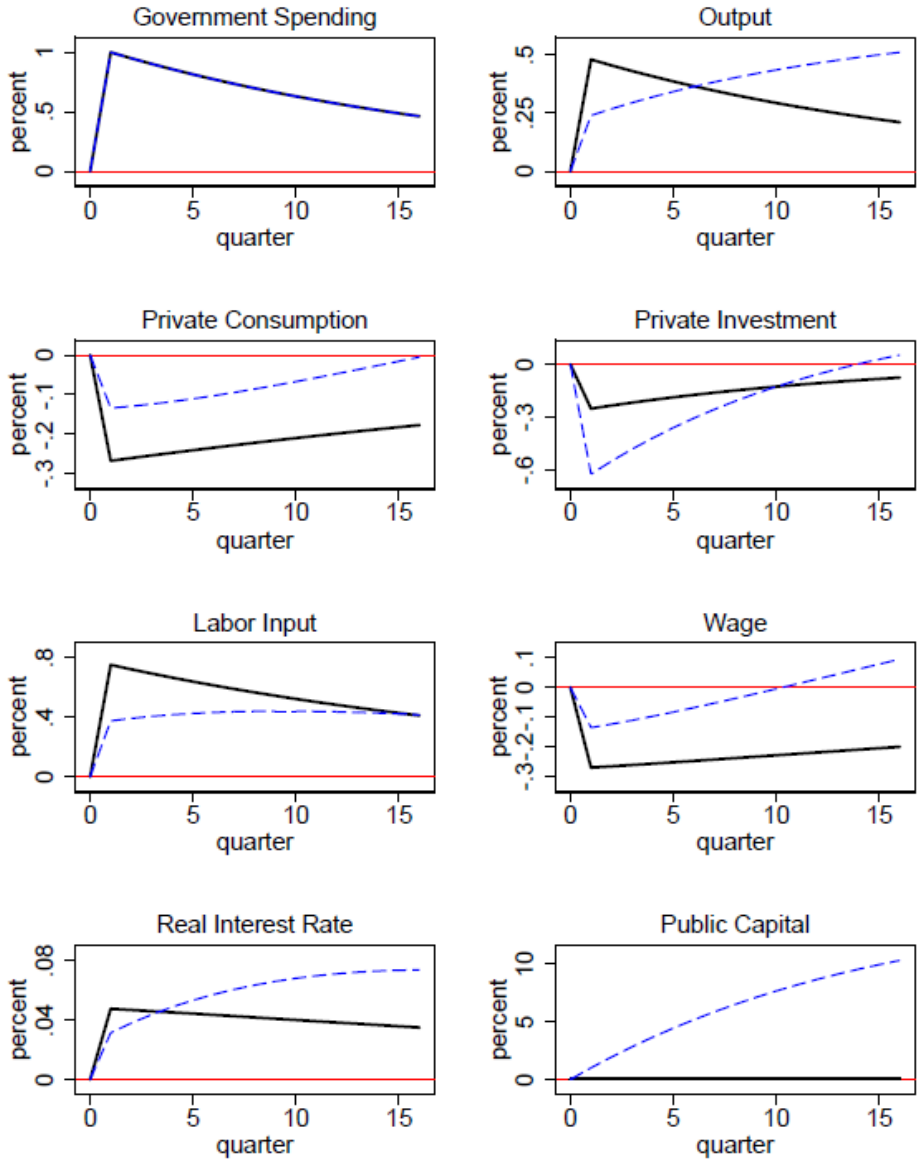
Calibration Of The Models

Additional parameters of the New Keynesian model

κ	5.2	Investment adjustment cost parameter
δ_1	0.025	Parameter on linear term of capital utilization cost
δ_2	0.05	Parameter on quadratic term of capital utilization cost
μ_P	1.2	Steady-state price markup
μ_W	1.2	Steady-state wage markup
θ_P	0.75	Calvo parameter on price adjustment
θ_W	0.75	Calvo parameter on wage adjustment
ε_P	6	Elasticity of substitution between types of goods
ε_W	6	Elasticity of substitution between types of labor
γ	0.5	Share of rule-of-thumb consumers
ψ_b	0.33	Debt feedback coefficient in fiscal rule
ψ_g	0.1	Spending feedback coefficient in fiscal rule
ψ_π	1.5	Monetary policy response to inflation

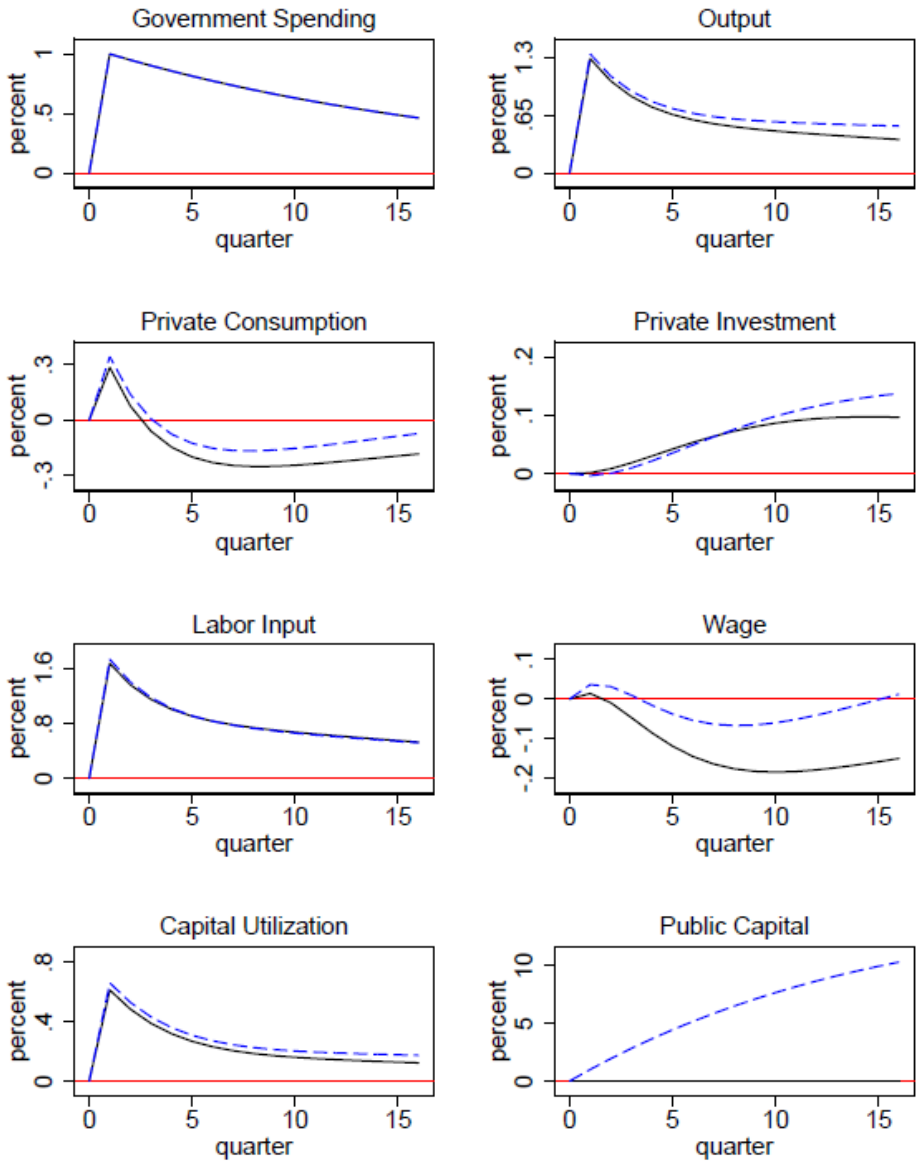
Results (Baseline Neoclassical Model)

Experiments with No Implementation Delays



Results (New Keynesian model)

Experiments with No Implementation Delays



Experiments with Time to Spend and Time to Build

- Typically there are delays between appropriations and actual outlays
- Moreover, many infrastructure projects do not become part of productive capital stock until the project is completed
- Time-to-spend delay

$$G_t^I = \sum_{n=1}^{N} \omega_n AP_{t-n} \tag{19}$$

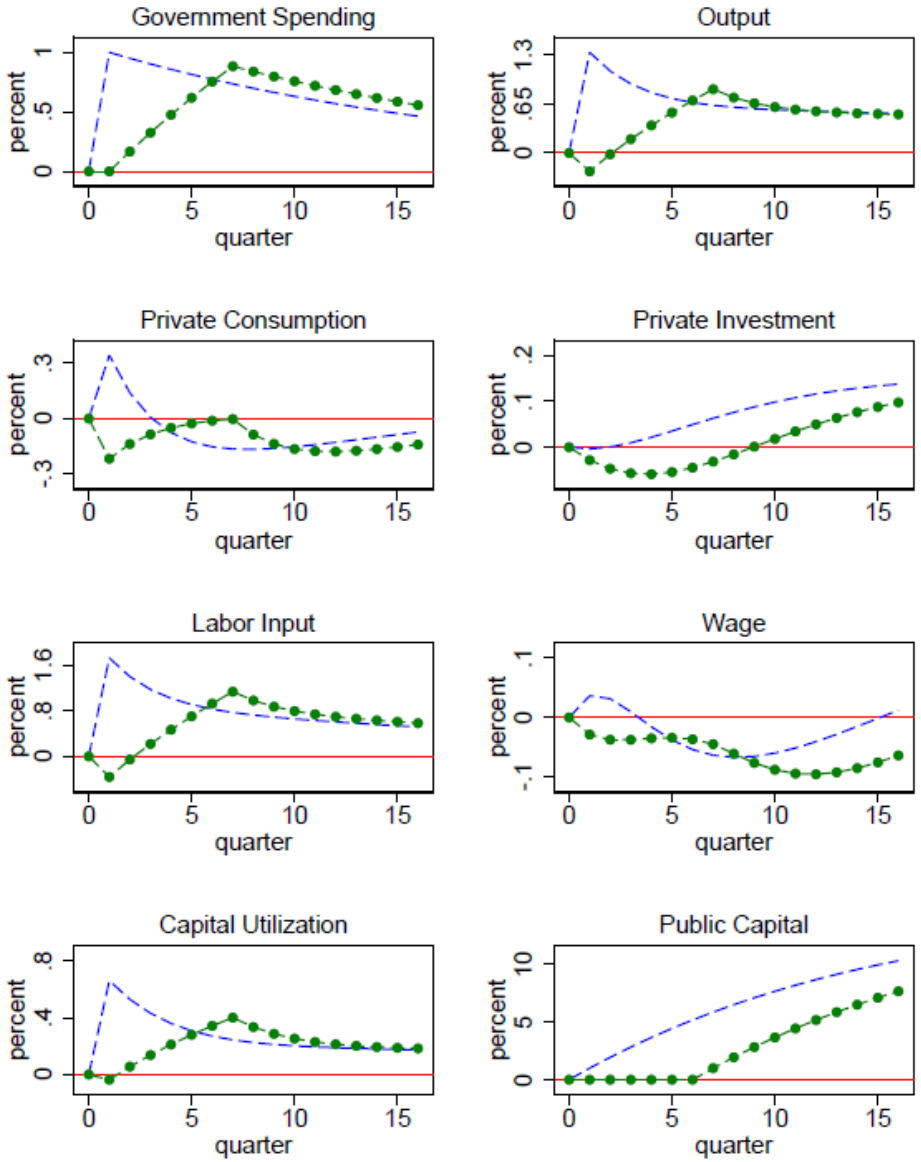
- Time-to-build feature

$$K_t^G = AP_{t-N} + (1-\delta)K_{t-1}^G \tag{20}$$

- N = 6 quarters and $\omega = 1/6$ to match the peak and cumulative spending of the ARRA on government grants

Results (New Keynesian model)

Experiments with Time To Spend and Time To Build



Short-run Multiplier Robustness

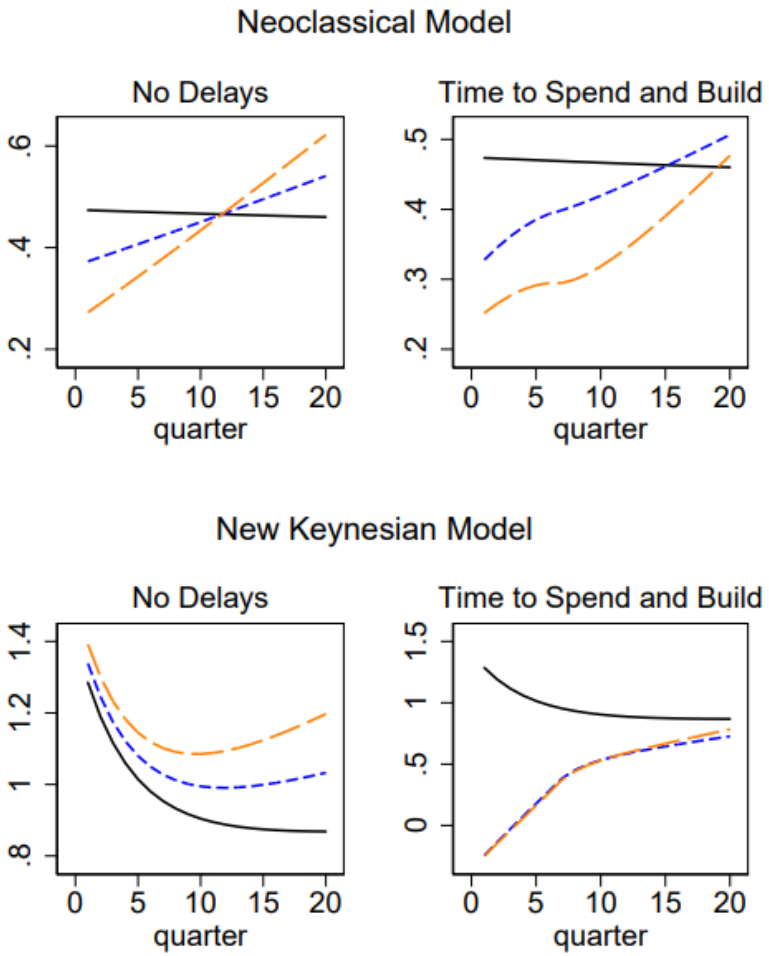
Table 2. Short-Run Multipliers from Simulated Models

Model Version ($\theta_G = 0.05$)	Govt consumption AR(1)	Govt investment AR(1)	Govt investment delays
Neoclassical Model			
Baseline	0.47	0.40	0.37
Frisch elasticity = 0.5	0.14	0.13	0.13
Invest. adj. cost, capital utiliz.	0.63	0.63	0.15
New Keynesian Model			
Baseline	1.06	1.12	0.08
No invest. adj. cost, no utiliz.	0.19	0.16	0.06
Frisch elasticity = 0.5	0.76	0.82	-0.20
No rule-of-thumb households	0.68	0.73	-0.05

Notes: These estimates are based on the calibrated models described in Section 2. The multipliers are equal to the ratio of the integrals of the impulse responses of output and appropriations.

Short-run vs. Long-run Multiplier

Figure 5. Present Discounted Value Integral Multipliers



Notes. Solid: government consumption shock; short dashed: government investment shock, $\theta_G = 0.05$; long dashed: government investment, is $\theta_G = 0.1$. These estimates are based on the baseline neoclassical and NK models.

Short-run vs. Long-run Multiplier

Table 3. Long-Run Multipliers from Simulated Models

Model Version	Present Discounted Value		Undiscounted Integral	
	Neoclassical	New Keynesian	Neoclassical	New Keynesian
Govt consumption	0.44	0.89	0.43	0.90
	Initial Steady State: Govt Investment/GDP = 3.5%			
No delays				
Govt investment, $\theta_G = 0.05$	1.3	1.8	2.4	3.0
Govt investment, $\theta_G = 0.10$	2.2	2.8	4.3	5.0
6-qrt time to spend & build				
Govt investment, $\theta_G = 0.05$	1.3	1.7	2.4	2.9
Govt investment, $\theta_G = 0.10$	2.1	2.5	4.3	4.9

Comparison to the Literature

Neoclassical Models

Table 4. Summary of Some Neoclassical Models from the Literature

Paper feature summary	Experiment	Govt investment multiplier
Baxter-King (1993)	Permanent increase in G	
Calibrated	Long-run multipliers	
Lump-sum taxation	$\theta_G = 0$	1.2
	$\theta_G = 0.05$	2.6
	$\theta_G = 0.40$	13.0
Leeper, Walker, Yang (2010)	AR(1) parameter 0.95	
Estimated	Short run, no delays	0.5
Investment adj. costs, utiliz.	Short run, 3 year delays	0.1 - 0.3
Distortionary tax response	Long run, across delay times	
Calibrated $\theta_G = 0.05$ or 0.10	$\theta_G = 0.05$	0.3 - 0.4
	$\theta_G = 0.1$	0.9 - 1.1
Ercolani-Valle e Azevedo (2014)	AR(1) parameter 0.94	
Estimated	Preferred estimate $\theta_G = 0$	
Features similar to medium NK	4-quarter	0.8
but no nominal rigidities	Long run	0.4
Distortionary tax, balanced budget	Unconstrained estim. $\theta_G = 0.09$	
Nonseparable utility in C and G	4-quarter	0.8
	Long run	3.6
Gallen and Winston (2019)	Multipliers calibrated to CEA	
Calibrated, transport infrastructure	Long run U.S.	1.5
Time-to-build	Long run Japan	0.9
Short-run disruption from construction		
Better transport saves household time		
$\theta_G = 0.038$		

Comparison to the Literature

New Keynesian Models

Table 5. Summary of Some New Keynesian Models from the Literature

Paper feature summary	Experiment	Govt investment multiplier
Coenen et al. (2012)	2-year stimulus, deficits	
Large scale policy models	Instantaneous multipliers	
+ 2 academic models	No monetary accommodation	0.9
U.S.	1 year monetary accommodation	1.1
	2 year monetary accommodation	1.6
Drautzburg-Uhlig (2015)	ARRA, distortionary taxation later	
Estimated medium scale model	Short-run multiplier	0.2 - 0.5
Distortionary taxes, respond to debt	Long-run multiplier	0.3
Calibrated $\theta_G = 0.023$		
Bouakez, Guillard, Roulleau-Pasdeloup (2017)	AR(1) parameter 0.8	
Calibrated	Impact multipliers	
No private capital (in baseline model)	Normal times, across delays	0.8 - 0.9
Lump-sum taxes	ZLB, no delays	1.8
Time to build, $\theta_G = 0.08$	ZLB, 4-year time-to-build delays	4
Sims-Wolff (2018)		
Estimated medium-scale model	AR(1) parameter 0.93	
Distortionary taxes, respond to debt	1 to 2-year multipliers	0.7 - 0.8
Nonseparable utility in C and G		
Calibrated $\theta_G = 0.05$		
Boehm (forthcoming)	AR(1) parameter 0.86	
Calibrated model, 2-sectors (C, I)	Short-run multiplier (0 to 20 quarters)	0.1 - 0.2
Imperfect labor mobility	Long-run multiplier	1.6
Lump-sum taxes		
$\theta_G = 0.05$		

Empirical Evidence on the Long-Run Effects of Public Capital and Infrastructure

Literature on the elasticity of output to public capital

- Aschauer (1989): $\epsilon_G = 0.39$ in US data
- Munnell's (1990): $\epsilon_G = 0.31 - 0.39$ in US data
- Bom and Ligthart's (2014): meta-analysis,ϵ_G of 0.08 in the short run and 0.12 in the long-run
- Ercolani and Valle e Azevedo (2014): medium-scale dynamic general equilibrium macroeconomics model: $\epsilon_G = 0.09$

Empirical Evidence on the Long-Run Effects of Public Capital and Infrastructure

Literature on the output multiplier of government investment

- Ilzetzki et al. (2013): long-run multiplier of 1.6 for OECD countries
- Leduc and Wilson (2013): Long-run multipliers of less than 2, using Federal highway grants to states
- Boehm (2019): long-run multiplier of 1.6 for OECD countries
- Leff Yaffe (2020): long-run multiplier of 1.6, using the U.S. interstate highway system
- Gardner (2019): The estimates are less optimistic for emerging economies

Empirical Evidence on the Long-Run Effects of Public Capital and Infrastructure

Two Leading Methodological Challenges

1. the distinction between production function elasticities and general equlibrium steady-state elasticities
   - θ_G is the elasticity of output to an increase in public capital, holding TFP, labor, and capital constant
   - So impulse-responses in most SVAR estimation is not the production function elasticity
   - The steady state output elasticity to government capital, ϵ_G^{ss} in the Neoclassical model is:

$$\epsilon_G^{SS} = 0.043 + 1.49 \cdot \theta_G \tag{21}$$

2. the endogeneity of public capital

Empirical Evidence

An overview of existing literature

Two Leading Methodological Challenges

1. the distinction between production function elasticities and general equlibrium steady-state elasticities
2. the endogeneity of public capital
   - larger and more wealthy economies invest in more public capital
   - moreover, higher public capital increases productivity and then demand for other inputs
   - one method for estimation the production elasticity in literature is to define :

$$\ln(TFP) = \ln(Y) - \alpha \ln(K) - (1-\alpha) \ln(N) \tag{22}$$

$$\ln(TFP) = \ln(A_t) + \theta_G \cdot \ln\left(K_t^G\right) \tag{23}$$

   - and then they estimate

$$\ln(TFP) = \theta_G \cdot \ln\left(K_t^G\right) + \varepsilon_t \tag{24}$$

Empirical Evidence on the Short-Run Effects of Public Capital and Infrastructure

- Ilzetzki et al. (2013): 0.4 in the short-run for OECD countries
- Boehm (2019): multipliers near zero for government investment and around 0.8 for government consumption for OECD countries, also finds evidence for crowding out effect only for government investment
- Leduc and Wilson (2013): using the US cross-state evidence show that highway spending is counterproductive as a short-run stimulus
- Wilson (2012), Chodorow-Reich, Gabriel and Woolston (2012), Leduc and Wilson (2017), Dupor (2017), and Garin (2019) find that the effects on (construction) employment are either small positive or negative

Conclusion

- This paper has studied the short-run and long-run macroeconomic effects of government investment, using both neoclassical and New Keynesian models
- Government investment has significant long-run effects, but short-run multipliers are less than government consumption in most situations
  - the effects of time-to-build delays
  - higher crowding out effect
- The long-run multipliers on government investment depend critically on both θ_G and on where the economy begins relative to the socially optimal level of public capital
- Short-run multiplier is higher under ZLB
- Some empirical studies suggests that the infrastructure spending leads to either no change or a decline in (construction) employment in the first several years