Public and Private Infrastructure

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Introduction

- Developing countries facing many infrastructure decisions.
  - Averaged 8.5% of GDP in China from 1992-2011, compared to 2.6% in USA
- Public and private infrastructure often complements or substitutes
  - Housing complements subway stations
  - Solar panels substitute for grid electricity
- Expectations over future public behavior affect private behavior, if infrastructure is durable
- In turn, private infrastructure affects demand for public infrastructure, and hence future public behavior

Introduction

- Dynamic coordination game between decentralized private agents and government can have multiple equilibria
- If government can commit, potential benefit of early announcement of future public infrastructure investment
- If government cannot commit, may be driven to second best policies, e.g.
  - early construction of public infrastructure
  - taxes of some types of private infrastructure

Introduction

- Easy to see when public and private infrastructure are complements
  - residential and commercial building with transport, water and electricity infrastructure
  - HD televisions with HD capable transmission networks
- Commitment to future location by government helps avoid:
  - mis-coordination
  - inefficient delays in private investment

We consider two cases when public and private infrastructure are substitutes

1. Public and private infrastructure perfect substitutes but public infrastructure has economies of scale
    - water filters vs. clean piped water
    - latrines vs. sewers
    - solar lanterns / panels vs. grid electricity
2. Government wishes to subsidize infrastructure, e.g. latrines due to health externalities

Setup

Preferences

- Individual utility $\int_0^\infty e^{-\rho t}(u(c_t) + u_t^l)dt$. Constant intertemporal elasticity of substitution θ
- Once installed, infrastructure gives flow utility u_L. No intensive margin. No depreciation.

Technology

- Private infrastructure has cost p_p, always available on perfectly competitive market.
- Public infrastructure has fixed cost F and marginal cost of connection $< p_p$. Individuals can only connect once it is built.
- Constant exogenous rate of technical change $g > 0$ in standard Ramsey model of closed economy with perfect financial markets.
  - Steady state $\Rightarrow r = \theta g + \rho$

Setup

Government

- Government trying to maximize welfare. Assume marginal consumption weighted equally across two types at $t = 0$
- Choose when to build, when to announce, lump sum taxes, price of connection to public infrastructure
- We also consider case when no taxes and investment has to be budget neutral

Endowments

- Two type wealth distribution, h with wealth w_H, l with w_L

Solution concept

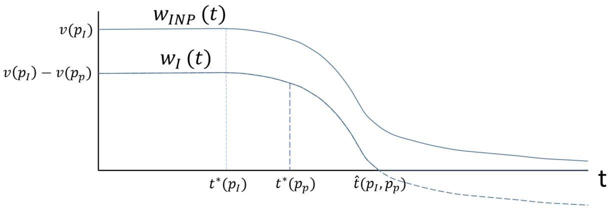
- Solve individual behavior given government policy, then optimal policy given individual behavior
- Typically results in fixed price of connection, p_l

Individual optimization problem, given prices

- Individuals choose consumption and infrastructure purchase plan
  - function of initial endowment, taxes, time of public infrastructure installation and price of public infrastructure
- Consumption grows at rate g and satisfies intertemporal budget constraint. Implies growing demand for infrastructure
- Consider case where only private infrastructure available
  - optimal purchase time: $t^*(p) = \frac{1}{\theta g} ln(\frac{u'(c_0)pr}{u_L})$
  - willingness to pay, **at time 0**, for the option to purchase in the future at price p: $v(p) = (\frac{u_L}{u'(c_0)r})^{r/\theta g} \frac{\theta g}{\rho} p^{-\rho/\theta g}$
- Consider case where public infrastructure available but no private
  - willingness to pay for option depends on construction time, t
  - same as above until $t > t^*(p_I)$
  - $w_{NP}(t) = \begin{cases} v(p_I) & \text{if } t \leq t^*(p_I) \\ e^{-rt}(\frac{u_L}{\rho u'(c_t)} - p_I) & \text{if } t > t^*(p_I) \end{cases}$

Demand with both public and private infrastructure

- Willingness to pay, in units of time 0 consumption, for public infrastructure construction at t
  - reduced by outside option of private, $v(p_p)$
  - for $t > t^*(p_p)$, depends upon earlier beliefs on public infrastructure construction - may have purchased private infrastructure at $t^*(p_p)$
  - zero beyond a certain $t := \hat{t}(p_I, p_p)$, since prefer to buy private infrastructure at $t^*(p_p)$ instead

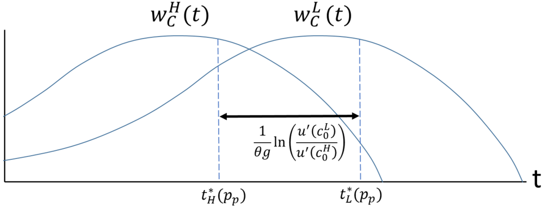


- Aggregate willingness to pay: $hw_I^H(t) + lw_I^L(t)$

Public infrastructure first best?

- Easier to work with willingness to pay **at construction time**

$$w_C(t) = \begin{cases} (\frac{\theta g}{\rho} p_l^{-\rho/\theta g} - \frac{\theta g}{\rho} p_p^{-\rho/\theta g}) p_l^{r/\theta g} e^{r(t-t^*(p_l))} & \text{if } t \leq t^*(p_l) \\ max\{\frac{p_p r}{\rho} e^{-\theta g(t^*(p_p)-t)} - \frac{p_p \theta g}{\rho} e^{-r(t^*(p_p)-t)} - p_l, 0\} & \text{if } t > t^*(p_l) \end{cases}$$



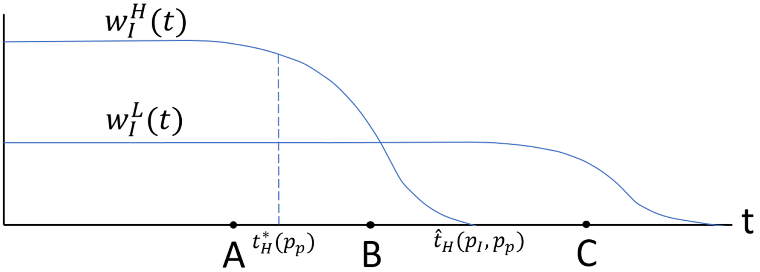
- Note $w_c^L(t)$ is just $w_c^H(t)$ shifted to right by $\frac{1}{\theta g} ln(\frac{u'(c_0^L)}{u'(c_0^H)})$

Public infrastructure first best?

- Public infrastructure built in first best if $hw_c^H(t) + lw_c^L(t) > F$ for some t
- Public infrastructure more likely if:
  - Cost of public infrastructure low relative to private infrastructure
  - Inequality low, since inequality pulls w_c curves apart
  - Growth rate, g, high
  - Intertemporal elasticity of substitution, θ, high
  - Impatience, ρ, low

Equilibria

- Surplus from construction at time t, in willingness to pay at t=0: $S(t) = hw_I^H(t) + lw_I^L(t) - Fe^{-rt}$
- First best: $t_{FB} = argmax_t\ S(t)$
- Suppose $S(t_{FB}) \geq 0$. Three cases for t_{FB}:



Equilibria

- **Case A** ($t_{FB} < t_H^*(p_p)$)
  - one equilibrium, all connect to public infrastructure
- **Case C** ($t_{FB} > \hat{t}_H(p_l, p_p)$)
  - efficient for H to install private infrastructure.
- **Case B** ($t_{FB} \in (t_H^*(p_p), \hat{t}_H(p_l, p_p)$)
  - Multiple equilibria if $lw_l^L(t) - Fe^{-rt} < 0 \; \forall t$:
    - both invest in private, H at $t_H^*(p_p)$ and L at $t_H^*(p_p)$, and public isn't built
    - or, H waits for public and connects to it as soon as it is built.

Tools available to government

If it can, government will commit to t before $t_H^*(p_p)$:

- If it has access to lump sum taxes, first best attained
- Assume instead infrastructure has to be budget neutral
  - If it can price discriminate by wealth, first best still attained
  - If it can only price discriminate by connection time, incentive compatibility constraint on H
    - Potential hold-up problem: ex-post, H willing to pay up to p_p for connection after $t_H^*(p_p)$
  - If it cannot price discriminate, may build public infrastructure later or tax private infrastructure to increase willingness to pay for public

If it cannot commit, government may:

- tax private infrastructure, first best in this example but potentially distortionary in more complex examples
- build public infrastructure early, at $t_H^*(p_p)$

Subsidies

- Assume one type of infrastructure technology and homogenous wealth
- Many types of infrastructure, such as latrines, have positive externalities u_S
- Standard response: Pigouvian subsidy
- Expectation over future rises in subsidy can delay investment
- Suppose subsidy s can only be implemented at time t. As $t \rightarrow$ latest time individual is willing to wait for the subsidy, $\hat{t}(p - s, p)$:
  - Ignoring externality, associated delay in investment will dissipate benefit to individual completely
  - Accounting for externality, subsidy may actually lower welfare
- Consider general case: subsidies $s(t)$, so $p(t) = p - s(t)$

Externalities

- Demand: $t^*(p(t)_{t\geq 0}) = argmax_t \frac{e^{-\rho t}}{\rho} \frac{u_L}{u'(c_0)} - e^{-rt}(p - s(t))$
- Expectations of future increases in s(t) push back t^*
- Socially optimal time: $t^*_S = \frac{1}{\theta g} ln(\frac{u'(c_0)pr}{u_L + u_S})$
- Achievable with subsidies. Lower cost if can commit to a one-off subsidy, or at least a subsidy which is not rising
- The contrasts the static viewpoint, where the subsidy should grow over time because the monetary value of the externality grows over time.
- General point when subsidizing durables: important to consider impact on expectations of future subsidies
- NGOs can make government commitment harder. Government may wish to regulate NGOs subsidies on durables

Conclusion

- Interactions of private investments with public infrastructure may result in a coordination game with multiple equilibria
- Expectations over future public infrastructure are important
- Commitment to future investments in public infrastructure ensures efficient outcome
- Absent commitment, taxes on private infrastructure or early construction of public infrastructure may help
    - Possible factor in China's huge infrastructure push
- Inequality leads to divergence in optimal times for infrastructure installation, making public infrastructure less likely
    - Potential driver of segregation
- For durables with externalities, expectations of future rises in subsidies may reduce welfare