Second-best Congestion Pricing Schemes in the Monocentric City

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Second-best congestion pricing

- Until recently: theoretical curiosity, but standard in practice
  - Cordon charge
  - Pay-lanes
  - Area charging
  - Parking policies
- Recently an upsurge in theoretical work
  - Often partial equilibrium (network) models
  - General equilibrium: labour market (Mayeres-Proost, Parry-Bento)
  - Urban spatial equilibrium models: focus on first-best pricing (second-best capacity); exceptions are Sullivan (1983) and Mun, Kunishi & Yoshikawa (2003)

Mun et al. (2003)

- Monocentric model, spaceless CBD, single radial road, place-dependent per-unit-of-distance (p.u.d.) congestion cost function
  - First-best: space-varying p.u.d. tolls
  - Surprising result: a single cordon (optimal location, 2nd-best optimal toll) yields 94% of first-best gains
  - Despite inherent weaknesses of the policy:
    - No charge for residents inside the corden
    - Charge > mec for residents outside but close to cordon
    - Charge < mec for residents outside cordon close to fringe

This paper...

- Endogenizing land markets
  - rent and urban density
- Endogenizing labour market
  - space-varying endogenous labour supply
- General spatial equilibrium
  - 3-way interactions between congestion, density, labour supply
- Two second-best congestion taxes
  - cordon charge
  - flat km charge

The model (1)

- The city is…
  - one-dimensional (z) of endogenous size (z^*)
  - closed (N)
- The CBD...
  - is spaceless
  - hosts the city's single sector; perfect competition
- Land rents...
  - are endogenous
  - with excess rents (above $z^* \times r_A$) lump-sum redistributed

The model (2)

- Consumers…
  - maximize a utility function with 3 arguments:
    - leisure (T_f)
    - space (s=1/n)
    - industrial goods (y)
  - under a financial gross budget constraint M
    - Specification of M assumes full time working; labour-leisure trade-off is modelled as if leisure is bought against net wage
  - under a time constraint
    - Total time T = leisure (T_f) + work (T_w) + commuting (T_c)
  - commuting time $T_c(z)$ is to be determined

The model (3)

- Travel time
  - $T_c(z) = T_w(z) \times T_t(z)$
  - $T_t(z)$ = Integral of p.u.d. travel times $t(x)$ between CBD (z=0) and residential location (z)
  - $t(x)$, in turn, depends (through congestion) on cumulative labour supply between point x and the urban fringe (z^*)
    - Complicated interactions: labour supply at a certain location depends on travel times, and hence on labour supply at all other locations
    - No analytical solutions

The model (4)

- Producers…
  - exogenous central location in spaceless CBD
  - linear production function with one input
    - labour
  - perfect competition drives profits to zero

The model (5)

- Important equilibrium conditions
  - Balanced budgets for consumers and government; zero-profit for firms; trade balance
  - Utility maximizing consumption of y, s and T_f at each location
  - Resulting utility constant over space
  - Rent at urban fringe equal to agricultural rent

The model (6)

- Equilibrium requires the solution of 19 equations in 19 unkowns, some of which are functions of location (z)
- Numerical approach
  - for Cobb-Douglas and CES utility
  - a linear p.u.d. travel time function
  - normalizations where possible (T, p, r_A; N=1000)
- Calibration: attempt to obtain reasonable key ratios
  - details in paper, but for example:
    - 26.5 hours of labour per 7-day working week
    - maximum travel time of 5 hours (return) per working day
    - equilibrium speed near CBD 20% of free-flow speed
    - financial budget shares: 43% on housing, 57% on other goods

Equilibrium *vs* optimum

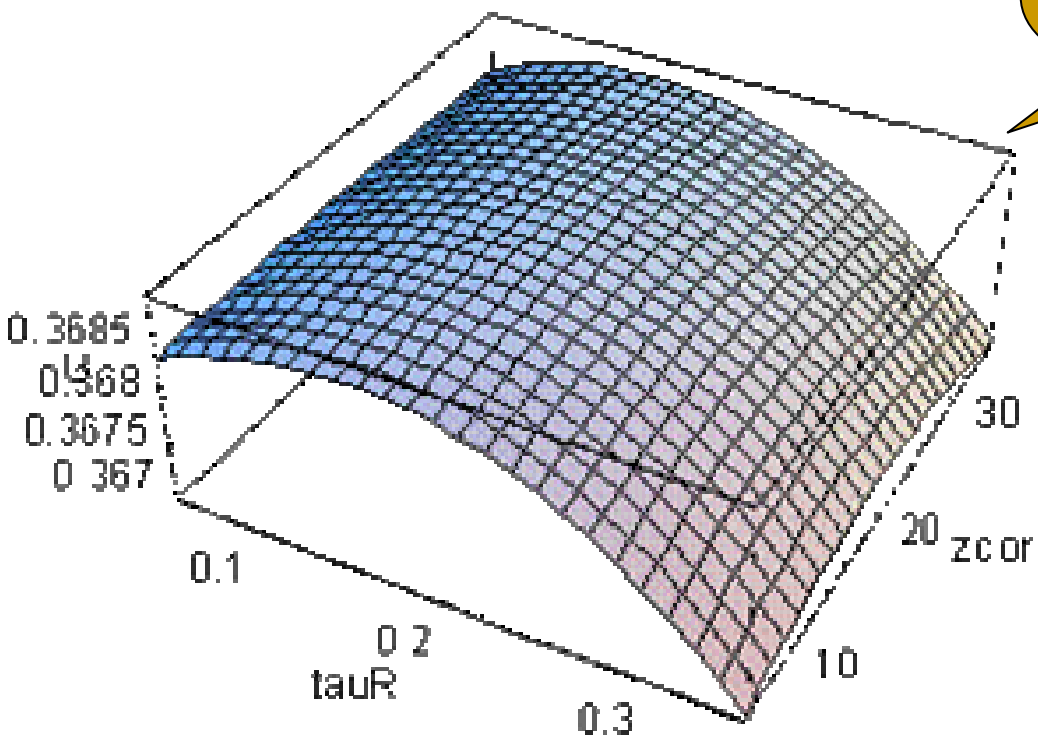
- Congestion entails externality
- Optimum requires
  - Space-varying p.u.d. Pigouvian congestion taxes
  - Lump-sum recycling of the revenues
  - Main effects in numerical model:
    - Aggregate labour supply decreases with 6.6%
    - Average density increases: city size decreases 9.7%
    - Total kilometrage decreases by 16.9%
    - Total time spent commuting decreases by 21.2%
    - Utility increases by equivalent of 0.3% increase of each of the three consumption goods11

Sources of efficiency gains

- Two relevant margins of behaviour
  - Labour supply / employment
  - Space consumption / density
- Relative contribution: hard to disentangle, assessed by introducing inelasticities
  - Urban densities fixed: $\omega = 0.64$
  - Inelastic labour supply: $\omega = 0.48$
    - Not additive
    - Short run: nearly 2/3rds of long-run efficiency gains

Cordon charging

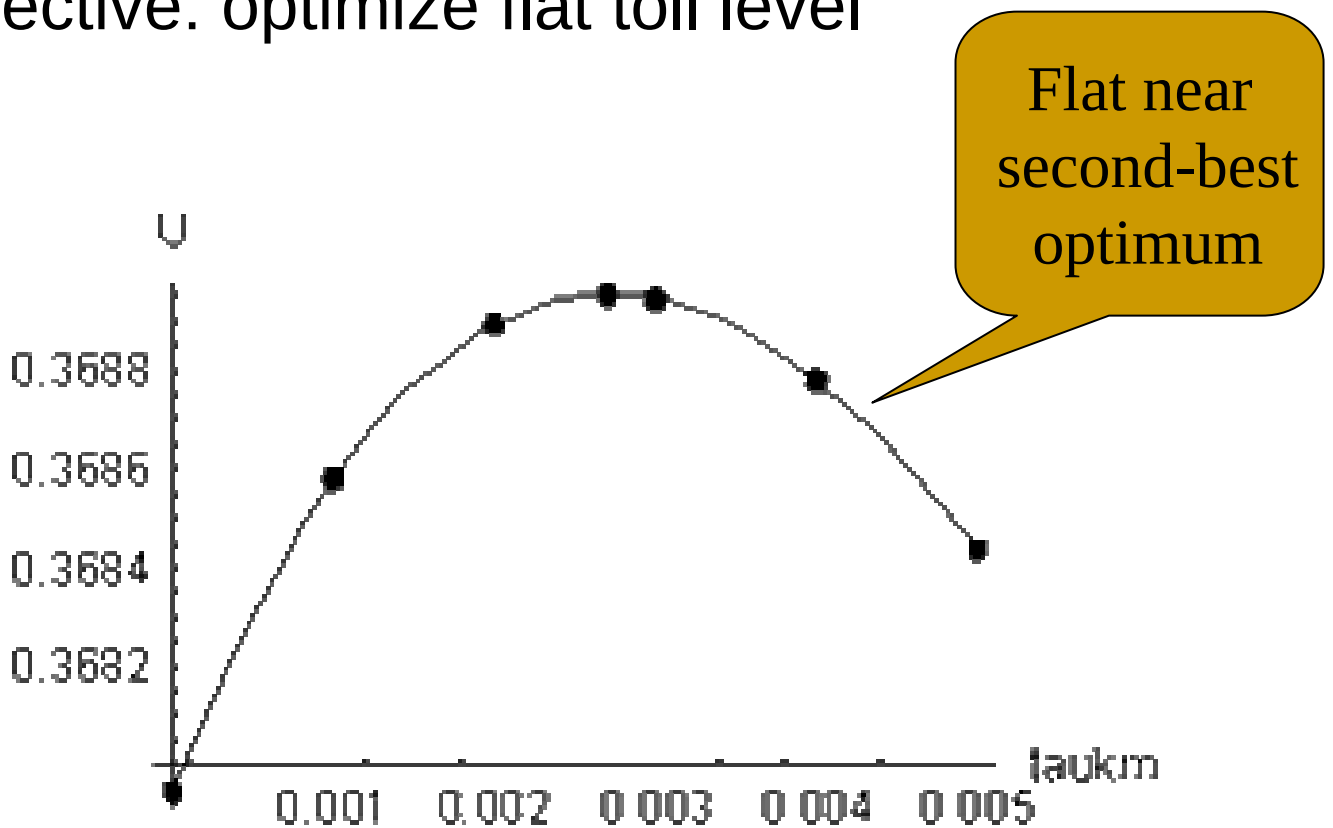
- Objective: optimize location and toll



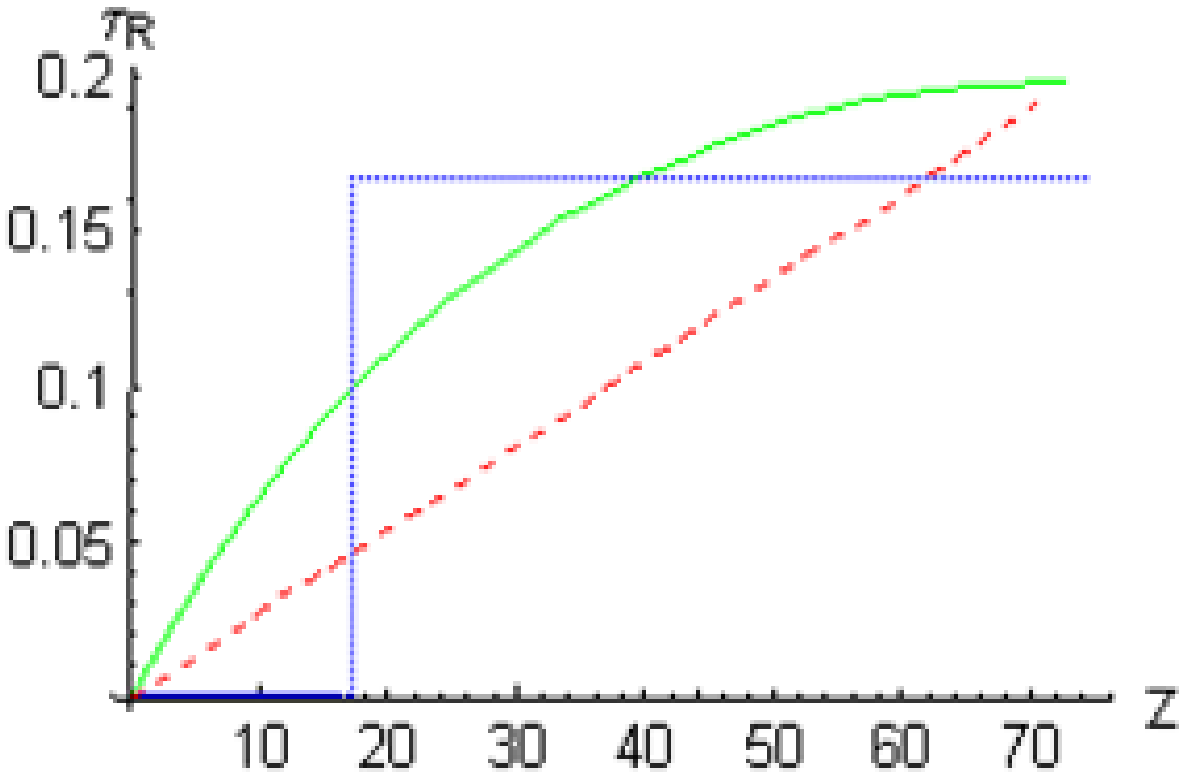
Flat near optimum
More sensitive wrt price than location

Flat km charge

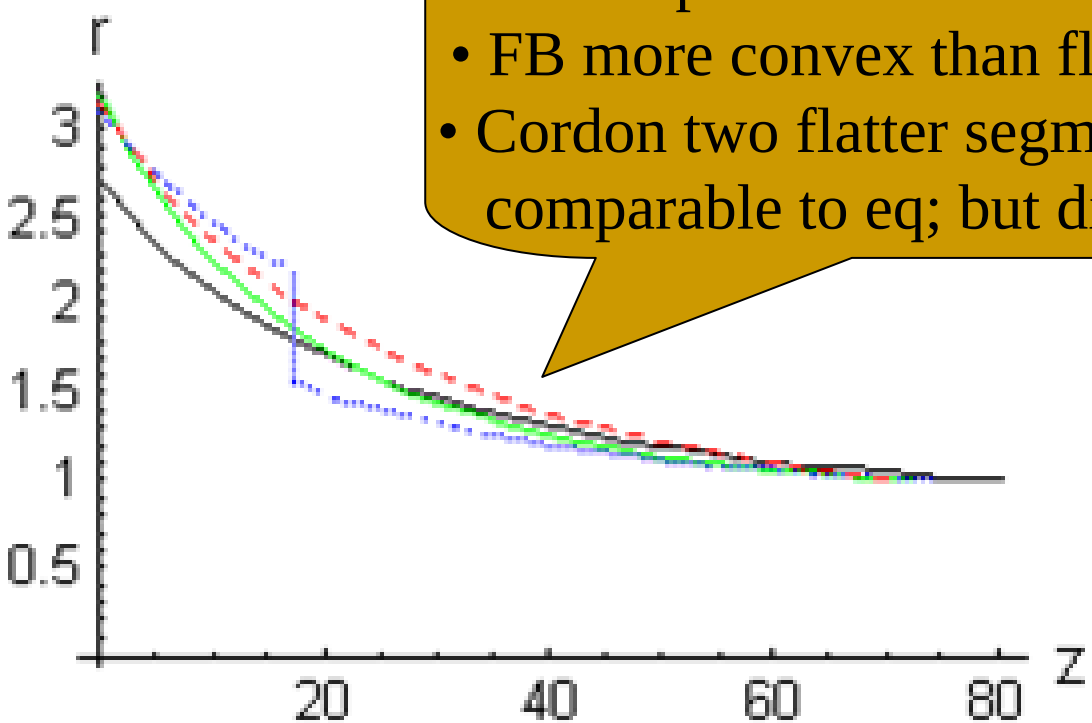
- Objective: optimize flat toll level



Full-trip tolls

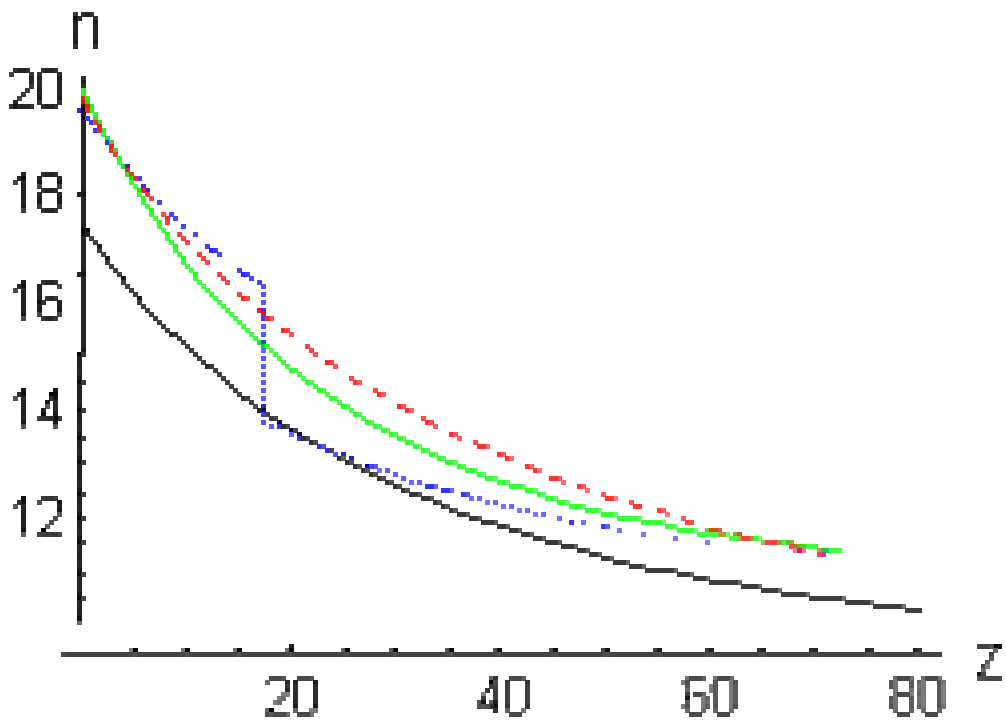


Rents



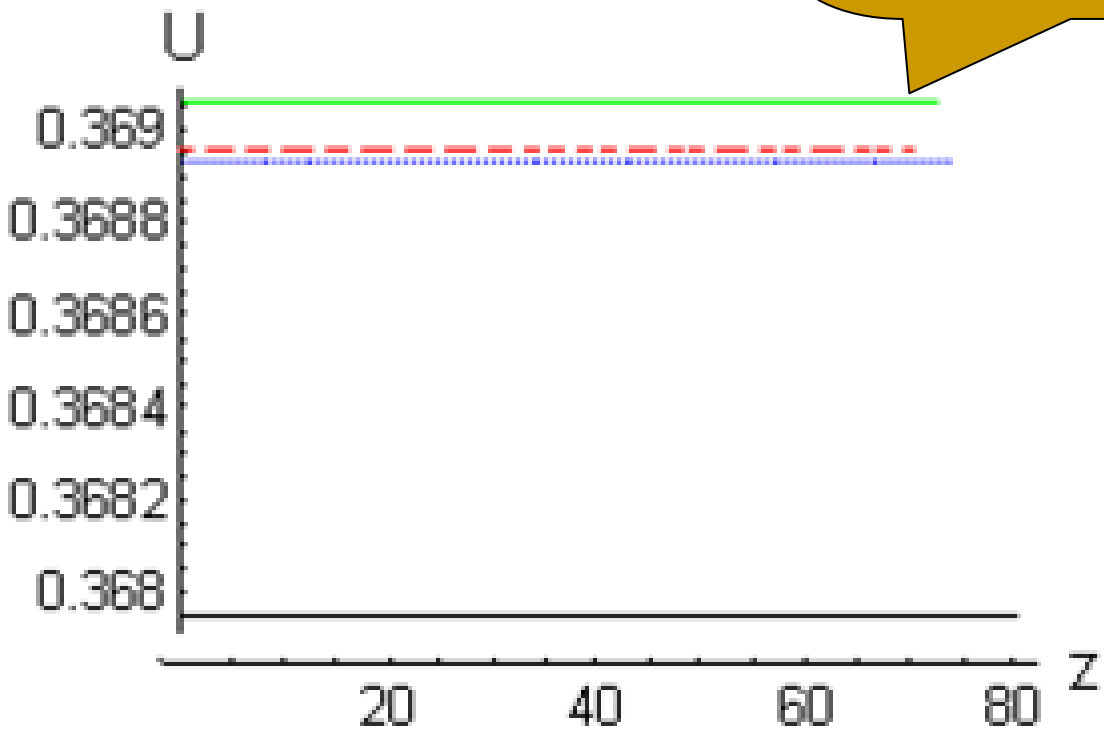
- FB steeper and more convex than eq.
- FB more convex than flat km charge
- Cordon two flatter segments than FB, comparable to eq; but discontinuity

Urban density



Utility

- Constant over space
- FB gains: 0.30%
- ω cordon: 0.880
- ω flat km: 0.899



Comparison with earlier work

- Cordon ω=0.88 close to Mun *et al.* (ω=0.94)
  - Surely, welfare loss have doubled
  - Nevertheless, inefficiencies in urban land and labour markets are apparently relatively small
- Flat km ω=0.90 way above Sullivan (ω=0.30)
  - Main difference appears to be naïve investment rule in Sullivan
  - Local ‘CBA’; ignores ‘network effects’ (i.e. upstream and downstream of point of evaluation)
  - But: effect so large?

CES results

- Elasticity of substitution = 0.5
- Otherwise calibrated to mimic Cobb-Douglas budget shares as closely as possible
- Relative efficiency results are very similar
  - ω cordon = 0.897
  - ω flat km = 0.911
- But relevant curves are typically flatter and less curved (more limited substitution)

Conclusion (1)

- Surprising result of Mun et al survives (to a large extent) when
  - endogenizing urban density and land rents
  - endogenizing labour supply
  - adopting general spatial equilibrium approach
  - for Cobb Douglas and CES utility functions
- Cordon charging causes kinks & imperfections, but:
  - reduces aggregate labour supply
  - increases average density
- Cordon charging is outperformed, but not by much, by flat km charging

Conclusion (2)

- Strong suspicion:
  - Monocentric configuration with spaceless CBD, both imposed exogenously, are ‘responsible’
  - Future work: test endogenous formation of ‘spacious’ agglomerations within urban area
- First priority
  - Explore the impacts of pre-existing distortive labour taxes
  - First result: relative performance of cordon and flat km charging is reversed for sufficiently high labour tax