北航中法工程师学院
Centrale Pékin

CentraleSupélec

SystemX
INSTITUT DE RECHERCHE TECHNOLOGIQUE

AnthroPOLIS
HUMAN CENTERED MOBILITY

Anthropolis Chair and Future Cities Lab

Joint Seminar Series 2021-2022

October 13th, 2021

Photo by Pierre Blanché, 2019 creative commons

Anthropolis Chair and Future Cities Lab Joint Seminar Series 2021-2022

- 14 seminars during this 2nd edition
- Presentations from the Anthropolis Chair, the Future Cities Lab and more
- Full programme available on our website www.chaire-anthropolis.fr
- Subscribe to our mailing list to stay informed about our events
- We are also on twitter: @CAnthropolis
- Stay tuned with the Future Cities Lab : www.futurecitieslab.city

北京航空航天大學 | 经济管理学院
BEIHANG UNIVERSITY | SCHOOL OF ECONOMICS AND MANAGEMENT

Does the labor competition really matter to urban agglomeration development?

Speaker:	Han Wang
Supervisor:	Hai-Jun Huang
Date:	13 October 2021

Contents

- Introduction
- Model
- Numerical example
- Future work

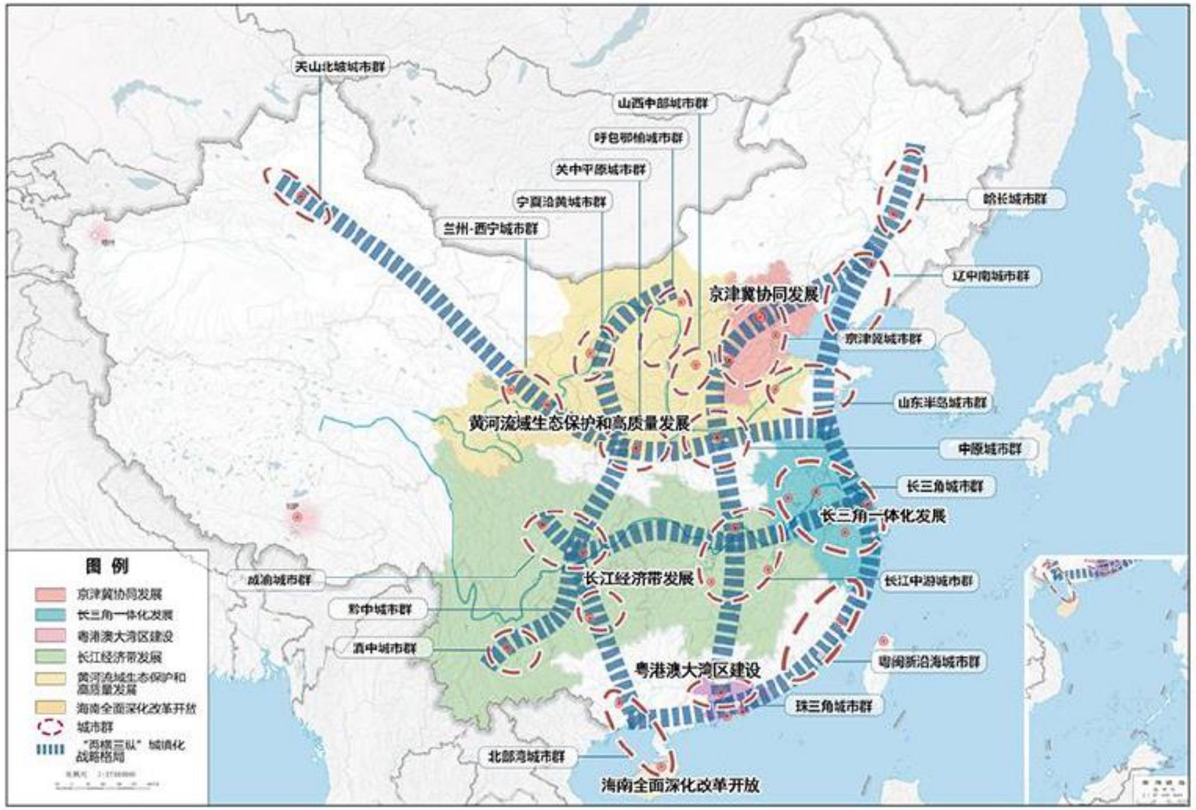
Introduction

Background

- Single city VS urban agglomeration

- Urban agglomeration is expected to:
  - ✓ release the congestion of core city
  - ✓ cooperate with adjacent cities to create larger welfare

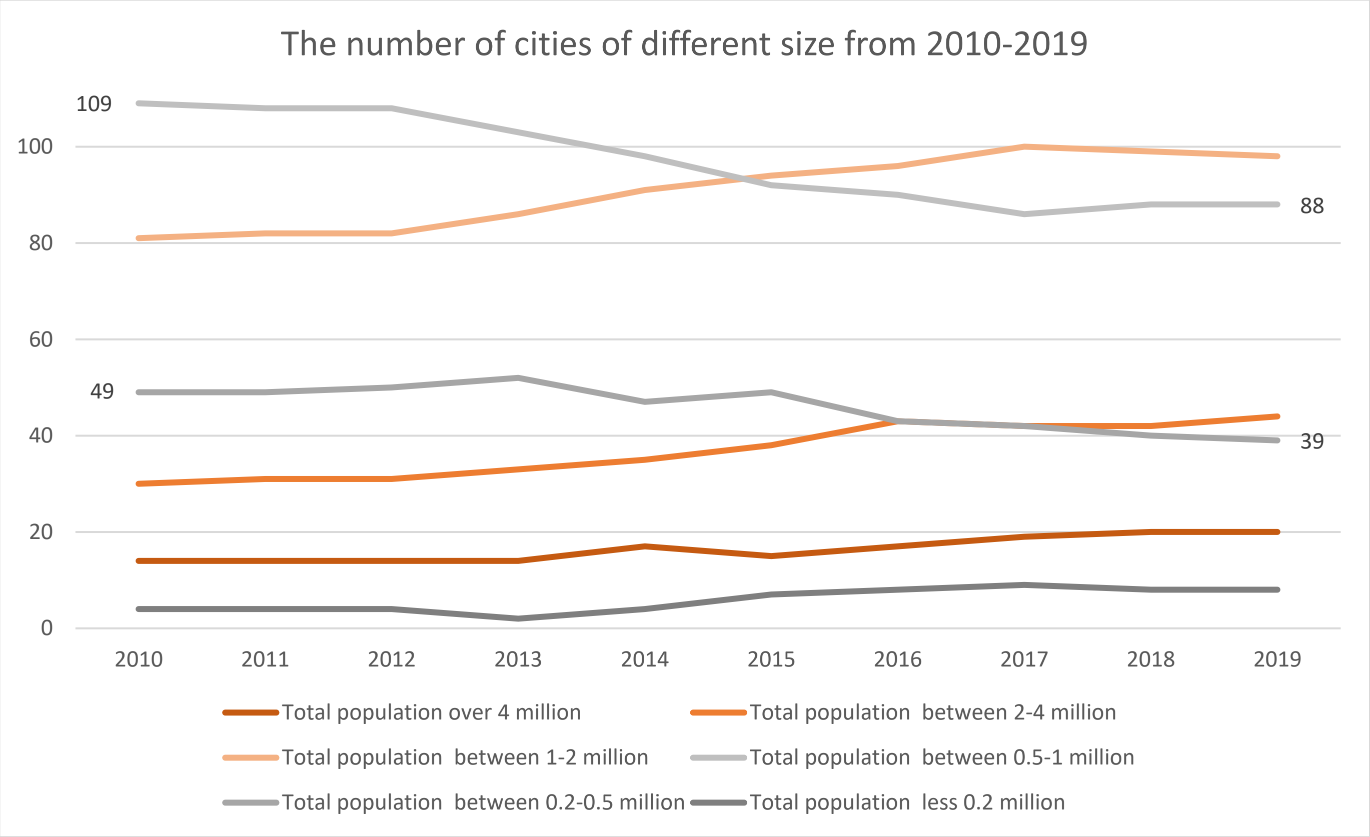
- Cooperation VS Competition



Introduction

Background

- About 300 cities in China
- The number of cities with a population between 0.2 to 1 million declined
- The number of cities with more than 1 million population increased



Introduction

Background

- Demographic dividend
- Unbalanced endowments
- Infrastructure conditions
- Geographic locations
- Aggregation effect

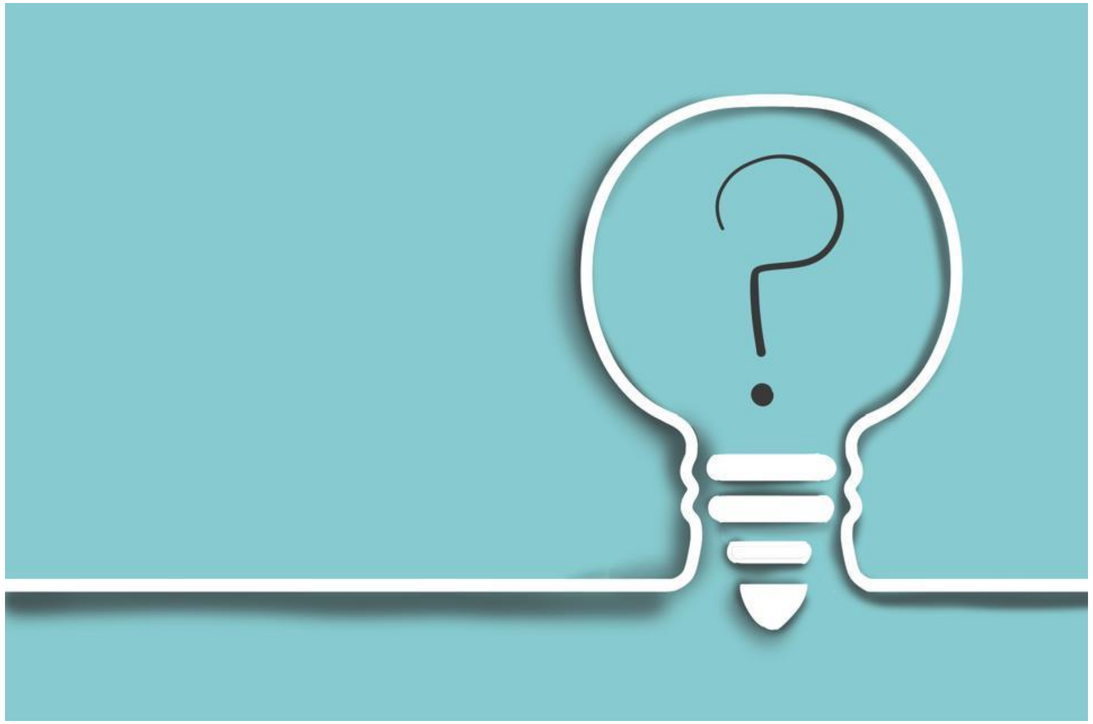
↓

People's working place choice → Labor force competition

Introduction

Questions

- whether social welfare of the small city will be affected?
- Whether the small city is doomed to vanish?
- How will the small and large city react?
- What fiscal instruments from the transportation perspective?
- Subsidy or tolls?
- What policy implications can be obtained for the future development of urban agglomeration in the real world?



Introduction

This work

- ✓ Separate government into local government and central government
- ✓ Endogenous wage
- ✓ Four regimes
- ✓ Algorithm for solving equilibrium household utility and different regimes
- ✓ Social welfare and spatial structure

Model

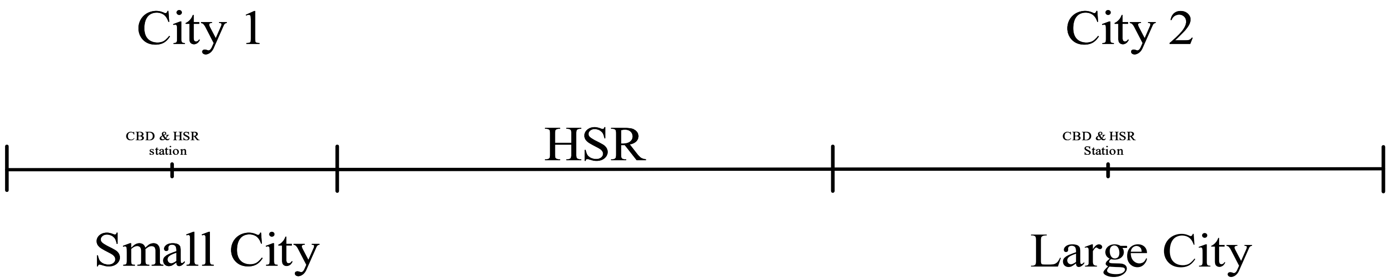
Assumptions

A1:

- A closing two-city system (total population is exogenously given)
- Linear
- Monocentric
- Free migration
- City 1 is the small city, and City 2 is the large city

A2:

- HSR (high-speed rail) station located in CBD
- All jobs in CBD
- HSR is the only traffic mode for intercity commuting
- Auto is the only traffic mode for intracity commuting



Model

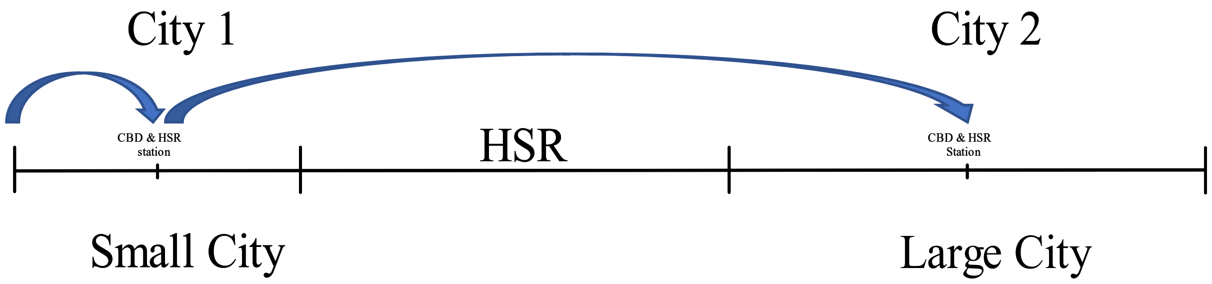
Assumptions

A3:

- Governments, households, property developers
- Governments include one central government and two local governments
- Each government can decide toll and subsidy level and make decisions independently

A4:

- Households are homogenous
- Households follow a Quasi-linear utility function
- Property developers follow a Cobb-Douglas production function
- Intercity commuters have to firstly go to living city's CBD then take HSR to another city's CBD

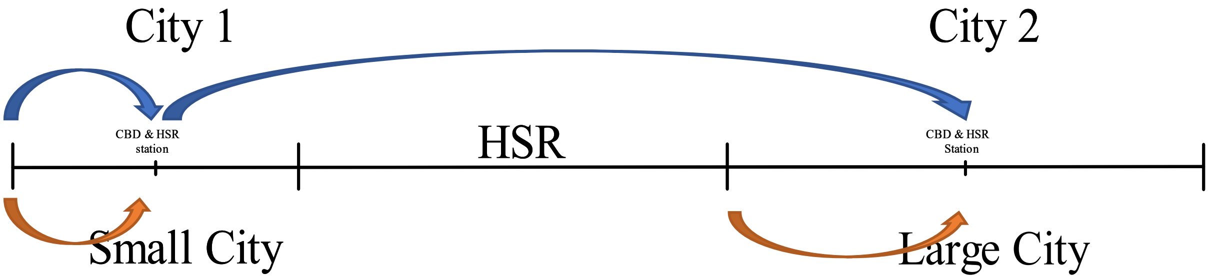


Model

Household location choice equilibrium

- ***The household utility:***

$$\underset{z,\,g}{Max}\quad U_{ij}(x) = \underbrace{Z_{ij}(x)}_{\text{General goods consumptions}} + \underbrace{\alpha \log g_{ij}(x)}_{\text{Housing space}}, \quad x \in [0, B_i], \tag{1}$$



- ***Budget constrain:***

$$s.t.\ \underbrace{Z_{ij} + R_{ij}(x) g_{ij}(x)}_{\text{Total consumptions}} = \underbrace{(1-\tau_{Y0}-\tau_{Yj})Y_j}_{\text{Wage}} - \underbrace{2\rho\varphi_{ij}(x)}_{\text{Travel costs}} + \underbrace{\mathbf{\Omega} + \boldsymbol{\tau}}_{\text{Subsidies \& Tolls}}, \tag{2}$$

- By combining equation (1) and (2) and first-order optimality condition, we can obtain endogenous: rental price $R_{ij}(x)$, housing space $g_{ij}(x)$ and goods consumptions $Z_{ij}(x)$

Model

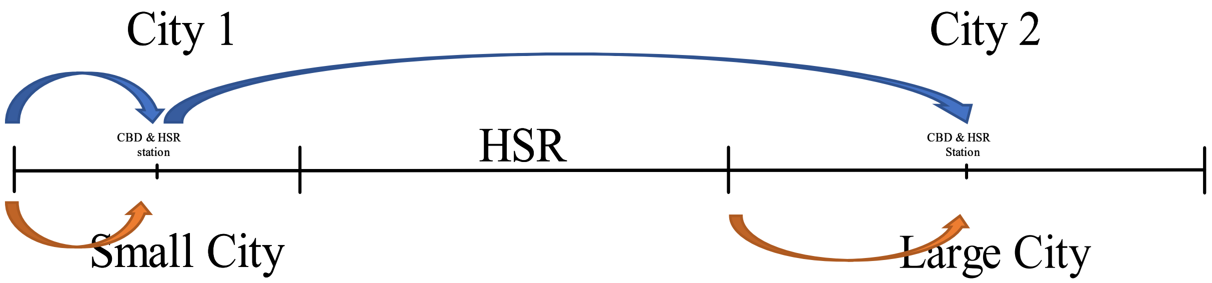
Household location choice equilibrium

- ***Endogenous wage:***

$$\underbrace{Y_i = \overbrace{A_i}^{\text{Total factor productivity}} \overbrace{N_i}^{\text{Labor force population}}}^{\beta}{}^{\overbrace{\beta}^{\text{Aggregation factor}}}, \qquad (3)$$

- ***Travel costs:***

$$\varphi_{ij}(x) = \begin{cases} \underline{(\overbrace{\frac{\lambda_j}{V_a}}^{\text{Time costs}} + \overbrace{\tau_0}^{\text{Direct costs}})x} & i = j \\ \underbrace{(\frac{\lambda_j}{V_a} + \tau_0)x}_{\text{Intracity travel costs}} + \underbrace{\frac{\lambda_j L_H}{V_H} + F_H}_{\text{HSR travel costs}} & i \neq j \end{cases} \quad x \in [0, B_i], \qquad (4)$$

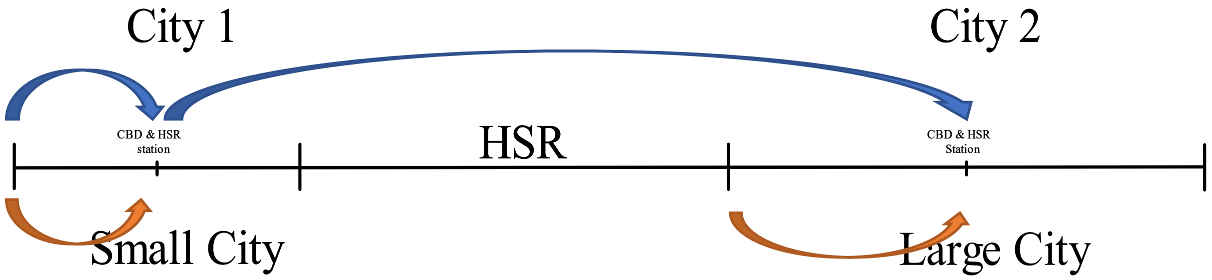


Model

Housing market equilibrium

- ***The property developers' production:***

$$\Lambda_i(\xi_i(x)) = \mu(\underbrace{\xi_i(x)}_{\text{Capital investment intensity}})^{\theta} \quad \mu,\theta \in (0,1), \quad i = 1,2, \qquad (5)$$



- ***The profits of property developers:***

$$\max_{\xi_i} \eta_i(x) = \underbrace{R_i(x)\Lambda_i((\xi_i(x))}_{\text{Profits}} - \underbrace{(r_i(x) + k\xi_i(x))}_{\text{Costs}}, \quad i = 1,2, \qquad (6)$$

- By combining the equation (5) and (6), we can obtain endogenous land value $r_i(x)$

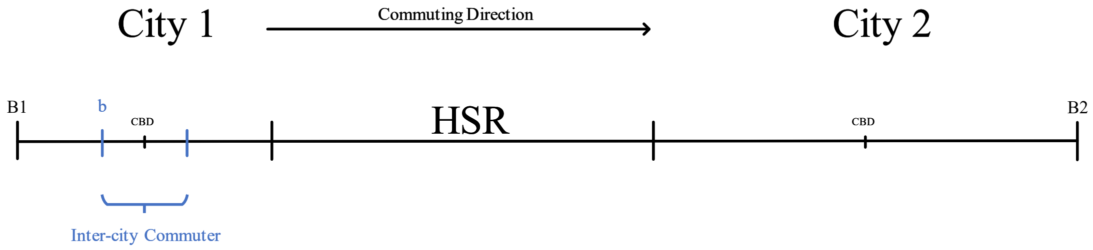
Model

Remark 1

We assume two cities are linear, and all households are homogenous before. Therefore, it has only one watershed line between intercity and intracity commuters (if intercity commuting happens), rather than the multi-layer structure.

- ***The housing supply:***

$$\Lambda_i(\xi_i(x)) = \sum_i g_{ij}(x)n_{ij}(x), \tag{7}$$



- By combining the previous equations we can obtain the endogenous residential density $n_{ij}(x)$

Remark 2

There only exists unidirectional intercity commuting that is from the small city to large city. If there have people who living in the large city but working in small city, they have to pay extra intercity travel costs than intracity commuters. Apparently, working locally is a better choice for large city’s commuters, and they will not choose to intercity commuting to the small city.

Model

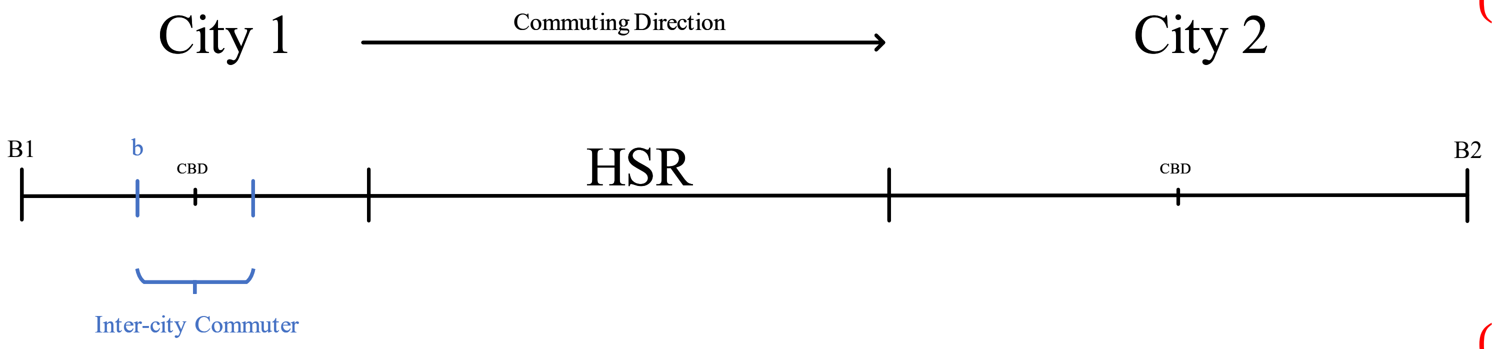
Housing market equilibrium

- ***The land value/opportunity cost constrains:***

$$r_1(B_1) = R_A, \quad (8)$$

← Agriculture land value

$$r_2(B_2) = R_A, \quad (9)$$



- ***The population constrains:***

$$2\int_0^{B_1} n_1(x)dx = N_1, \quad (10)$$

$$2\int_0^{B_2} n_2(x)dx = N_2, \quad (11)$$

$$N_1 + N_2 = N, \quad (12)$$

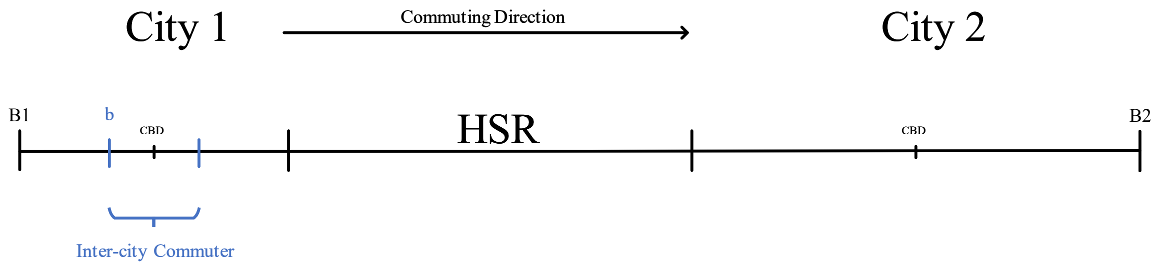
Model

Proposition 1

The intercity commuting only happens when following conditions are satisfied.

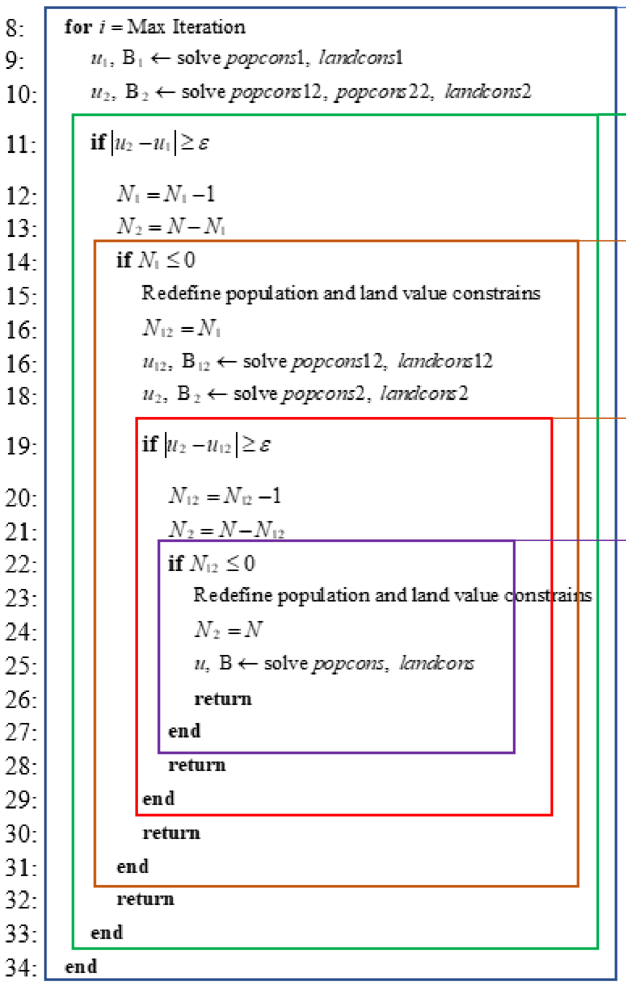
$$R_{11}(b) = R_{12}(b), \tag{13}$$

$$b = \frac{\overbrace{(1-\tau_{Y0}-\tau_{Y2})A_2 N_2{}^{\beta} - (1-\tau_{Y0}-\tau_{Y1})A_1 N_1{}^{\beta}}^{\text{Wage difference}} - \overbrace{2\rho(\frac{\lambda_2 L_H}{V_H} + F_H) + \boldsymbol{\Omega} + \boldsymbol{\tau}}^{\text{HSR costs, tolls and subsidies}}}{2\rho(\frac{\lambda_2 - \lambda_1}{V_a})} > 0, \tag{14}$$



Model

Algorithm for solving equilibrium utility



```
for $i = $ Max Iteration
    $u_1$, $B_1$ ← solve $popcons1$, $landcons1$
    $u_2$, $B_2$ ← solve $popcons12$, $popcons22$, $landcons2$
    if $|u_2 - u_1| \ge \varepsilon$
        $N_1 = N_1 - 1$
        $N_2 = N - N_1$
        if $N_1 \le 0$
            Redefine population and land value constrains
            $N_{12} = N_1$
            $u_{12}$, $B_{12}$ ← solve $popcons12$, $landcons12$
            $u_2$, $B_2$ ← solve $popcons2$, $landcons2$
            if $|u_2 - u_{12}| \ge \varepsilon$
                $N_{12} = N_{12} - 1$
                $N_2 = N - N_{12}$
                if $N_{12} \le 0$
                    Redefine population and land value constrains
                    $N_2 = N$
                    $u$, B ← solve $popcons$, $landcons$
                    return
                end
                return
            end
            return
        end
        return
    end
end
```

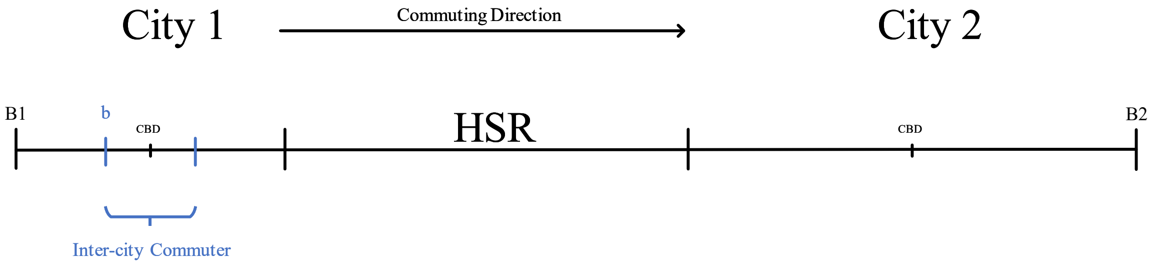
If the intercity commuting happen

If the equilibrium has been reached

If the all households of City 1 are intercity commuter

If the equilibrium has been reached

If all household both working and living in City 2



Model

Governments' objective

- ***Local government's objective is maximizing their fiscal revenues. If it involves the tolls and subsidies, we assume the intercity commuters will be charged by the small city, and be subsidized by the large city.***

- ***For City 1:***

$$ANLV = \int r(x) - R_A dx$$

$$\underset{\tau_{12}}{Max} \quad \pi_1 = \tau_{Y1} Y_1 N_1 + (1 - \tau_{L0}) ALV_1 + \tau_{12} N_{12}, \qquad (15)$$

Tax from wage

Aggregate land value

Tolls from intercity commuters

- ***For City 2:***

$$\underset{\Omega_2}{Max} \quad \pi_2 = \tau_{Y2} Y_2 N_2 + (1 - \tau_{L0}) ALV_2 - \Omega_2, \qquad (16)$$

Tax from wage

Aggregate land value

Subsidies to intercity commuters

Model

Governments' objective

- ***Central government's objective is maximizing total social welfare.***

- ***For central government:***

All households' utility

$$\underset{\Omega_0}{Max}\ SW = Nu$$

$$\underline{+\tau_{Y0}\sum_j Y_j N_j + \tau_{L0}\sum_i ALV_i + 2\rho F_H \int_0^b n_{12}(x)dx - \Omega_0} \qquad (17)$$

$$\underline{+\pi_1 + \pi_2},$$

Fiscal revenue of two local governments

Fiscal revenue of central government:
- Tax from wages
- Tax from aggregate land values
- Ticket price of HSR
- Subsidies

Model

Regimes

	No Local Government Game	Have Local Government Game
No Central Government Supervision	Regime 1 $\Omega_0 = 0, \ \Omega_2 = 0$ $\tau_{12} = 0$	Regime 2 $\Omega_0 = 0, \ \Omega_2 \neq 0$ $\tau_{12} \neq 0$
Have Central Government Supervision	Regime 3 $\Omega_0 \neq 0, \ \Omega_2 = 0$ $\tau_{12} = 0$	Regime 4 $\Omega_0 \neq 0, \ \Omega_2 \neq 0$ $\tau_{12} \neq 0$

Model

Regimes 1

- Regime 1 only focuses on the evolution of intercity commuting and migration without government intervention, and no tolls or subsidies are implemented.

Regimes 2

- Comparing to Regime 1, Regime 2 assumes that two local governments could compete for the labor force freely by implementing their own tolls and subsidies policy.

- In regime 2, we use thoughts of the *Stackerberg game model* to depict the labor force competition between local governments.

  1. Firstly, City 1 optimizes the toll level based on the results of Regime 1.
  2. City 2 knows the City 1’s toll level and optimizes the subsidy level based on the results of the last step.
  3. City 1 knows City 2’s reaction strategy (subsidy), and City 1 make decisions finally.

Model

Regimes 3

- Comparing to Regime 2, Regime 3 only considers the central government behaviour.
- Induce UE to SO

Regimes 4

- Most complicated one
- Considering both central government and local governments' strategy.
- Each step in Regime 2 can be transferred to three-level programming model.

Numerical example

Parameter calibration

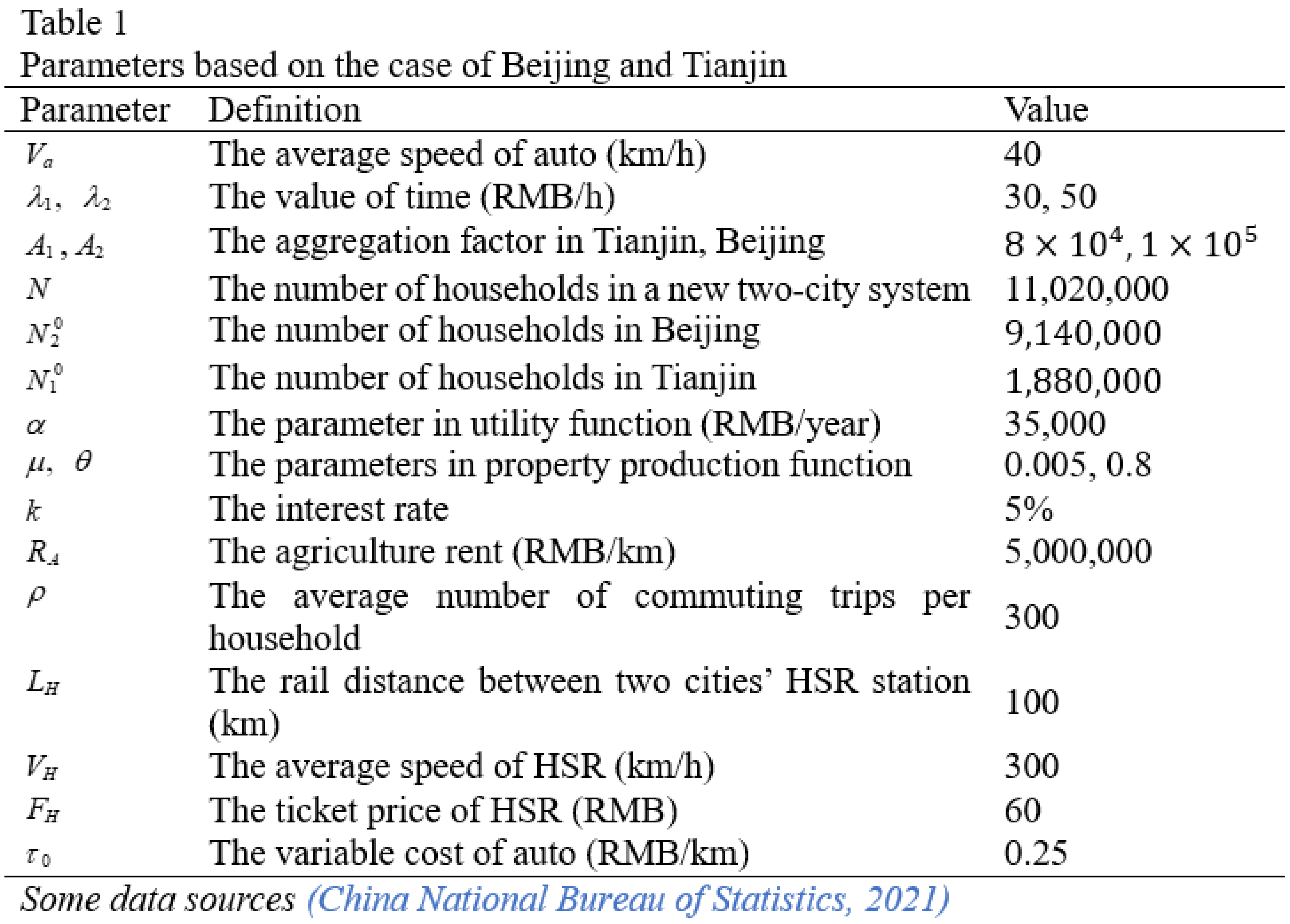


Table 1

Parameters based on the case of Beijing and Tianjin

Parameter	Definition	Value
V_a	The average speed of auto (km/h)	40
λ_1, λ_2	The value of time (RMB/h)	30, 50
A_1, A_2	The aggregation factor in Tianjin, Beijing	$8 \times 10^4, 1 \times 10^5$
N	The number of households in a new two-city system	11,020,000
N_2^0	The number of households in Beijing	9,140,000
N_1^0	The number of households in Tianjin	1,880,000
α	The parameter in utility function (RMB/year)	35,000
μ, θ	The parameters in property production function	0.005, 0.8
k	The interest rate	5%
R_A	The agriculture rent (RMB/km)	5,000,000
ρ	The average number of commuting trips per household	300
L_H	The rail distance between two cities' HSR station (km)	100
V_H	The average speed of HSR (km/h)	300
F_H	The ticket price of HSR (RMB)	60
τ_0	The variable cost of auto (RMB/km)	0.25

Some data sources (China National Bureau of Statistics, 2021)

Numerical example

Results

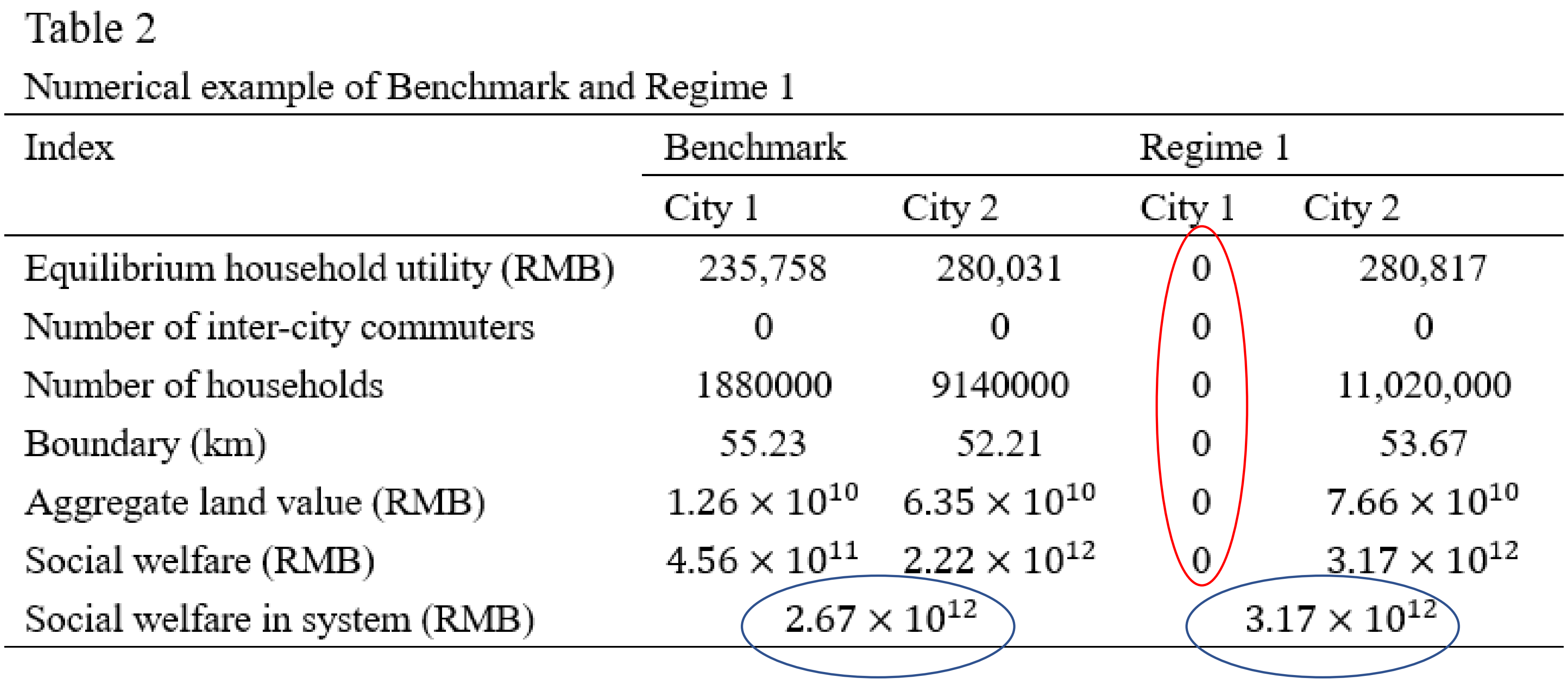


Table 2

Numerical example of Benchmark and Regime 1

Index	Benchmark		Regime 1	
	City 1	City 2	City 1	City 2
Equilibrium household utility (RMB)	235,758	280,031	0	280,817
Number of inter-city commuters	0	0	0	0
Number of households	1880000	9140000	0	11,020,000
Boundary (km)	55.23	52.21	0	53.67
Aggregate land value (RMB)	1.26×10^{10}	6.35×10^{10}	0	7.66×10^{10}
Social welfare (RMB)	4.56×10^{11}	2.22×10^{12}	0	3.17×10^{12}
Social welfare in system (RMB)	2.67×10^{12}		3.17×10^{12}	

Future work

Next…

- Model & parameters modification
- Conduct comparative static analysis
- Conduct sensitive analysis
- Design the bi-level and three-level programming algorithm for Regime 2 & 4

Thanks

Next Seminar

MASS-GT AND MULTIAGENT FREIGHT MODELING

Michiel DE BOK, Researcher, TU Delft

WEDNESDAY, November 10th, 2021 | 10-11 AM CEST

Link to the seminar