Analysis of Business Model of Co-Creation Digital-Twin City Using Evolutionary Game

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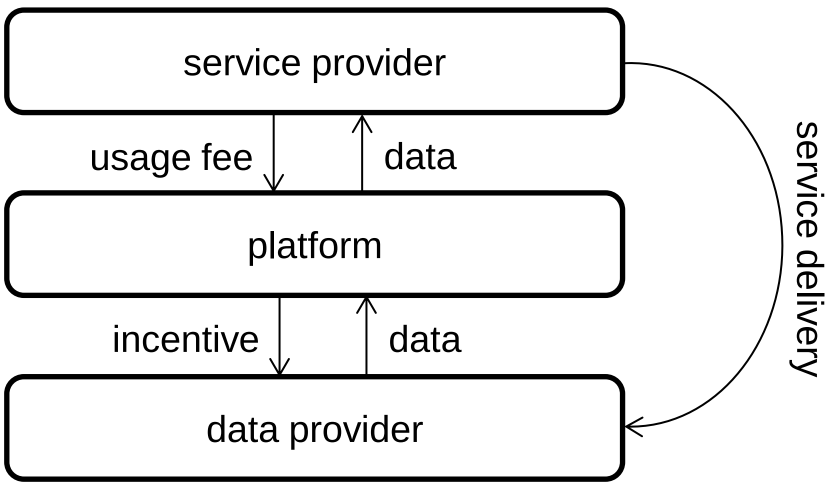
Background(1/2)

- Digital twin
  - Concept proposed by Michael Greaves of the University of Michigan in 2002
  - Providing many kinds of real world data in cyberspace
  - Predicting various phenomena that occur in the real world
  - Mechanism that enables monitoring and simulation by constructing a twin in digital space that is a counterpart of the real world.

Background(2/2)

- Co-creation digital twin city
  - Digital twin collects data from “city residents”
  - Predicting the future state and conditions of the society in which people live
  - QoS (Quality of Service) of a city can be upgraded and the quality of life of city residents can be improved
    - disaster prevention, urban planning, mobility, energy, nature, wellness, education, work styles, and industry



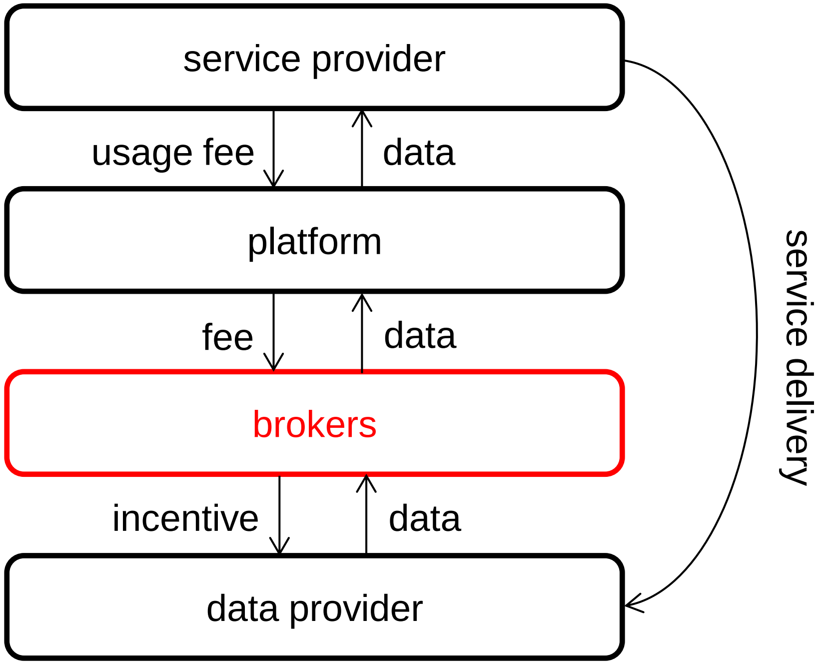
Traditional Co-creation digital twin city

Purpose

- Issue: Co-creation digital twin city is not yet realized
- Goal: establishing a mechanism for realizing a healthy market
- Purpose of the presentation
  - Modeling broker incentives for Co-creation digital twin city
  - Analyzing broker market dynamics using evolutionary games

Broker

- By using a broker(intermediary), different pricing plans can be offered to data providers
  - The variety of brokers allows us to collect a wide range of data
  - The platform does not need to do the work of collecting data
- Conducting an analysis of the broker

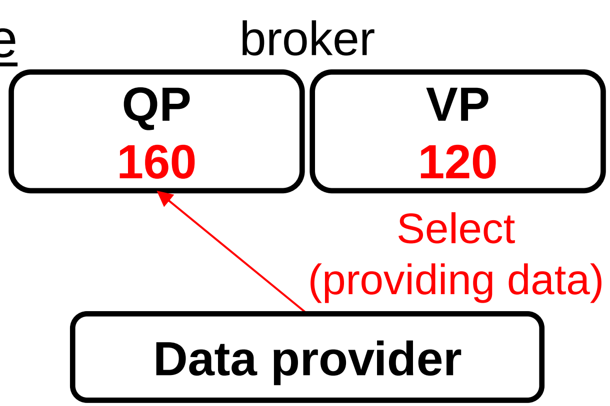


Co-creation digital twin city in this paper

Two pricing plans

- Data is evaluated by brokers on two dimensions: quality q and volume v
- α: the weight is on q(the weight for v is $1-\alpha$)
- Quality Prioritize vs Volume Prioritize
  - QP : heavy weight on $q(\alpha_{\mathrm{QP}} > 0.5)$
  - VP : heavy weight on $v(\alpha_{\mathrm{VP}} < 0.5)$
- Data providers compare the QP and VP amounts and select the broker with the bigger amount
- fee : $p(s,i) = \alpha_s\, q_i + (1-\alpha_s)\, v_i$

example



weight

$\alpha_{\mathrm{QP}} = 0.6,\quad 1-\alpha_{\mathrm{QP}} = 0.4$

$\alpha_{\mathrm{VP}} = 0.2,\quad 1-\alpha_{\mathrm{VP}} = 0.8$

$q = 200,\quad v = 100$

Amount offered by QP

$160 = 0.6 \times 200 + 0.4 \times 100$

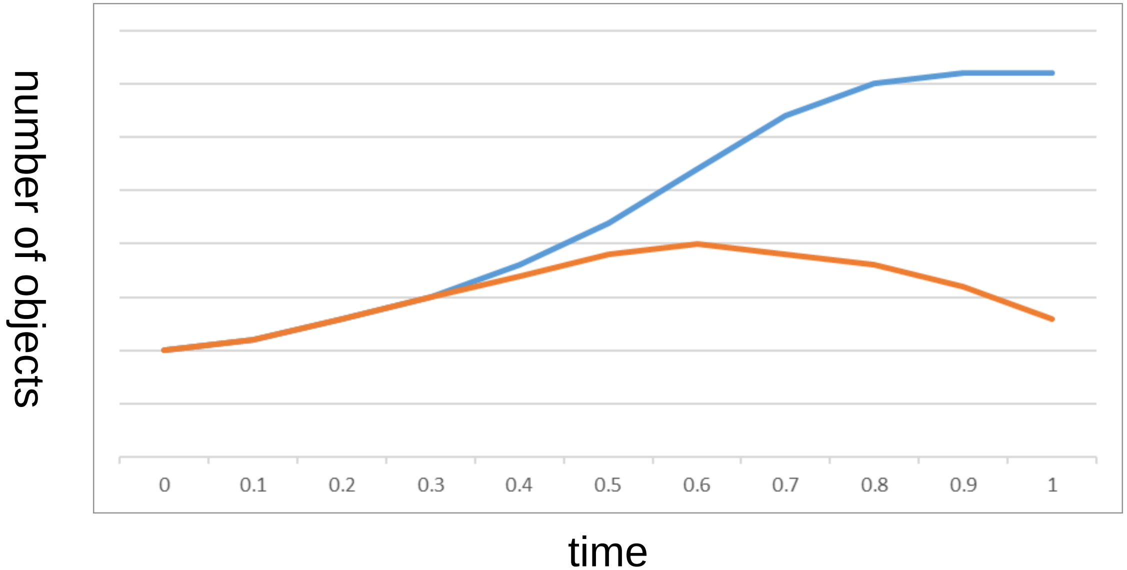
Amount offered by VP

$120 = 0.2 \times 200 + 0.8 \times 100$

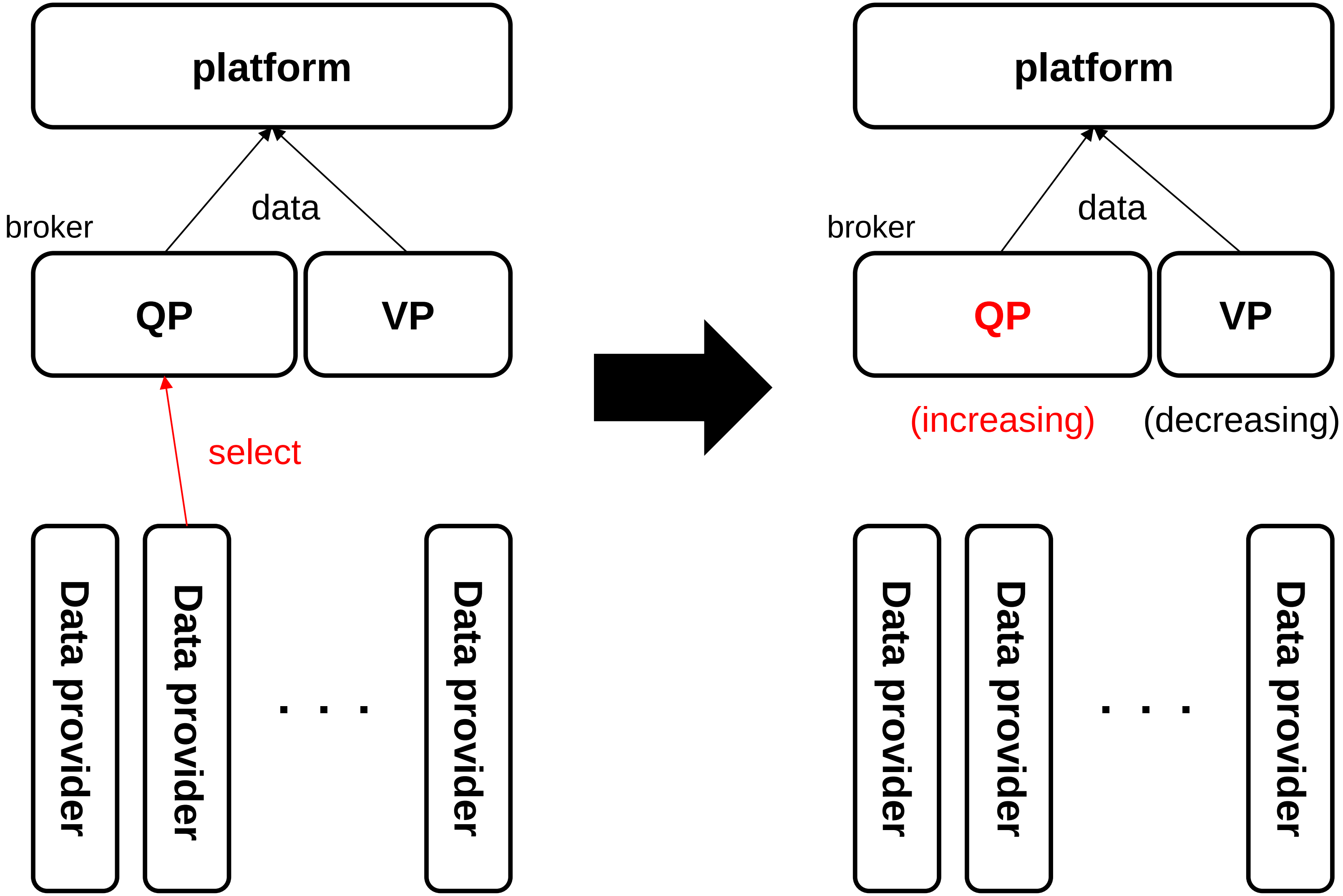
Evolutionary game theory

- Game theory
  - A theory that analyzes "situations in which one acts while anticipating the other person's behavior"
- Evolutionary game theory
  - It is possible to analyze the change in the number of configurations of each group over time

Example of changes in the number of objects using an evolutionary game

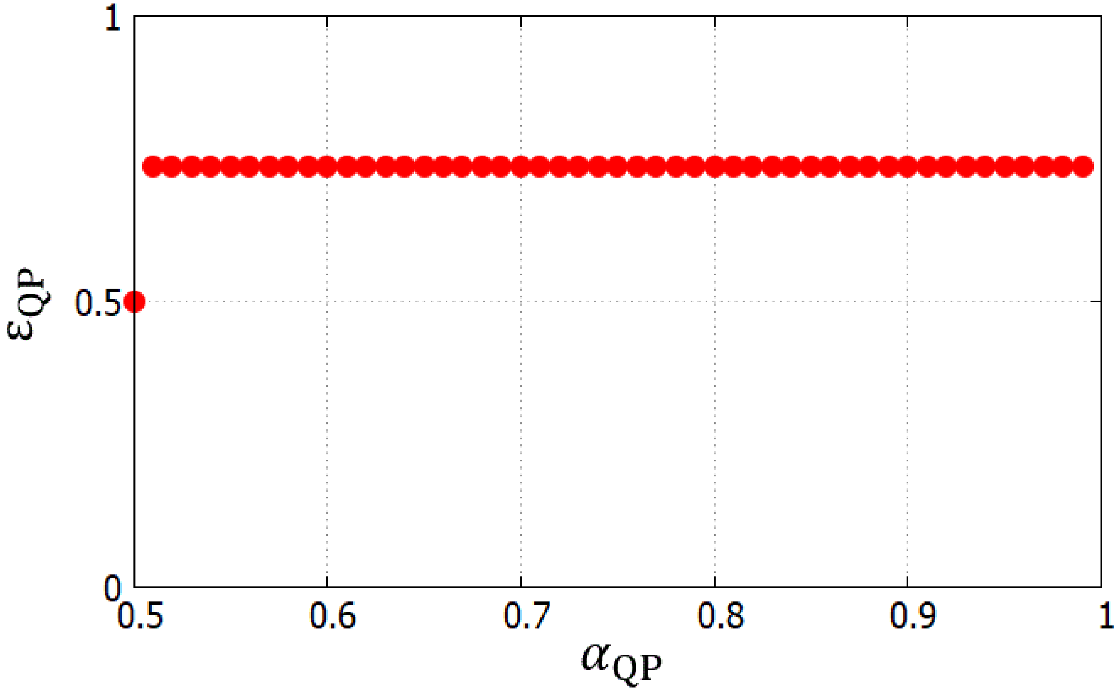


How to use evolutionary game theory



Selection probability $\varepsilon_{\mathrm{QP}}$

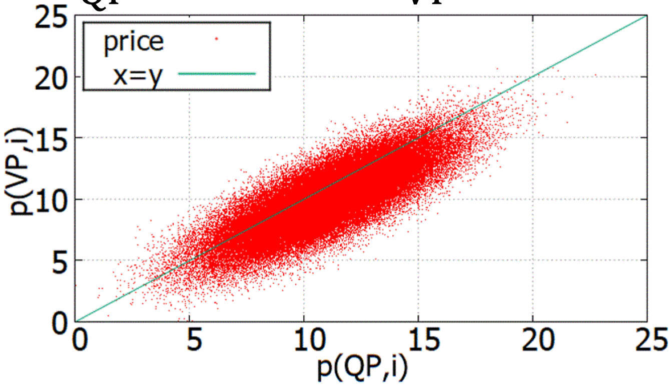
- $\varepsilon_{\mathrm{QP}}$: The selection probability of QP when the weight of QP is α_{QP}
- For convenience, $\alpha_{\mathrm{VP}} = 1 - \alpha_{\mathrm{QP}}$
- When α_{QP} = 0.5, $\varepsilon_{\mathrm{QP}}$ = approximately 0.5
- When 0.5< α_{QP} <1, ε_QP is approximately 0.7



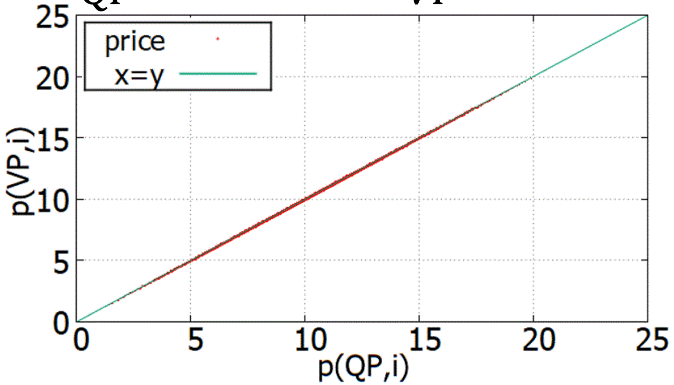
Amount distribution

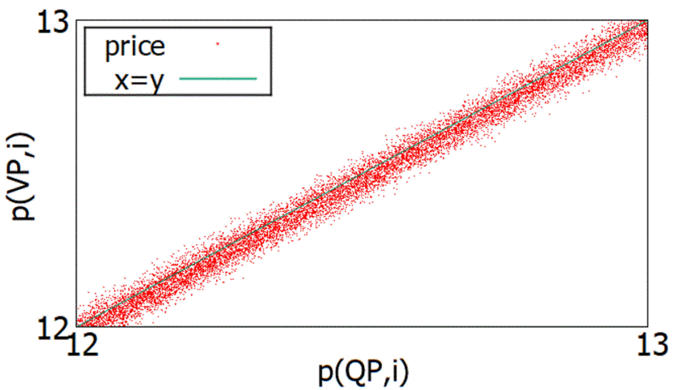
- Amount distribution of each data provider's rate plan(100,000 people)
- If point is below $x = y$, you select QP
- If point is higher than $x = y$, you select VP

$\alpha_{\mathrm{QP}} = 0.99, \quad \alpha_{\mathrm{VP}} = 0.01$



$\alpha_{\mathrm{QP}} = 0.51, \quad \alpha_{\mathrm{VP}} = 0.49$





Procedures for evolutionary game adaptation

- Simulation
  1. Calculate the probability $\varepsilon_{\mathrm{QP}}$ that the strategy will be selected
  2. Calculate the number of brokers (m_1, m_2) for each step
     1. Calculate the expected value of profit π
        - Calculated from selection probability $\varepsilon_{\mathrm{QP}}$, revenue r, number of brokers (m_1, m_2), etc.
     2. Determine broker increase/decrease rate
        - Use gain function $\varphi(\pi)$
  3. Plot the change in the number of brokers (m_1, m_2)

Parameters used for evaluation

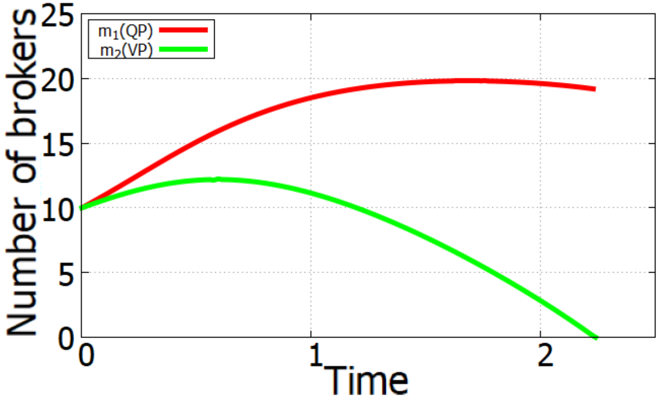
- Assuming a large city, $W = 100{,}000$
- Data quality and volume follow normal distribution
- μ_q(Average of quality) > μ_v(Average of volume)
  - Assuming that QP will be advantageous
  - Assuming that there is a difference in the value of data quality and volume

variable	value	variable	value	variable	value
W	100,000	$x_1^{(0)}$	10	$x_2^{(0)}$	10
ρ	0.8	μ_q	11	σ_q	2.5
r	15	μ_v	10	σ_v	2.5
X	5000	z	10000	L	1

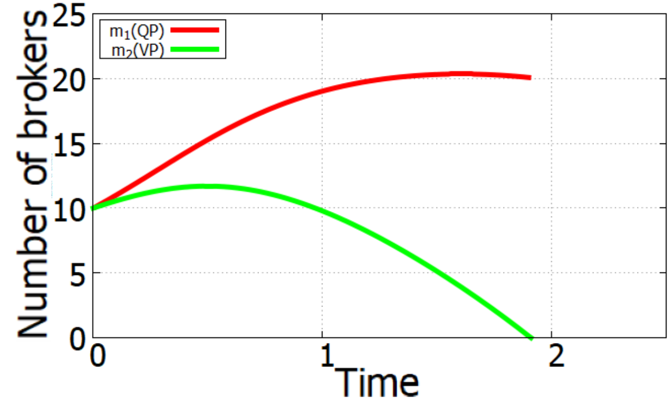
Change in number of brokers when weight changes(1/2)

- The advantage of the broker is determined by the difference in profits.

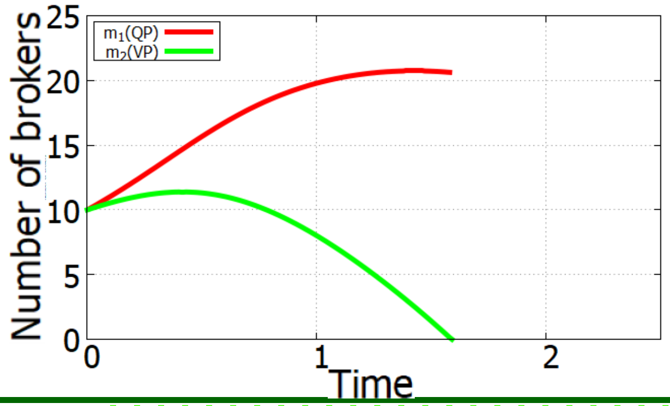
$\alpha_{\mathrm{QP}} = 0.99$, $\alpha_{\mathrm{VP}} = 0.49$
(profit of VP - profit of QP = approx. 0.8)



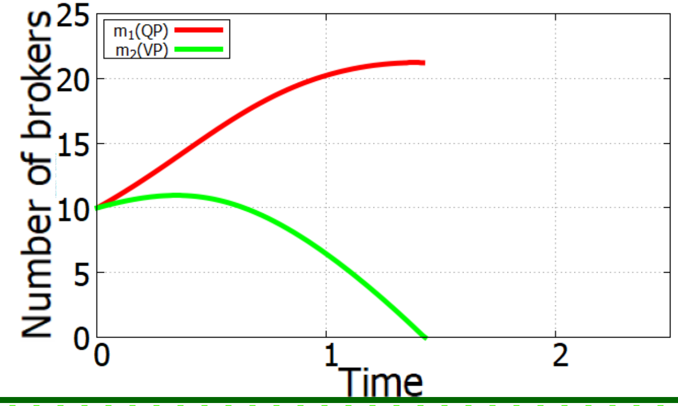
$\alpha_{\mathrm{QP}} = 0.99$, $\alpha_{\mathrm{VP}} = 0.01$
(profit of VP - profit of QP = approx. 0.3)



$\alpha_{\mathrm{QP}} = 0.51$, $\alpha_{\mathrm{VP}} = 0.49$
(profit of VP - profit of QP = approx. 0.0)



$\alpha_{\mathrm{QP}} = 0.51$, $\alpha_{\mathrm{VP}} = 0.01$
(profit of VP - profit of QP = - approx. 0.5)



Change in number of brokers when weight changes(2/2)

- It is desirable to have multiple types of brokers in the market
  - For stable co-creation city digital twin operation
- Since it is desirable for advantageous brokers to occupy the market themselves, they are motivated to reduce the weight
  - We need a mechanism to incentivize favorable brokers to increase their weight

Summary/Future plan

- Summary
  - Modeling Co-creation digital twin city broker incentive method
  - Analyzing broker dynamics using evolutionary games
- Future plan
  - In addition to the two elements of data attributes, quality and volume, make the data elements more detailed by adding other elements and subdividing the quality
  - Running simulation by changing parameter values