

Distributed Cloud Market: Who Benefits from Specification Flexibilities?

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Motivation

- 30% CAGR cloud 2013-2018
→ Plethora of cloud providers



Google Cloud Platform



Motivation

- Customer specifications?



Motivation

- Customer specifications?

Urgent!



CUSTOMERS



Cheap!

Motivation

- Presence of resource broker?



Let me handle that for you.



Urgent!

Cheap!

CUSTOMERS

Motivation

- Presence of resource broker?

salesforce



Amazon
Services™

1. Who benefits from specification flexibilities?
2. How does a broker fit into the system?

leap!



CUSTOMERS

Overview

- 1) Horizontal market
- 2) Vertical market (broker)
- 3) Resource buying strategies

Model

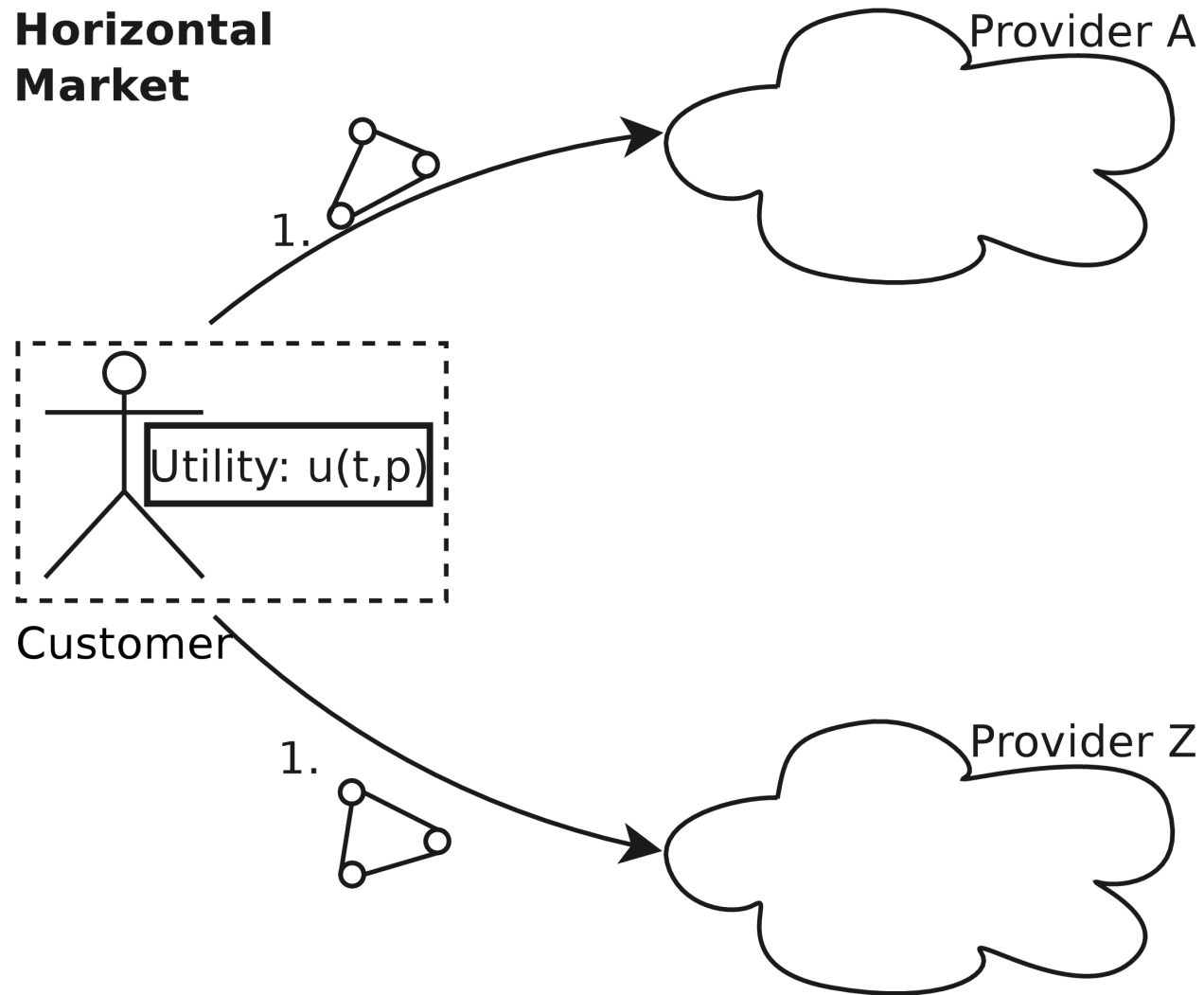
- 3 types of customer
 - Flexible in time
 - Flexible in price (or inflexible in time)
 - Standard
- Provider fixed prices $P1 < P2 < P3$
- Virtual network requests
 - SLAs on server and network resources

Model

- 3 types of customer
 - Flexible in time $u(t, p) = -t - x \cdot p$
 - Flexible in price (inflexible in time) $u(t, p) = -x \cdot t - p$
 - Standard $u(t, p) = -t - p$
- Provider fixed prices $P1 < P2 < P3$
- Virtual network requests
 - SLAs on server and network resources

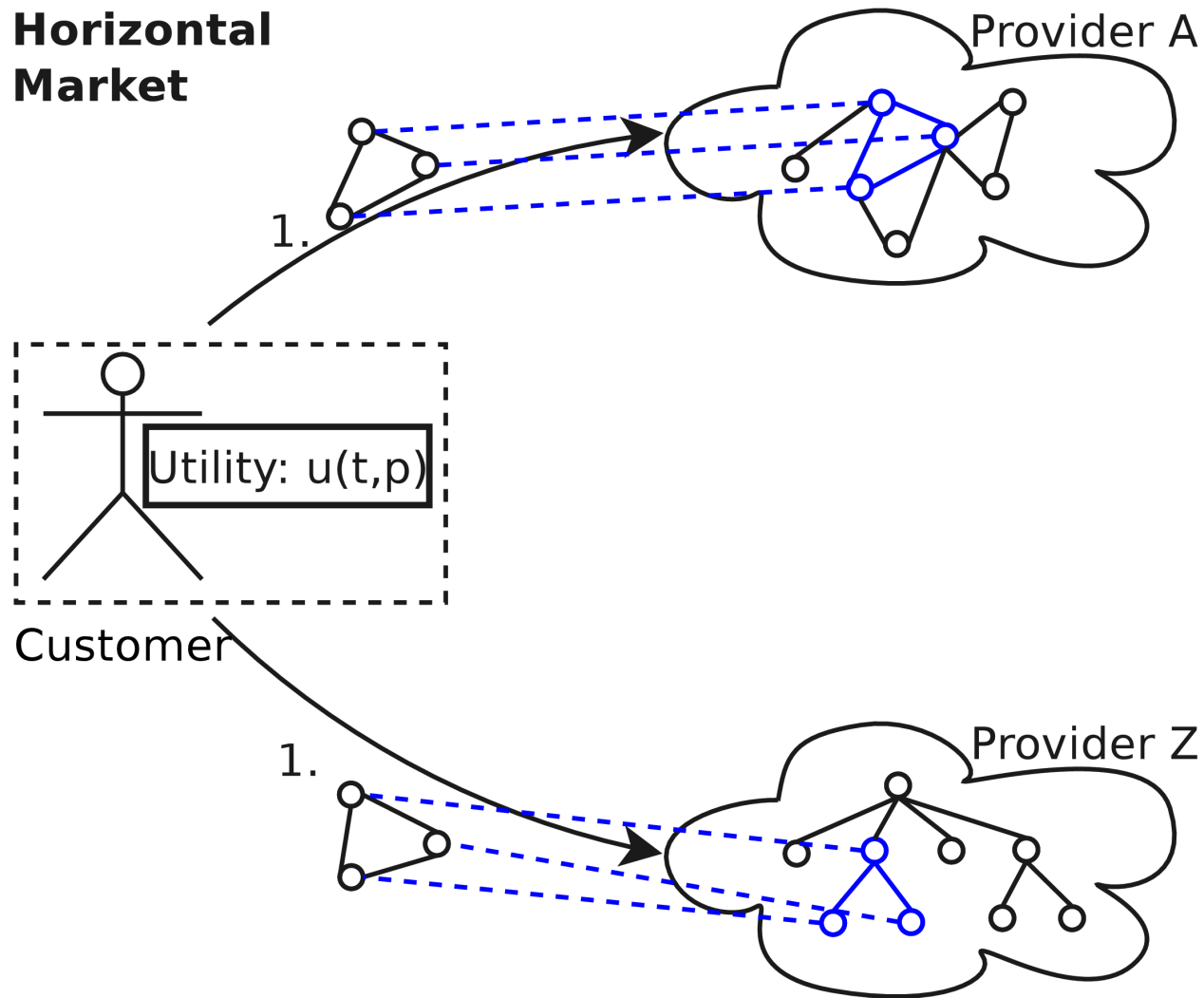
Horizontal market

**Horizontal
Market**



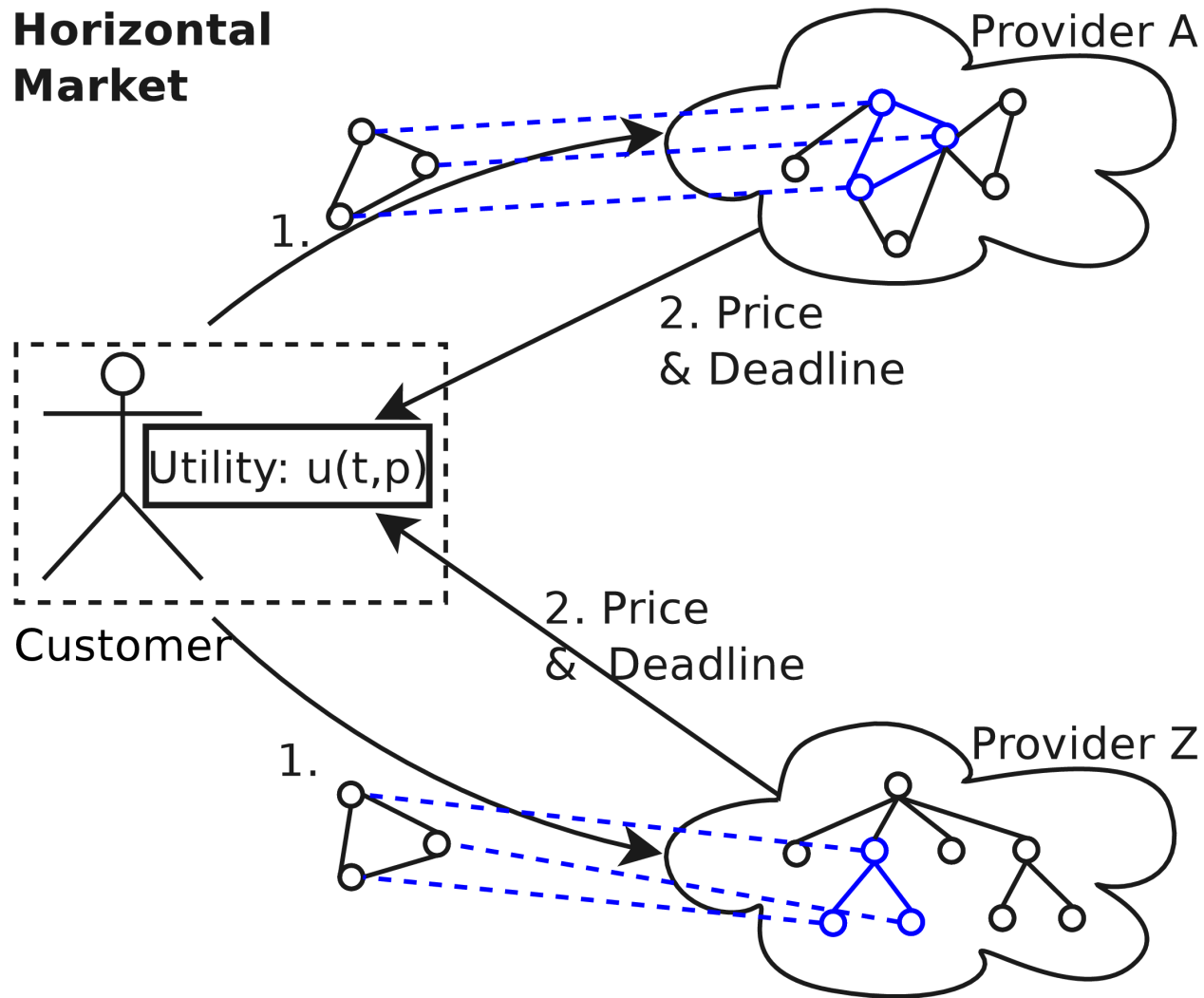
Horizontal market

**Horizontal
Market**



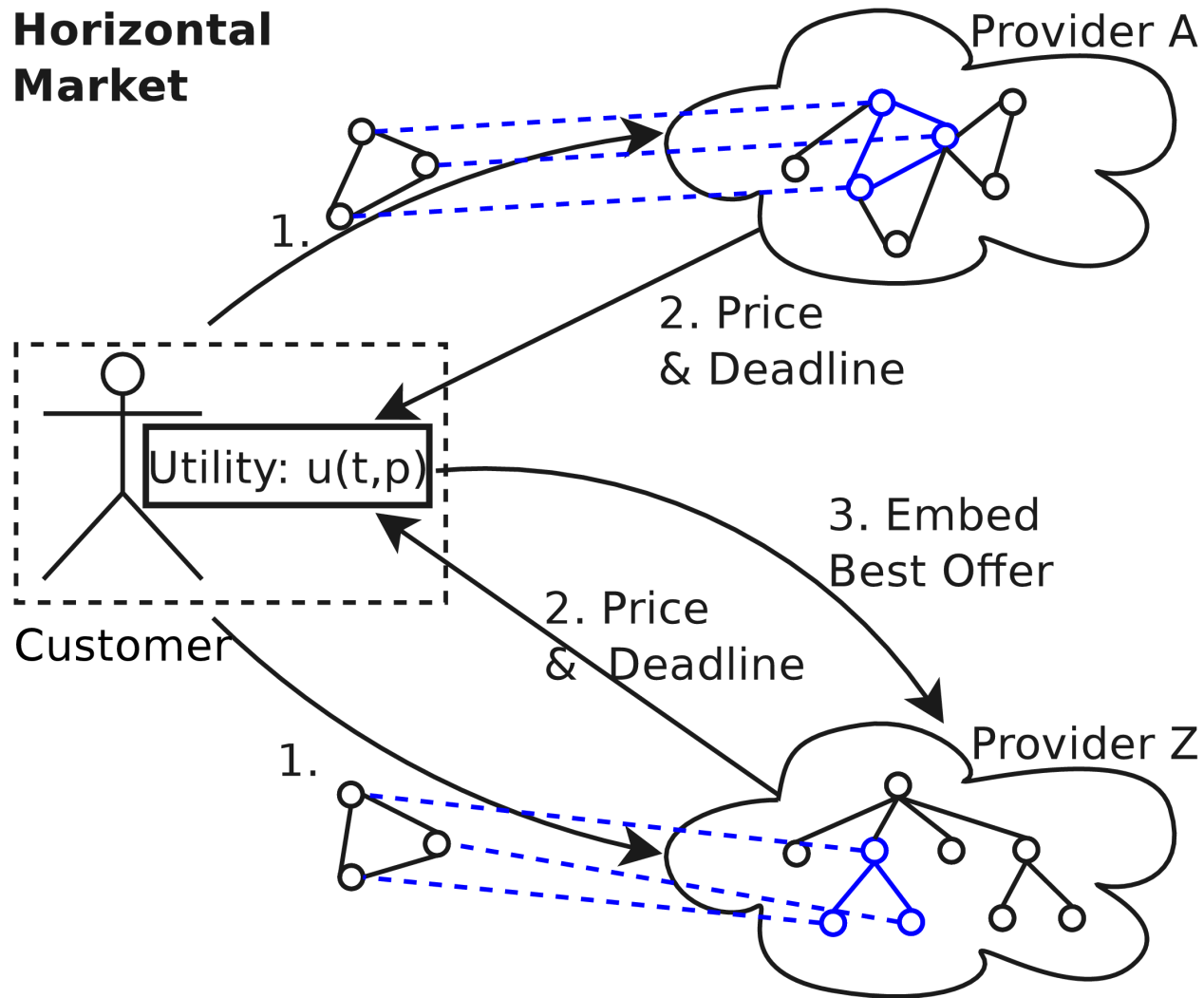
Horizontal market

Horizontal Market

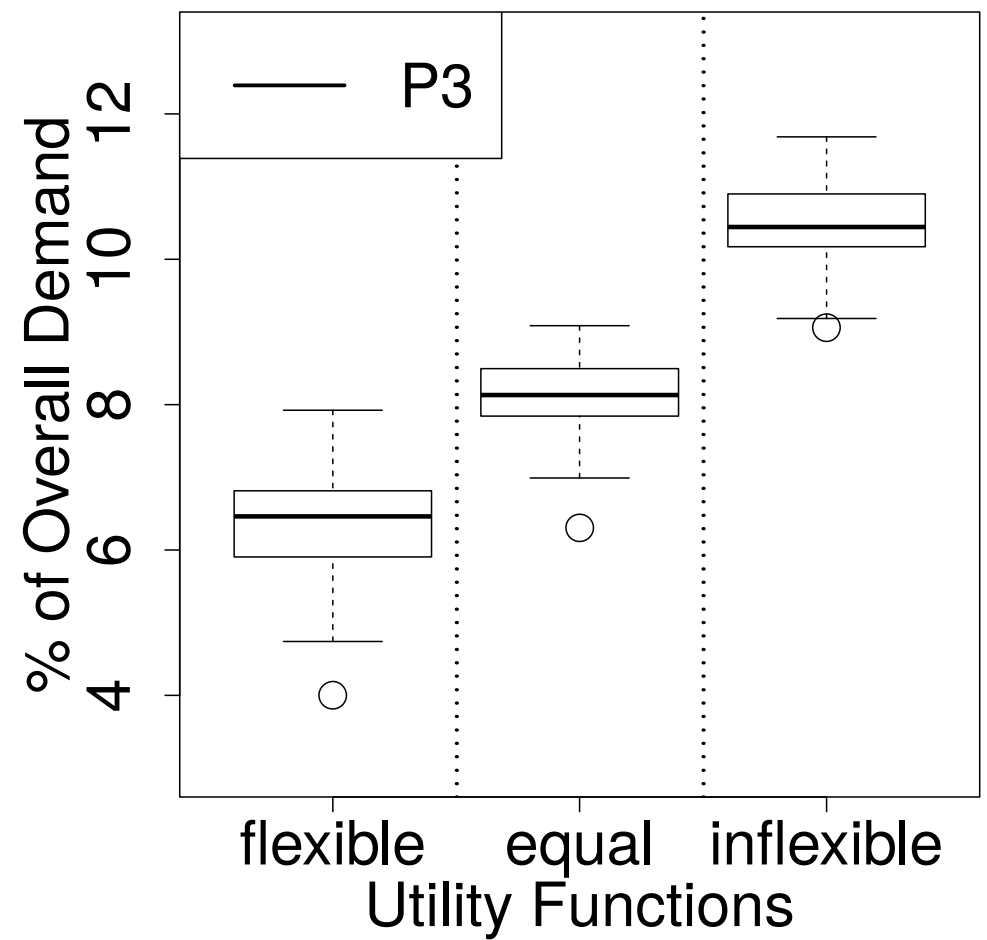
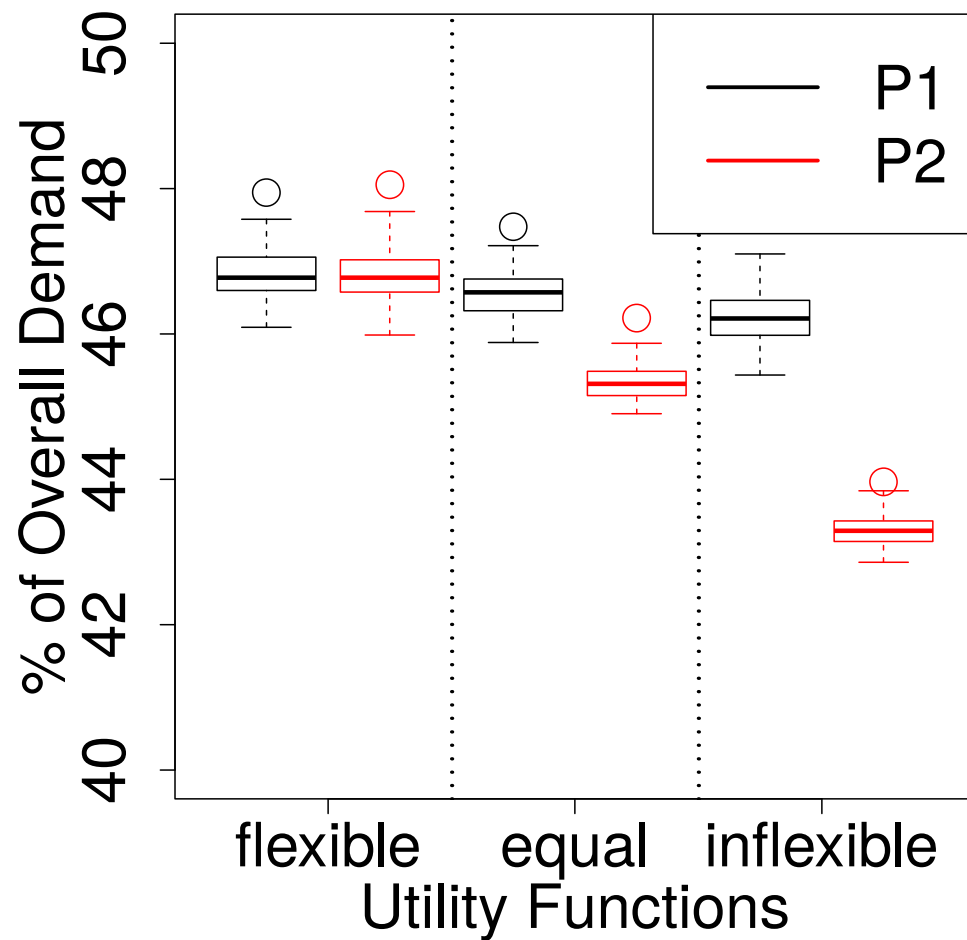


Horizontal market

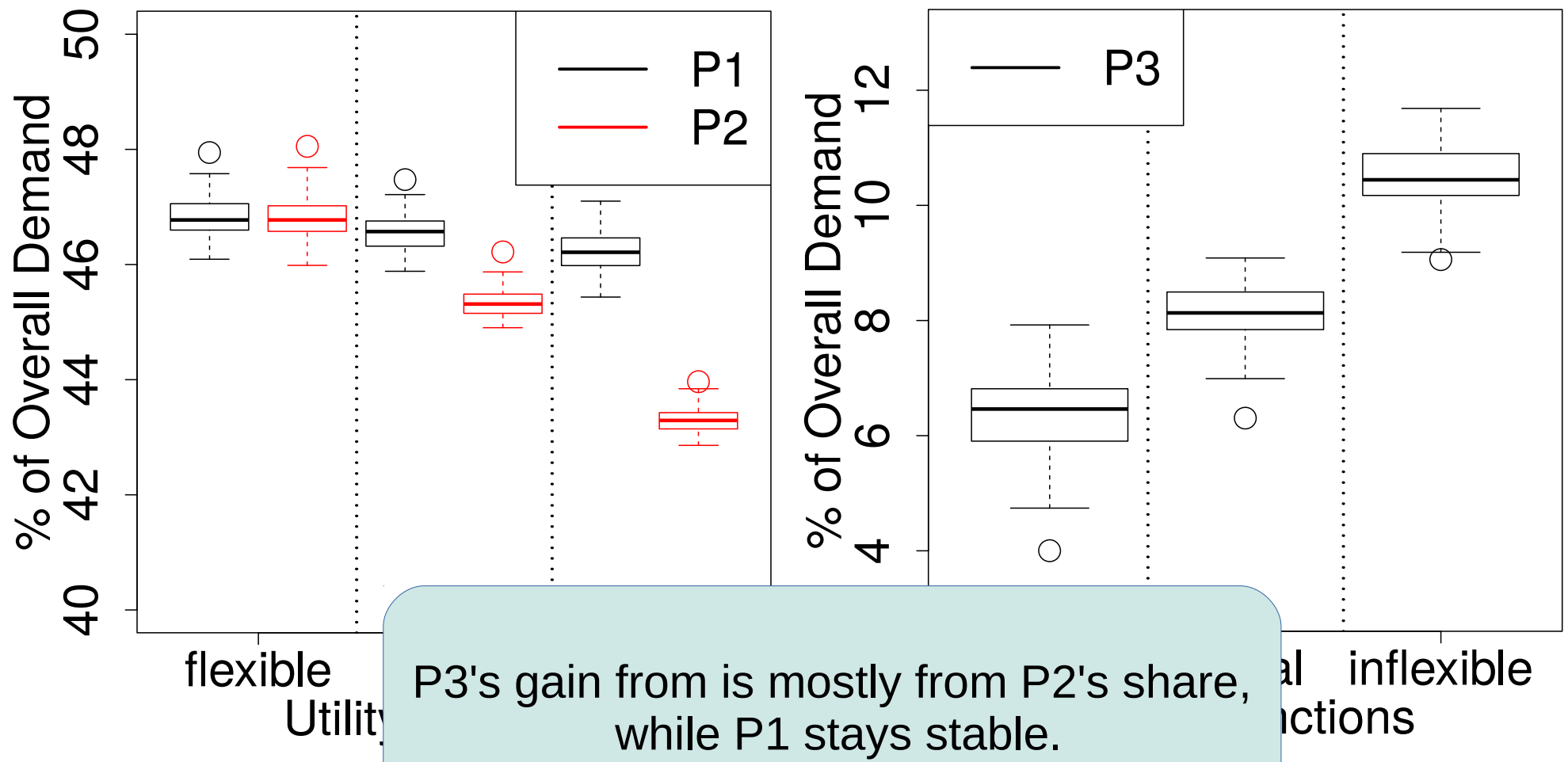
Horizontal Market



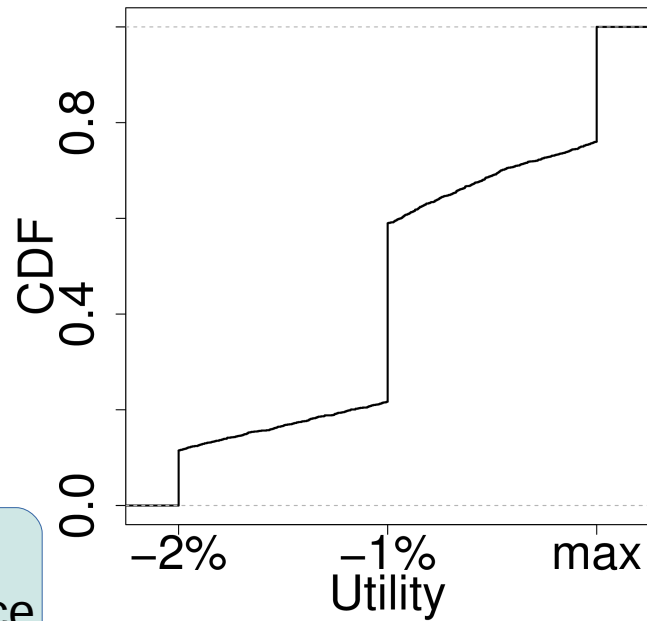
Provider benefits



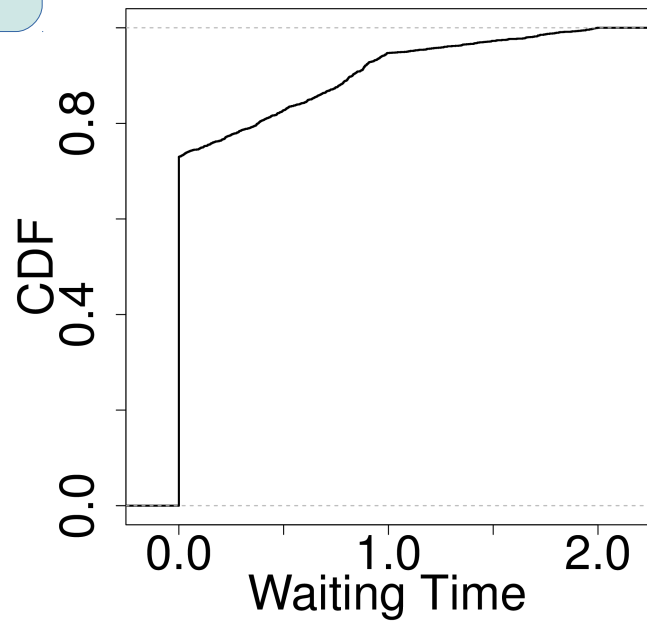
Provider benefits



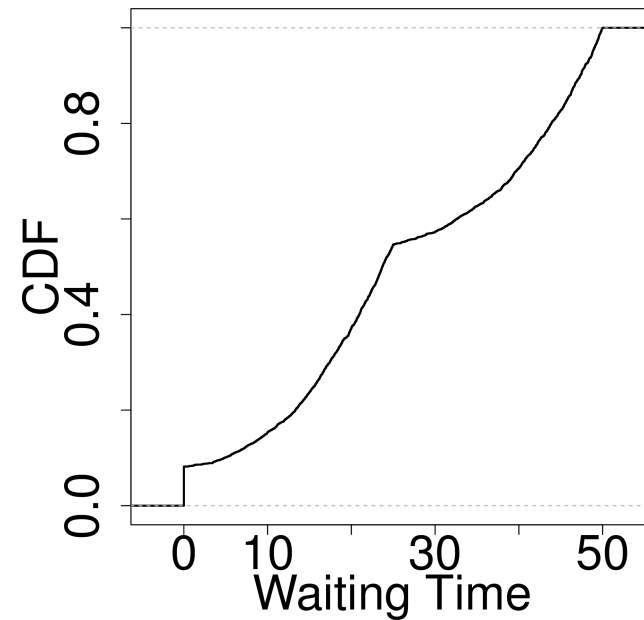
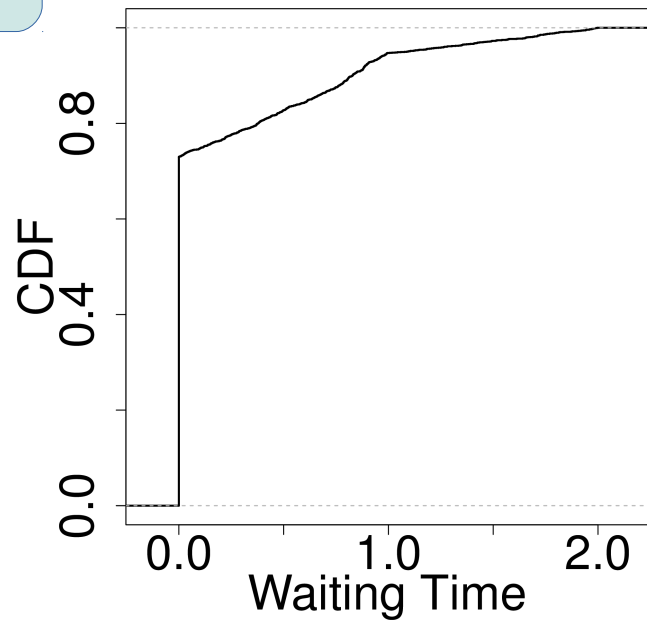
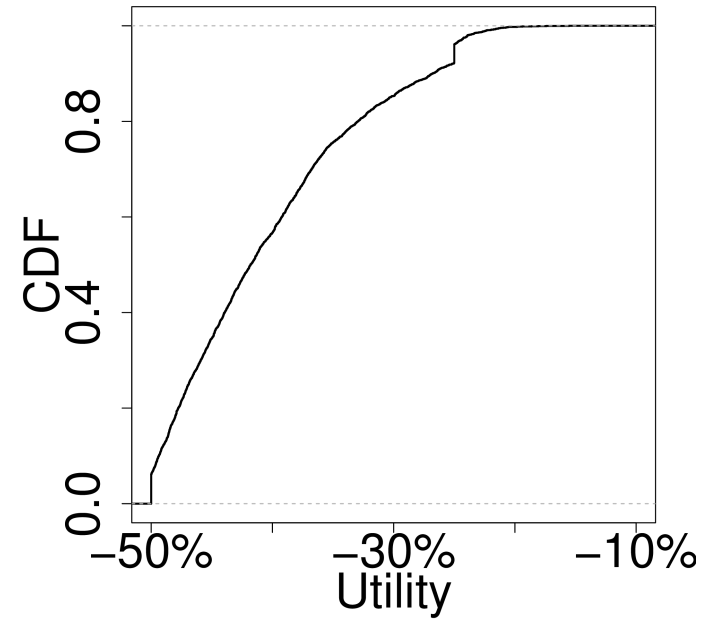
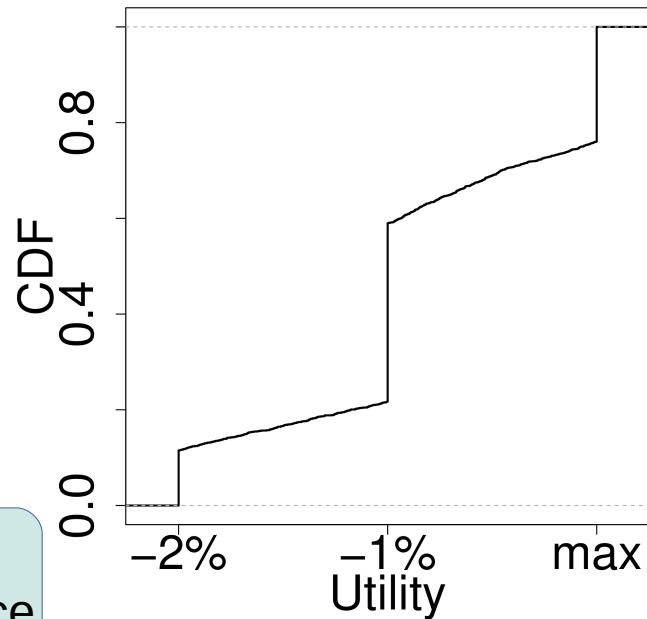
Customer utility



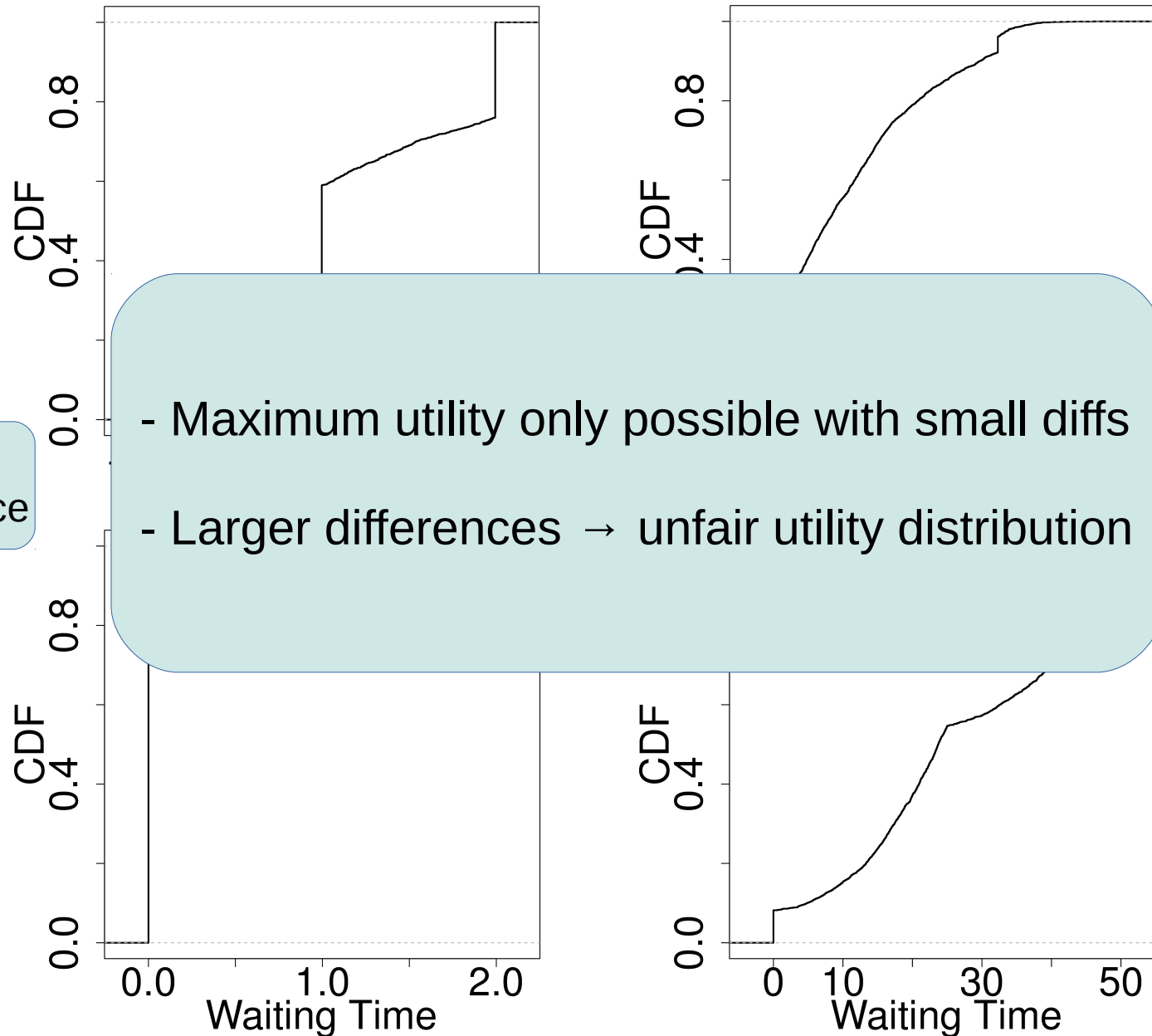
1%
Price difference



Customer utility



Customer utility

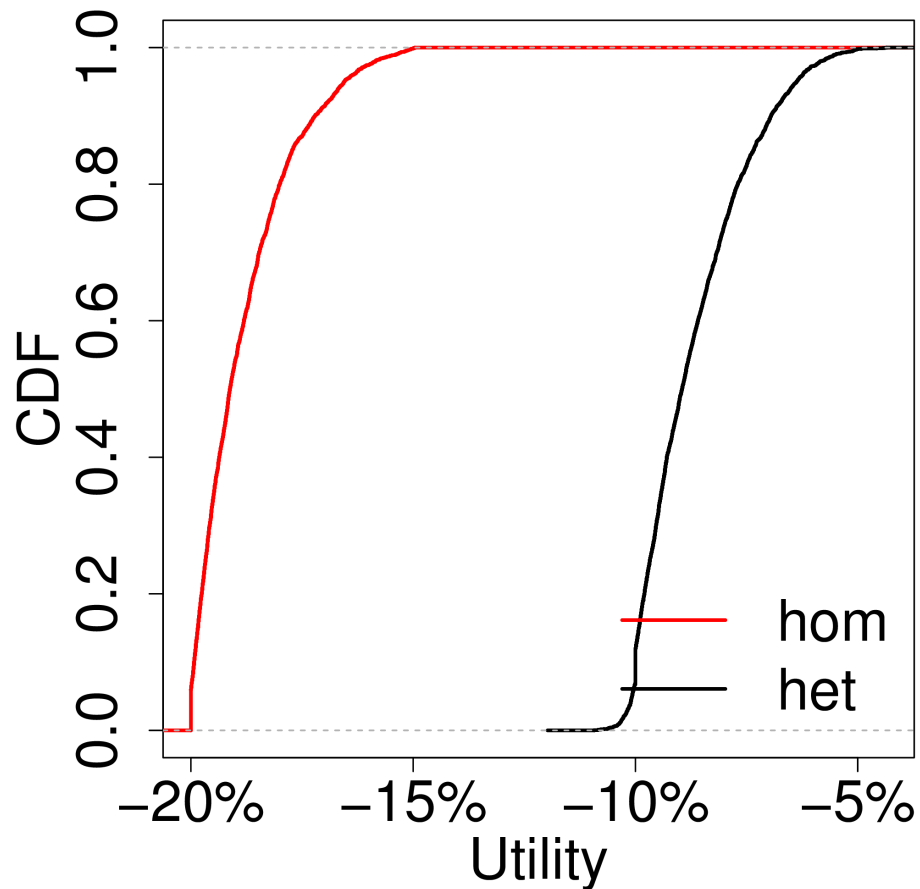


1%
Price difference

25%
Price difference

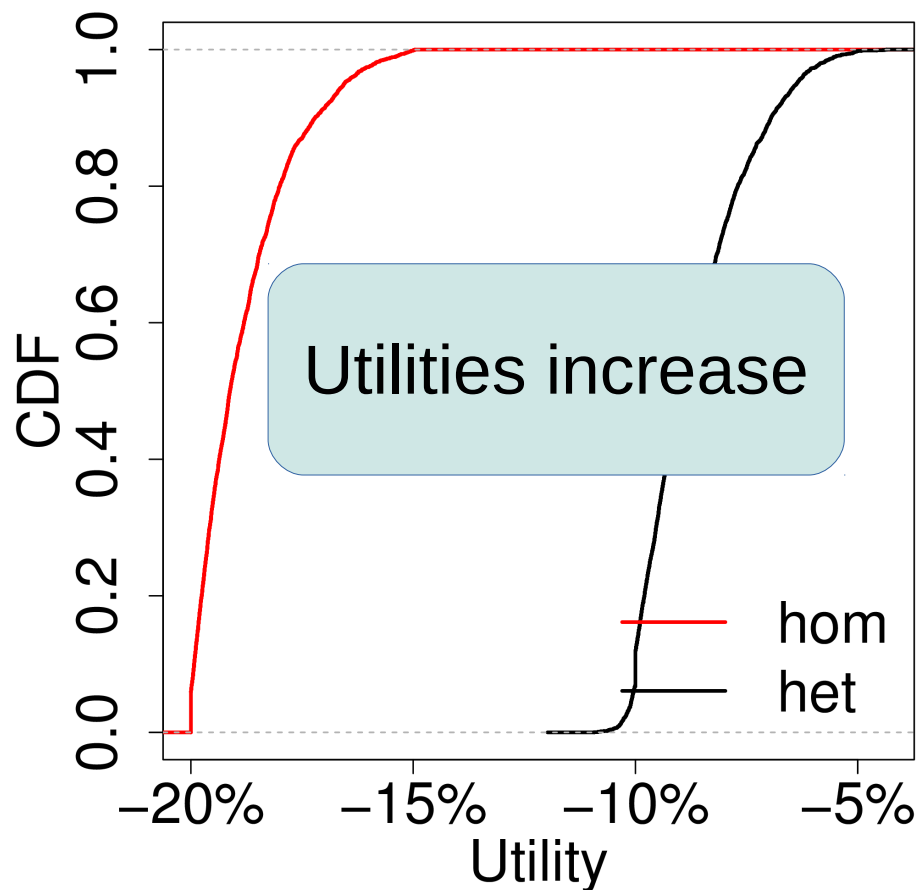
Customer utility

Utilities of (time) flexible user



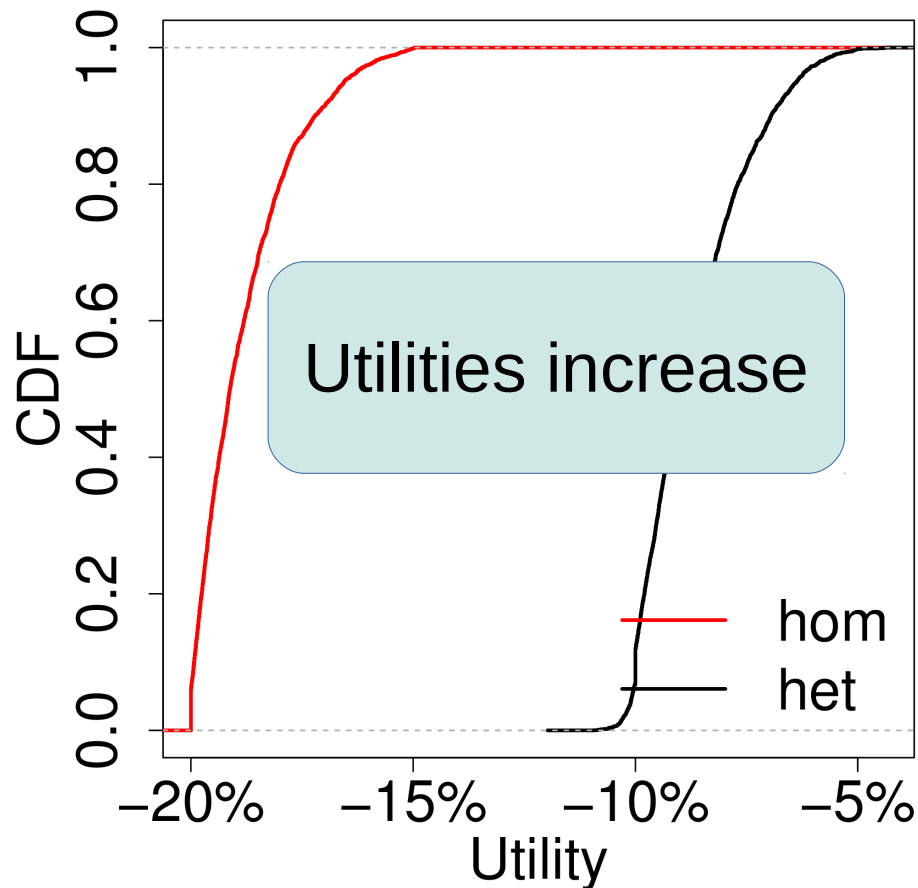
Customer utility

Utilities of (time) flexible user

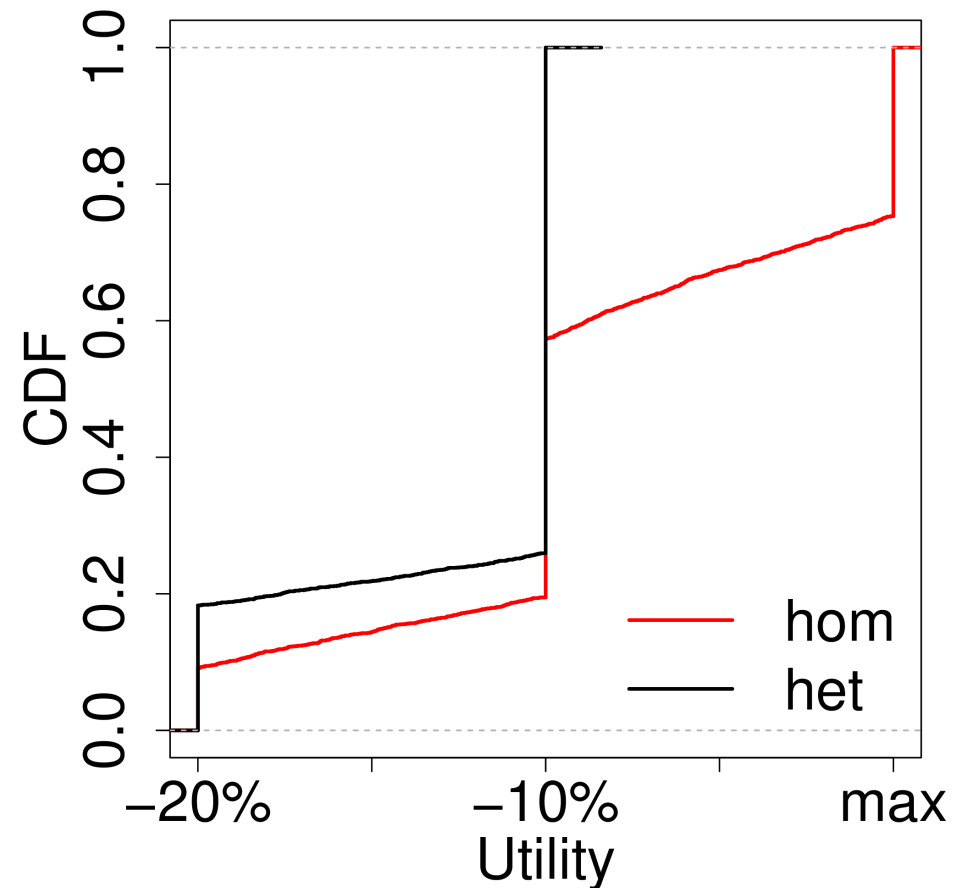


Customer utility

Utilities of (time) flexible user

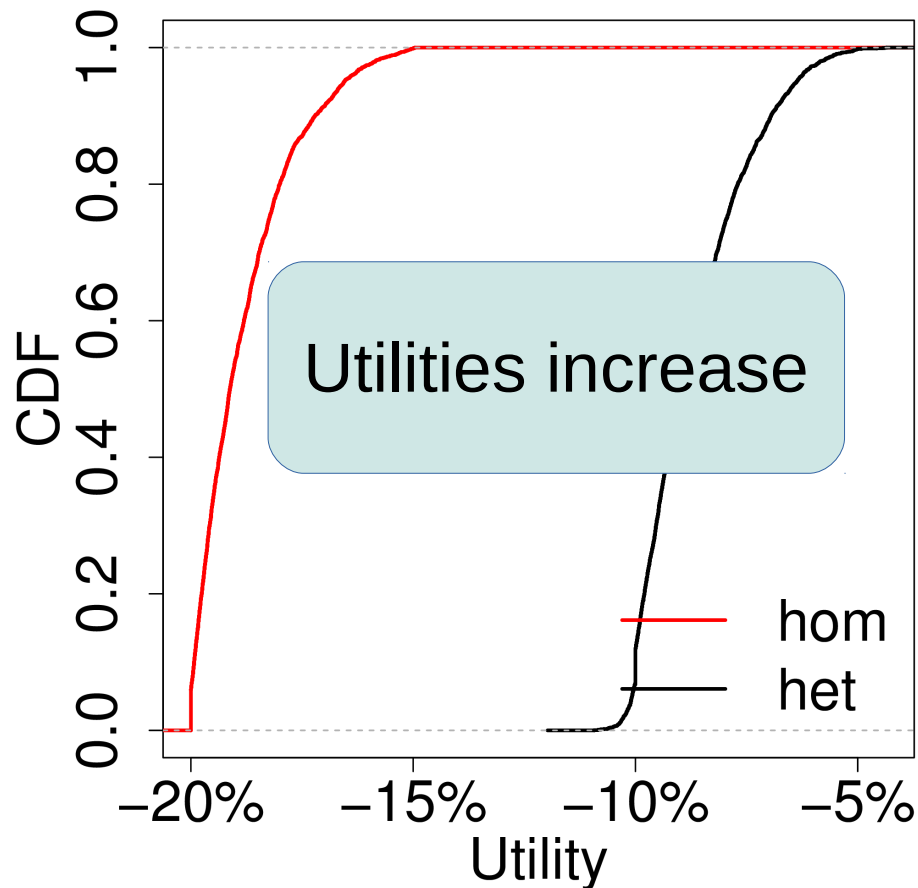


Utilities of (time) inflexible user

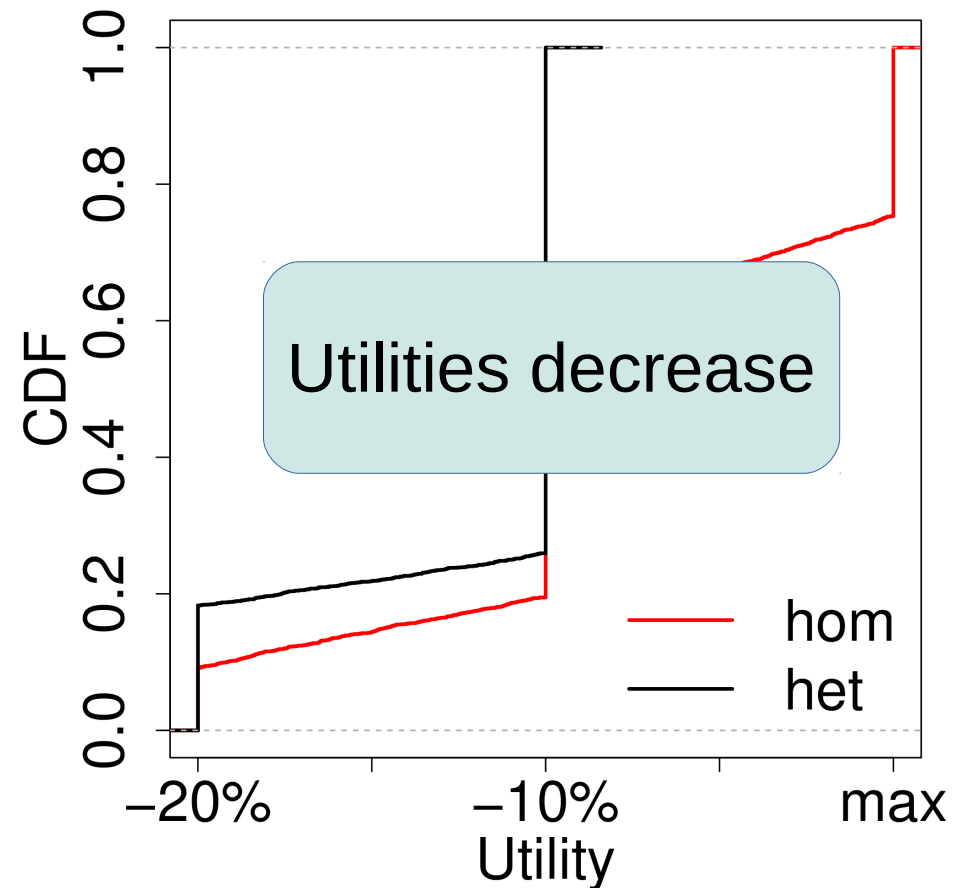


Customer utility

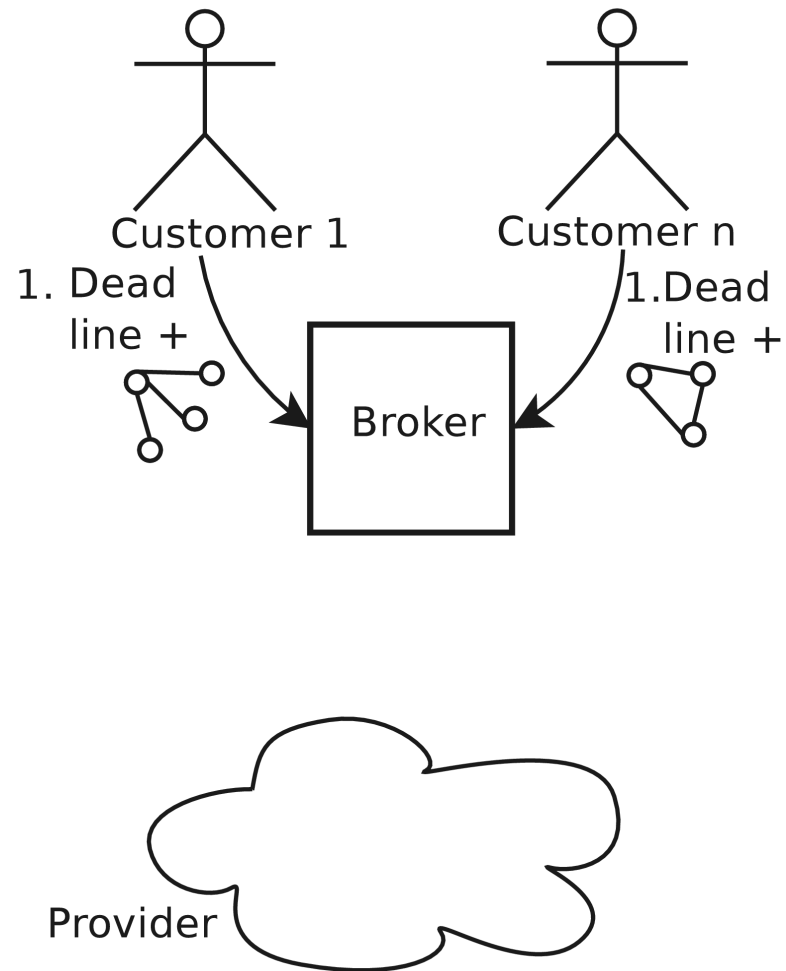
Utilities of (time) flexible user



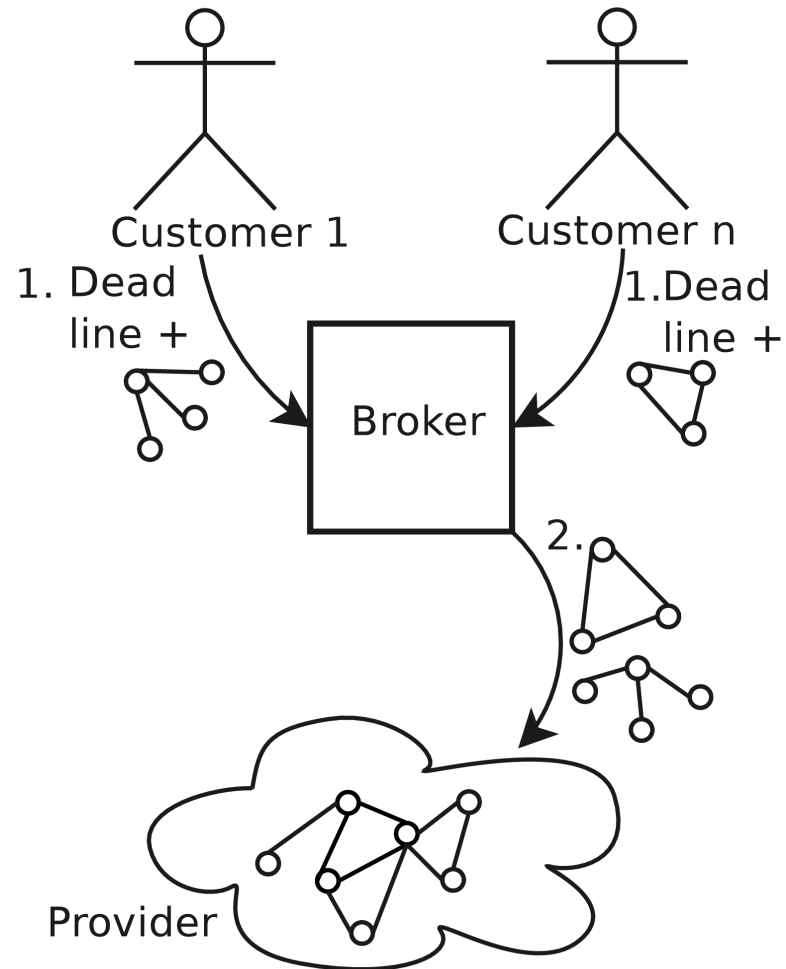
Utilities of (time) inflexible user



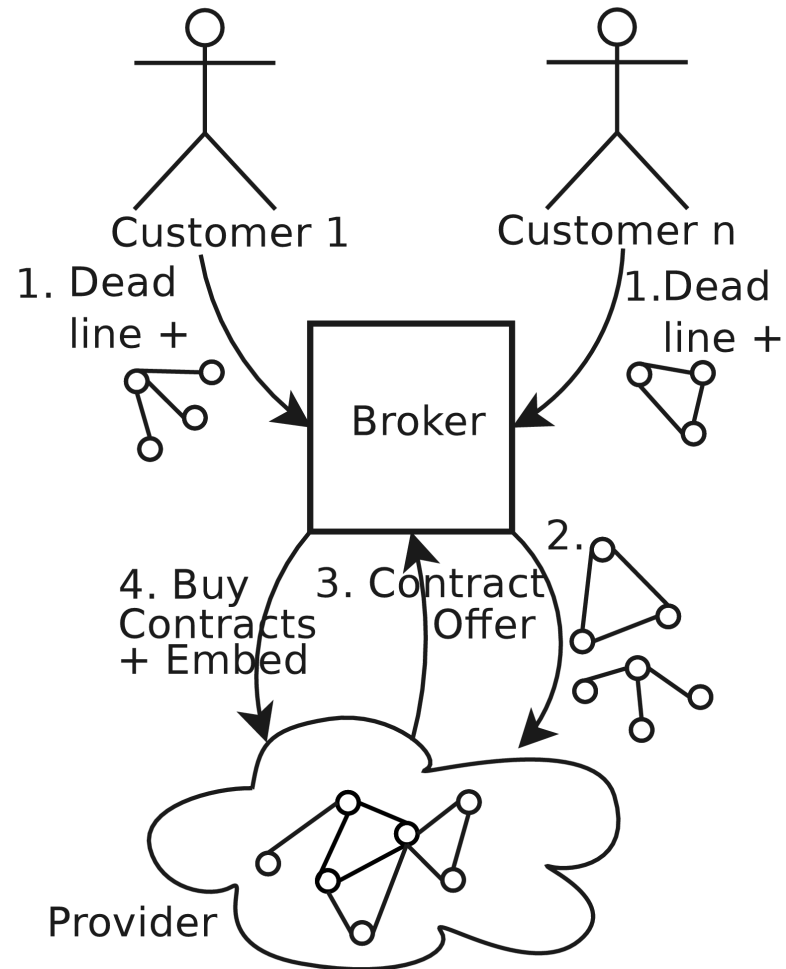
Vertical market



Vertical market



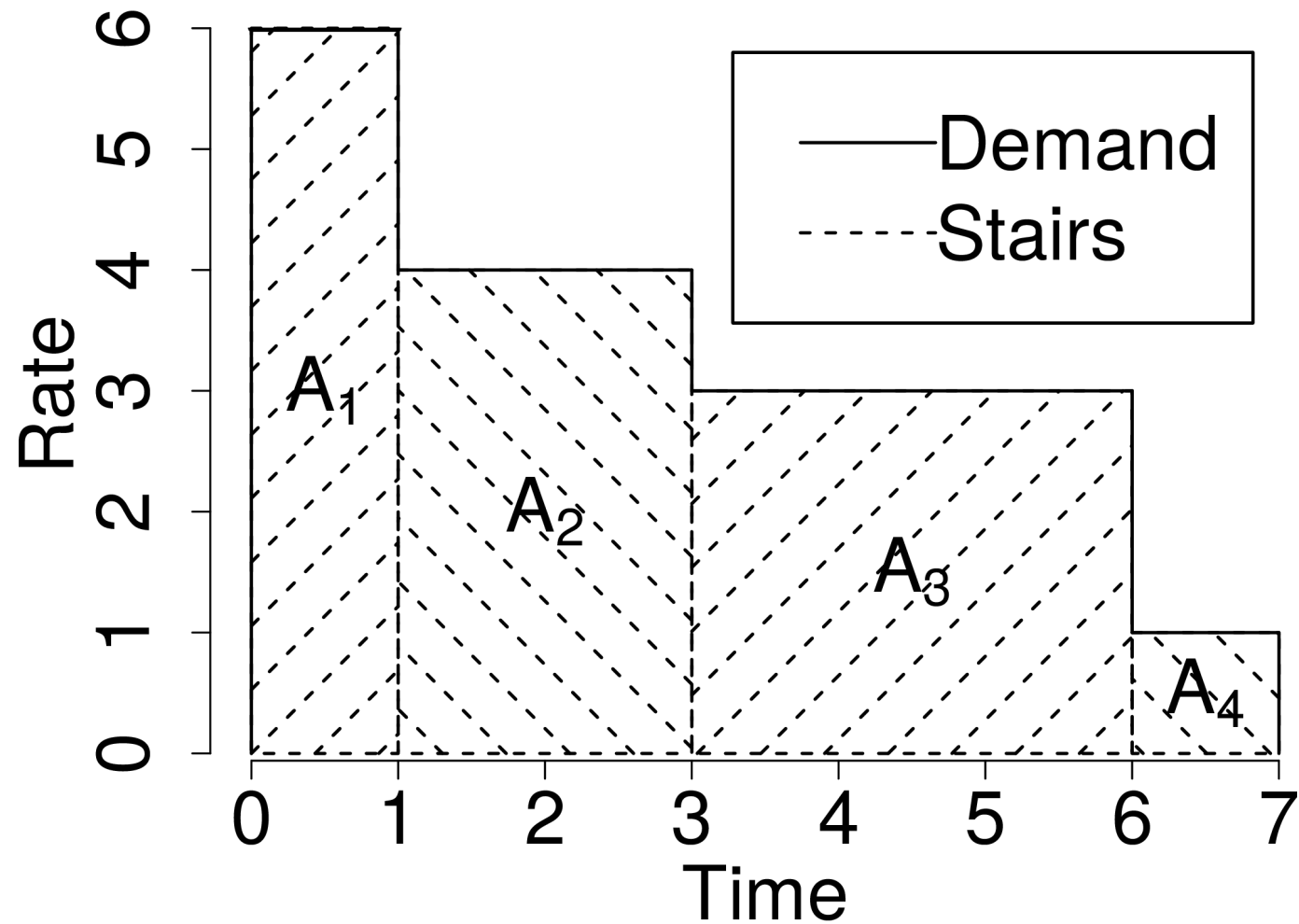
Vertical market



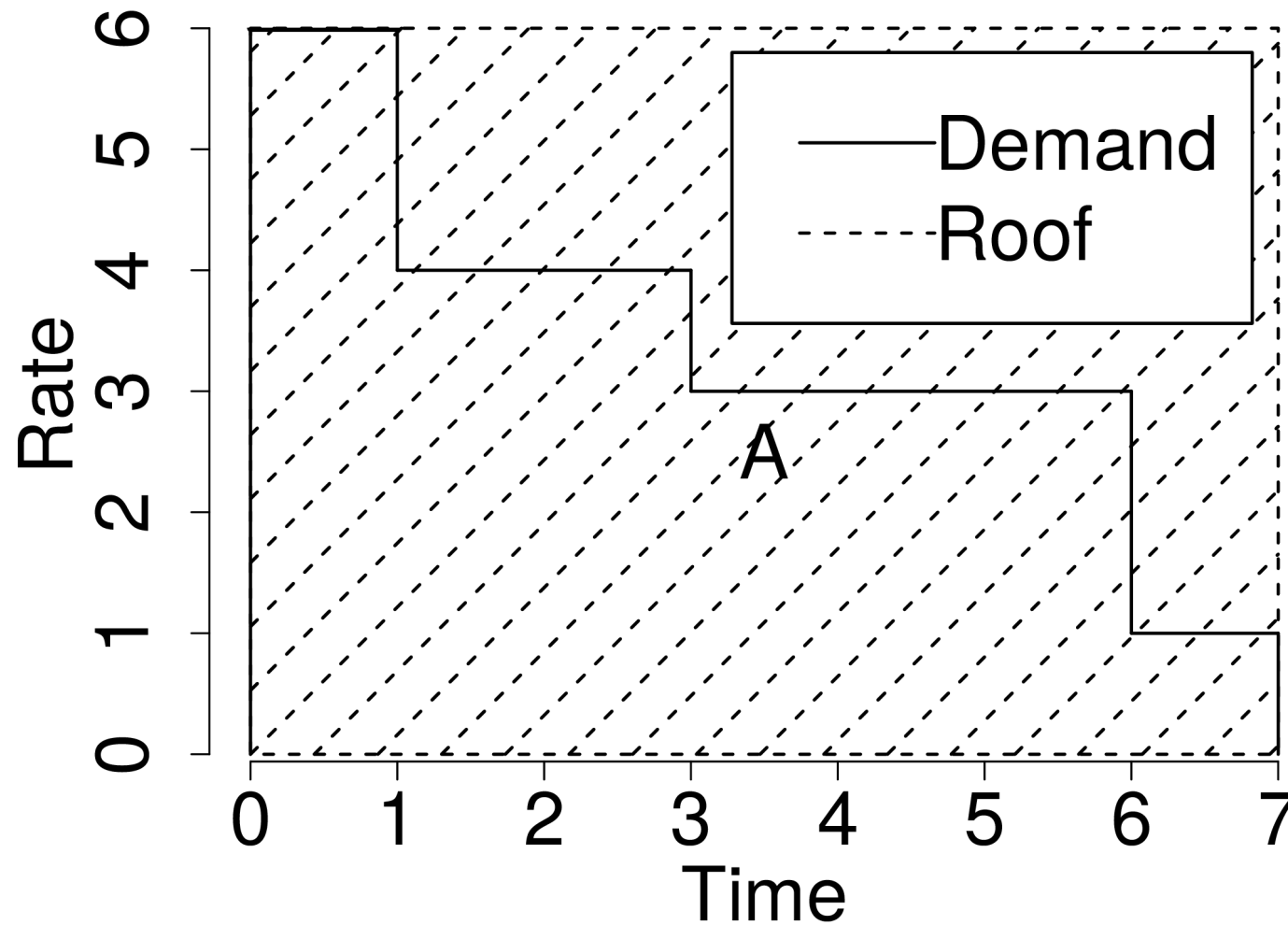
Vertical market

- More resources → smaller price per unit
- Broker can buy (rate, time)“rectangle“ contracts
- VNet request have fixed deadline
- Customers are flexible/inflexible regarding the deadline

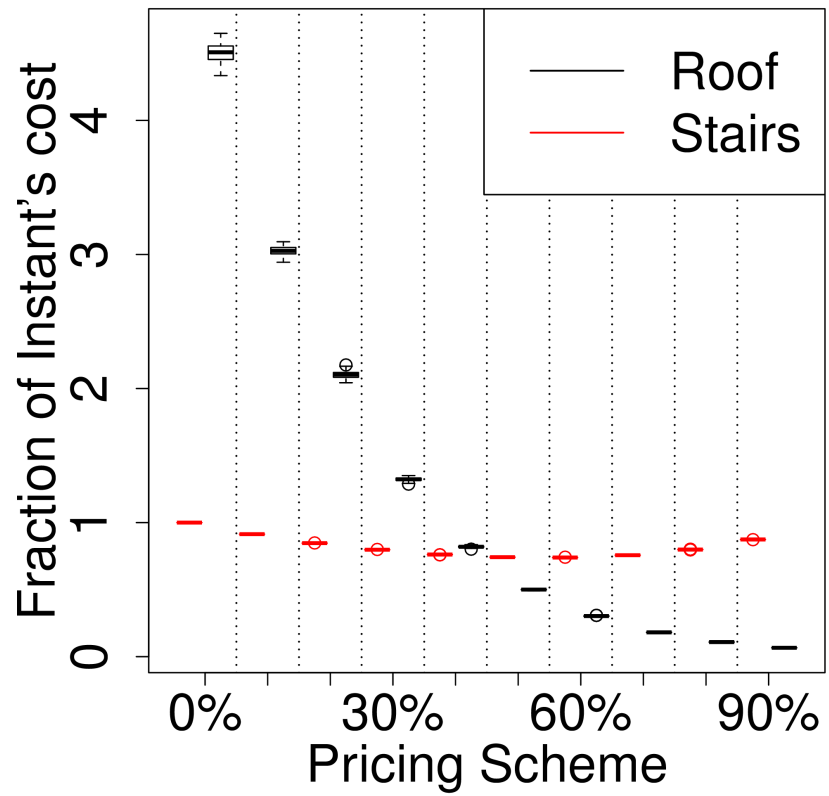
Broker strategy: stairs



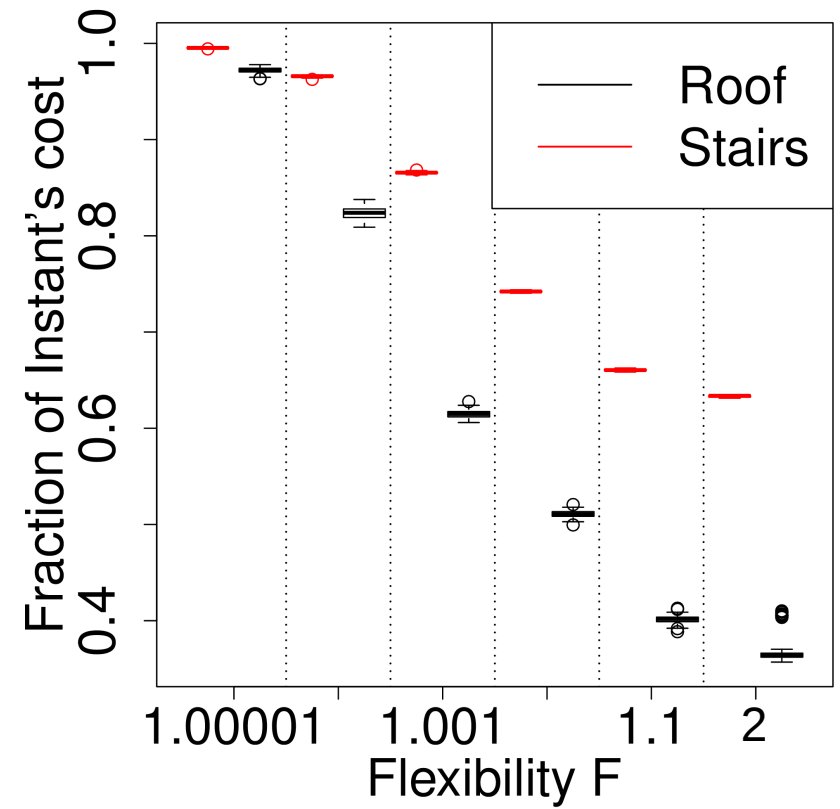
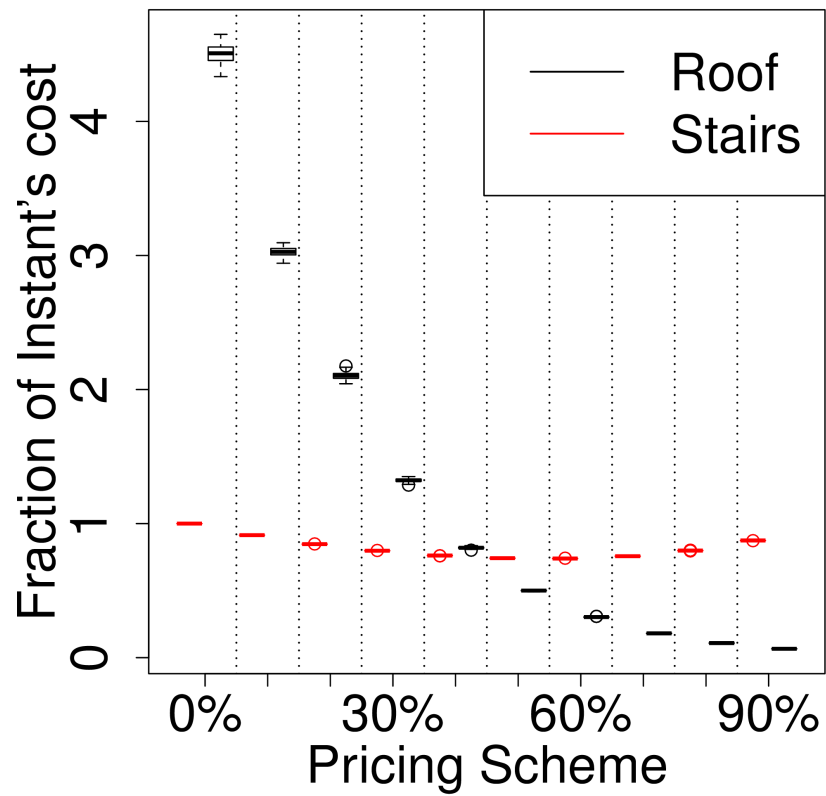
Broker strategy: roof



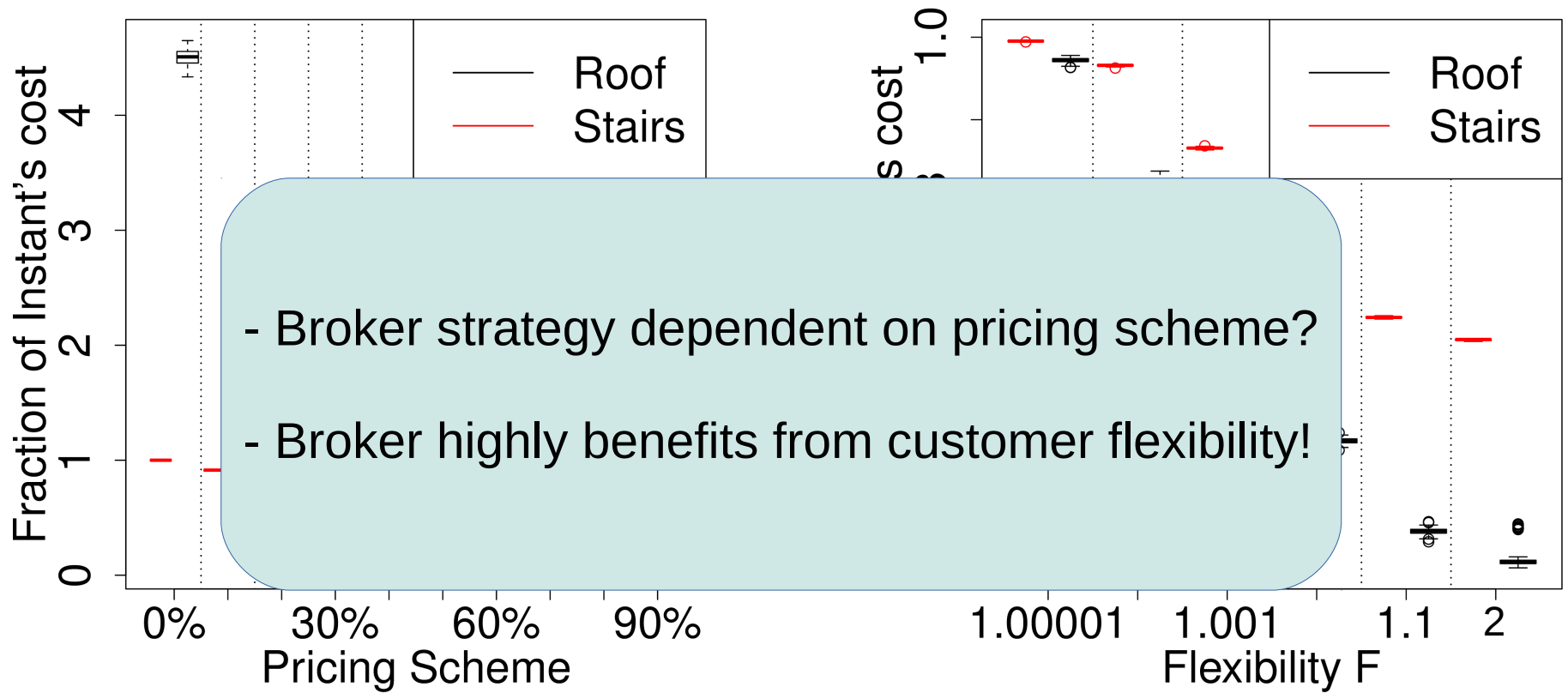
Results



Results



Results



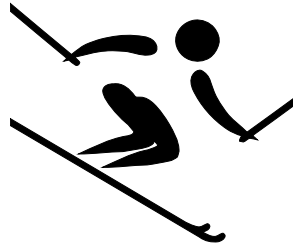
Outlook: resource allocation

Is there a better way to buy
discounted resources?

Related work

- Ski rental (classical problem):

- Buy or rent skis?



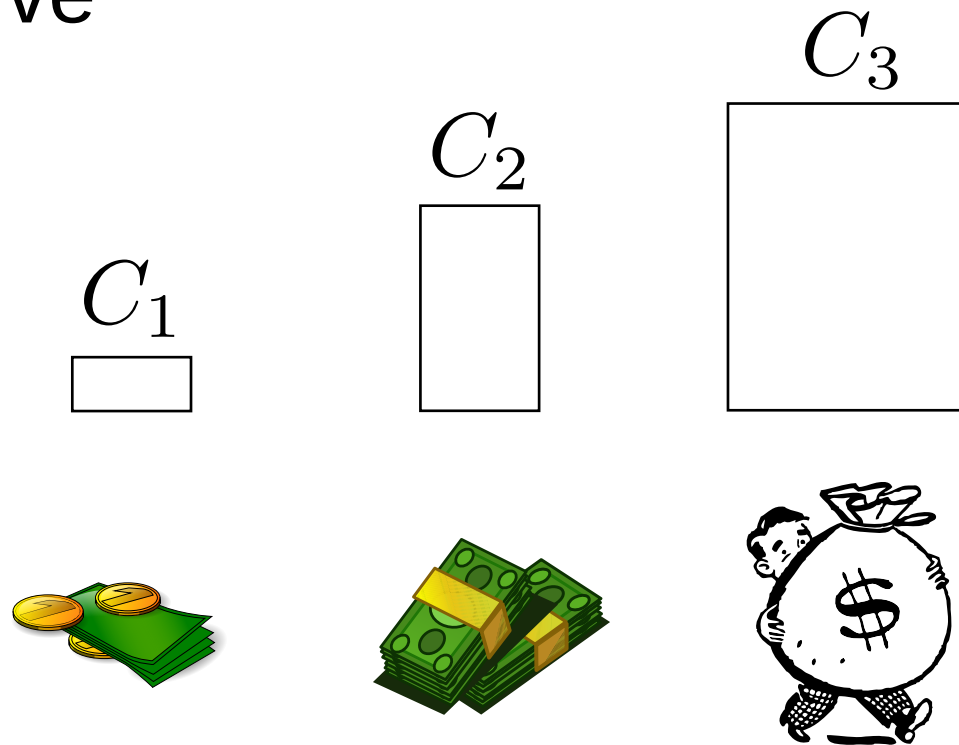
- Parking Permit Problem (Meyerson 2005):

- Unpredictable car usage.
 - Discount on longer permits.
 - Which duration to buy?



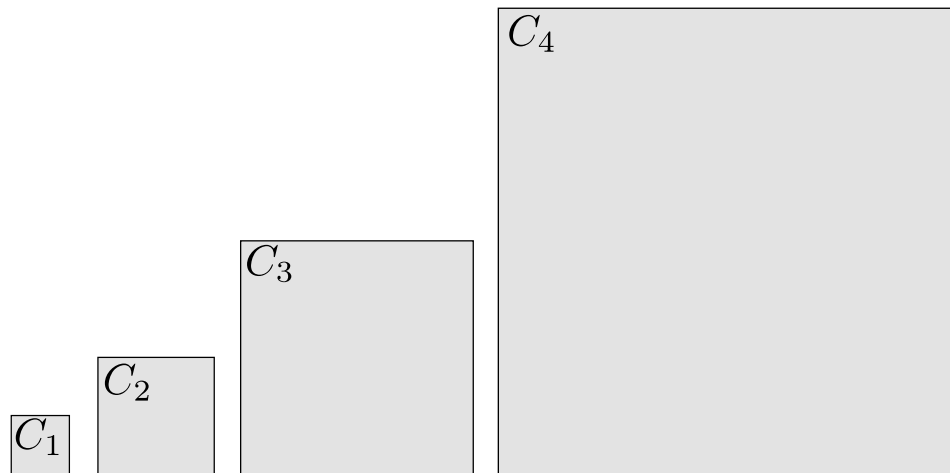
Model - assumptions

1. *Monotonic Prices*, i.e. larger contracts – more expensive



Model - assumptions

1. *Monotonic Prices*
2. *Multiplicity*, i.e., the next larger contract has a multiple of duration and rate



Model

- Single resource (generalizable to multiple)
- Complete demand needs to be covered
- One lookahead model
- Objective: minimize overall price
 - Minimize competitive ratio

Competitive Strategy for Resource Allocation with Discounts?

Online algorithm - ON2D

- ON2D mimics the offline algorithm OFF2D:
 - Compare previously bought contracts with the contracts OFF2D buys
 - If current demand is not covered, buy the new contracts

Upper bound

1. Contract independence
2. Worst case classification
3. Maximum cumulative price

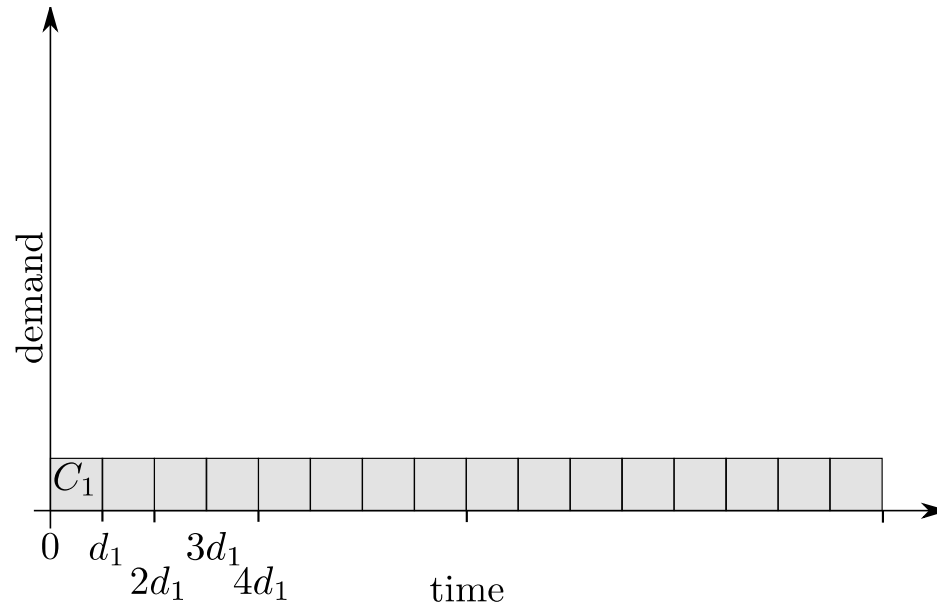
→ k -competitive (k = number of contracts)

Upper bound contract independence

- p_1 covered by C_i , at time t
- p_2 covered by C_j , at time t
 - No contract C at time $t' < t$ such that, C covers both p_1 and p_2

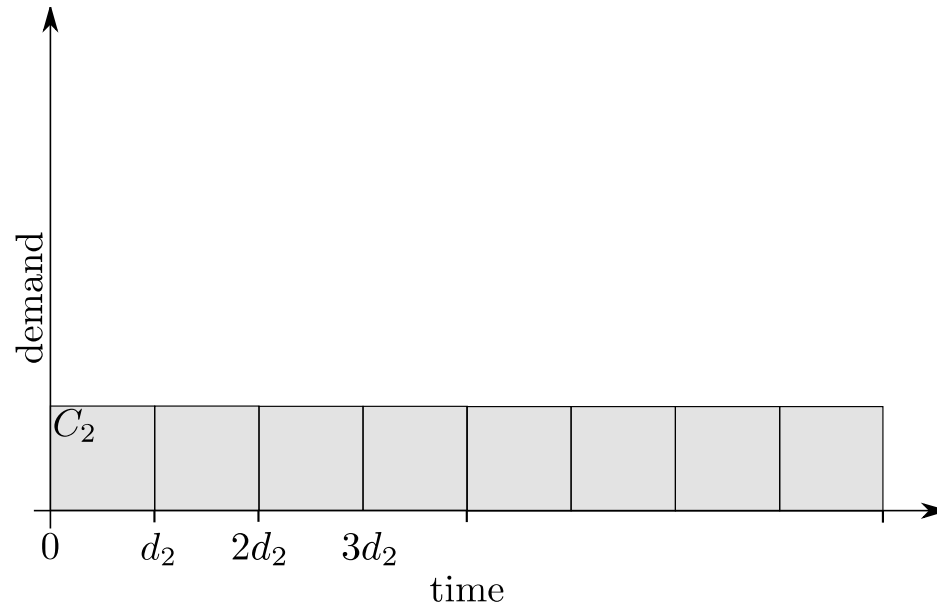
Upper bound contract independence

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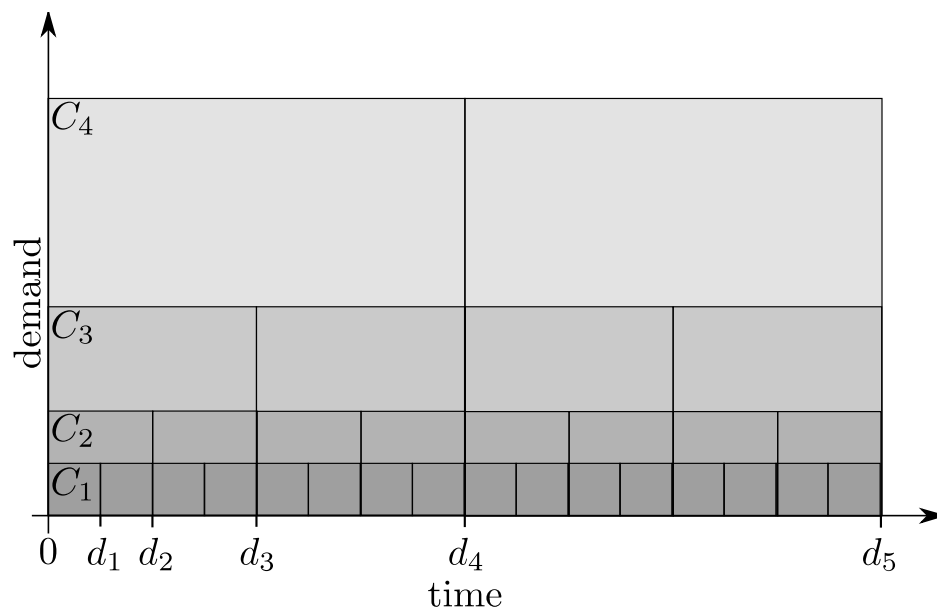
Upper bound contract independence

- p_1 covered by \mathcal{C}_i , at time t
- p_2 covered by \mathcal{C}_j , at time t
 - No contract \mathcal{C} at time $t' < t$ such that, \mathcal{C} covers both p_1 and p_2



Upper bound contract independence

- p_1 covered by C_i , at time t
- p_2 covered by C_j , at time t
 - No contract C at time $t' < t$ such that, C covers both p_1 and p_2



Upper bound worst case

- Worst case: OFF2D buys only one contract
- Proof by contradiction:
 - OFF2D buys \mathcal{C}_i and \mathcal{C}_j
 - ON2D buys a couple of contracts to cover both
 - Due to contract independence, the competitive ratio is the max of the competitive ratios for both single scenarios

Upper bound maximum cumulative price

- $\sum price_{ON}(\mathcal{C}_i) \leq i \cdot price(\mathcal{C}_i)$
 - Inductive proof in the paper
- ON2D is k -competitive, where k is the total number of contracts

Online algorithm - ON2D

- ON2D mimics the offline algorithm OFF2D:
 - Compare previously bought contracts with the contracts OFF2D buys
 - If current demand is not covered, buy the new contracts
- Deterministic online algorithm $O(k)$
- Almost optimal (lower bound $k/3$)
- Polynomial offline algorithm

Conclusion

- Shed light on specification benefits in
 - Horizontal markets
 - Lower priced providers profit the most
 - Flexible users benefit from inflexibles (not vice versa)
 - Vertical markets
 - Broker benefits from user flexibility
- Outlook: How to handle resource allocation (to appear @ICDCS)