Cloud Computing
Time-Dummy Hedonics for U.S. PPI

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U.S. PPI Cloud Classification

- **Data Processing, hosting, and related services (NAICS 518210)**
  - ▶ IaaS - Infrastructure as a service
    - – Leasing of basic computing structures. IaaS is the base of all other cloud services
  - ▶ PaaS - Platform as a service
    - – Use of applications created by programming languages
  - ▶ SaaS - Software as a service
    - – Software published by others

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Cloud Services Pricing

- Cloud service pricing
  - Fee-based transactions: average, standard, or pre-paid rates
  - Estimated flat-fee: most commonly seen in long term contracts

Similar Published Research

■ Coyle and Nguyen Cloud Quality Adjusted Price Index

▶ UK price index

▶ Amazon Web Services

— Uses single class of cloud services, the M product line

• 4 tiers of instance size: small, medium, large, xlarge

▶ Makes quality adjustments based on processing performance.

Similar Published Research

- Byrne, Corrado, and Sichel Cloud Price Model
  - ▶ Price indexes use data for AWS services
    - IaaS Products: virtual machine rental, data storage
    - PaaS Products: database services
    - Prices from Virginia, California, Oregon

Similar Published Research

■ **Byrne, Corrado, and Sichel Cloud Price Model**

▶ Virtual Machine Rental Hedonic

  – Price determining characteristics used: processor power, memory, storage, Operating System

  – Model characteristics:

   • Unweighted adjacent- quarter regressions

    ❖ Due to unavailability of quantity data

   • Time-dummy variable hedonic specification

   • AWS ECU for CPU performance

   • Log price dependent variable

U.S. PPI Cloud Hedonic Model

- Used much of the same structure as the Byrne, Corrado, and Sichel approach
  - Differences between the models:
    - Sample includes products from 3 service providers
    - Specification selection
    - Storage and computing characteristics exist in the same model
    - Additional price determining characteristics
      - Including microprocessor price determining characteristics

U.S. PPI Cloud Hedonic Model

- IaaS
  - ▶ IaaS is the basis for other cloud services
- Time dummy with overlapping quarters (17Q2-19Q2)
- Log price per hour as dependent variable
- AWS, Azure, and Google

U.S. PPI Cloud Model

- Quality adjusted price change from market entry and exit

    ▶ Prices flat

- "Weighted" regressions using quantity based on ratio of products from each service provider

- Specification selection using statistical learning technique from Sawyer and So microprocessors article

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Price Determining Characteristics

- Microprocessor

- Virtual Central Processing Units (vCPU)

- Operating system

- Memory

- Data storage

- Type of price

- Region

Microprocessor Attributes

- Cores

- Threads

- Thermal design power (TDP)

- Base frequency

- Turbo frequency

- Cache

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AWS ECU

- Elastic Compute Cloud (EC2) compute unit (ECU)
  - ▶ Credible measure of microprocessor performance
- Compare models with ECU to those with characteristics
  - ▶ Validate characteristics models
- AWS has since discontinued publication of ECU details

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ECU Models

- **Using ECU as one of the pricing characteristics**
  - ▶ Only two quarters over two years showed price changes
    - – Supporting that prices changes are due to service entry/exit
  - ▶ Coefficients revealed that characteristic variables are correlated with each other
  - ▶ Very high R^2 for each time dummy model

Characteristics Models

- Omit vCPU
  - ▶ Strongly correlated with cache and TDP
  - ▶ Cache and TDP are proportional to number of vCPUs (threads or sometimes cores)
- Base and turbo frequency are closely correlated
  - ▶ Small number of different microprocessors models
- Model selection done twice
  - ▶ Once with base frequency included
  - ▶ Once with turbo frequency included

AWS Results Summary

	17Q4-18Q1	18Q3-18Q4
ECU quarter dummy	-0.0296	0.0671
CPU base freq quarter dummy	-0.0358	0.0708
CPU turbo freq quarter dummy	-0.0422	0.083

Use of Specification Selection

- For all service provider models:
  - Most variables selected
  - Technique suggests models not over-specified
  - In production, use of all variables may simplify implementation of models
- Azure and Google
  - Average price changes of base and turbo frequency models as there is no target model to compare

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Potential Future Work

- Weighting observations by revenue

- Models for PaaS and SaaS

- Hedonic quality adjustment model or hedonic imputation

  - The type of model needed partly depends on the information provided by PPI respondents

Conclusion

- Time dummy hedonic models are able to estimate quality adjusted price change for IaaS

- AWS using characteristics tracks closely with AWS using ECU

- Sample selection critical because quality adjusted price changes are due to entry and exit

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