The Role of Industrial Composition in Driving the Frequency of Price Change

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Federal Reserve Bank of Boston

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Motivation

- **Frequency of price change**: crucial parameter in monetary economics
  - Extent of transmission of nominal shocks to the real economy
  - Key **determinant of the slope** of the Phillips curve

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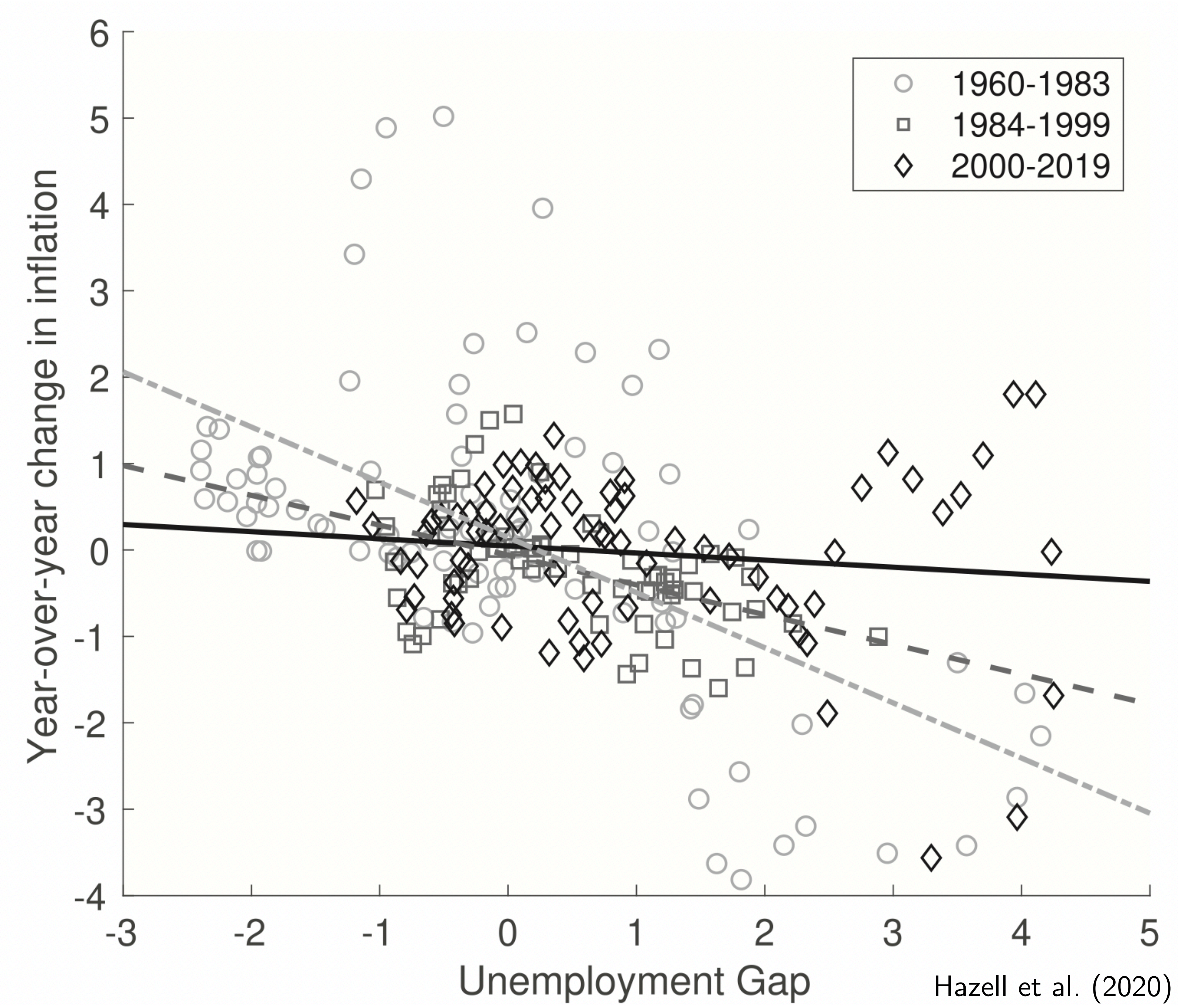
- **Long-term decline** in the slope of the Phillips curve in the United States (US)



Hazell et al. (2020)

Motivation

- **Frequency of price change**: crucial parameter in monetary economics
  - Extent of transmission of nominal shocks to the real economy
  - Key **determinant of the slope** of the Phillips curve
- **Long-term decline** in the slope of the Phillips curve in the United States (US)
- One potential reason for the slope decline: **fall in the frequency of price change**

Frequency of Price Change

- Can fall for two reasons:
  - Fall in the frequency of price change of individual products
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  - Shift in the distribution towards products with a lower frequency of price change
- Shift in the product distribution due to industrial composition shifts

Why Industrial Composition?

- Natural candidate to explain the **long-term decline**
- Infeasible to directly use BLS product weights:
  - Limited data availability of product weights from the BLS
  - Reclassification of products in the BLS

Goals

- Impact of changes in industrial composition on the distribution of frequency of price change

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    - Quantitative model

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- Impact of changes in industrial composition on the distribution of frequency of price change
  - Empirical analysis
- Consequent impact on the slope of the Phillips curve
  - Quantitative model
- Focus: US, 1947–2019
- Methodology general and more broadly applicable
  - Other countries/time periods/price-change statistics

Related Literature

Heterogeneity in frequency of price change across products in monetary models

Nakamura and Steinsson (2008, 2010), Carvalho (2006), Nakamura et al. (2018), Montag and Villar (2022)

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Reasons for the decline in the slope of the Phillips curve

Del Negro et al. (2020), Mangiante (2022), Crump et al. (2019), Daly and Hobijn (2014), Moscarini and Postel-Vinay (2018), Daly and Hobijn (2014), Bernanke et al. (2010), Jørgensen and Lansing (2019), Borio and Filardo (2007), Iakova (2007), Rubbo (2020), Mangiante (2022), Kaihatsu, Katagiri, and Shiraki (2022)

This paper: explanation for a long-term decline in the slope from late 1940s–present

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- Goal: Δ Industrial composition $\Longrightarrow$ Δ Aggregate frequency of price change?

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- Distribution of frequency of $\mathrm{P}\Delta_t = \mathrm{F}\left(\text{Frequency of P}\Delta\text{ of product}_i, \text{Share of product in economy}_{it}\right)$

Data

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  - BLS microdata on prices
- Available for 272 CPI + 348 PPI products
- Static measure: 1998–2005 average

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Share of product in economy$_{it}$:

Own algorithm based on:

- Product–Industry mapping
- Expenditure weights
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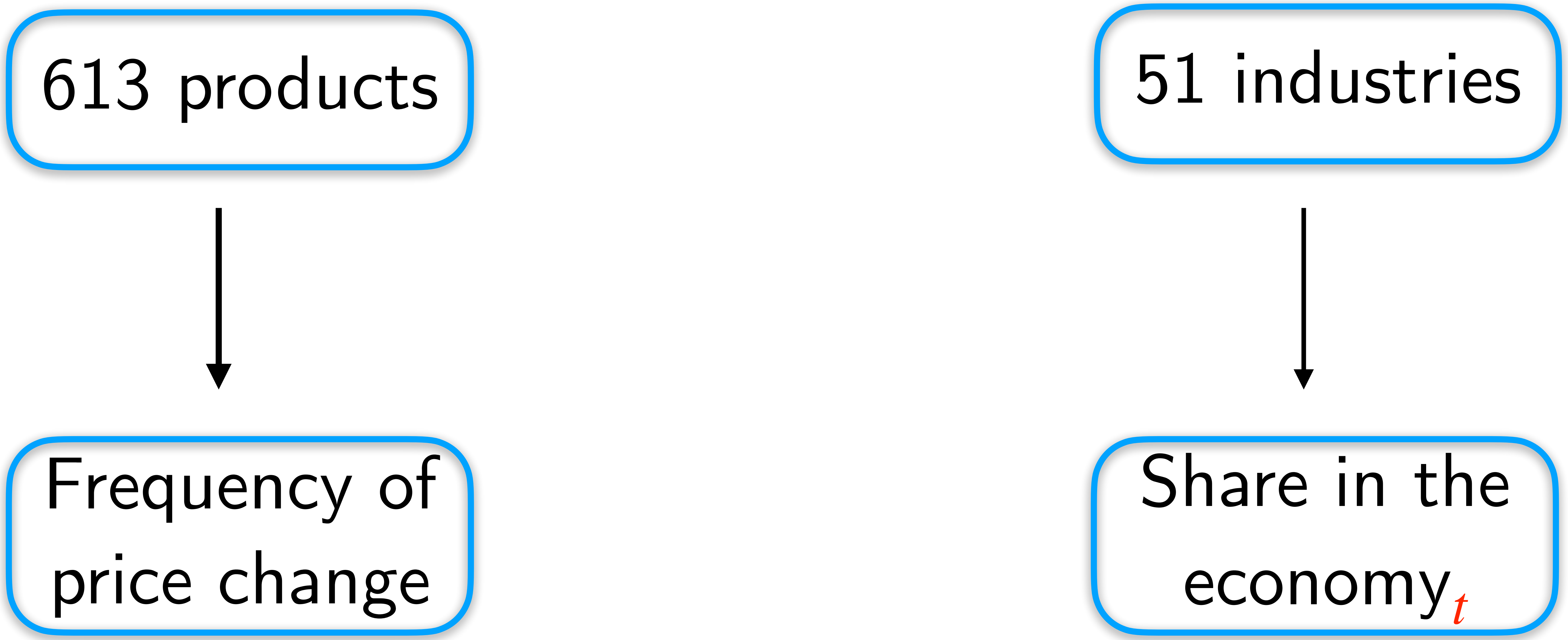
Share of industry in the economy$_{jt}$:

- BEA and World KLEMS Initiative
- Available for 65 industries
- Dynamic: 1947–2019 annual data

Result of the Algorithm



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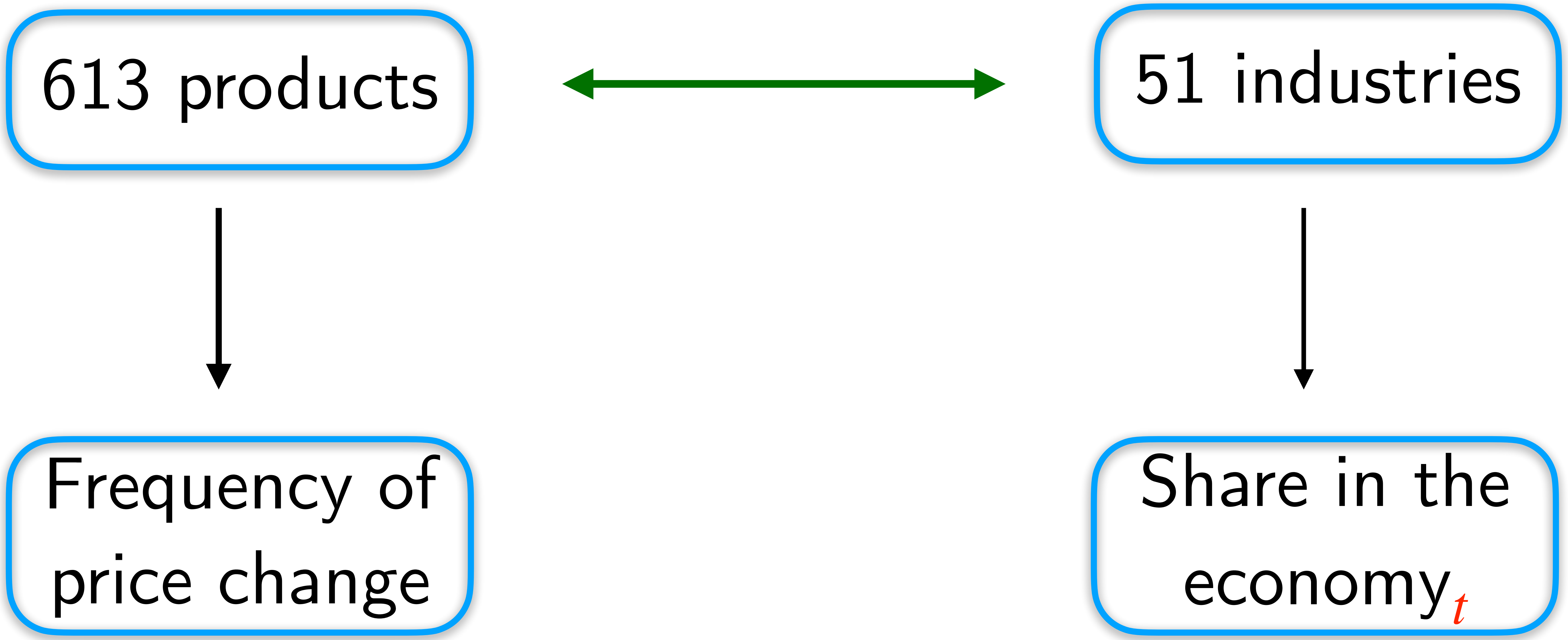

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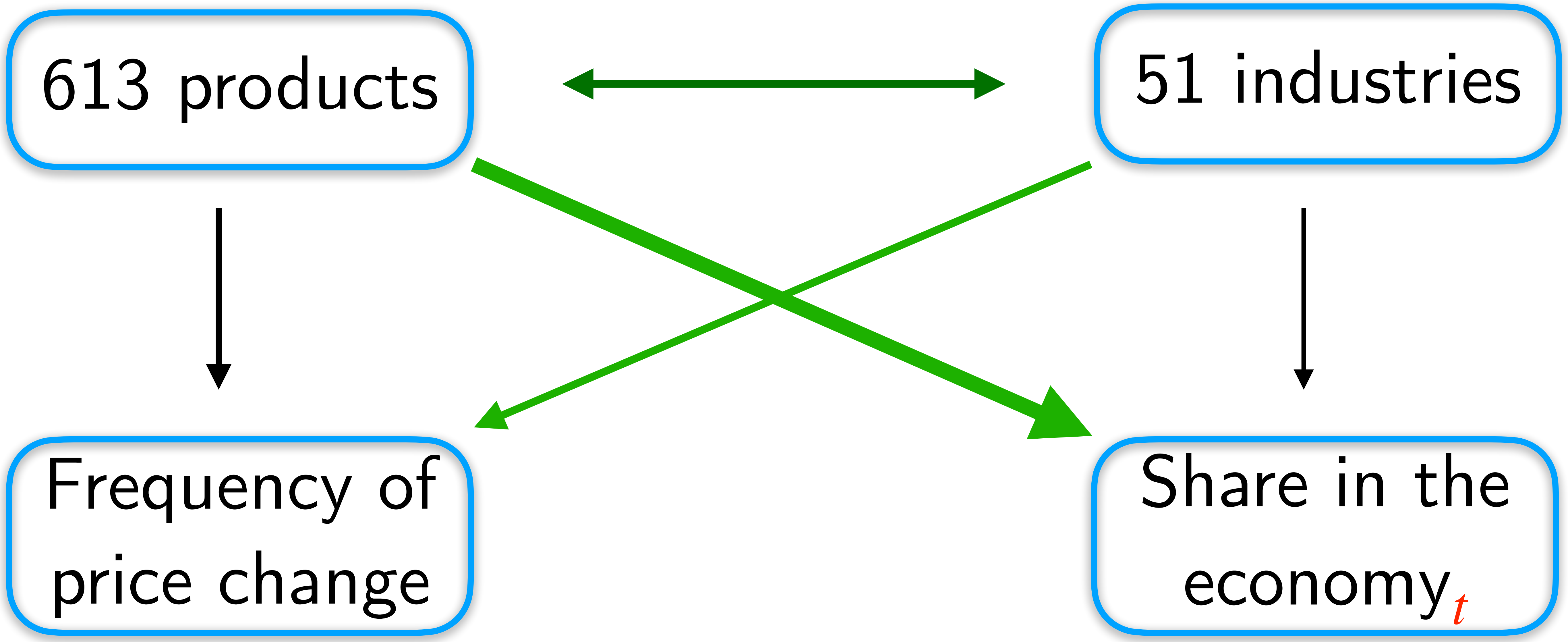

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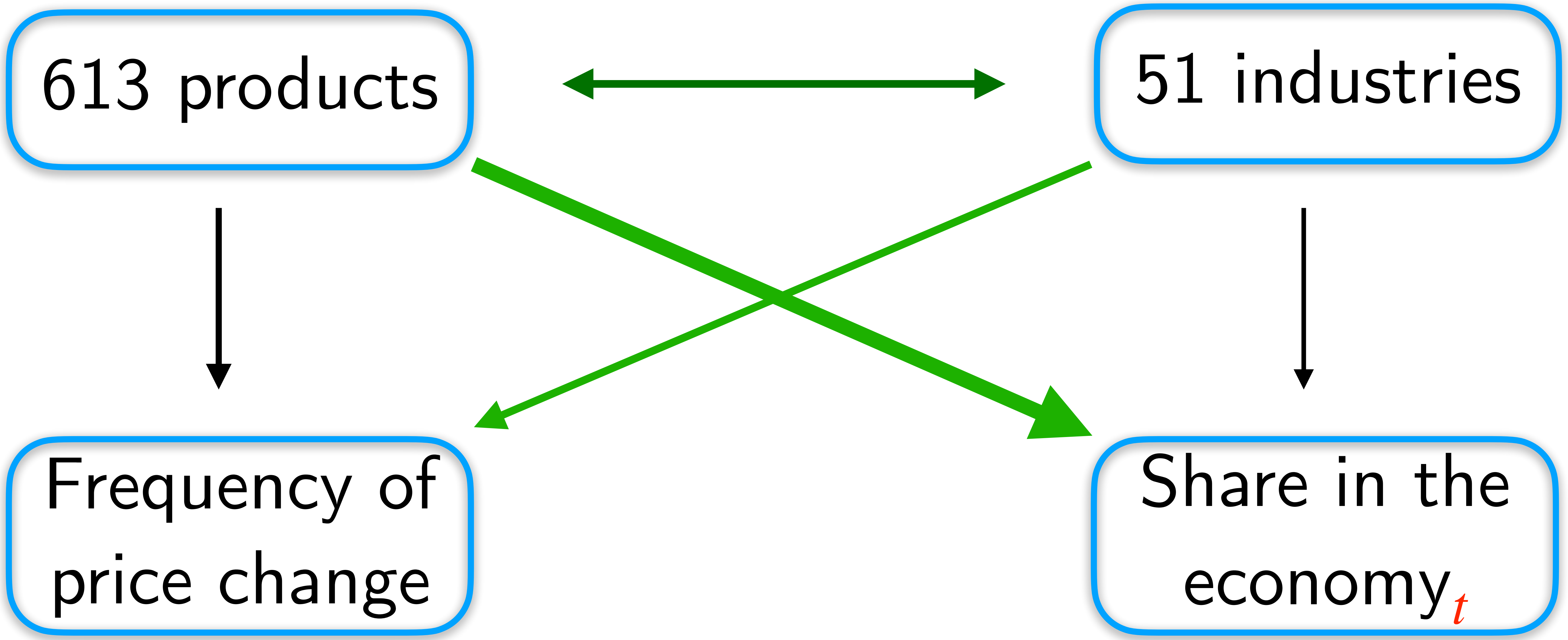

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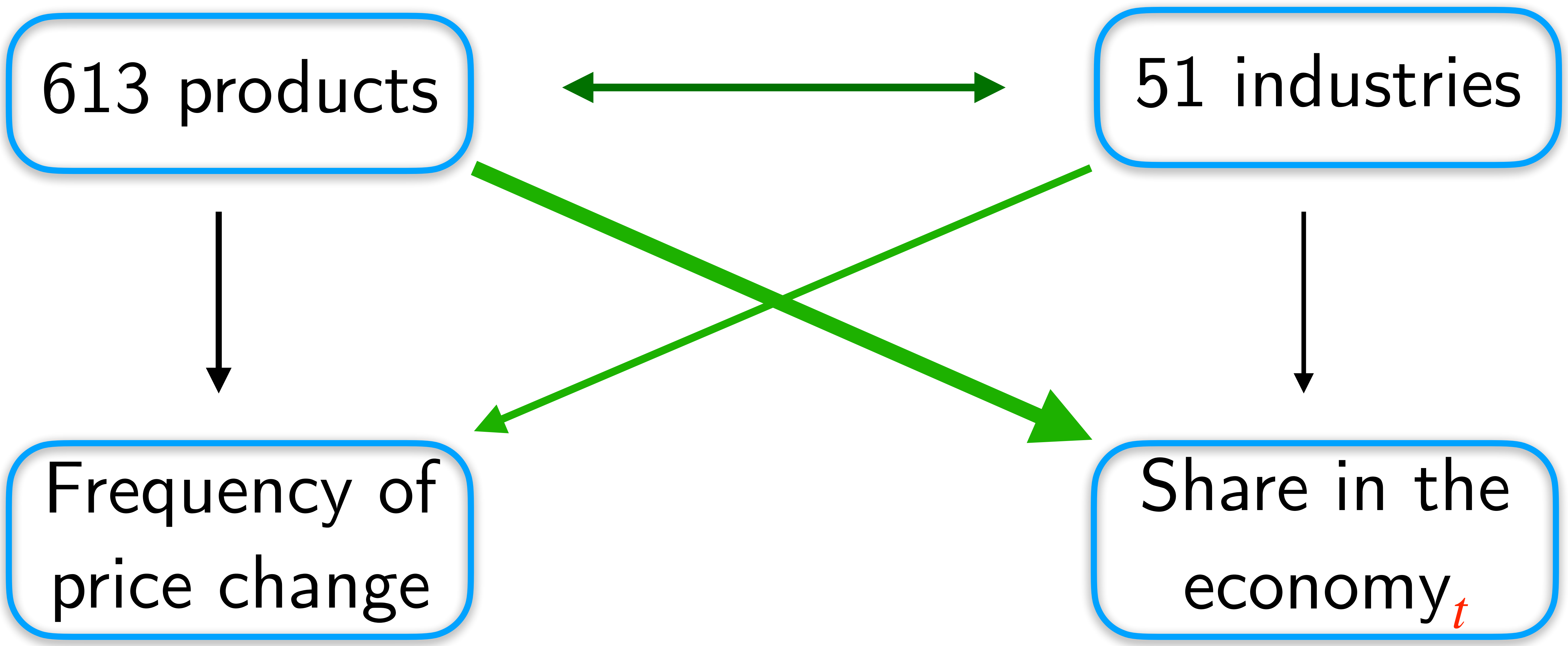

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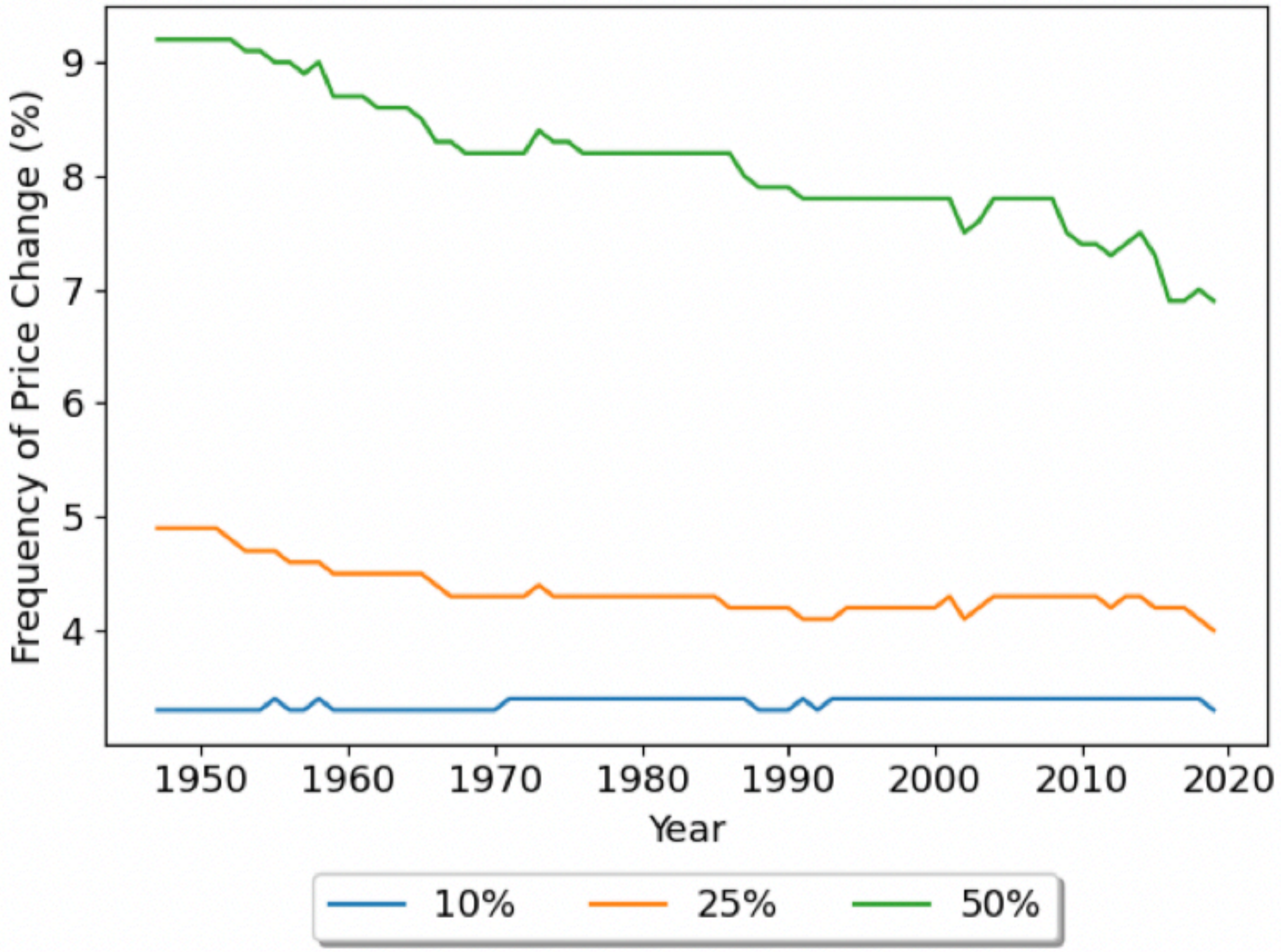
  - It can be used to compute the distribution for any statistic available at the level of the product

Distribution of any statistic of product$_t$ = F (Statistic of product$_i$, Share of product in economy$_{it}$)

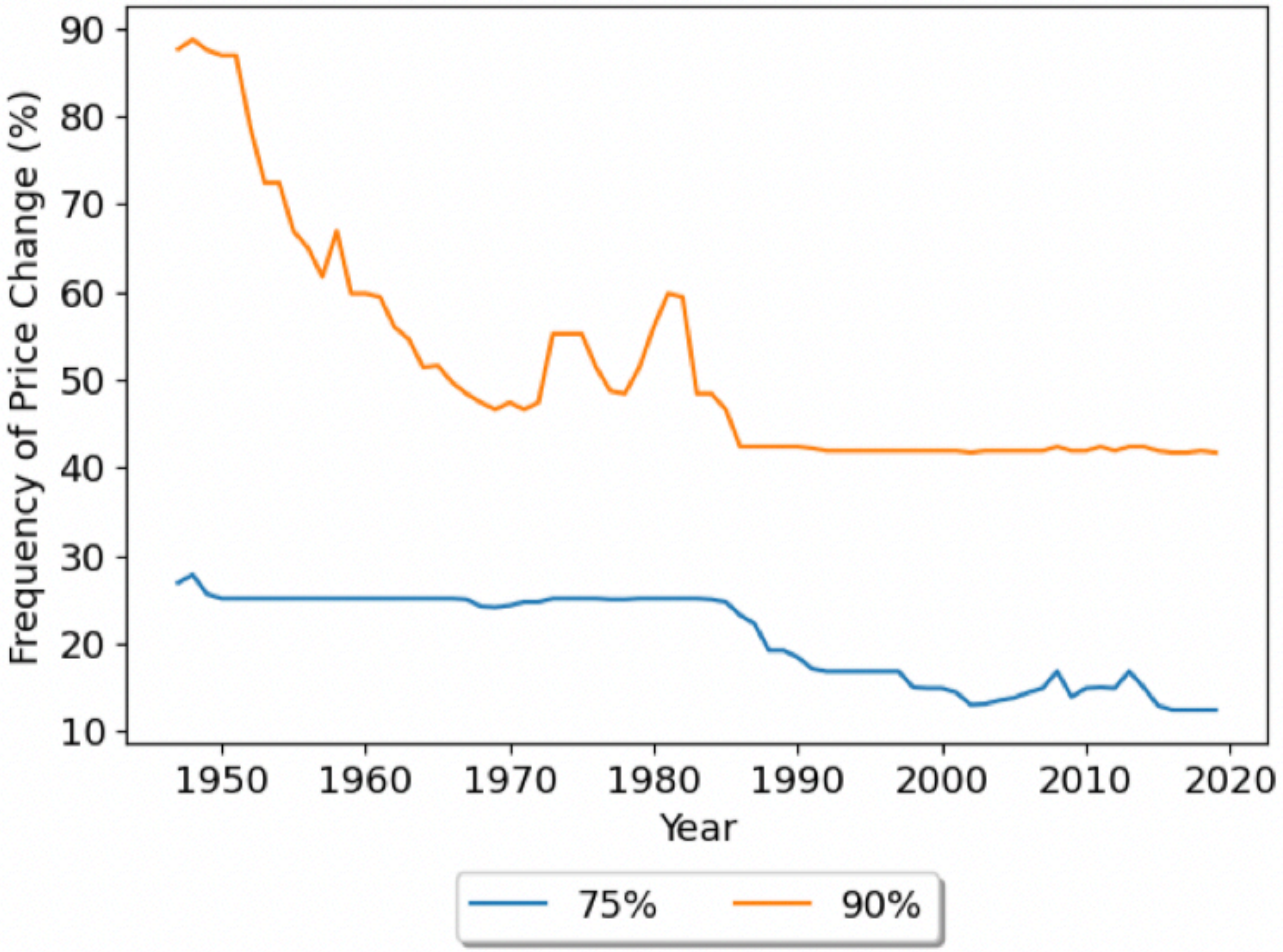
Abs. size | Prob. pos.

Result 1

- Changes in industrial composition have led to **large declines across the distribution of the frequency of price change** over the 1947–2019 period



(a) For Low Percentiles



(b) For High Percentiles

Compare NS

Result 1

- Changes in industrial composition have led to **large declines across the distribution of the frequency of price change** over the 1947–2019 period

Year	10%	25%	50%	75%	90%
1947	3.3	4.9	9.2	26.9	87.6
1957	3.3	4.6	8.9	25.1	61.7
1967	3.3	4.3	8.3	25.0	48.4
1977	3.4	4.3	8.2	25.0	48.7
1987	3.4	4.2	8.0	22.2	42.4
1997	3.4	4.2	7.8	16.8	41.9
2007	3.4	4.3	7.8	14.9	41.9
2017	3.4	4.2	6.9	12.4	41.7
2019	3.3	4.0	6.9	12.4	41.7

Result 1

- Median frequency of price change has fallen from 9.2% to 6.9% over the 1947–2019 period

Year	10%	25%	50%	75%	90%
1947	3.3	4.9	9.2	26.9	87.6
1957	3.3	4.6	8.9	25.1	61.7
1967	3.3	4.3	8.3	25.0	48.4
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Result 1

- Similar declines for other percentiles (except 10th) of the distribution of frequency of price change over the 1947–2019 period

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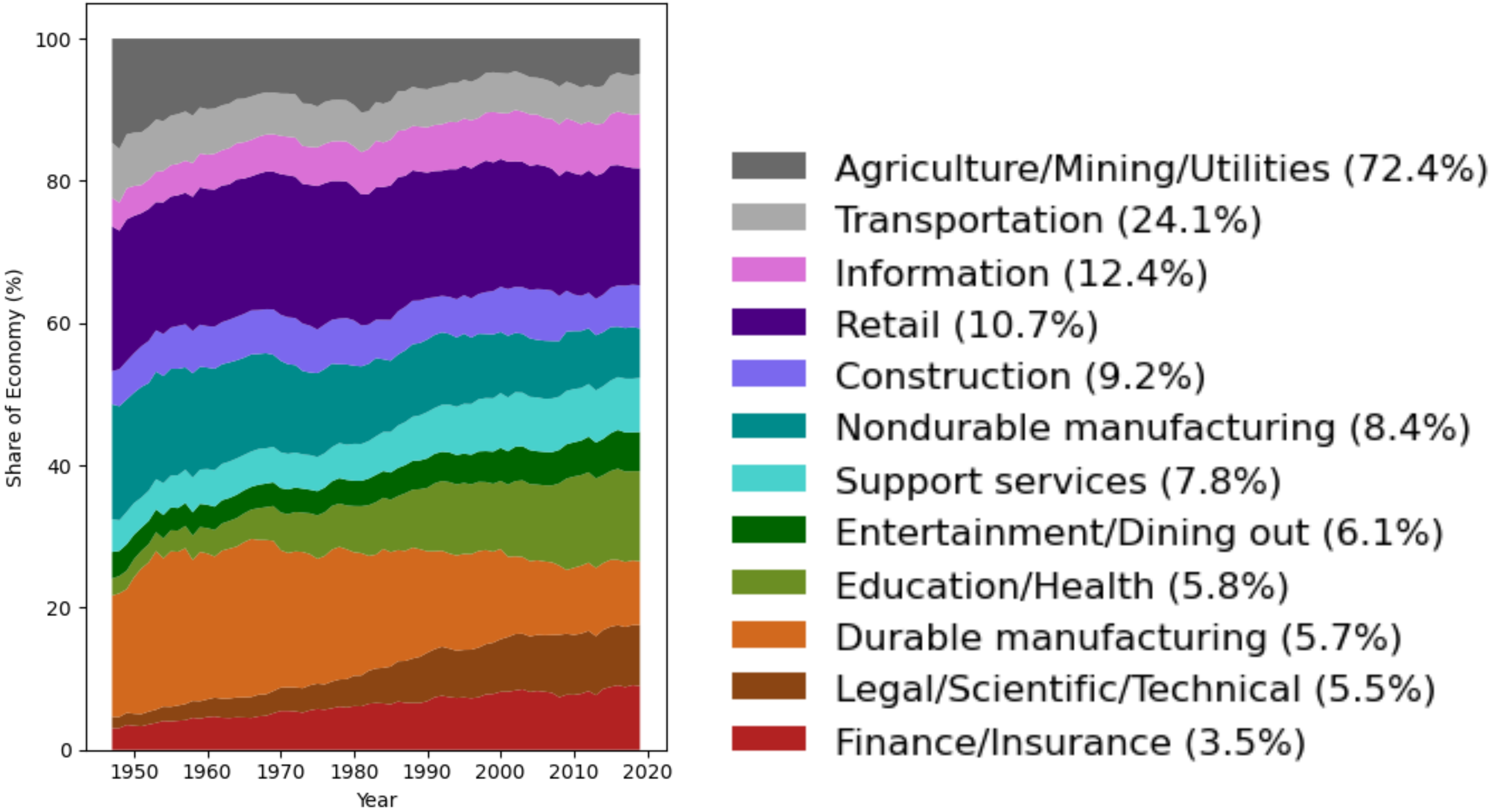
Robustness

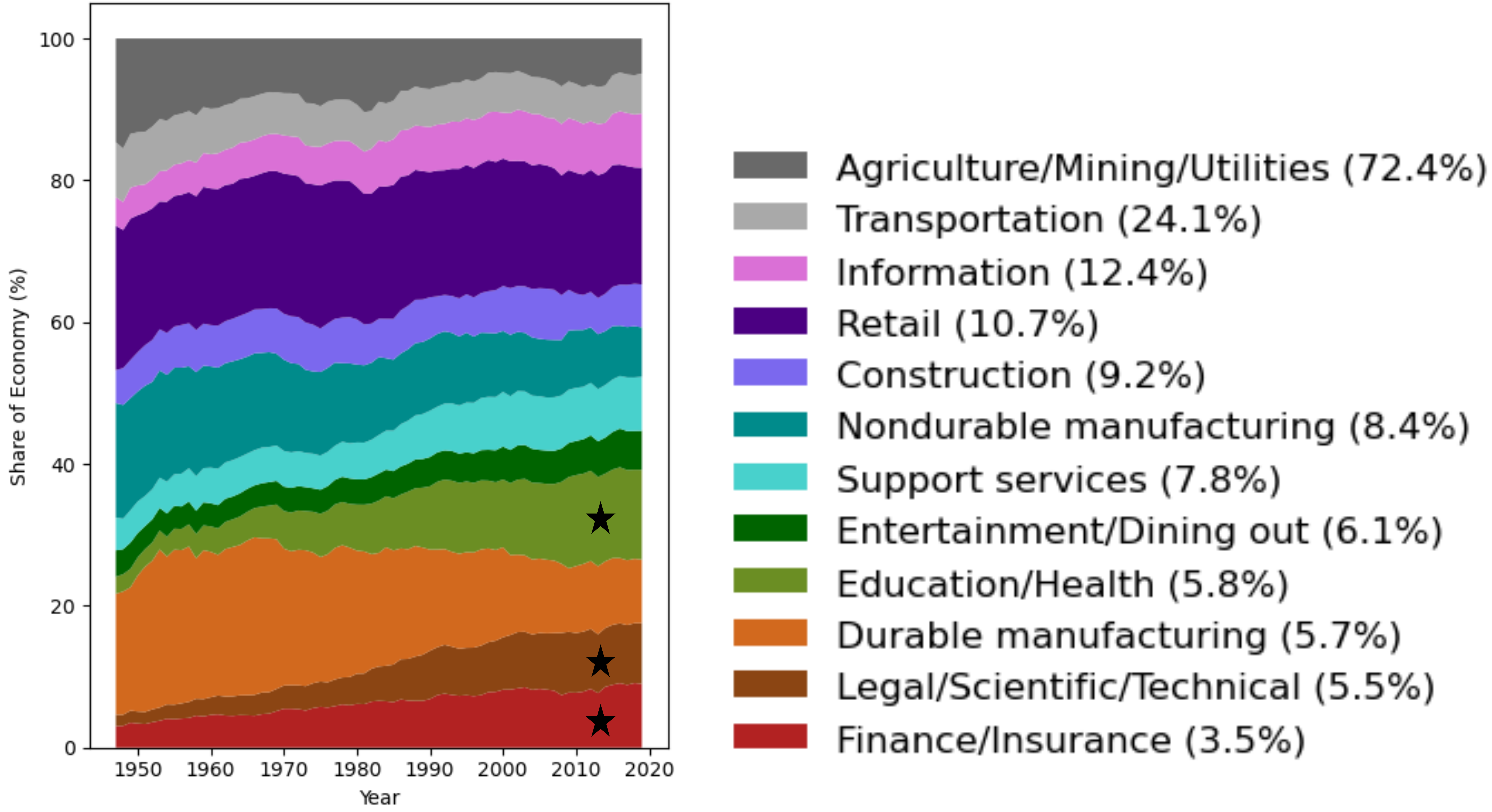
Result 2

- These declines across the distribution were driven by a **shift from primary and secondary industries to tertiary industries** over the 1947–2019 period



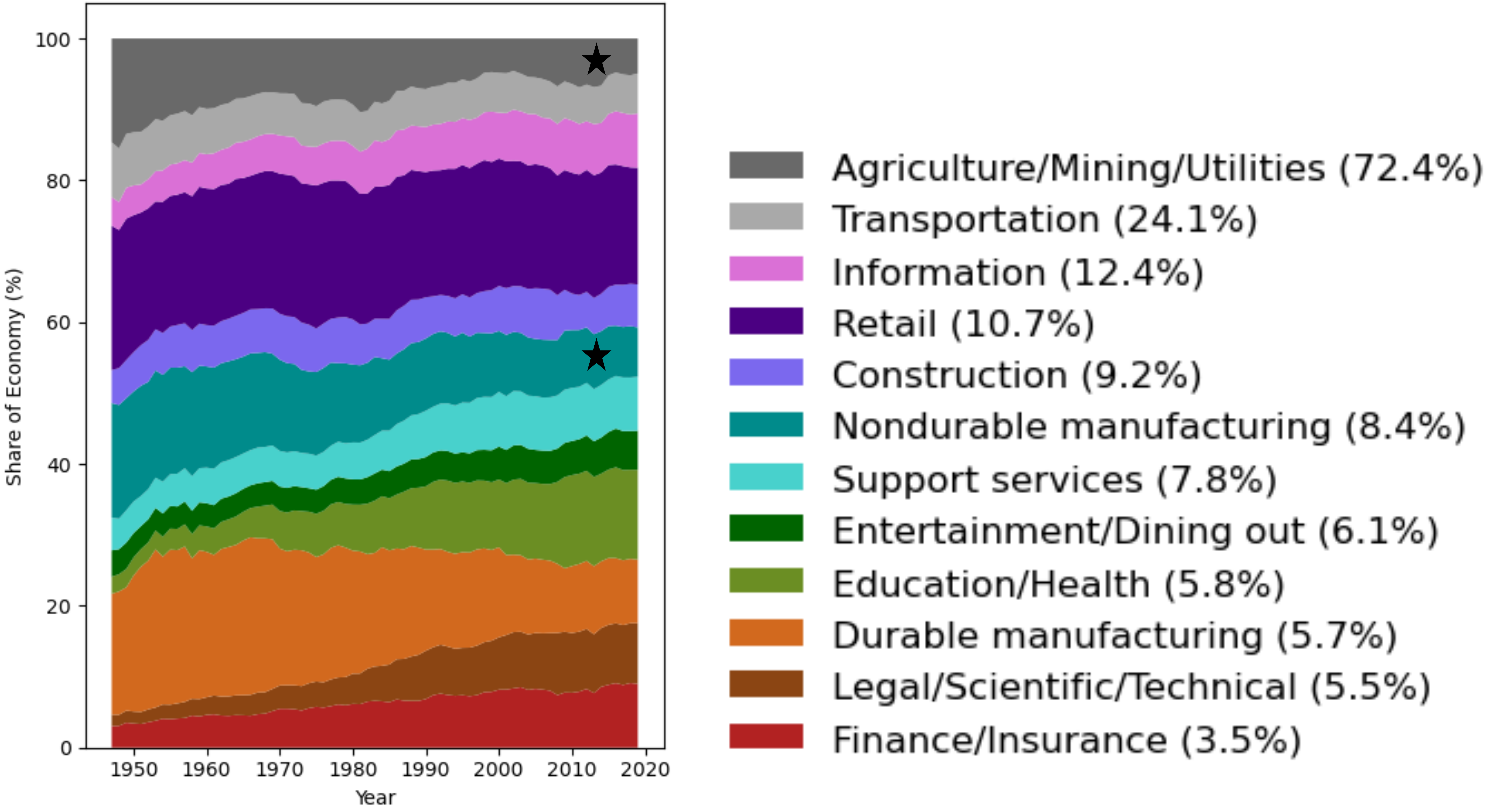
Result 2

- Finance/insurance, legal/scientific/technical, and education/health grew
  - All have low frequencies of price change



Result 2

- Nondurable manufacturing and agriculture/mining/utilities shrunk
  - Both have high frequencies of price change



Result 2

- All the five industries that grew the most:
  - Show substantially lower frequencies of price change than industries that shrunk
  - Are tertiary (service) industries

Industries with the top 5 largest increases in share of the economy

Industry Name	Freq.	1947	1983	2019
Miscellaneous professional scientific and technical services	8.2	1.1	3.5	6.7
Ambulatory health care services	3.4	1.0	3.0	5.3
Hospitals Nursing and residential care facilities	6.3	0.9	3.1	4.6
Administrative and support services	4.3	0.5	1.8	4.1
Federal Reserve banks credit intermediation and related activities	3.5	1.7	3.9	4.8

Result 2

- Three of the five industries that shrunk the most:
  - Have relatively higher frequencies of price change
  - Are primary or secondary (that extract raw materials and those that process them, respectively) industries

Industries with the top 5 largest decreases in share of the economy

Industry Name	Freq.	1947	1983	2019
Farms	94.8	10.0	1.7	0.9
Retail Trade	10.7	12.2	9.9	7.9
Food and beverage and tobacco products	22.2	5.8	3.1	1.8
Rail transportation	24.1	4.0	0.8	0.3
Primary metals	34.8	2.8	1.2	0.4

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- The remaining two industries are associated with the sale and transportation of their goods

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  - Idiosyncratic productivity shocks → sector-specific distribution with std. dev. $\sigma_{\epsilon,j}$
  - Menu cost → sector-specific χ_j

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- Model solved for a **given distribution of sectors** (share of sector in the economy$_{jt}$)
- Simulate Phillips curve in response to **aggregate nominal demand shocks**

Details

Parameters

Calibration

Sector #	Target Moments: Price change		Weight (%)
	Frequency (%)	Absolute Size (%)	(1983)
1	2.34	13.59	7.93
2	3.34	14.16	3.72
3	3.64	17.54	11.24
4	4.39	9.94	6.03
5	5.34	8.54	6.74
6	6.15	10.92	7.27
7	7.59	6.44	8.97
8	8.99	9.31	9.64
9	10.11	8.38	3.02
10	13.25	6.75	7.15
11	22.34	13.93	3.18
12	30.23	8.71	11.60
13	49.61	7.78	6.16
14	92.95	5.31	7.30

Calibration

Sector-specific menu cost

Sector #	Target Moments: Price change		Estimated Parameters		Weight (%)
	Frequency (%)	Absolute Size (%)	χ_j	$\sigma_{\epsilon,j}$	(1983)
1	2.34	13.59	0.0057	0.0685	7.93
2	3.34	14.16	0.0074	0.0824	3.72
3	3.64	17.54	0.0043	0.0877	11.24
4	4.39	9.94	0.0013	0.0471	6.03
5	5.34	8.54	0.0008	0.0403	6.74
6	6.15	10.92	0.0011	0.0531	7.27
7	7.59	6.44	0.0004	0.0306	8.97
8	8.99	9.31	0.0005	0.0377	9.64
9	10.11	8.38	0.0005	0.0396	3.02
10	13.25	6.75	0.0001	0.0242	7.15
11	22.34	13.93	0.0000	0.0195	3.18
12	30.23	8.71	0.0004	0.0712	11.60
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Model v Data

- **Data: slope of the Phillips Curve in 1983 = –0.15**
  - Headline inflation
  - Real GDP minus CBO's potential output
  - Estimation sample: 1973–1993

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- **Model: slope of the Phillips Curve in 1983 = –0.148**
  - Also comparable to Rubbo (2020)
    - Slope of 0.12 in 1980 through a calibrated multisector menu cost model with input–output linkages

Δ Industrial Composition $\implies$ Δ Phillips Curve

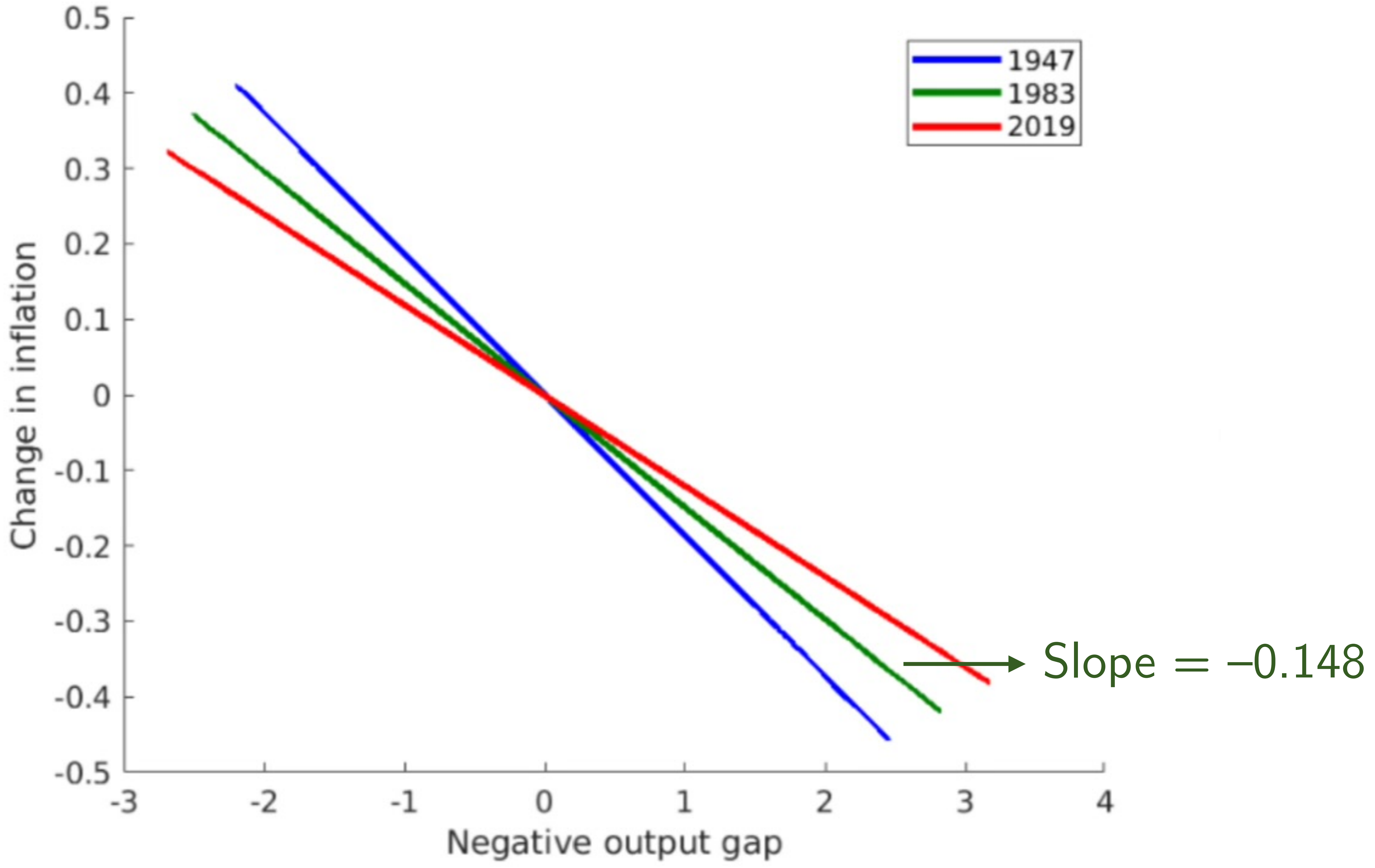
- Hold fixed:
  - Calibrated parameters
  - Nominal demand shocks

- **Change only share of sector in the economy**$_{jt}$
  - As implied by the share of product in the economy$_{it}$
    - As implied by the industrial composition of the economy for the given year

- **Simulate the Phillips curve given the new sector distribution**
  - One for each year: 1947–2019

Result 3

- These changes in the industrial composition have led to a **35.7 percent flattening** of the slope of the Phillips curve over the 1947–2019 period



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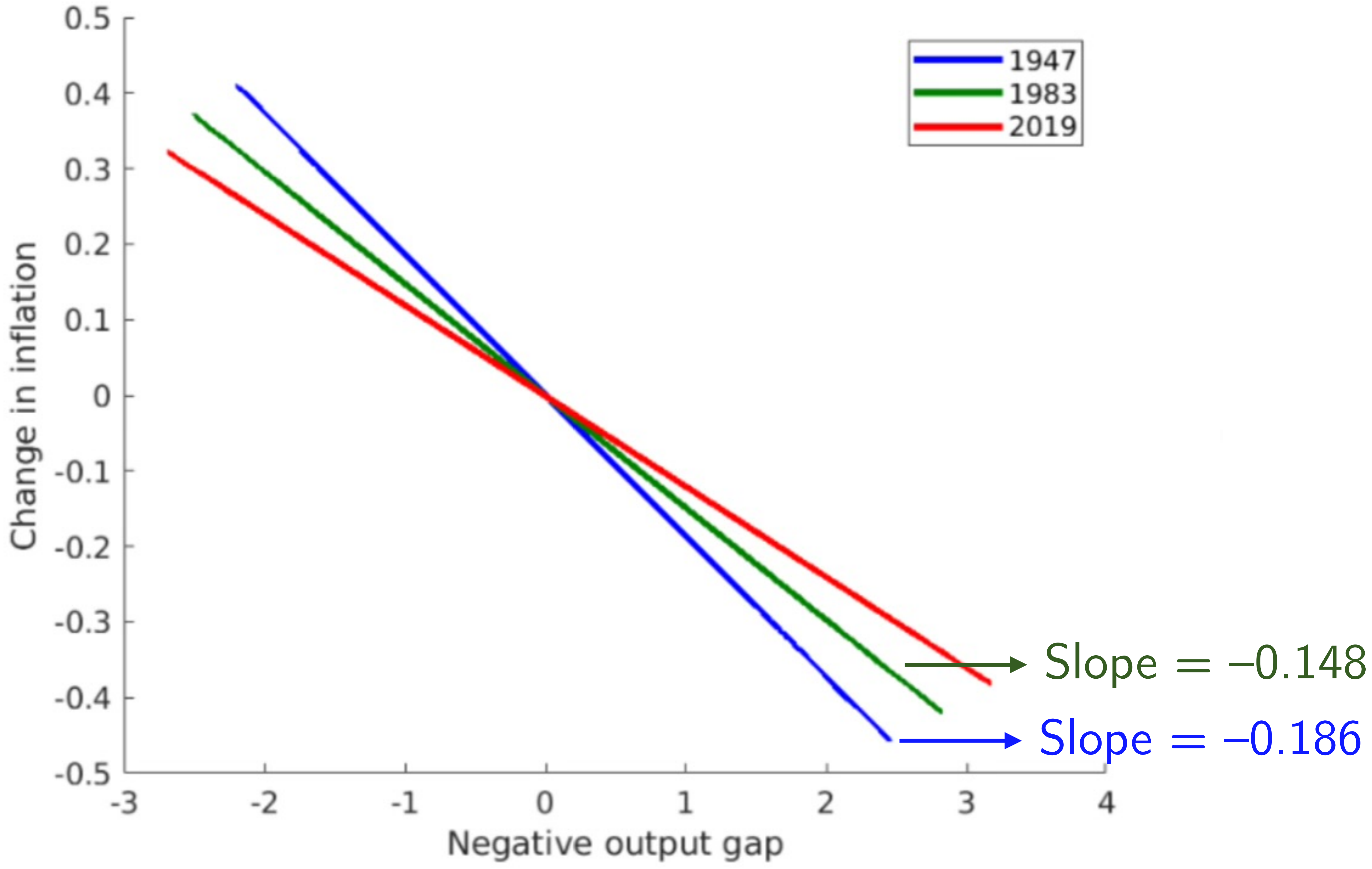

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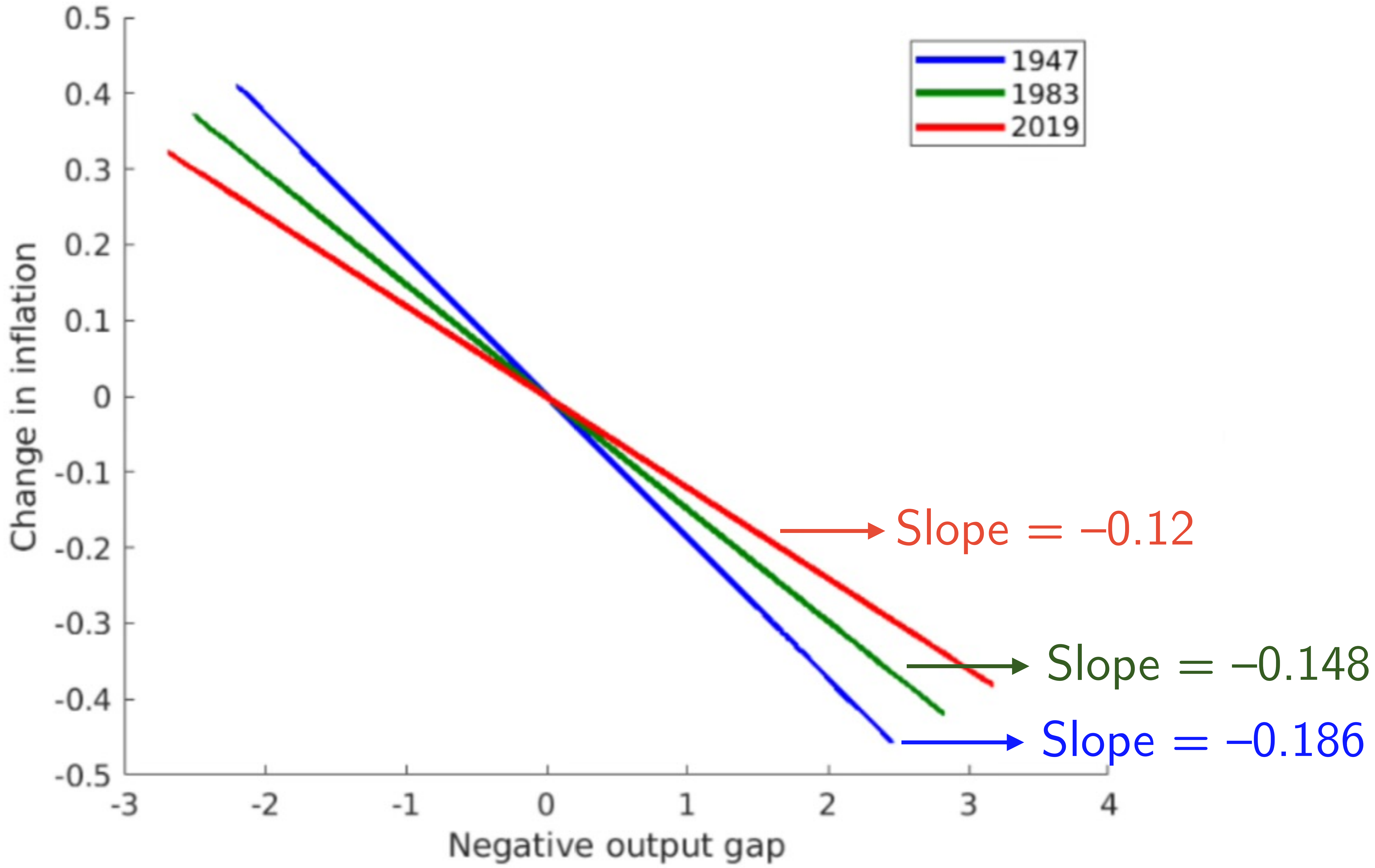

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Summary of the Results

- What is the effect of industrial composition changes on the distribution of price change frequency?

- What industrial composition shifts have driven this effect?

- What do these shifts imply for the slope of the Phillips curve?

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- What do these shifts imply for the slope of the Phillips curve?
  - Slope flatter by 35.7%

Limitation of BLS Weights

- **CPI:**
  - Weights only available at a higher level of aggregation (item strata rather than ELI)
  - Major reclassification of products (1977, 1988, 1998)
    - Nakamura and Steinsson (2008) provide concordance for a consistent panel between 1977–2019
    - But pre-1977 data cannot be used in the same distribution
- **PPI:**
  - Weights only available starting in 1998
  - Products line up imperfectly with the products for which Nakamura and Steinsson (2008) compute a frequency of price change

Discussion of Assumptions

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  - Estimates of price–change frequency from a different sample period (BLS microdata)
  - Time–varying estimates of price-change frequency in the service sector (Nakamura and Steinsson (2018))

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- **Check to determine if the second assumption may be introducing bias:**
  - Time–varying weights of PPI products (BLS)

Static Price–Change Frequency From Different Periods

- **BLS microdata on prices:**
  - Compute price–change frequency for CPI products from different samples
    - 1998–2005 (baseline)

Price-Change Freq. From	1947	1983	2019
1998–2005	9.2	8.2	6.9

Static Price–Change Frequency From Different Periods

- BLS microdata on prices:
  - Compute price–change frequency for CPI products
    - 1998–2005 (baseline)
    - 1988–1997

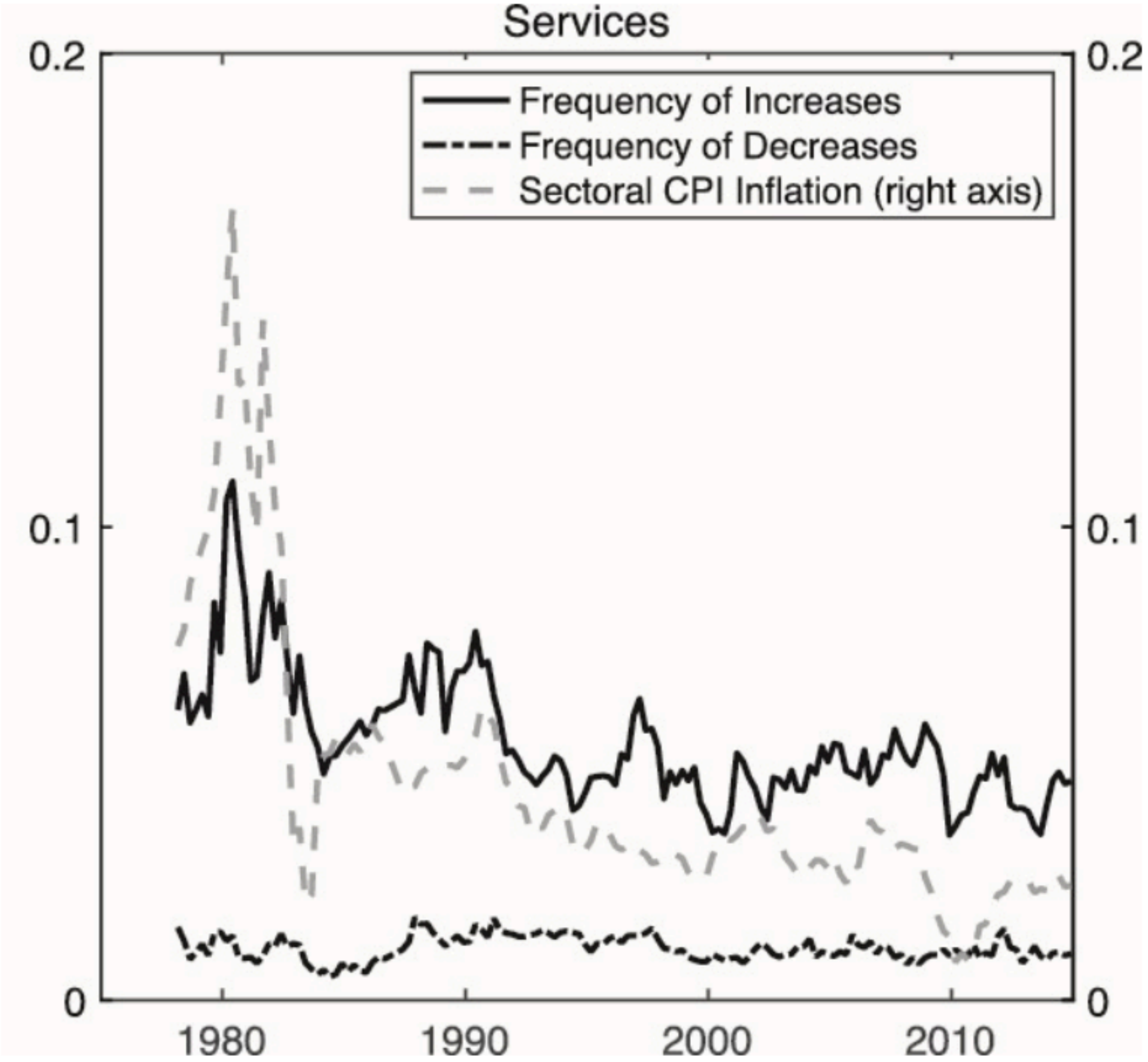
Price-Change Freq. From	1947	1983	2019
1998–2005	9.2	8.2	6.9
1988–1997	9.0	8.4	7.3

Static Price–Change Frequency From Different Periods

- BLS microdata on prices:
  - Compute price–change frequency for CPI products
    - 1998–2005 (baseline)
    - 1988–1997
    - 2010–2019

Price-Change Freq. From	1947	1983	2019
1998–2005	9.2	8.2	6.9
1988–1997	9.0	8.4	7.3
2010–2019	10.1	8.4	6.9

Service Sector: Time–Varying Price Change Frequency



The figure shows the frequency of price change (increases and decreases) for products in the service industry from 1978 through 2015. To construct the frequency series plotted in this figure, Nakamura et al. (2018) calculates the mean frequency of price increases and decreases in each ELI for each month. They then take the weighted median across ELIs for services separately and plot them. Sources: Nakamura et al. (2018).

PPI Products: Time–Varying Weights

- Employ time–varying PPI weights data and compare to the fixed weights baseline
  - Weights capture the intensity of products sold within an industry
  - Available starting in 1998

PPI Products: Time–Varying Weights

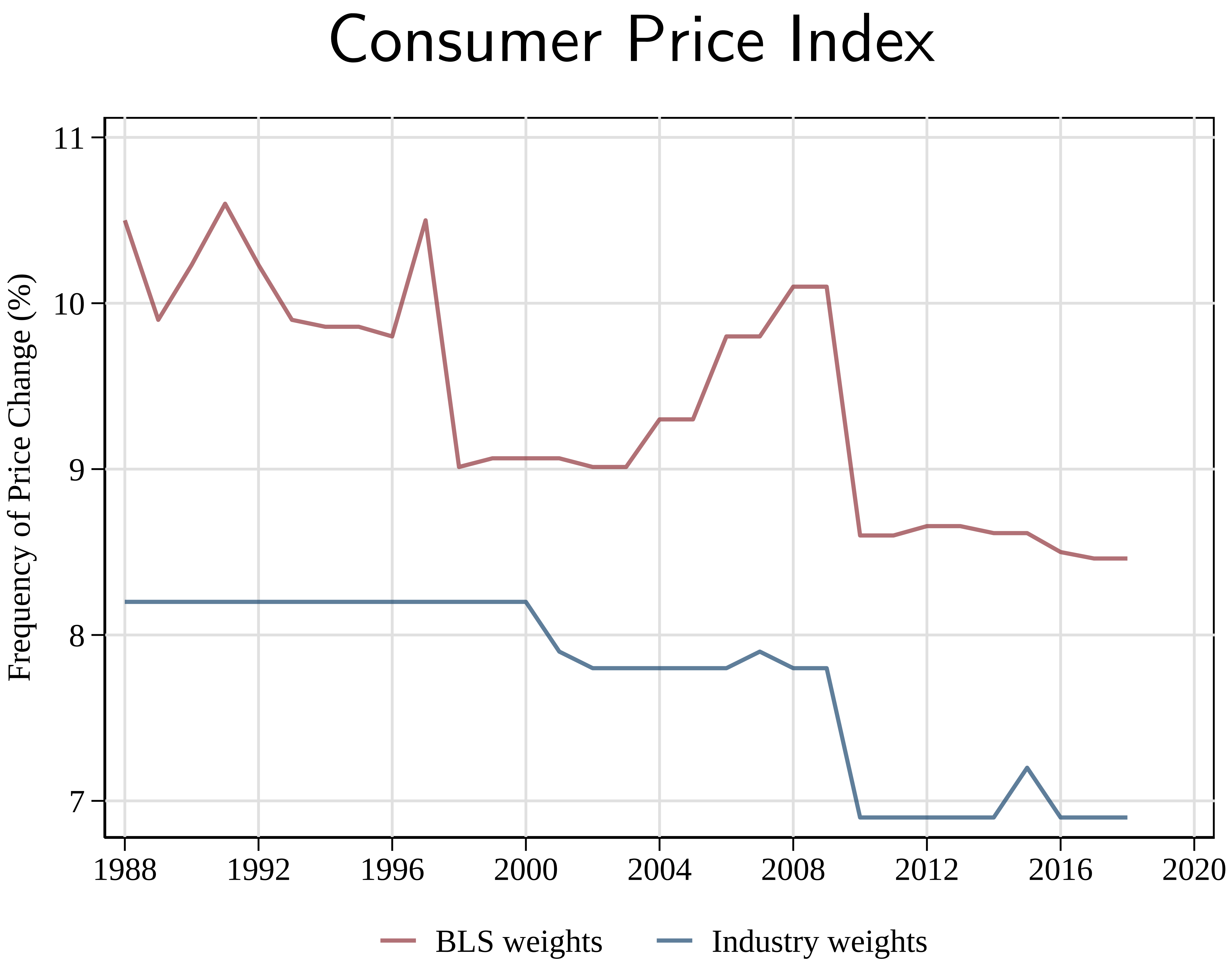
- Employ time–varying PPI weights data and compare to the fixed weights baseline
  - Weights capture the intensity of products sold within an industry
  - Available starting in 1998
  - The price–change frequency distributions are similar

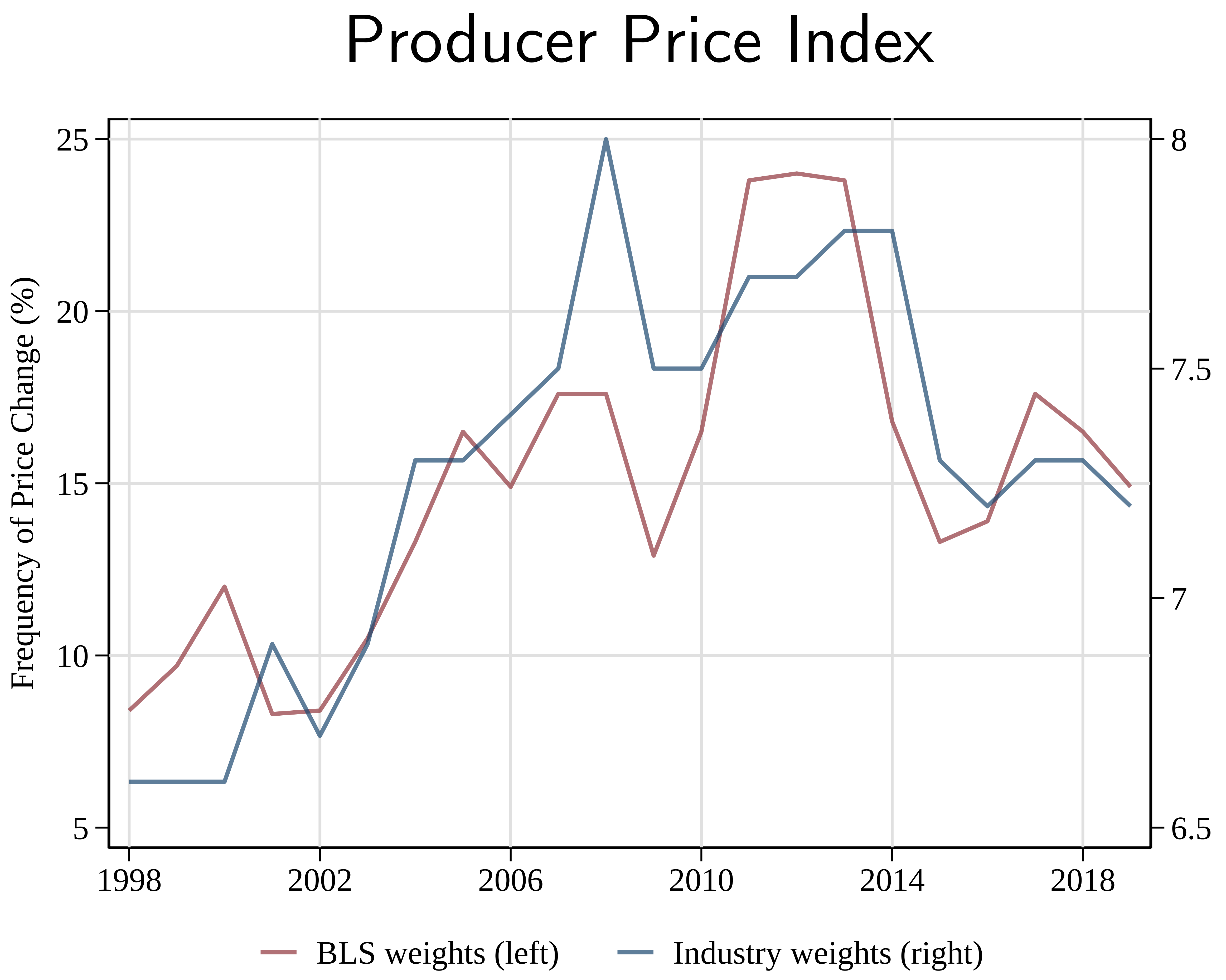
Percentile	1998	2004	2009	2014	2019
Panel A: Weights Fixed to 1998 Weights					
10%	3.1	3.2	3.2	3.2	3.1
25%	4.3	4.5	4.5	4.5	4.3
50%	7.9	7.9	7.8	7.8	7.4
75%	14.9	13.8	12.7	13.9	12.1
90%	41.9	42.4	42.4	43.1	41.9
Panel B: Varying Weights					
10%	3.1	3.1	3.2	3.3	3.2
25%	4.3	4.5	4.5	4.5	4.3
50%	7.9	7.9	7.8	7.8	7.5
75%	14.9	14.4	13.3	14.9	12.4
90%	41.9	42.4	42.4	46.5	41.9

Limitation of BLS Weights

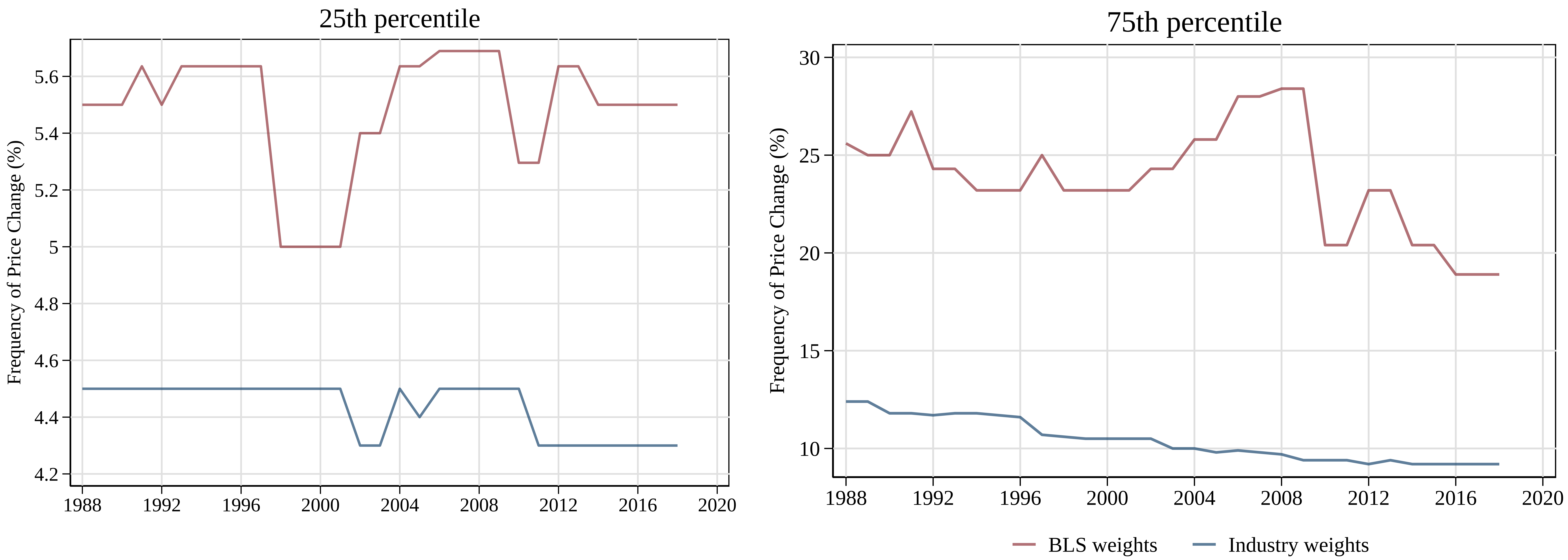
- **CPI:**
  - Weights only available at a higher level of aggregation (item strata rather than ELI)
  - Major eclassification of products (1977, 1988, 1998)
    - Nakamura and Steinsson (2008) provide concordance for a consistent panel between 1977–2019
    - But pre-1977 data cannot be used in the same distribution

Robustness: BLS Weights vs Industry Weights





Other Percentiles: BLS Weights vs Industry Weights



Conclusion

- We isolate the impact of changes in industrial composition during 1947–2019 on:
  - the distribution of products in the US economy
  - consequently the distribution of the frequency of price change across the products
- We found: US economy exhibits greater price stickiness in 2019 compared to 1947
  - Median frequency of price change fallen from 9.2% to 6.9%
  - Mean frequency of price change fallen from 24.2% to 15.1%

Conclusion

- We isolate the impact of changes in industrial composition during 1947–2019 on:
  - the distribution of products in the US economy
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- We found: US economy exhibits greater price stickiness in 2019 compared to 1947
  - Median frequency of price change fallen from 9.2% to 6.9%
  - Mean frequency of price change fallen from 24.2% to 15.1%
- Then we analyzed the degree to which these distributional changes affected the slope of the Phillips curve over this period
- We found: US Phillips curve 35.7% flatter
  - Cause: long-term structural forces, unlikely to revert
  - Central banks should account for the flattening in their decisions

Thank you!

Product–Industry Mapping Examples

Source	**Item category**	**Industry**
CPI	Books not through book clubs (RG022)	(451211) Book Stores
CPI	Automobile batteries (TC021)	(441310) Automotive Parts and Accessories Stores
CPI	Motor oil (TC022)	(441310) Automotive Parts and Accessories Stores
CPI	Tax prep & other accounting (GD052)	(541213) Tax Preparation Services
CPI	Tax prep & other accounting (GD052)	(541219) Other Accounting Services
PPI	Soft drinks (0262)	(312111) Soft Drink Manufacturing
PPI	Residential natural gas (0551)	(221210) Natural Gas Distribution
PPI	Commercial natural gas (0552)	(221210) Natural Gas Distribution
PPI	Textile housefurnishings (0382)	(314110) Carpet and Rug Mills
PPI	Textile housefurnishings (0382)	(314120) Curtain and Linen Mills

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Algorithm

$$\text{Share of product in economy}_{it} = \sum_j \underline{\text{Share of industry in economy}}_{jt} \times \underline{\text{Share of product in industry}}_{ij}$$

- BEA and World KLEMS Initiative
- Available for 65 industries
- Dynamic: 1947–2019 annual data

1. 620 products (272 CPI + 348 PPI) mapped to one or more of 2017 6-digit NAICS industries (of which there are 65)
   - We are able to map 613 products to 51 industries
2. Aggregate industries to the BEA/KLEMS World-level for which we have industry-shares data
3. Compute the *share of product in industry*$_{ij}$ using:

i) set $a_{i,j} = 1$ if product i sold in industry j; zero otherwise

ii) compute raw weight of product i sold in industry j : $b_{i,j} = \dfrac{a_{i,j}}{\sum_j a_{i,j}}$

iii) compute proportion of industry j sold by product i : $c_{i,j} = \dfrac{\omega_i b_{i,j}}{\sum_i \omega_i b_{i,j}}$, where ω_i = expenditure weight*

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* expenditure weight available for CPI products; for PPI products we set it to 1 divided by the total # of PPI products

Robustness Checks

Method	1947	1983	2019
A. Baseline	9.2	8.2	6.9
B. Including sales	11.5	8.7	7.8
C. One Klems	9.2	8.2	6.9
D. PPI weight	10.5	8.7	7.8
E. Same weight	9.1	8.0	7.2
F. No large products	9.4	7.8	6.9
G. Aggregate by industry	10.7	8.4	8.2
H. CPI Only	9.2	8.2	6.9
I. PPI Only	9.7	7.4	7.2
J. Gross Output	9.2	8.2	7.8
K. Intermediate Inputs	9.5	8.7	8.2
L. Labor Compensation	9.2	7.4	6.3
M. Consumption Share	10.9	10.9	9.2
N. Consumption Share with Shelter	10.9	8.0	8.0

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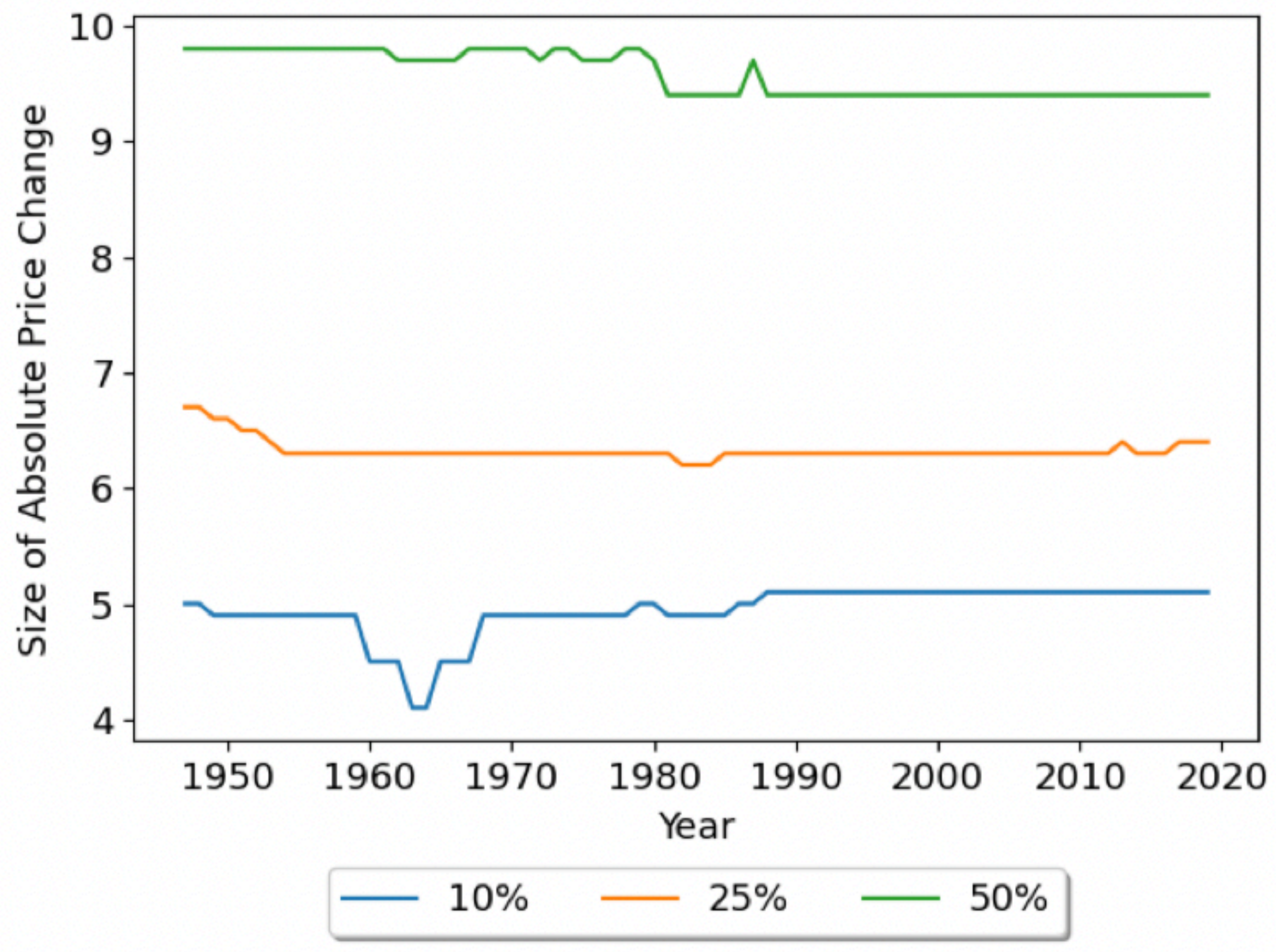
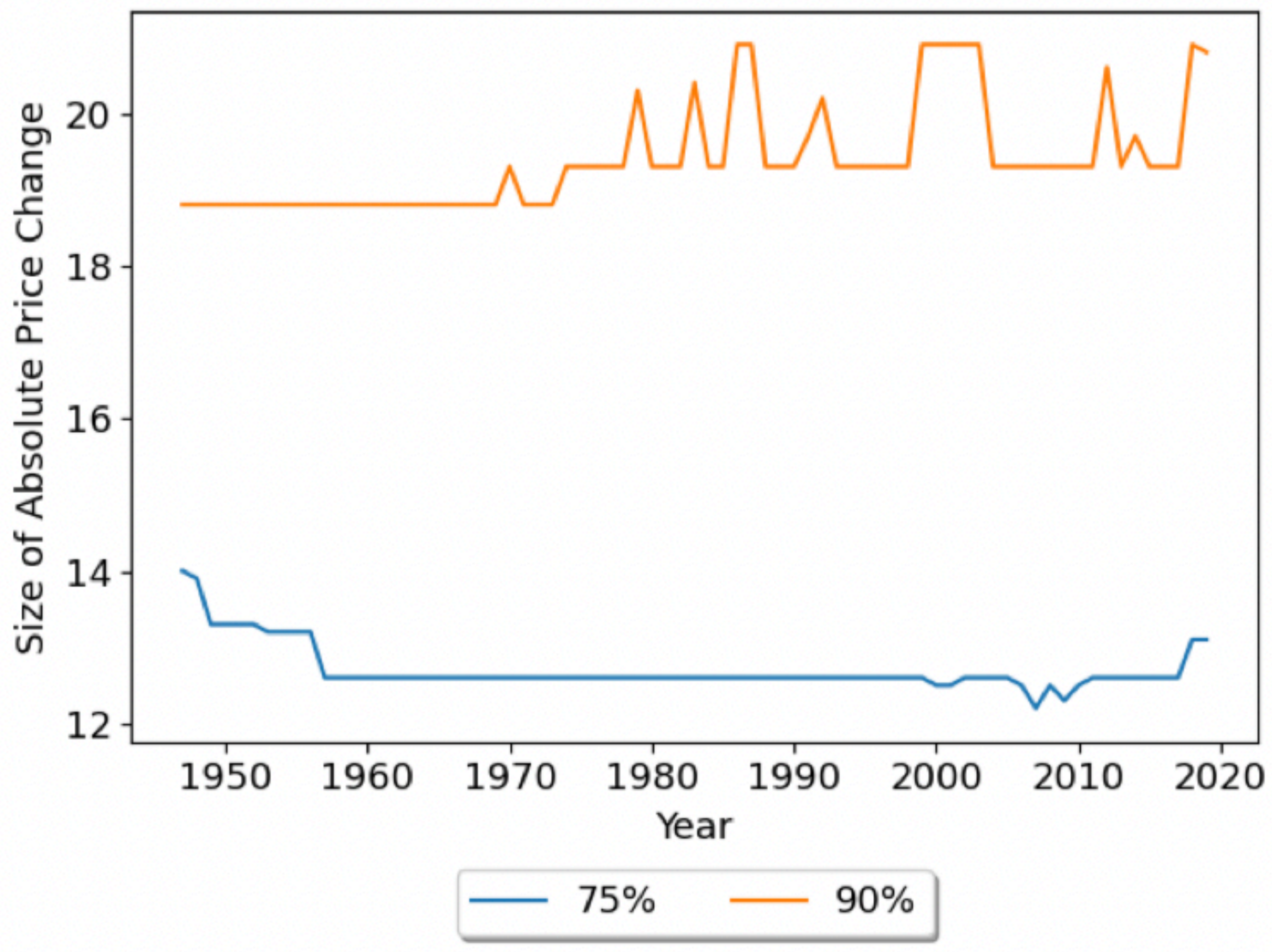
Distribution of absolute size of price change: 1947–2019



(a) For Low Percentiles

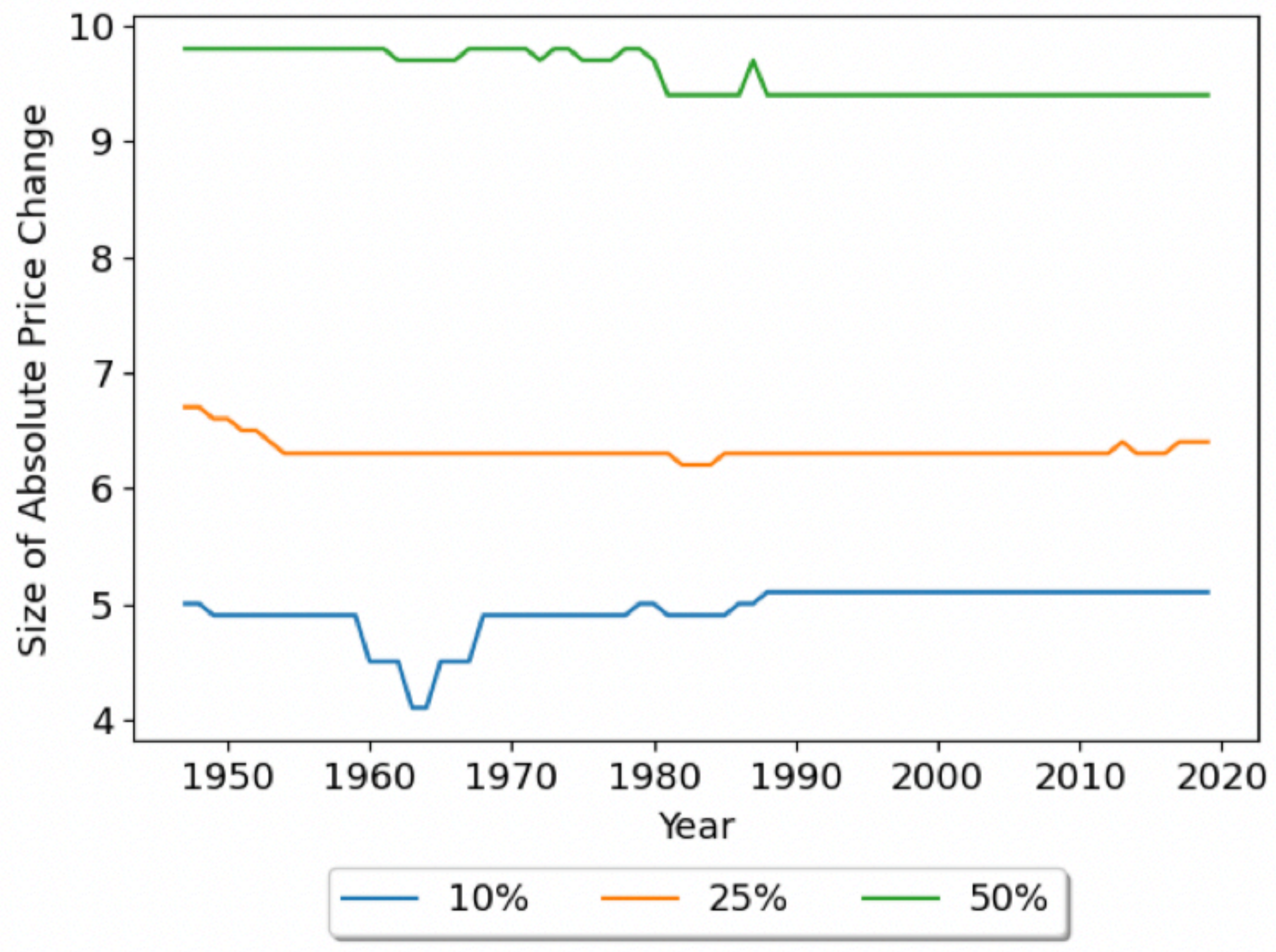


(b) For High Percentiles

- No systematic impact

Compare NS　Back

Distribution of absolute size of price change: 1947–2019



(a) For Low Percentiles

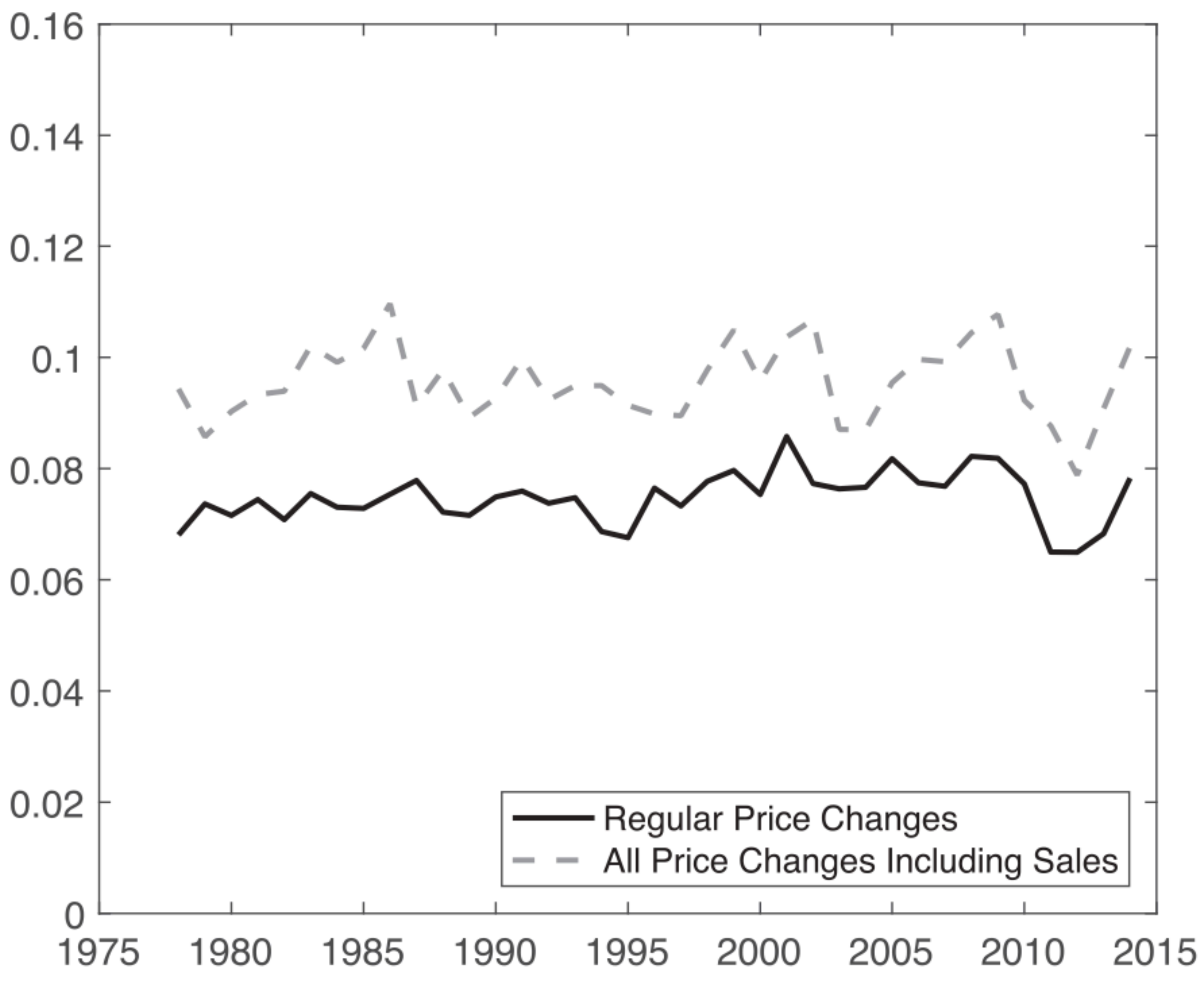


FIGURE IX

Absolute Size of Price Changes in U.S. Data

- Nakamura et al. (2018) also find roughly no change in the abs. size. of P change

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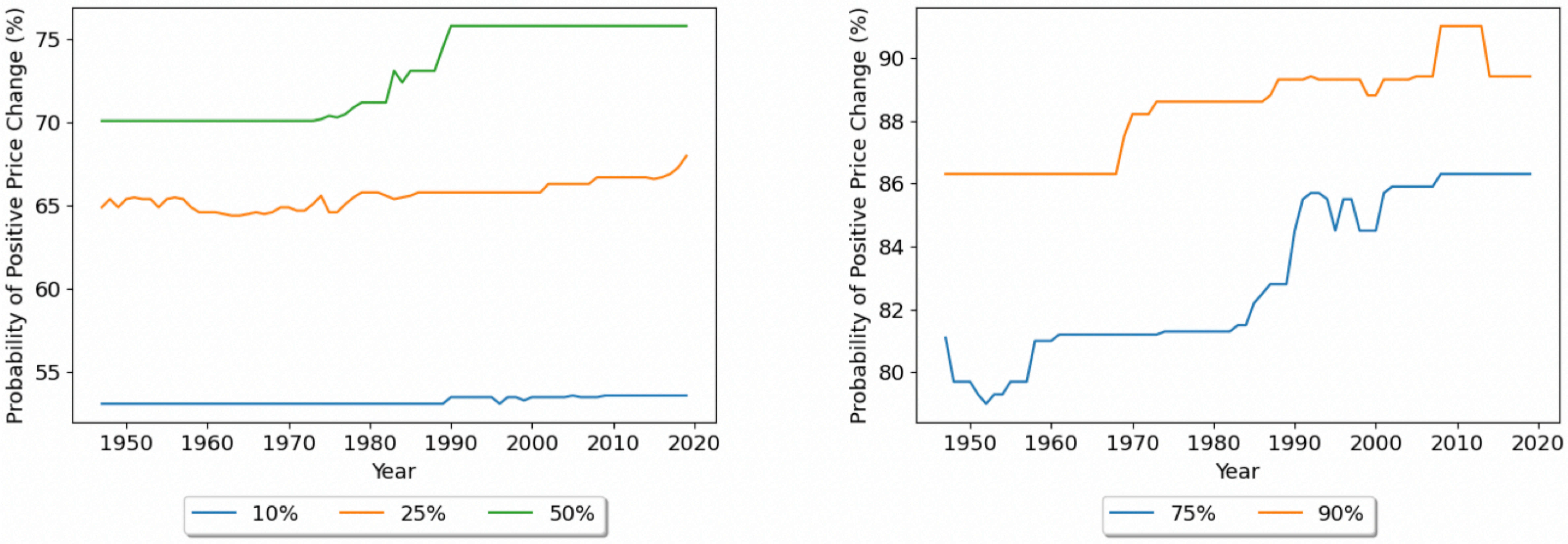
Distribution of probability of positive price change: 1947–2019



(a) For Low Percentiles

(b) For High Percentiles

- Shifted up

Compare NS

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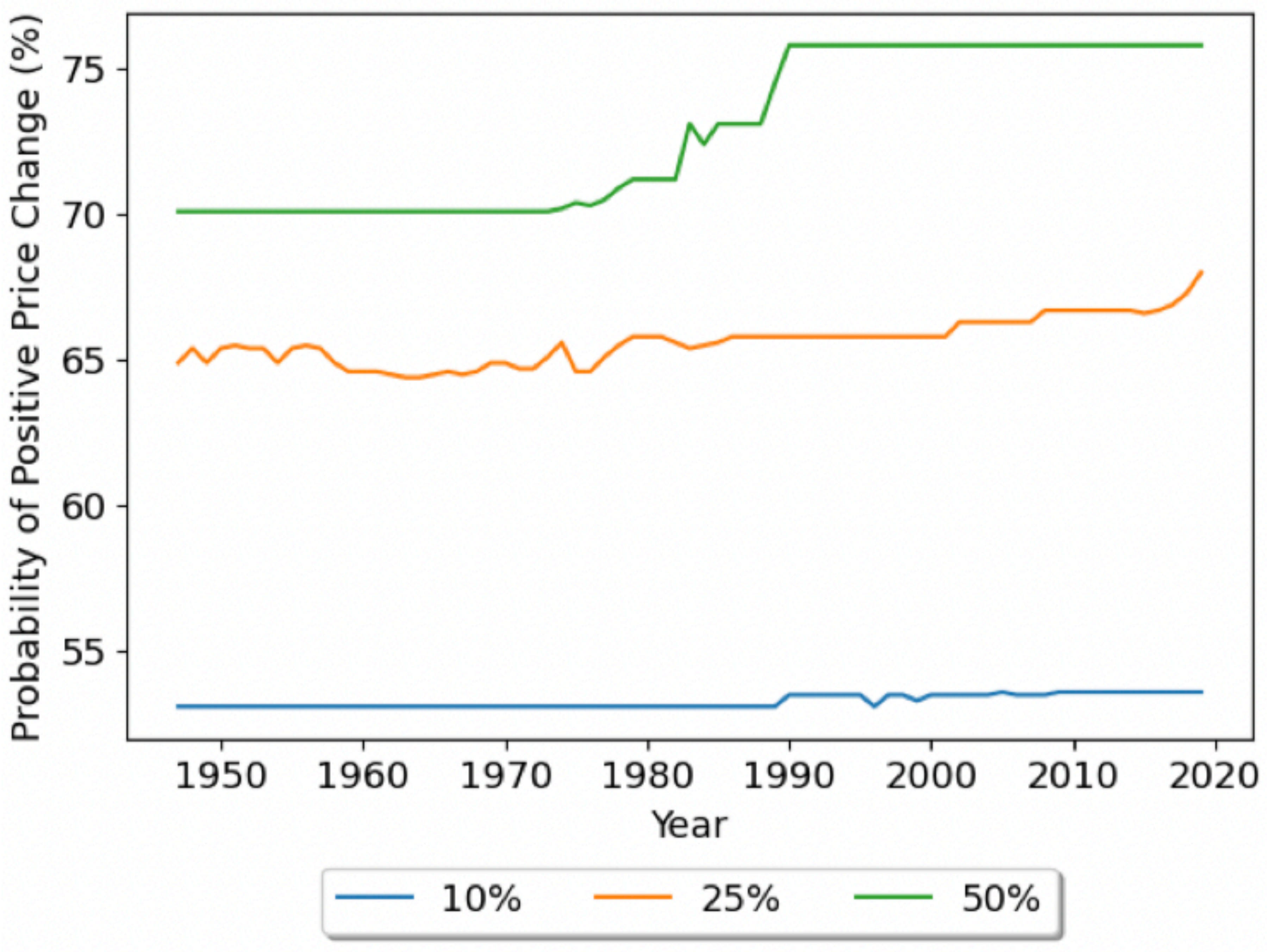
Distribution of probability of positive price change: 1947–2019



(a) For Low Percentiles

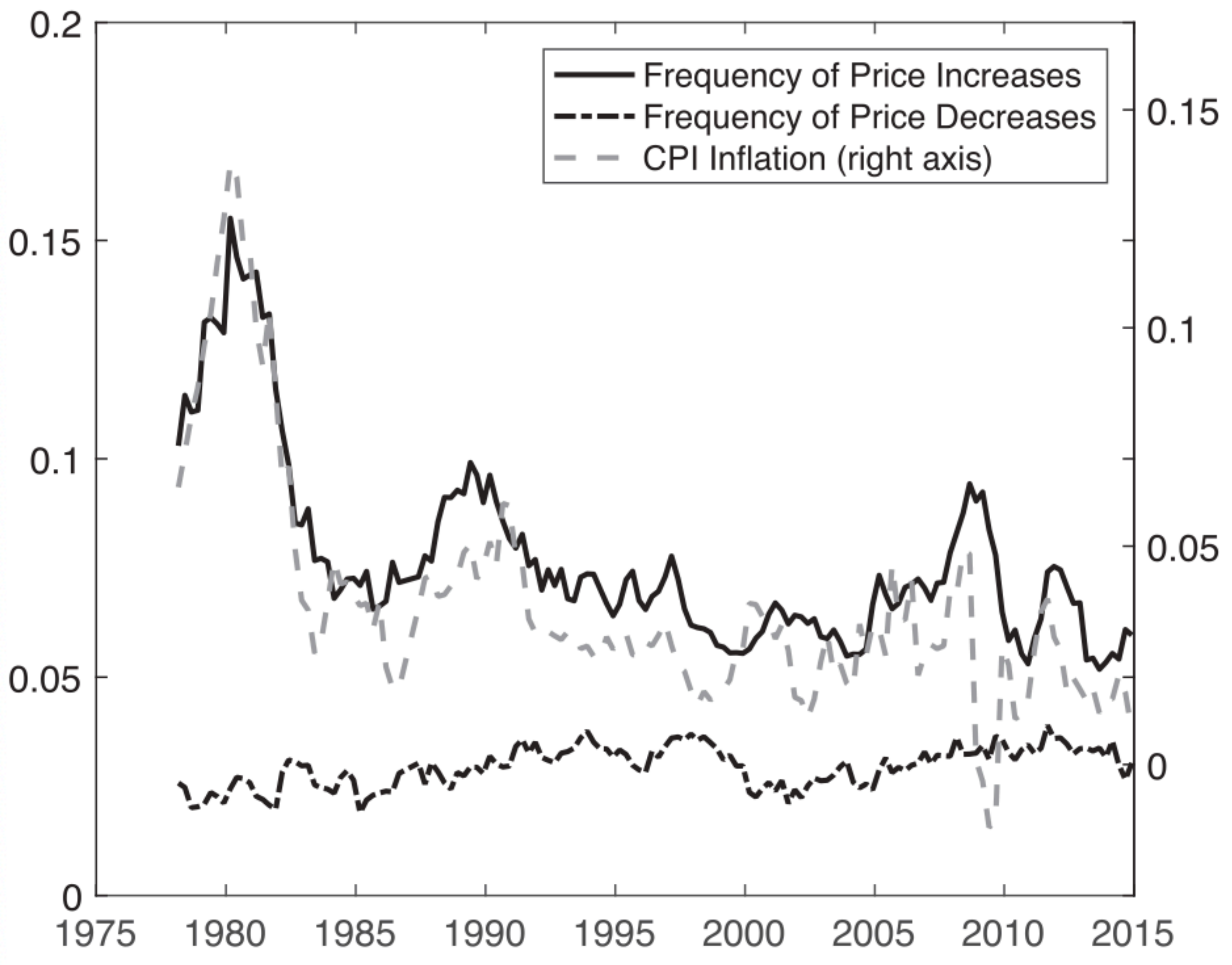


FIGURE XV

Frequency of Price Increases and Decreases

- Nakamura et al. (2018) find a reduction in the median prob. of positive P change

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Model Details

- 14 sectors
- Sector-specific:
  - Price stickiness in the form of menu costs χ_j
  - Standard deviation of firms' idiosyncratic productivity shocks $\sigma_{\epsilon,j}$
- Round-about production structure
  - Intermediate inputs as well as labor used in production
- Nominal target for monetary policy:
  - Nominal aggregate demand : $S_t = P_t C_t$
  - Monetary authority targets a path of S_t
- Idiosyncratic shocks to firms' productivity:

$$\log A_t(z) = \varrho \log A_{t-1}(z) + \epsilon_t(z) \text{ where } \epsilon_t \sim N(0, \sigma^2_{\epsilon,j}) \text{ are independent}$$

- Aggregate shocks to nominal demand:

$$\log S_t = \mu + \log S_{t-1} + \eta_t \text{ where } \mu \text{ represents trend inflation, } \eta_t \sim N(0, \sigma^2_\eta) \text{ are independent}$$

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Model Details

- Menu cost $\implies$ Firms' optimal price-setting decision is dynamic
- Recursive formulation:

$$V\left(A_t(z), \frac{p_{t-1}(z)}{P_t}, \frac{S_t}{P_t}\right) = \max_{p_t(z)} \left\{ \Pi_t^R(z) + \mathbb{E}_t \left[D_{t,t+1}^R V\left(A_{t+1}(z), \frac{p_t(z)}{P_{t+1}}, \frac{S_{t+1}}{P_{t+1}}\right)\right]\right\}$$

- Solution: intractable because state space of the firm's problem includes the aggregate price level P_t, which is an infinite dimensional object
- Assumption to make the model tractable: price level perceived to evolve depending on only the nominal demand deflated by the preceding period's aggregate price level:

$$\frac{P_t}{P_{t-1}} = \Gamma\left(\frac{S_t}{P_{t-1}}\right)$$

  - P_{t-1}, though endogenous, is in the information's set at time t
  - S_t exogenous
- General equilibrium solution computed using Value Function Iteration on a discretized state space

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Calibration

Parameter	Description	Value
σ	Coefficient of relative risk aversion	1
ψ	Labor disutility convexity	0
β	Discount factor	$0.96^{\frac{1}{12}}$
θ	Elasticity of substitution	4
L	Steady-state labor supply	0.33
μ	Mean growth rate of nominal AD	0.0028
σ	Std. dev. of the growth of nominal AD	0.0065
s_m	Share of int. inputs in production	0/0.7
ρ	Persistence in firms' productivity	0.7

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Model Robustness

Year	Frequency (%)		Absolute Size (%)		Prob. Positive (%)	
	Data	Model	Data	Model	Data	Model
Panel A. *Mean*						
1947	24.2	24.0	10.8	9.4	70.2	71.2
1983	18.7	18.6	10.0	10.1	71.9	73.0
2019	15.1	15.0	10.3	10.3	74.9	75.0
Panel B. *Median*						
1947	9.2	9.2	9.8	8.6	70.1	70.5
1983	8.2	7.4	9.4	9.9	73.1	73.4
2019	6.9	7.3	9.4	9.9	75.8	73.6

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Basic New Keynesian Phillips Curve

$$\pi_t = \kappa mc_t + \beta \mathbb{E}_t \pi_{t+1}$$

Under log utility and linear labor disutility:

$$\pi_t = \kappa y_t + \beta \mathbb{E}_t \pi_{t+1}$$

where

$$\kappa = \frac{\lambda \left[1 - (1 - \lambda)\beta\right]}{1 - \lambda}$$

- Monthly parameters:
  - $\beta = 0.96^{\frac{1}{12}}$
  - λ = aggregate frequency of price change
    - Time-varying $\implies \kappa_t$

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Basic New Keynesian Phillips Curve

$$\pi_t = \kappa_t y_t + \beta \mathbb{E}_t \pi_{t+1}$$

- $\lambda_{1947} = 9.2\% = 0.092$
- $\kappa_{1947} = 0.0096$
- Impact of known 1 p.p. rise in y_t for one year:
  - 12 months of high y_t
  - In earlier months, future inflation also rises
- Rise of 0.74 p.p. in inflation

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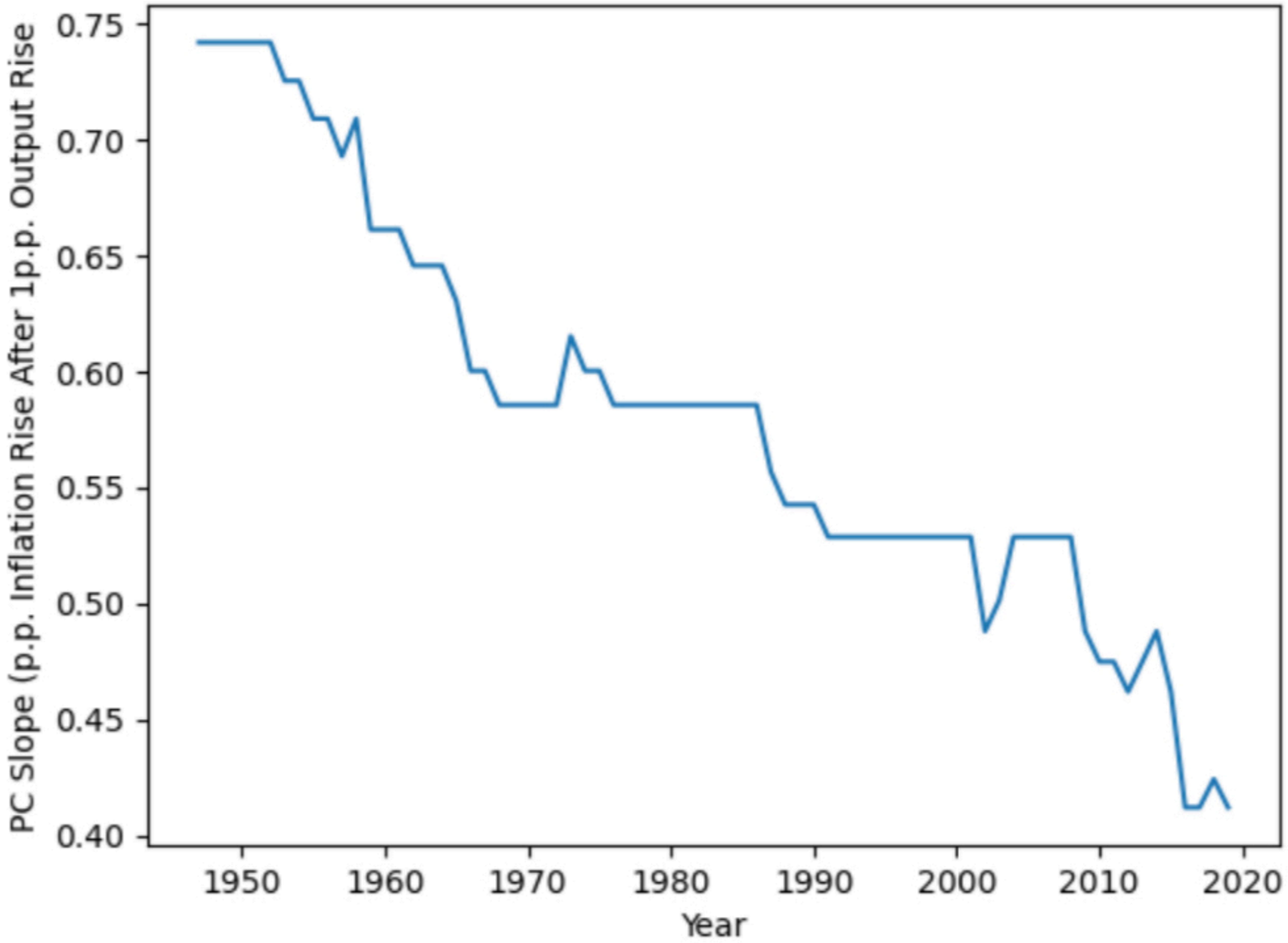
Basic New Keynesian Phillips Curve



- Slope declines from –0.74 in 1947 to –0.59 in 1983 to –0.41 in 2019
- Amount to a 44.5% flattening from 1947 to 2019

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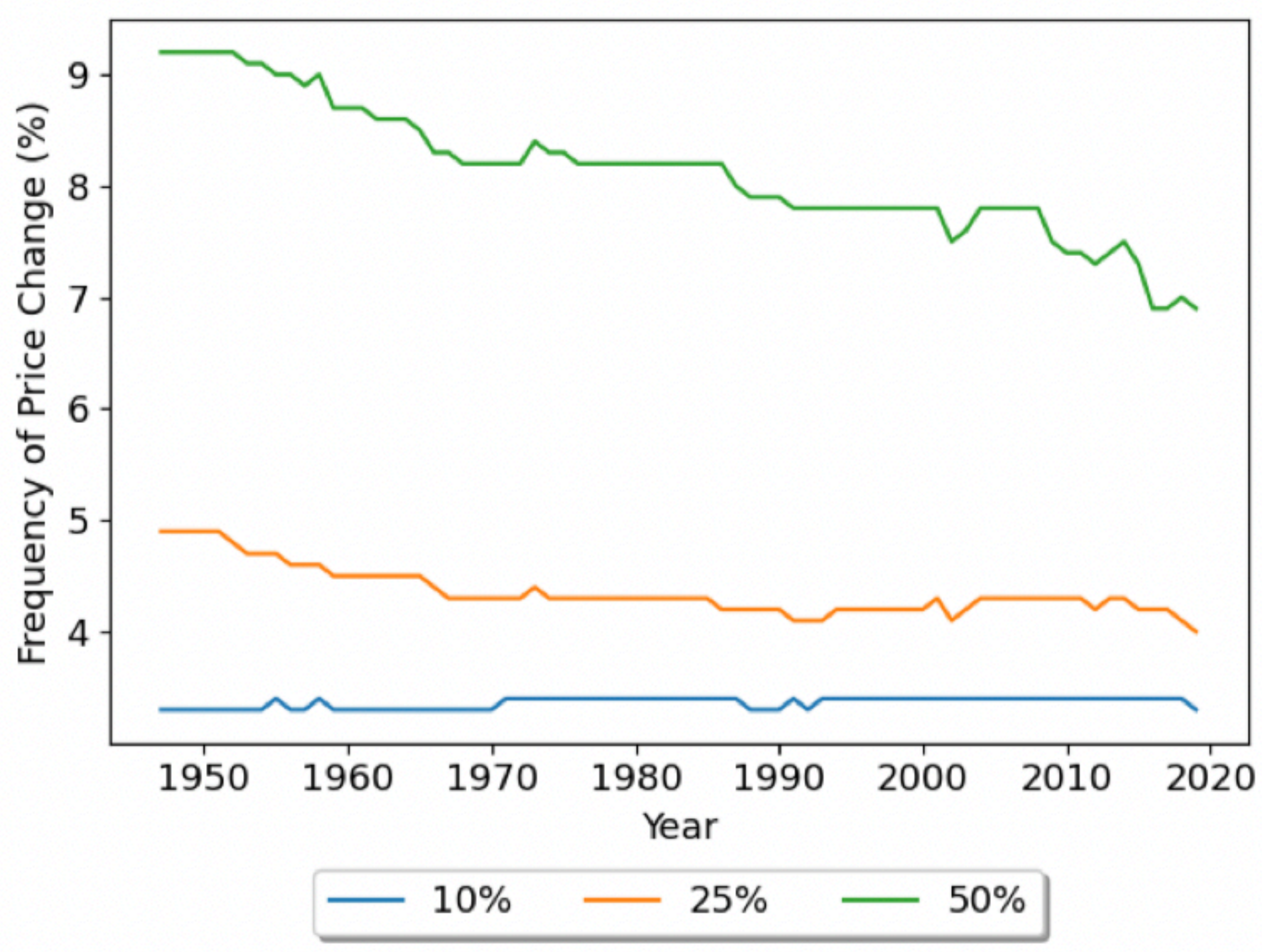
- Left panel: Economy's composition has shifted towards products/industries with relatively low frequency of price change
- Right panel: The frequency of price change at the product-level has also declined
- **Therefore, the overall distribution plausibly shifted even further down**



(a) For Low Percentiles

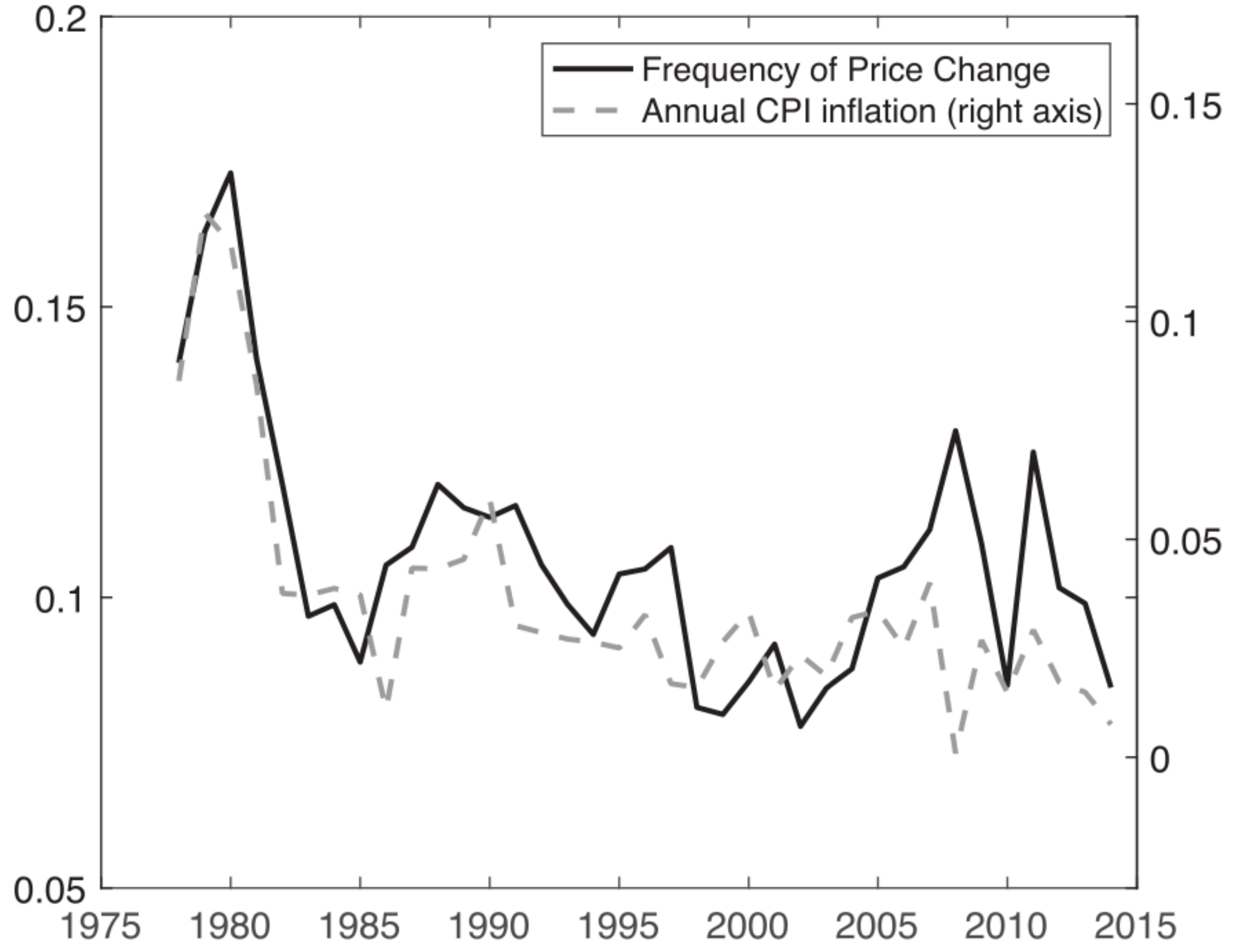


FIGURE XIV

Frequency of Price Change in U.S. Data

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