# The Price Adjustment Hazard Function

## Evidence from High Inflation Periods

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# Introduction

- Real effects of monetary policy depend on nominal rigidities
- Nature of price adjustment frictions is crucial
- Caballero and Engel (1993, 2007): think about sticky prices with hazard function

$$H(x) = P(\Delta p_t | x \equiv p_t^* - p_{t-1})$$

- Does not require specifying/solving model
- Complementary with price adjustment models
- This paper
  - Use price micro data to estimate hazard function
  - Show implications for monetary non-neutrality

# Aggregate Flexibility

- Important determinant of aggregate flexibility: selection effect
- Caballero and Engel (2007) show flexibility can be derived from hazard function:

$$\Delta p_t'(\Delta m = 0) = \underbrace{\int H(x) f_t(x) dx}_{\text{frequency of price change}} + \underbrace{\int x H'(x) f_t(x) dx}_{\text{extensive margin}}.$$

- EM = 0 in Calvo, high in Ss case
- Slope is crucial

# Approach

- Challenge: do not observe price misalignment
- Method:
  - Specify process for optimal price
  - Hazard function yields distribution of price changes
  - Look for hazard function to match empirical moments
  - Use differences between high and low inflation periods
- Data: prices underlying U.S. CPI from 1977 onwards
- Existing estimates
  - Berger and Vavra (2018), Petrella et al. (2019): period-by-period estimates
  - We use data on **high inflation periods** and co-movement beween **inflation and price change moments**

# Set-up

- Idiosyncratic and aggregate shocks to desired/optimal price:

$$p^*_{it} = z_{it} + m_t$$

- Specify processes for shocks:

$$z_{it} = \begin{cases} \rho z_{it-1} + \epsilon_t, & \text{P}= p_\epsilon \\ z_{it-1}, & \text{P}= 1 - p_\epsilon \end{cases}, \ \epsilon_t \overset{iid}{\sim} N(0, \sigma^2_\epsilon)$$

$$m_t = \mu + m_{t-1} + \eta_t, \ \eta_t \overset{iid}{\sim} N(0, \sigma^2_\eta)$$

- Hazard function determines price adjustment probability:

$$H(x) = P(\Delta p_t | x \equiv p^*_t - p_{t-1})$$

- $p^*$ observed only when price changes
- Must also estimate parameters of underlying shock process

# Functional Form

- Flexible quadratic functional form:

$$H(x)^{\text{quad}} = \begin{cases} 1, & \text{if} \quad x < c^- \\ p_0 + a^- \cdot x + b^- \cdot x^2, & \text{if} \quad c^- \leq x < 0 \\ p_0, & \text{if} \quad x = 0 \\ p_0 + a^+ \cdot x + b^+ \cdot x^2, & \text{if} \quad 0 < x \leq c^+ \\ 1, & \text{if} \quad x > c^+ \end{cases} .$$

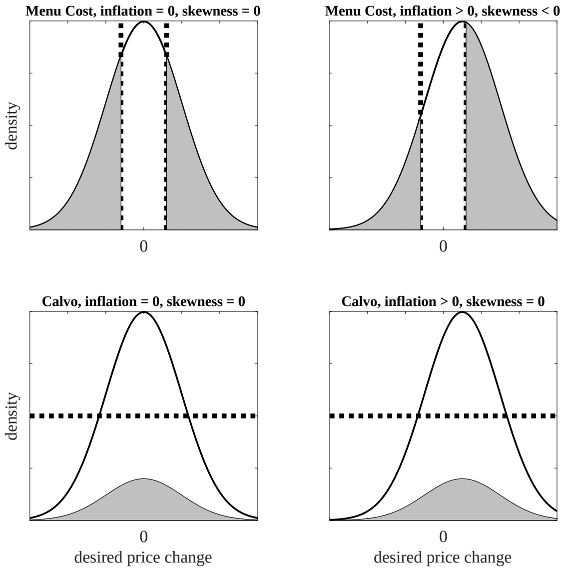
- Allows for asymmetry around zero
- Nests Ss functions with threshold parameter
- Also use logistic and non-parametric form
- All are flexible, yield similar results

# Moments Used

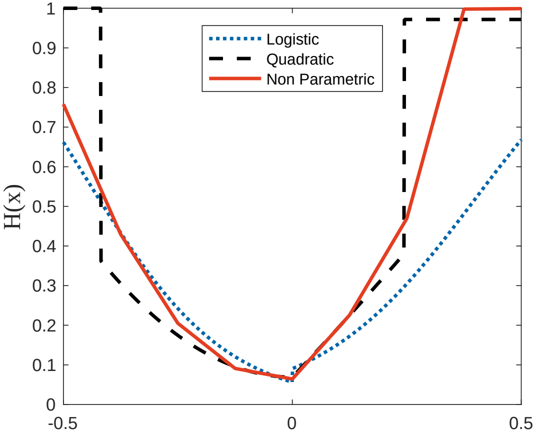
- Standard unconditional moments:
  - Average frequency of price change
  - Frequency of increases and decreases
  - Average absolute price change (increases and decreases)
- Additional unconditional moments:
  - Average fraction of small price changes
  - Average dispersion and skewness
- Moment correlations:
  - $Corr(Freq, \pi) > 0$
  - $Corr(IQR, \pi) < 0$
  - $Corr(Skew, \pi) \geq 0$
- Exploit variation in inflation over sample period

Moment Values

# Illustration



# Results




Moment Values | By sub-period

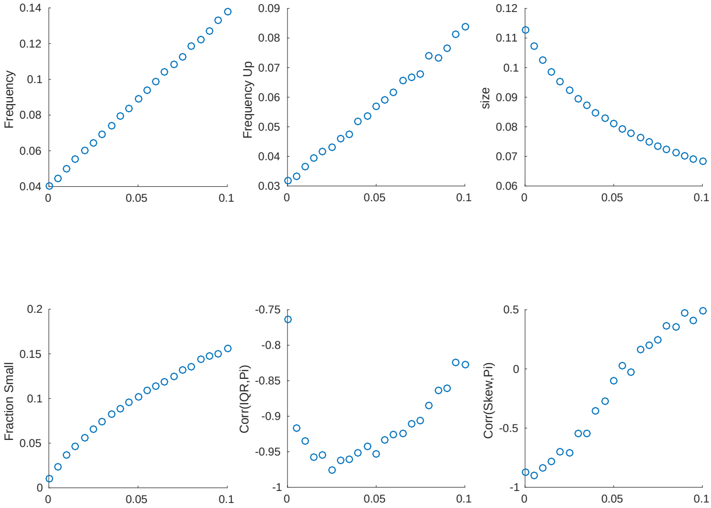
Note: we estimate $p_0 = 0.069$, $a^+ = 1.224$, $b^+ = 0.208$, $c^+ = 0.244$, $a^- = -0.005$, $b^- = 1.665$, $c^- = -0.412$, $\sigma_\epsilon = 0.055$, $p_\epsilon = 0.485$ in the quadratic hazard function.

# Key Features

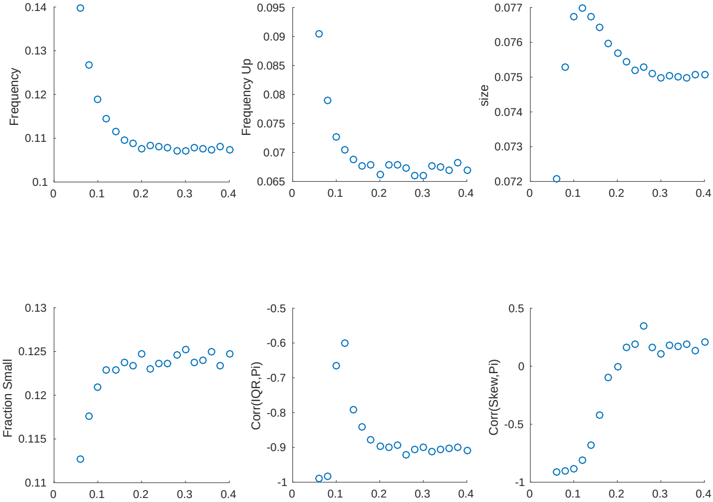
- Find that to match data, hazard function must have three important features:
    1. Significant $p_0$: Calvo feature
    2. Asymmetry: price increases more likely
    3. Probability increases only slowly in $|x|$
- Skewness correlation key to establish these features

  Without Skewness Correlation
- Important implications for non-neutrality

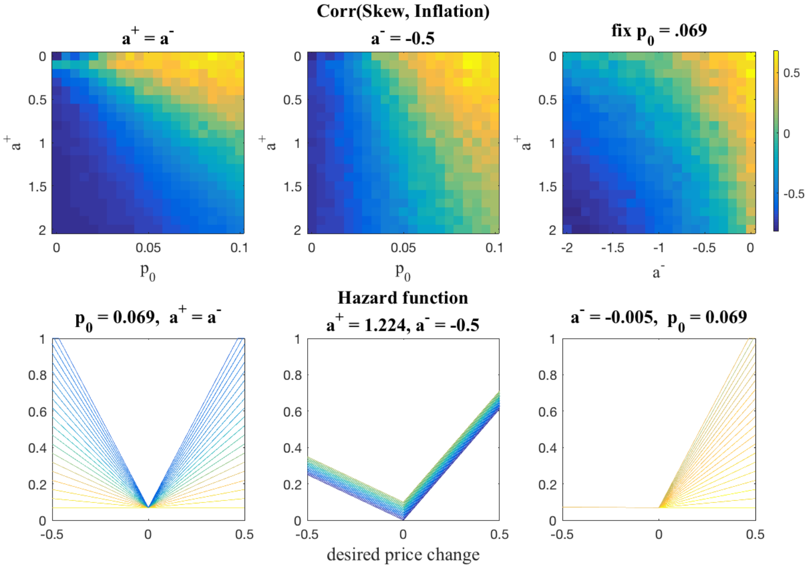
# Illustration with $p_0$



# Illustration with $c^+$



# Use of Skewness Correlation



# Monetary Non-Neutrality

- Compute $Var(c_t)$ induced by aggregate shocks
- Use Hazard function to derive price level
- Similar results to Luo and Villar (2019)

| Hazard Function | $Var(c_t) \times 10^4$ |
|---|---|
| Calvo | 0.537 |
| **Non-Parametric** | **0.312** |
| **Logistic** | **0.334** |
| **Flexible Quadratic** | **0.329** |
| Midrigan/CalvoPlus | 0.195 |
| Caballero & Engel | 0.176 |
| Golosov & Lucas | 0.064 |

# Conclusion

- Hazard function allows us to directly evaluate question of selection effect, indirectly evaluate models
- Estimate hazard function using new data and moments
- Find hazard function has small extensive margin/selection effect
- Significant asymmetry between price increases and decreases
- Flexible framework to evaluate price flexibility
- Possible next steps/extensions:
  - Relevance of asymmetry for response to shocks
  - Use framework to evaluate imperfect information models
  - Better understand processes that determine price gaps

# Moment Values

Table: Target Moments

| Unconditional Moments | | Conditional Moments | |
|---|---|---|---|
| Avg. Frequency | 10.7% | Corr(Frequency,$\pi$) | 0.69 |
| Avg. Dispersion (IQR) | 9.9% | Corr(IQR,$\pi$) | -0.676 |
| Avg. Skewness | -0.14 | Corr(Skewness,$\pi$) | 0.361 |
| Avg. absolute price change | 7.5% | | |
| Fraction of Small Changes | 13.2% | | |
| Avg. Frequency of Increases | 7.64% | | |
| Avg. Frequency of Decreases | 2.97% | | |
| Avg. Size of Increases | 7.2% | | |
| Avg. Size of Decreases | 7.9% | | |
| Dispersion of Price Increases | 7.7% | | |
| Dispersion of Price Decreases | 8.7% | | |

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# Moments

| Moment | Data | Quadratic | Logistic | Non-Parametric |
|---|---|---|---|---|
| Avg. Frequency | 0.107 | 10.8 | 0.108 | 0.107 |
| Frequency Increases | 0.076 | 0.067 | 0.068 | 0.068 |
| Frequency Decreases | 0.030 | 0.041 | 0.040 | 0.039 |
| Avg. Size | 0.075 | 0.075 | 0.077 | 0.077 |
| Avg. Size Increases | 0.072 | 0.075 | 0.076 | 0.076 |
| Avg. Size Decreases | 0.079 | 0.076 | 0.080 | 0.078 |
| Fraction Small | 13.2% | 12.4% | 13.0% | 13.5% |
| Corr(Frequency,$\pi$) | 0.70 | 0.91 | 0.82 | 0.91 |
| Corr(IQR,$\pi$) | -0.68 | -0.91 | 0.88 | -0.92 |
| Corr(Skew,$\pi$) | 0.36 | 0.22 | 31 | 0.11 |

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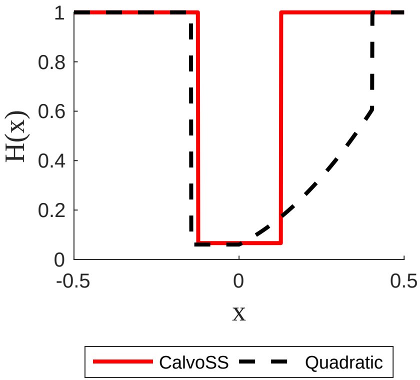
# Estimating with Static Moments

Two hazard functions estimated to match moments from one period:

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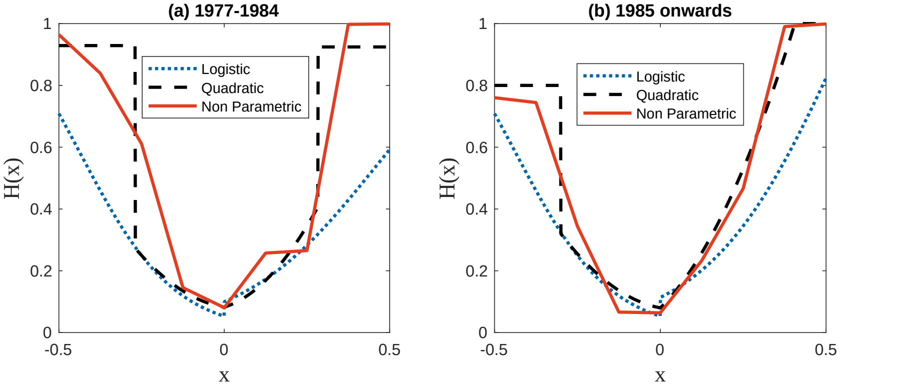
# Estimation for Sub-Periods

Two hazard functions estimated to match moments from one period:

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