

# A Framework for Decomposing Shocks and Measuring Volatilities Derived from Multi-Dimensional Panel Data of Survey Forecasts

Econometrics in Public Policy

University at Albany

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## Dimensionality of Forecast Data Sets

1. Uni-dimensional: Cross-Sectional or Longitudinal
  - Multiple forecasters aim at a single target (cross-sectional)
  - A single forecaster aims at multiple targets (longitudinal)
2. Two-dimensional (panel data): Combined cross-sectional and longitudinal
  - Multiple forecasters aim at multiple targets
3. Three-dimensional: Combined cross-sectional, longitudinal, and horizontal
  - Multiple forecasters aim at multiple targets from multiple horizons

## Increases in Data Dimensionality Pre-Date Requisite Analytic Techniques

Three-dimensional data sets have a reasonably long history:

Livingston Survey (from 1946)

ASA-NBER Survey of Professional Forecasters (from 1968)

Blue Chip Survey of Professional Forecasters (from 1976)

Not until early 1990's that the first two-dimensional analytic techniques were employed:

Swindler and Ketcher (JMCB, 1990)

Keane and Runkle (AER, 1990)

Batchelor and Dua (JMCB, 1991)

De Bont and Bange (JFQA, 1992)

## Increases in Data Dimensionality Pre-Date Requisite Analytic Techniques

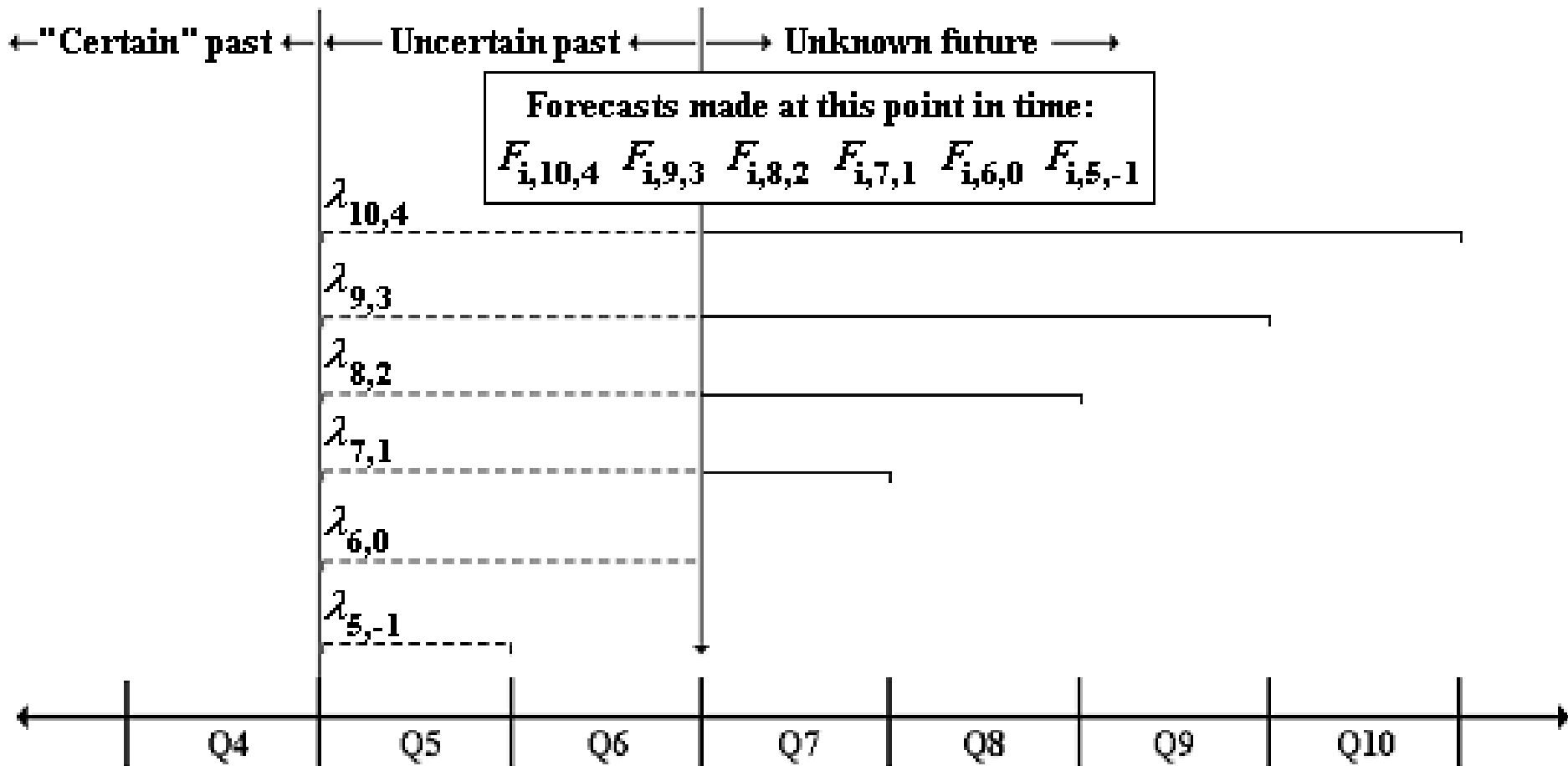
Not until late 1990's that first three-dimensional techniques were developed

Davies and Lahiri (JE, 1995; Analysis of Panels..., 1999)

Developed for the purpose of testing forecast rationality, the Davies-Lahiri framework also implied the existence of new measures of economic shocks and volatility.

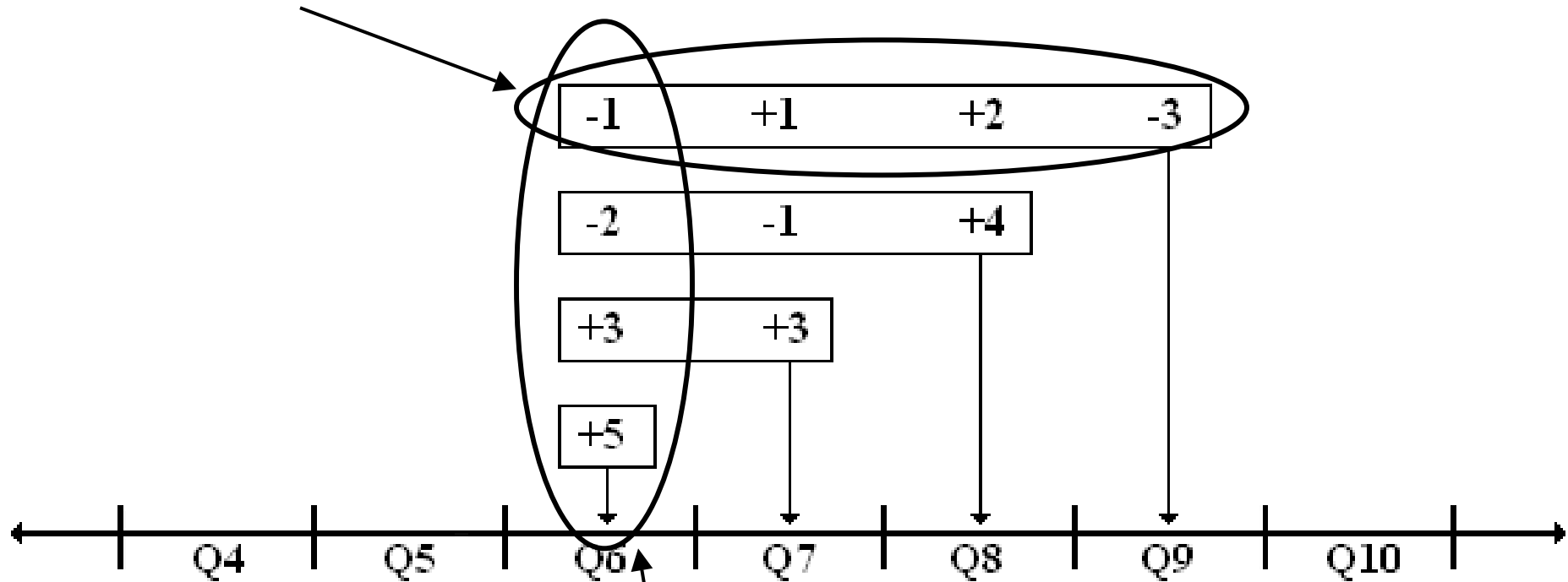
The purpose of this research is to extract the shocks and volatilities implied in the Davies-Lahiri framework.

# Three-Dimensional Structure of the ASA-NBER Data Set



## Timing of Shock Occurrence vs. Shock Impact

These shocks all impact inflation in quarter 9 but occur in different quarters.



These shocks all occur in quarter 6 but impact inflation in different quarters.

# Categories of Shocks

Cross-sectional shocks

$u_{9,4}$     $u_{9,3}$     $u_{9,2}$     $u_{9,1}$

$v_{9,4}$     $v_{9,3}$     $v_{9,2}$     $v_{9,1}$

-1   +1   +2   -3

$v_{8,3}$     $v_{8,2}$     $v_{8,1}$

-2   -1   +4

$v_{7,2}$     $v_{7,1}$

+3   +3

$v_{6,1}$

+5

$\lambda_{9,4}$

Discrete shocks

Cumulative shocks

# Shock Measures

Shock Measure	Shocks Occur From	Shocks Impact Inflation From
<b>Cumulative shocks</b> $\lambda_{th}$	<b>Beginning of quarter <math>t - h</math> to the end of quarter <math>t</math>.</b>	<b>Beginning of quarter <math>t - h</math> to the end of quarter <math>t</math>.</b>
<b>Cross-sectional shocks</b> $u_{th}$	<b>Beginning of quarter <math>t - h</math> to the end of quarter <math>t - h</math>.</b>	<b>Beginning of quarter <math>t - h</math> to the end of quarter <math>t</math>.</b>
<b>Discrete shocks</b> $v_{th}$	<b>Beginning of quarter <math>t - h</math> to the end of quarter <math>t - h</math>.</b>	<b>Beginning of quarter <math>t</math> to the end of quarter <math>t</math>.</b>

# Davies-Lahiri Framework

Inflation for quarter  $t$

Cumulative shocks to inflation impacting from  $h$  quarters prior to the end of quarter  $t$  to the end of quarter  $t$

$$A_t = A_{th}^* + \gamma_{th} + \lambda_{th}$$

(Possibly unobserved) inflation at  $h$  quarters prior to the end of quarter  $t$

Unbiased and efficient forecasted change in inflation anticipated to occur from  $h$  quarters prior to the end of quarter  $t$  to the end of quarter  $t$

# Davies-Lahiri Framework

Individual  $i$  forecast for quarter  $t$   
made  $h$  quarters prior to the end  
of quarter  $t$

Individual  $i$  forecast bias  
specific to horizon  $h$  forecasts

$$F_{ith} = A_{th}^* + \gamma_{th} + \phi_{ih} + \varepsilon_{ith}$$

(Possibly unobserved) inflation  
at  $h$  quarters prior to the end of quarter  $t$

Idiosyncratic error (assumed white  
noise over all three dimensions)

Unbiased and efficient forecasted change in inflation anticipated to  
occur from  $h$  quarters prior to the end of quarter  $t$  to the end of  
quarter  $t$

## Implied Shock Measures

$$\hat{\lambda}_{th} = \frac{1}{N} \sum_{i=1}^N \left( A_t - F_{ith} - \frac{1}{T} \sum_{t=1}^T (A_t - F_{ith}) \right)$$

$$\hat{u}_{th} = \hat{\lambda}_{th} - \hat{\lambda}_{t,h-1} = \frac{1}{N} \sum_{i=1}^N \left( -F_{ith} + F_{i,t,h-1} - \frac{1}{T} \sum_{t=1}^T (-F_{ith} + F_{i,t,h-1}) \right)$$

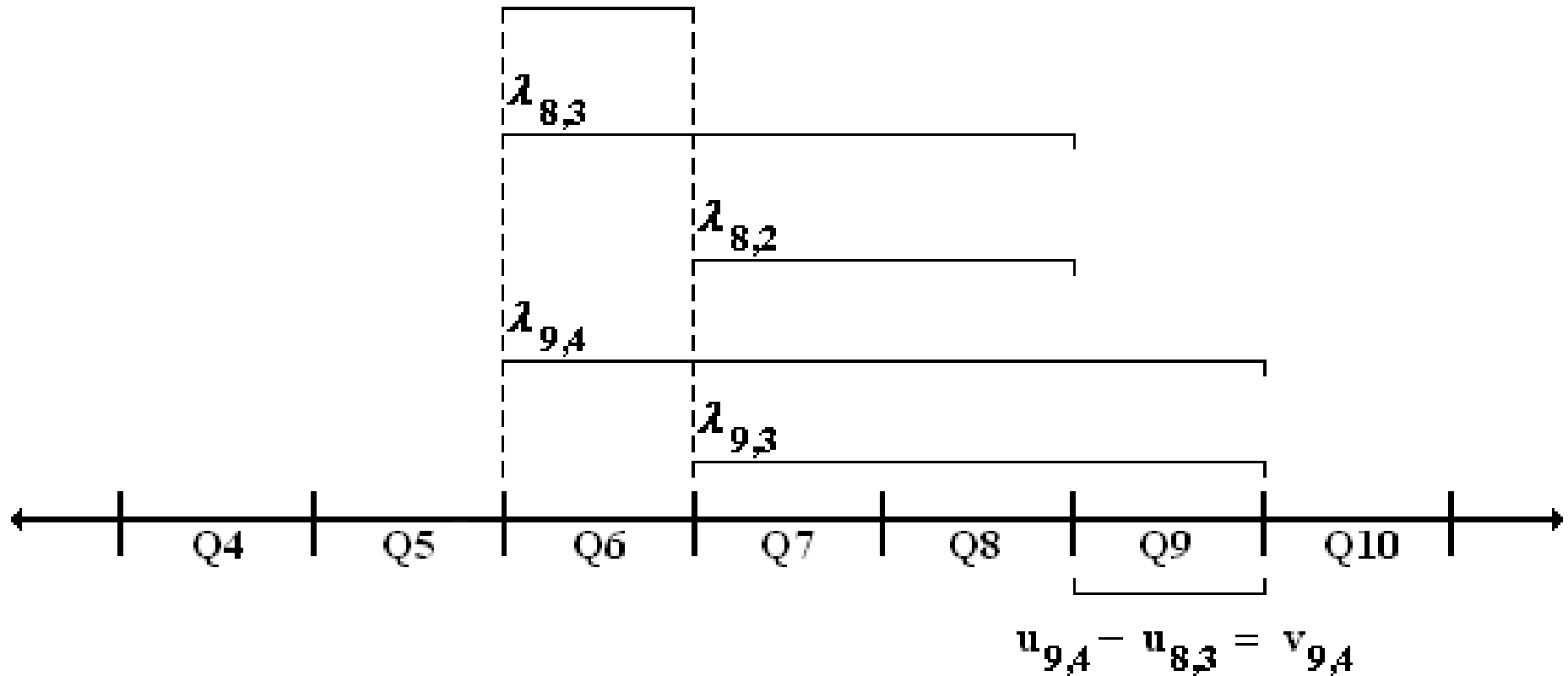
$$\hat{v}_{th} = \hat{u}_{th} - \hat{u}_{t-1,h-1} = \hat{\lambda}_{th} - \hat{\lambda}_{t,h-1} - (\hat{\lambda}_{t-1,h-1} - \hat{\lambda}_{t-1,h-2})$$

$$= \frac{1}{N} \sum_{i=1}^N \left( -F_{ith} + F_{i,t,h-1} + F_{i,t-1,h-1} - F_{i,t-1,h-2} - \frac{1}{T} \sum_{t=1}^T (-F_{ith} + F_{i,t,h-1} + F_{i,t-1,h-1} - F_{i,t-1,h-2}) \right)$$

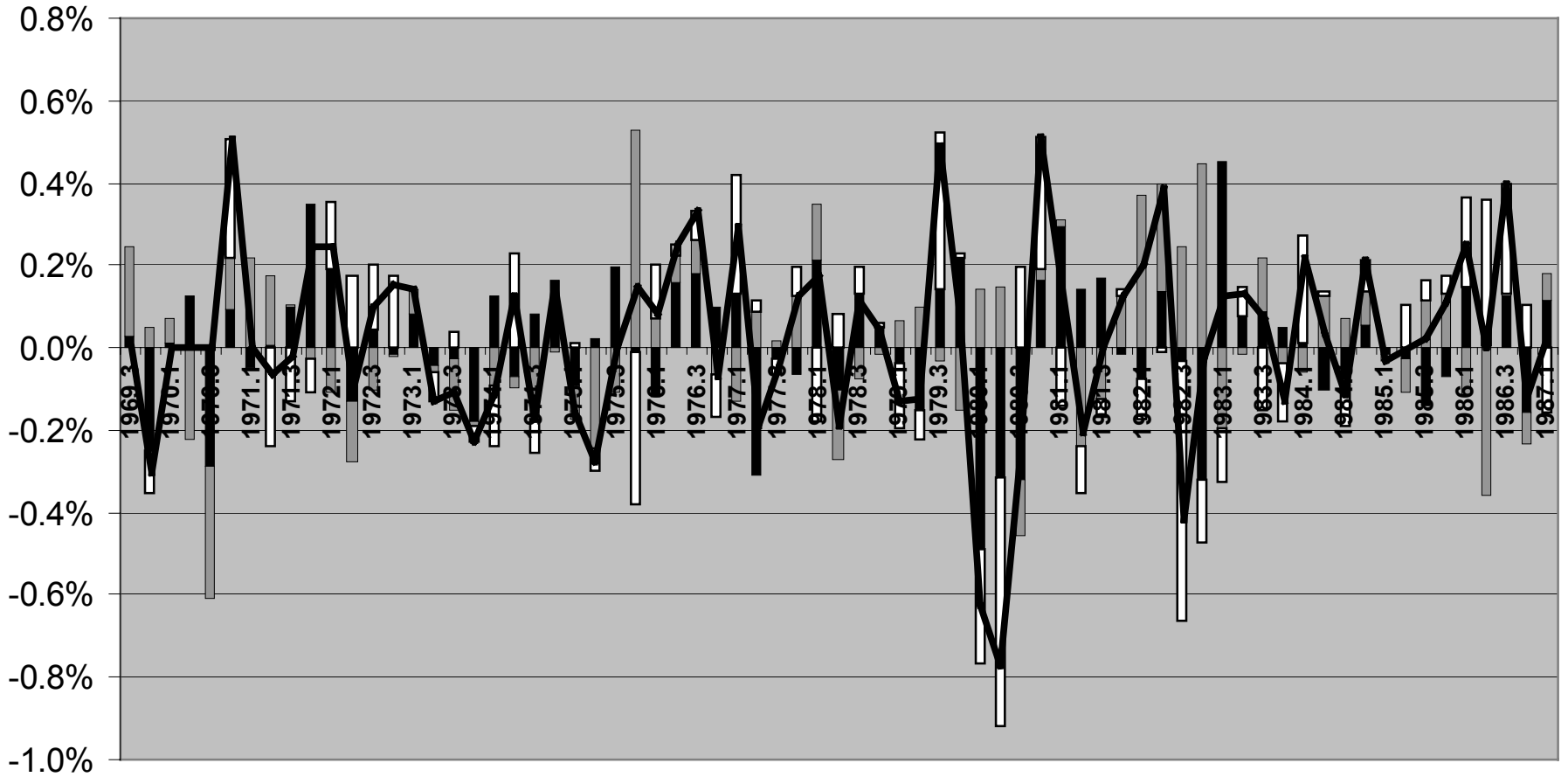
# Implied Shock Measures

$$\lambda_{9,4} - \lambda_{9,3} = u_{9,4}$$

$$\lambda_{8,3} - \lambda_{8,2} = u_{8,3}$$

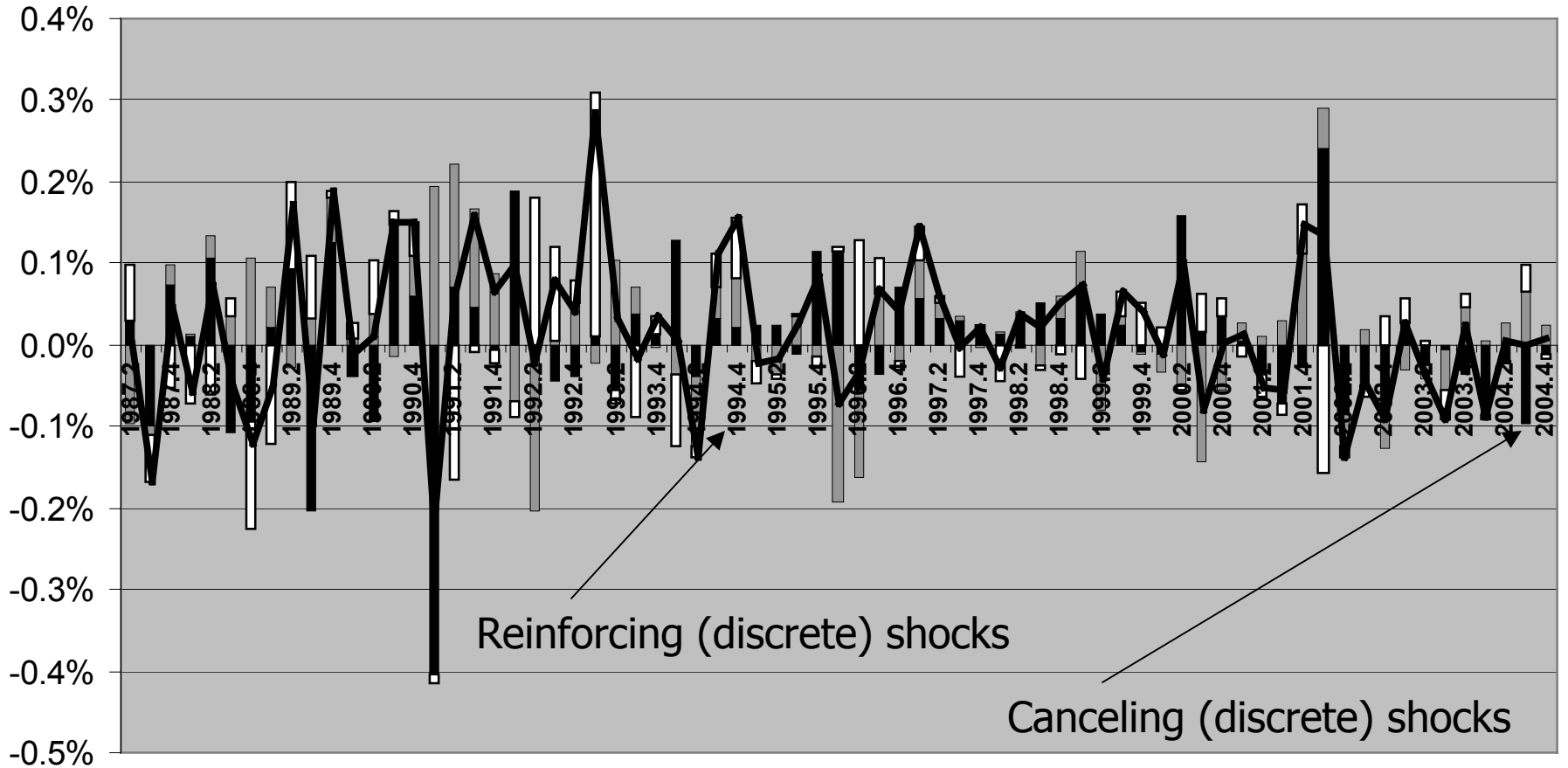


### Shocks to IPD Inflation According to Time of Impact (1969-III to 1987-I)



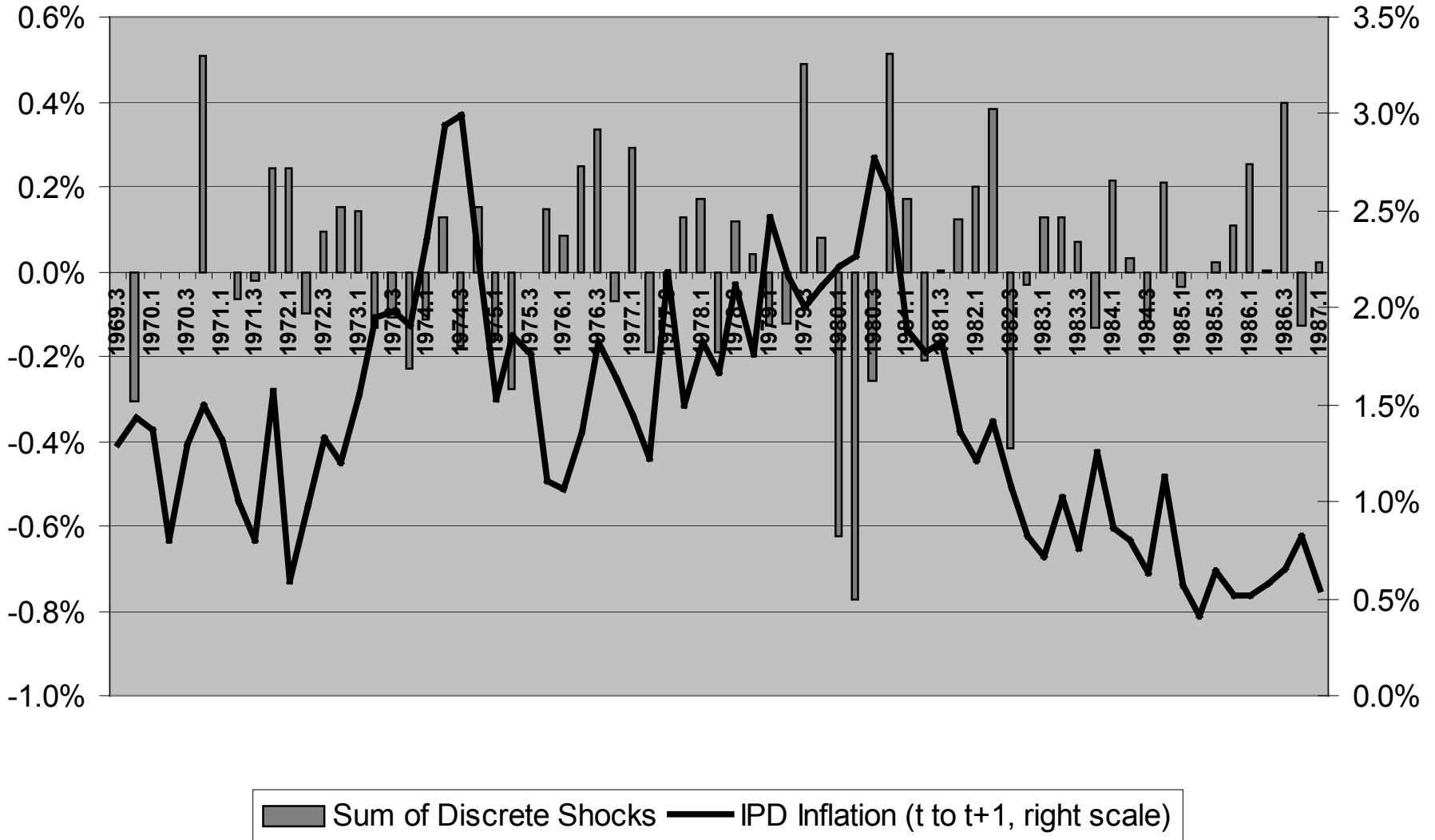
Shock Occurred 2Q in Past
  Shock Occurred 3Q in Past  
 Shock Occurred 4Q in Past
  Sum of Discrete Shocks

## Shocks to IPD Inflation According to Time of Impact (1987-II to 2004-IV)

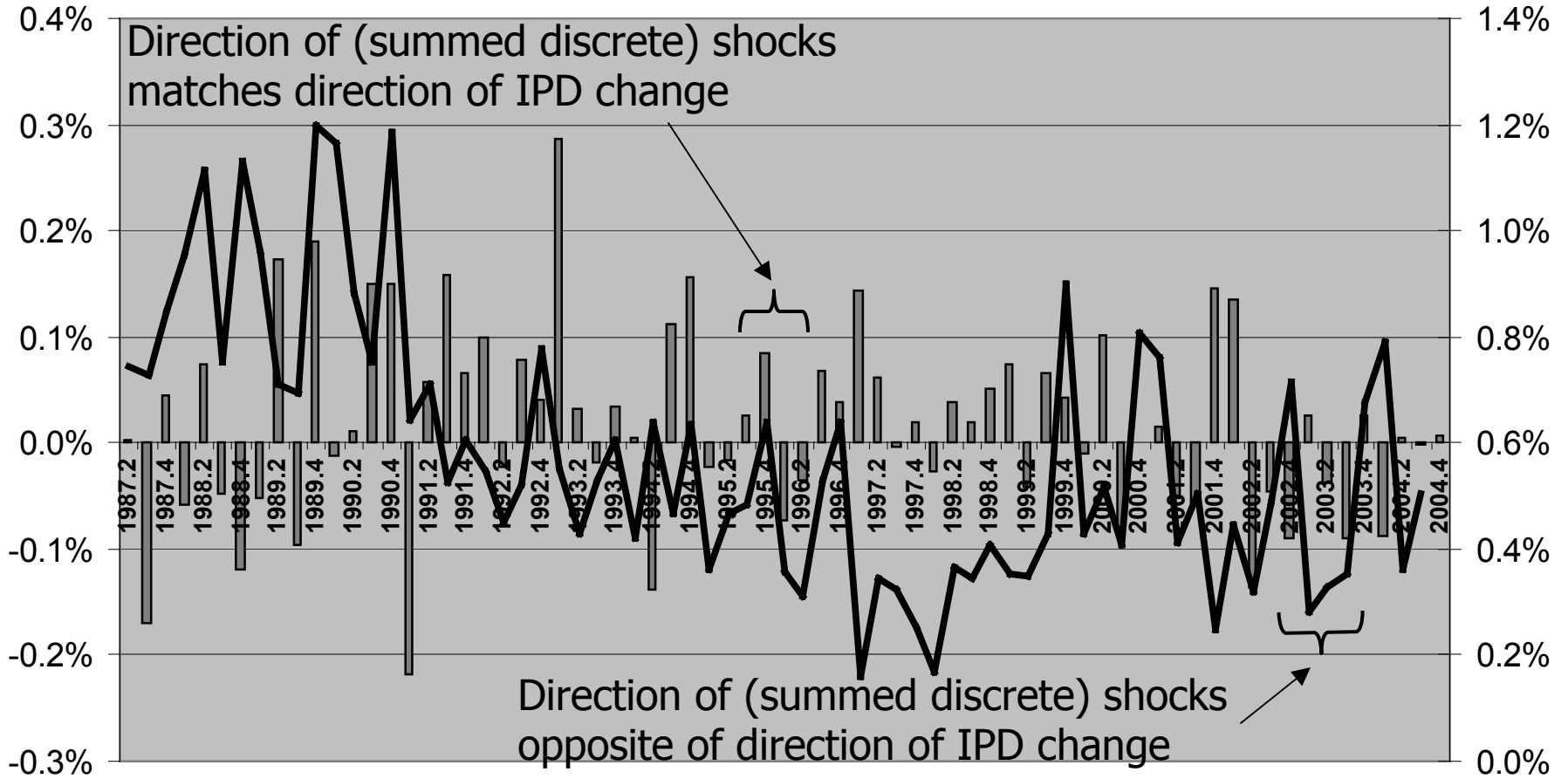


Shock Occurred 2Q in Past
  Shock Occurred 3Q in Past  
 Shock Occurred 4Q in Past
  Sum of Discrete Shocks

### Shocks to IPD Inflation According to Time of Impact (1969-III to 1987-I)



### Shocks to IPD Inflation According to Time of Impact (1987-II to 2004-IV)



Sum of Discrete Shocks
  IPD Inflation (t to t+1, right scale)

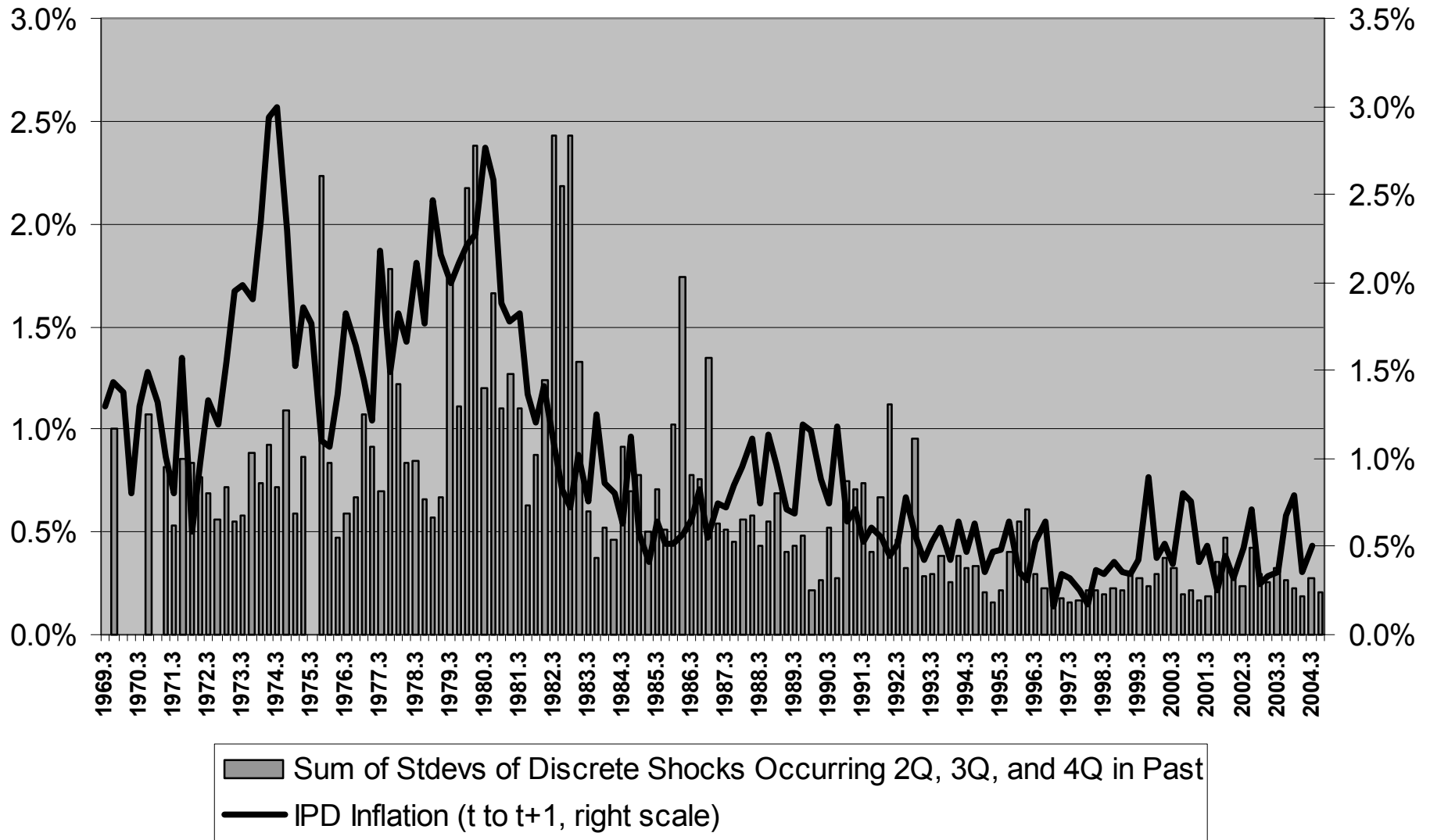
# Volatility

The three categories of shock measure imply three corresponding categories of volatility measure.

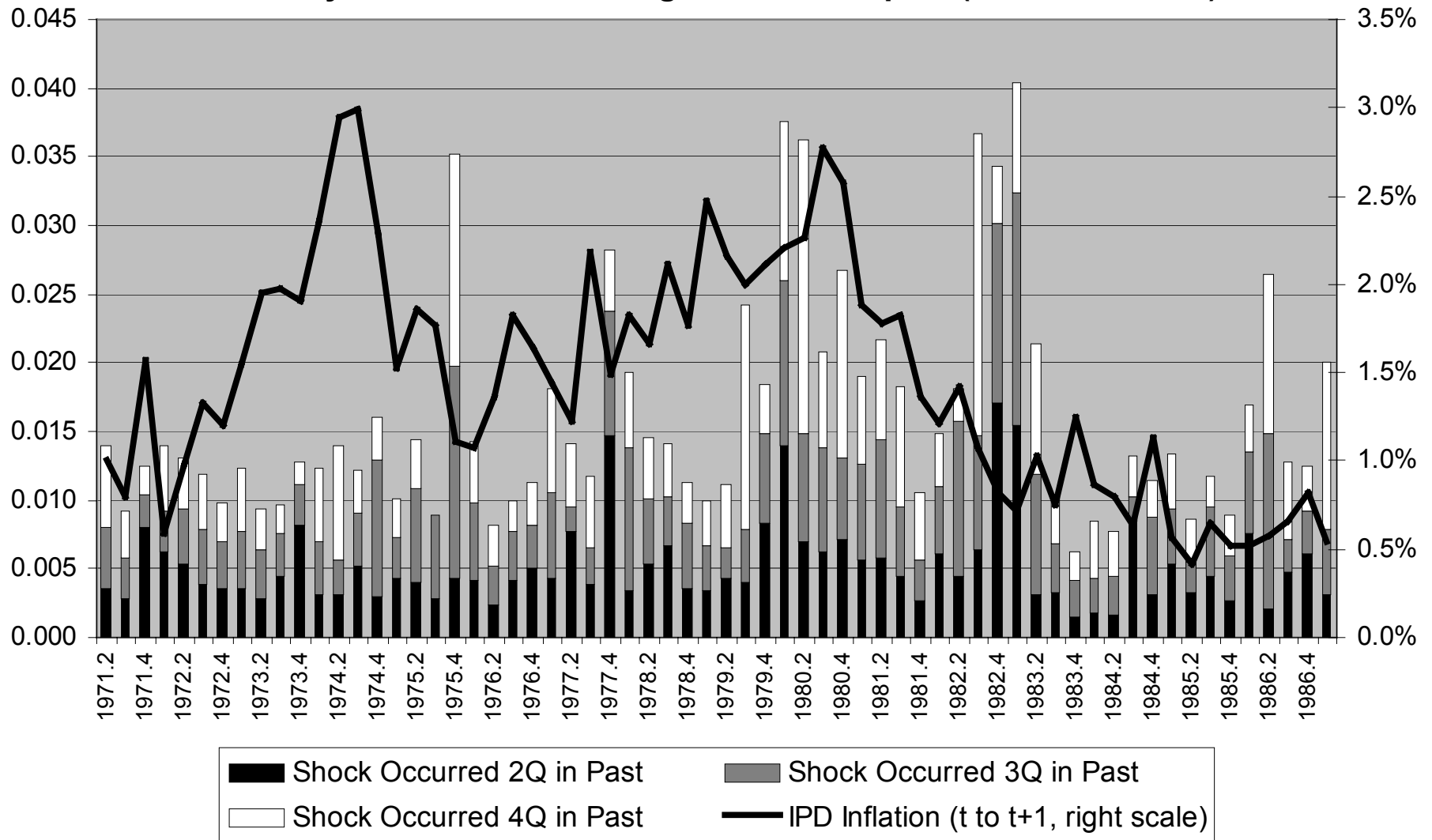
## Discrete shock volatility:

$$\hat{\sigma}_{v_{th}}^2 = \frac{1}{N} \sum_{i=1}^N \left( -F_{ith} + F_{i,t,h-1} + F_{i,t-1,h-1} - F_{i,t-1,h-2} + \hat{\phi}_{ih} - 2\hat{\phi}_{i,h-1} + \hat{\phi}_{i,h-2} - \hat{v}_{th} \right)^2$$

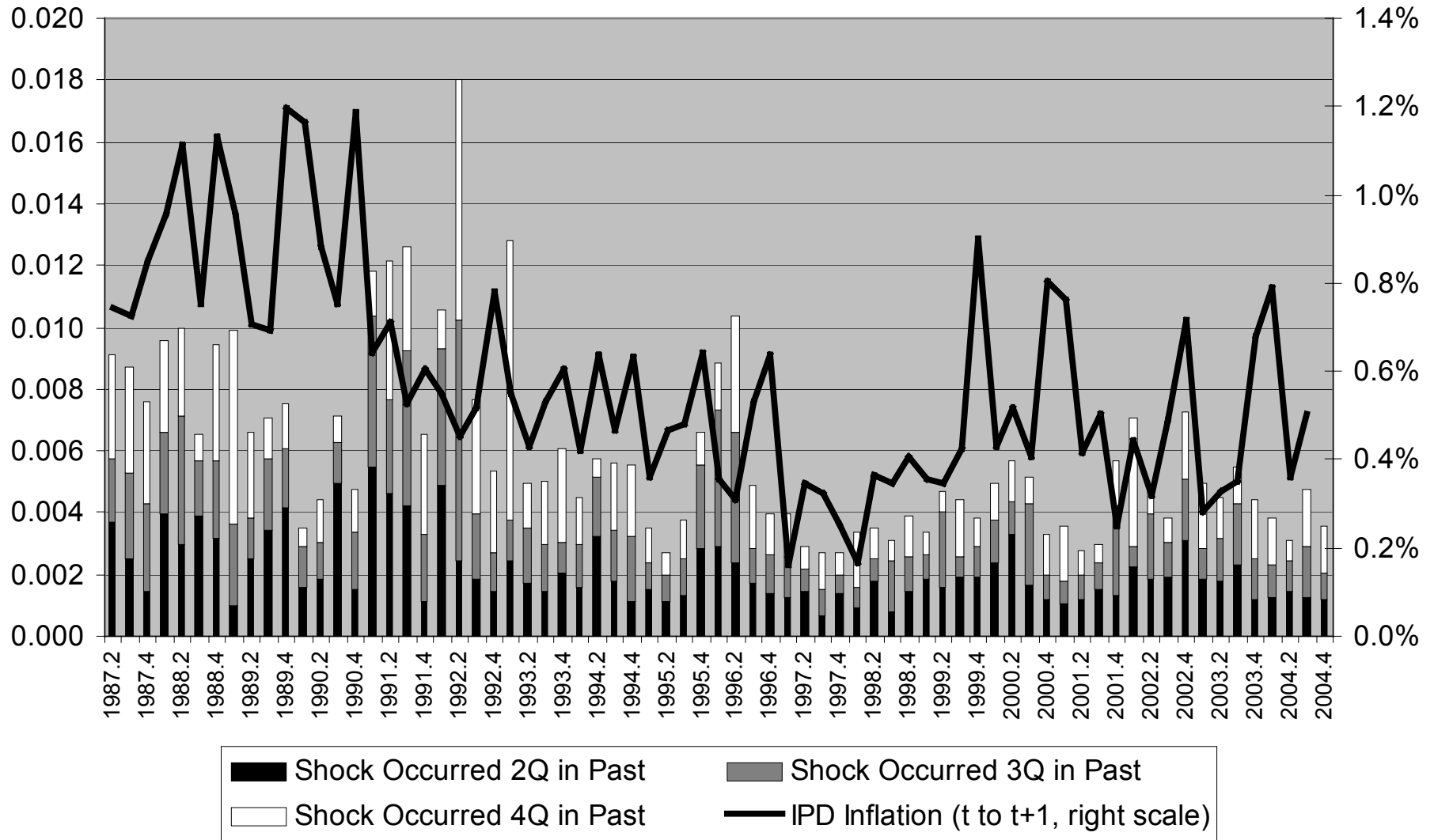
## Volatility of Shocks According to Time of Impact (1969-III to 2004-IV)



## Volatility of Shocks According to Time of Impact (1971-II to 1987-I)



## Volatility of Shocks According to Time of Impact (1987-II to 2004-IV)



# Davies-Lahiri Framework

$$\Sigma = \begin{bmatrix} \mathbf{A}_1 & \mathbf{B} & \mathbf{B} & \dots & \mathbf{B} & \mathbf{B} \\ \mathbf{B} & \mathbf{A}_2 & \mathbf{B} & \dots & \mathbf{B} & \mathbf{B} \\ \vdots & & & & & \\ \mathbf{B} & \mathbf{B} & \mathbf{B} & \dots & \mathbf{B} & \mathbf{A}_N \end{bmatrix}_{NTH \times NTH}$$

where  $\mathbf{A}_i = \sigma_{\varepsilon_i}^2 \mathbf{I} + \mathbf{B}$

$$\mathbf{B} = \begin{bmatrix} \mathbf{b}_{1,1} & \mathbf{c}_{1,2} & \mathbf{d}_{1,3} & \mathbf{e}_{1,4} & \mathbf{f}_{1,5} & \mathbf{g}_{1,6} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{c}'_{2,1} & \mathbf{b}_{2,2} & \mathbf{c}_{2,3} & \mathbf{d}_{2,4} & \mathbf{e}_{2,5} & \mathbf{f}_{2,6} & \mathbf{g}_{2,7} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{d}'_{3,1} & \mathbf{c}'_{3,2} & \mathbf{b}_{3,3} & \mathbf{c}_{3,4} & \mathbf{d}_{3,5} & \mathbf{e}_{3,6} & \mathbf{f}_{3,7} & \mathbf{g}_{3,8} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{e}'_{4,1} & \mathbf{d}'_{4,2} & \mathbf{c}'_{4,3} & \mathbf{b}_{4,4} & \mathbf{c}_{4,5} & \mathbf{d}_{4,6} & \mathbf{e}_{4,7} & \mathbf{f}_{4,8} & \mathbf{g}_{5,9} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{f}'_{5,1} & \mathbf{e}'_{5,2} & \mathbf{d}'_{5,3} & \mathbf{c}'_{5,4} & \mathbf{b}_{5,5} & \mathbf{c}_{5,6} & \mathbf{d}_{5,7} & \mathbf{e}_{5,8} & \mathbf{f}_{6,9} & \mathbf{g}_{6,10} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{g}'_{6,1} & \mathbf{f}'_{6,2} & \mathbf{e}'_{6,3} & \mathbf{d}'_{6,4} & \mathbf{c}'_{6,5} & \mathbf{b}_{6,6} & \mathbf{c}_{6,7} & \mathbf{d}_{6,8} & \mathbf{e}_{7,9} & \mathbf{f}_{7,10} & \mathbf{g}_{7,11} & \mathbf{0} & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{0} & \mathbf{g}'_{7,2} & \mathbf{f}'_{7,3} & \mathbf{e}'_{7,4} & \mathbf{d}'_{7,5} & \mathbf{c}'_{7,6} & \mathbf{b}_{7,7} & \mathbf{c}_{7,8} & \mathbf{d}_{8,9} & \mathbf{e}_{8,10} & \mathbf{f}_{8,11} & \mathbf{g}_{8,12} & \mathbf{0} & \dots & \mathbf{0} \\ \vdots & & & & & & & & & & & & & & & \\ \mathbf{0} & \dots & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{g}'_{T,T-5} & \mathbf{f}'_{T,T-4} & \mathbf{e}'_{T,T-3} & \mathbf{d}'_{T,T-2} & \mathbf{c}'_{T,T-1} & \mathbf{b}_{T,T} \end{bmatrix}_{TH \times TH}$$

# Davies-Lahiri Framework

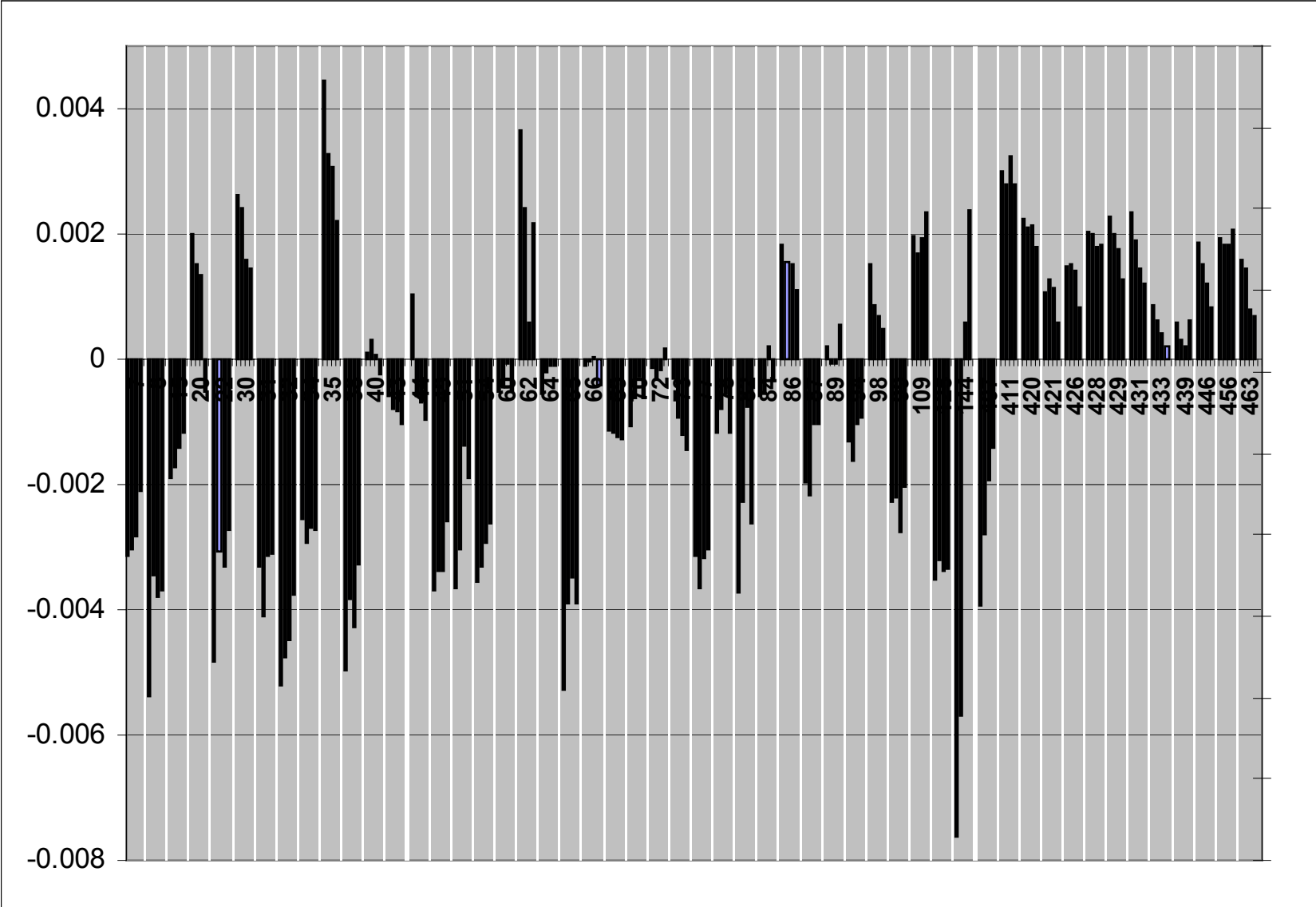
$$\mathbf{b}_{t_1, t_2} = \begin{bmatrix} \sum_{h=-1}^4 \sigma_{u_s, h}^2 & \sum_{h=-1}^3 \sigma_{u_s, h}^2 & \sum_{h=-1}^2 \sigma_{u_s, h}^2 & \sum_{h=-1}^1 \sigma_{u_s, h}^2 & \sum_{h=-1}^0 \sigma_{u_s, h}^2 & \sum_{h=-1}^{-1} \sigma_{u_s, h}^2 \\ \sum_{h=-1}^3 \sigma_{u_s, h}^2 & \sum_{h=-1}^3 \sigma_{u_s, h}^2 & \sum_{h=-1}^2 \sigma_{u_s, h}^2 & \sum_{h=-1}^1 \sigma_{u_s, h}^2 & \sum_{h=-1}^0 \sigma_{u_s, h}^2 & \sum_{h=-1}^{-1} \sigma_{u_s, h}^2 \\ \sum_{h=-1}^2 \sigma_{u_s, h}^2 & \sum_{h=-1}^2 \sigma_{u_s, h}^2 & \sum_{h=-1}^2 \sigma_{u_s, h}^2 & \sum_{h=-1}^1 \sigma_{u_s, h}^2 & \sum_{h=-1}^0 \sigma_{u_s, h}^2 & \sum_{h=-1}^{-1} \sigma_{u_s, h}^2 \\ \sum_{h=-1}^1 \sigma_{u_s, h}^2 & \sum_{h=-1}^1 \sigma_{u_s, h}^2 & \sum_{h=-1}^1 \sigma_{u_s, h}^2 & \sum_{h=-1}^1 \sigma_{u_s, h}^2 & \sum_{h=-1}^0 \sigma_{u_s, h}^2 & \sum_{h=-1}^{-1} \sigma_{u_s, h}^2 \\ \sum_{h=-1}^0 \sigma_{u_s, h}^2 & \sum_{h=-1}^0 \sigma_{u_s, h}^2 & \sum_{h=-1}^0 \sigma_{u_s, h}^2 & \sum_{h=-1}^0 \sigma_{u_s, h}^2 & \sum_{h=-1}^0 \sigma_{u_s, h}^2 & \sum_{h=-1}^{-1} \sigma_{u_s, h}^2 \\ \sum_{h=-1}^{-1} \sigma_{u_s, h}^2 & \sum_{h=-1}^{-1} \sigma_{u_s, h}^2 & \sum_{h=-1}^{-1} \sigma_{u_s, h}^2 & \sum_{h=-1}^{-1} \sigma_{u_s, h}^2 & \sum_{h=-1}^{-1} \sigma_{u_s, h}^2 & \sum_{h=-1}^{-1} \sigma_{u_s, h}^2 \end{bmatrix}, \quad s = \min(t_1, t_2) - 1$$

# Davies-Lahiri Framework

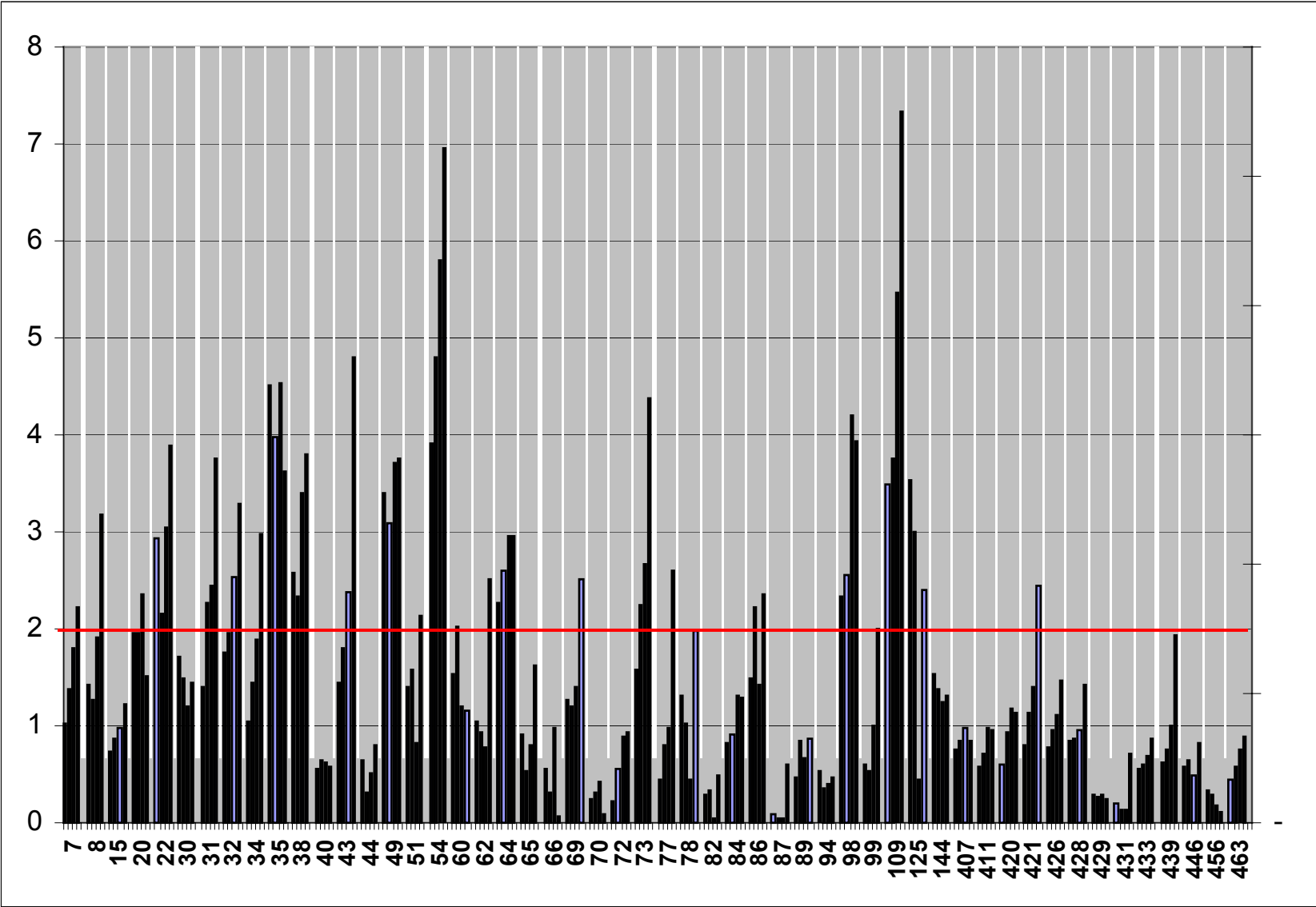
## Feasible GMM

58 million elements in the error covariance matrix based on 146 parameter estimates.  
208 regressors corresponding to 4 bias terms for each of 52 forecasters.

# Forecaster Biases (four horizons per forecaster)



# Significance of Forecaster Biases (four horizons per forecaster)



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