

Bernanke's 2010 US Economic Recovery: Evidence From A Minimal Spanning Tree Study

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Acknowledgments

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Time Series Segmentation

- **Non-stationary time series**
 - $\mathbf{x} = (x_1, x_2, \dots, x_N)$
 - Assume consists of M stationary segments
 - Data points in segment m drawn from $N(\mu_m, \sigma_m^2)$
- **Recursive segmentation**
 - One time series \rightarrow two segments
 - Each segment \rightarrow two subsegments
 - Iterate + optimize
 - Terminate

Jensen-Shannon Divergence

- **Single-segment likelihood** for (x_1, x_2, \dots, x_N)

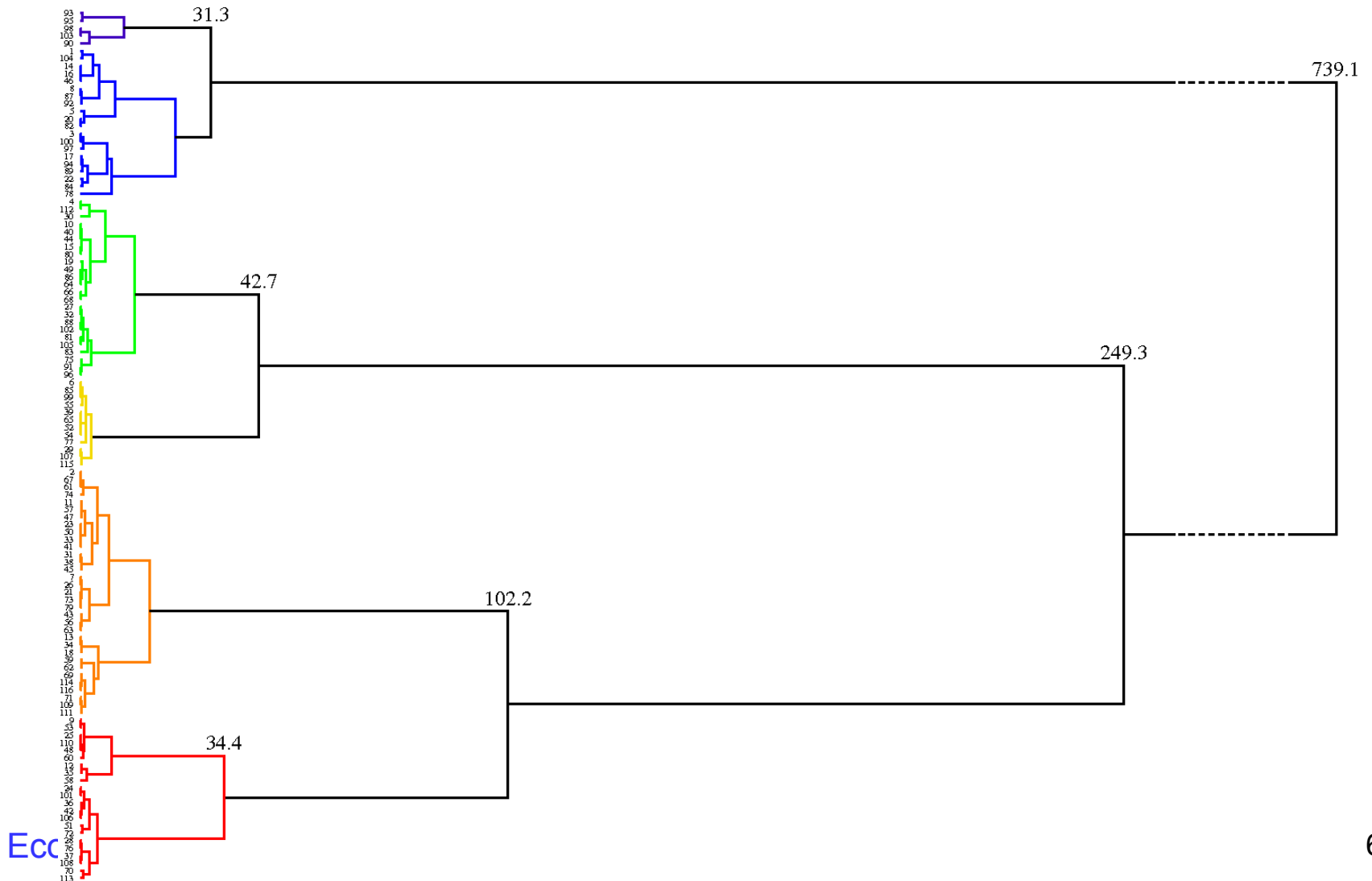
$$L_1 = \prod_{i=1}^N \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left[-\frac{(x_i - \mu)^2}{2\sigma^2}\right]$$

- **Two-segment likelihood** for $(x_1, \dots, x_t, x_{t+1}, \dots, x_N)$

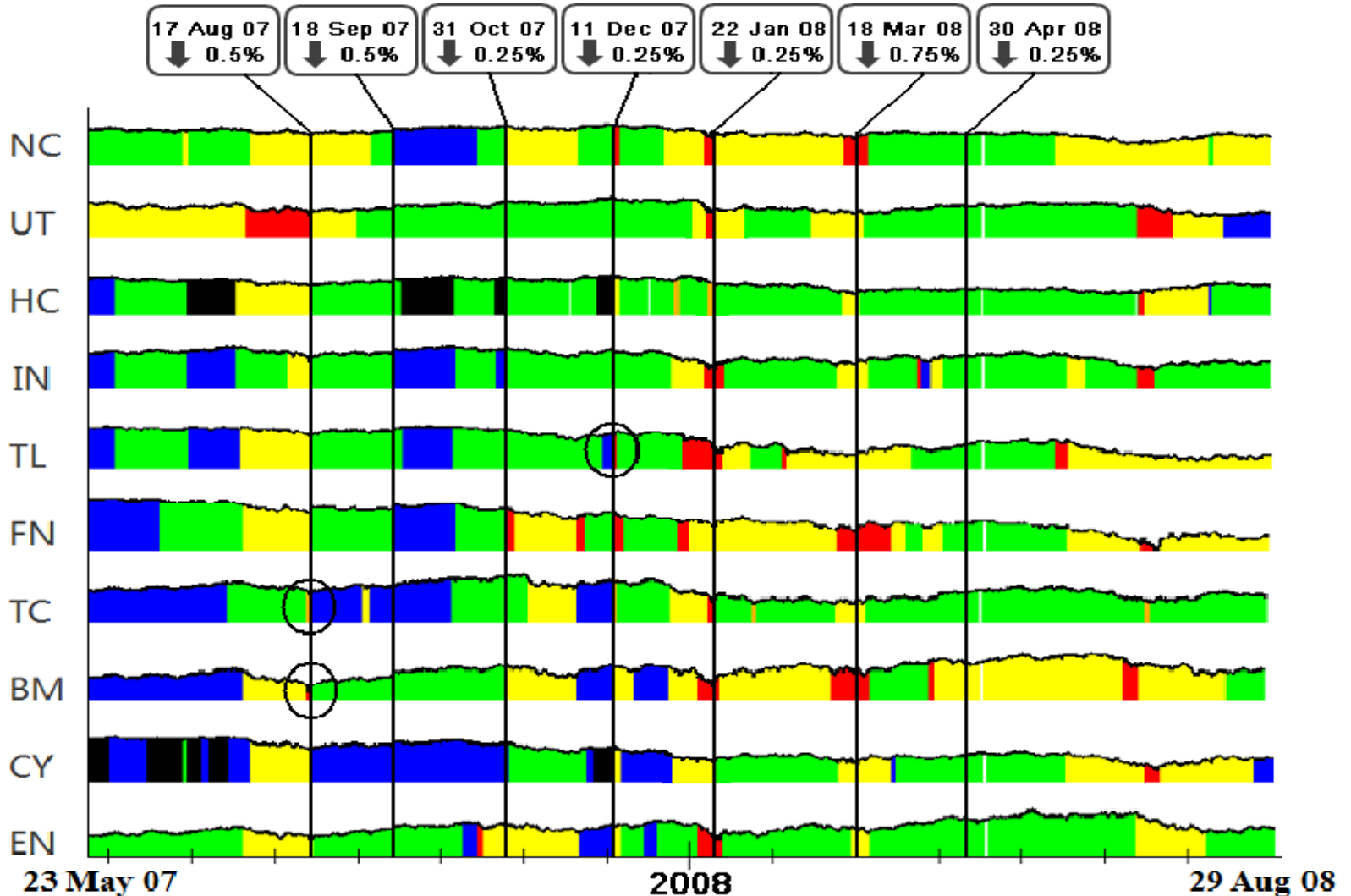
$$L_2(t) = \prod_{i=1}^t \frac{1}{\sqrt{2\pi\sigma_L^2}} \exp\left[-\frac{(x_i - \mu_L)^2}{2\sigma_L^2}\right] \prod_{i=t+1}^N \frac{1}{\sqrt{2\pi\sigma_R^2}} \exp\left[-\frac{(x_i - \mu_R)^2}{2\sigma_R^2}\right]$$

- ML estimates $\hat{\mu}, \hat{\mu}_L, \hat{\mu}_R, \hat{\sigma}^2, \hat{\sigma}_L^2, \hat{\sigma}_R^2$
- **Jensen-Shannon divergence** $\Delta(t) = \ln \frac{L_2(t)}{L_1} \geq 0$

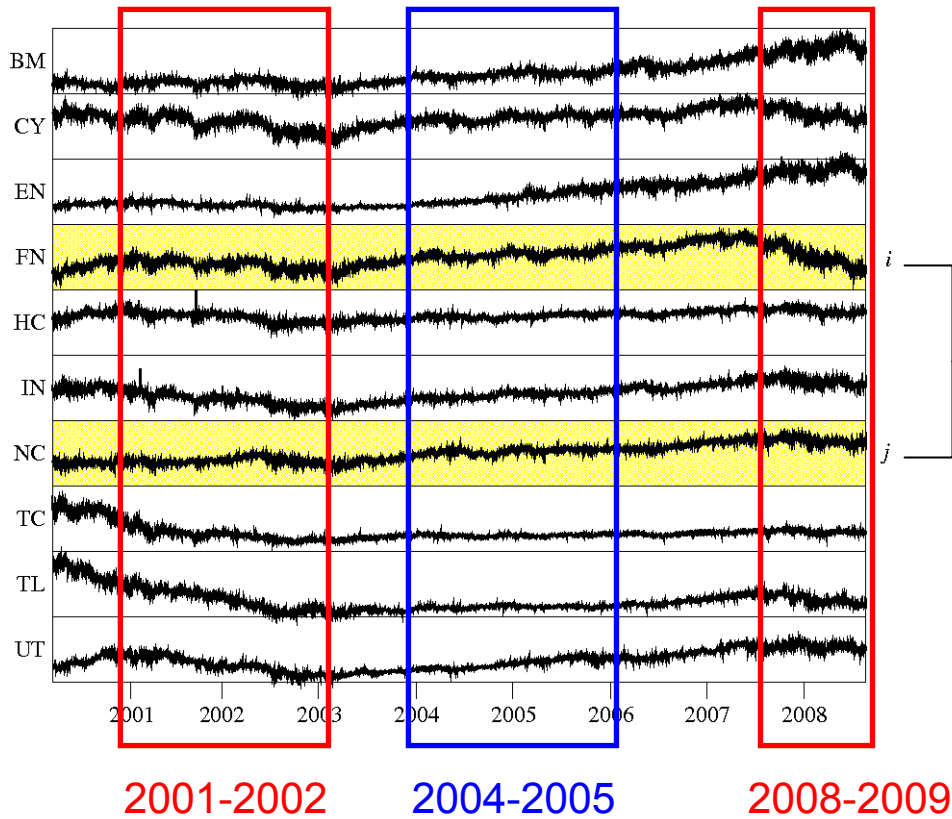
Segmentation + Clustering



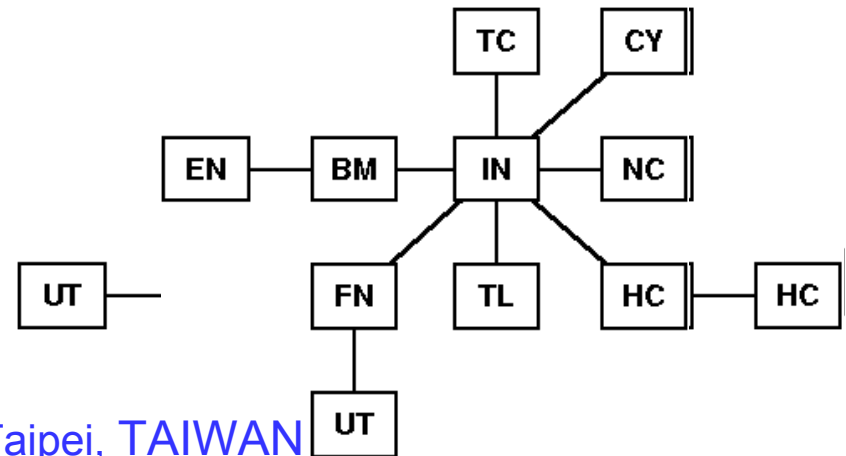
Dow Jones US Economic Sectors



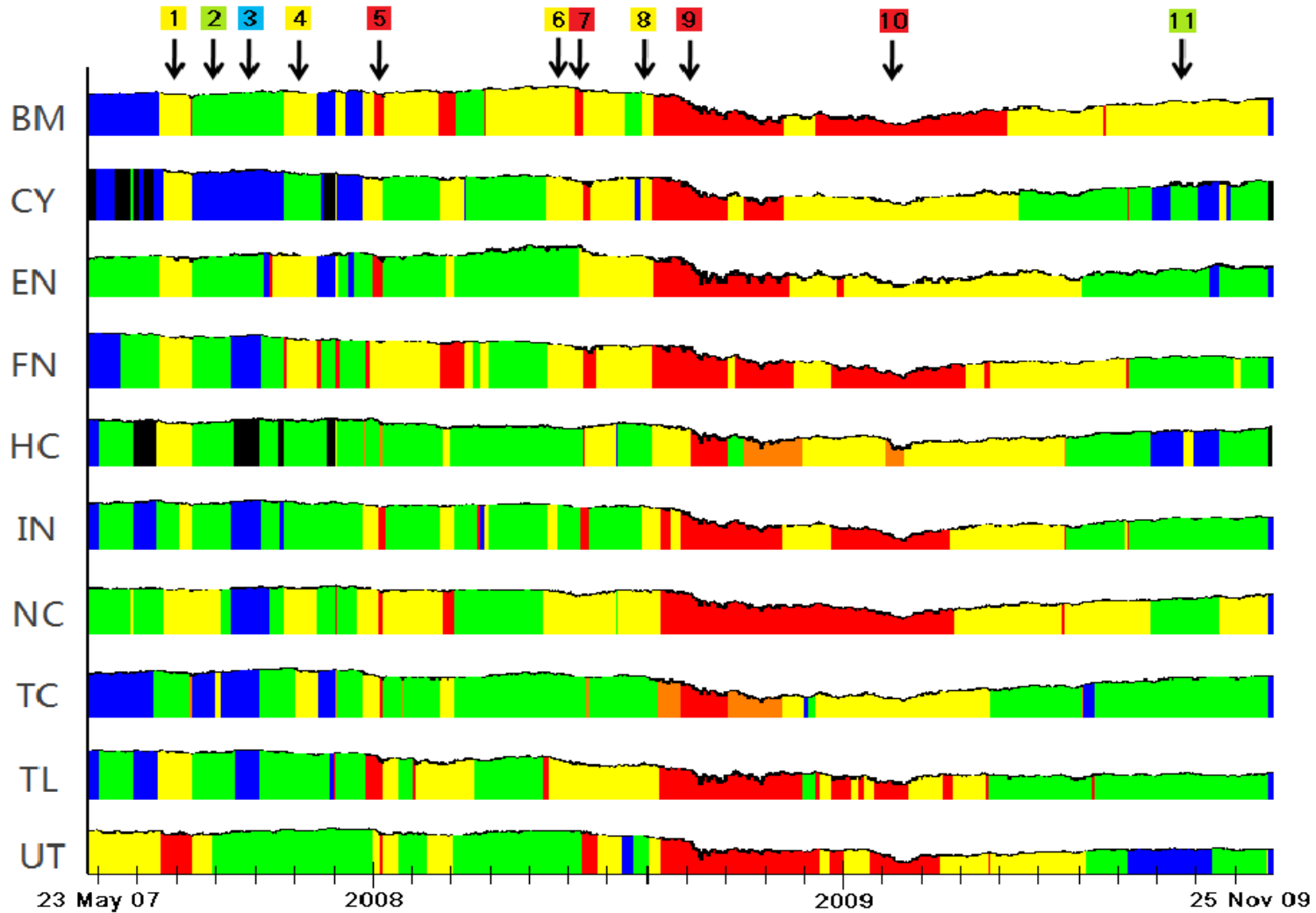
Macroeconomic MSTs



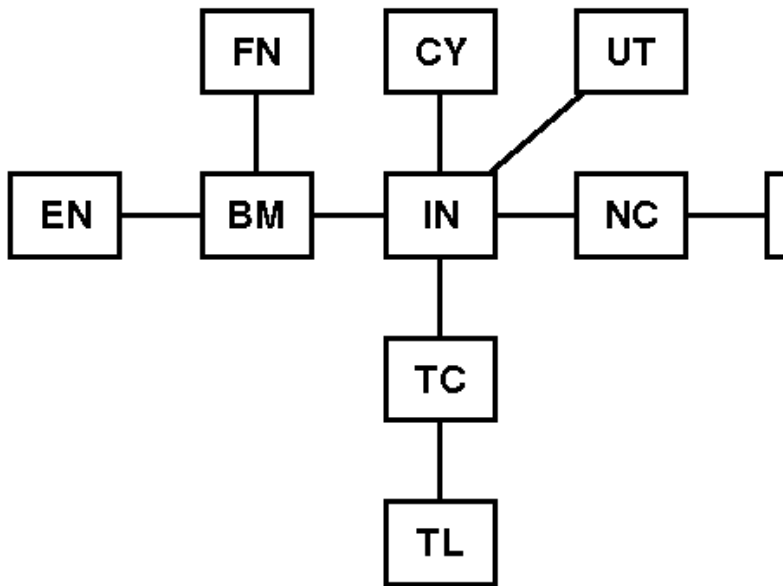
$$C_{ij} = \frac{\langle (x_i - \bar{x}_i)(x_j - \bar{x}_j) \rangle}{\sigma_i \sigma_j} = \left\langle \frac{\delta x_i}{\sigma_i} \frac{\delta x_j}{\sigma_j} \right\rangle$$



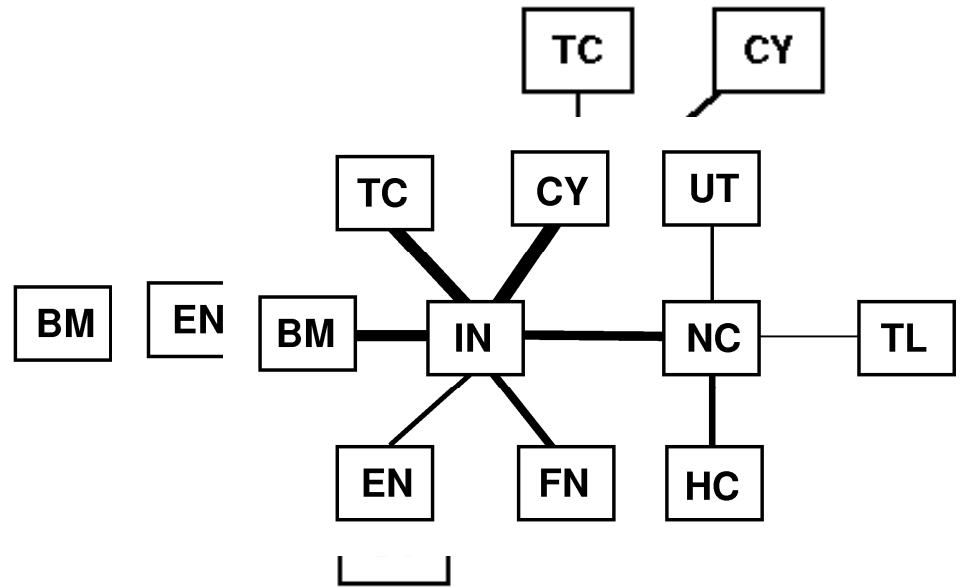
Mesoeconomic MSTs



Early Signs of Economic Recovery?



Sep 2009



21 Jan 2010
31 Mar 2010
25 Feb 2010
10 Dec 2009

Conclusions

- **Previous study on US economy**
 - 1.5-year recovery from previous crisis
 - 2-month descent into present crisis
 - Strong driving from Fed rate cuts
- **Present study on US economy**
 - Robust star-like MST within growth phase
 - Robust chain-like MST within crisis phase
- **Early indication of economic recovery**
 - Nearly star-like MST in Sep 2009
 - Robust star-like MSTs throughout Greek Debt Crisis

Thank You!

- **Contact Information**

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