Estimating Turning Points using Large Data Sets

(*work in progress*)

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Banca d'Italia

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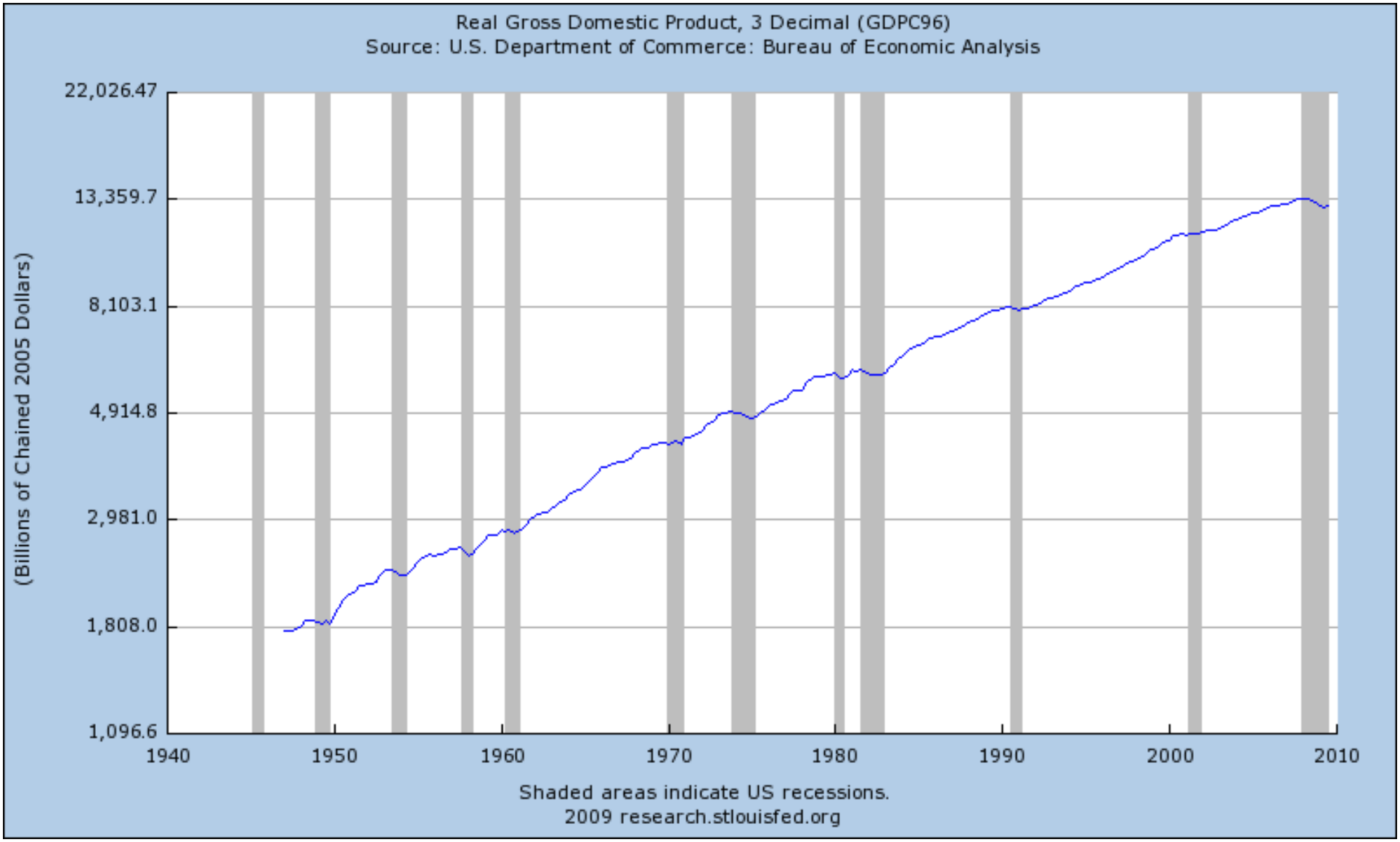
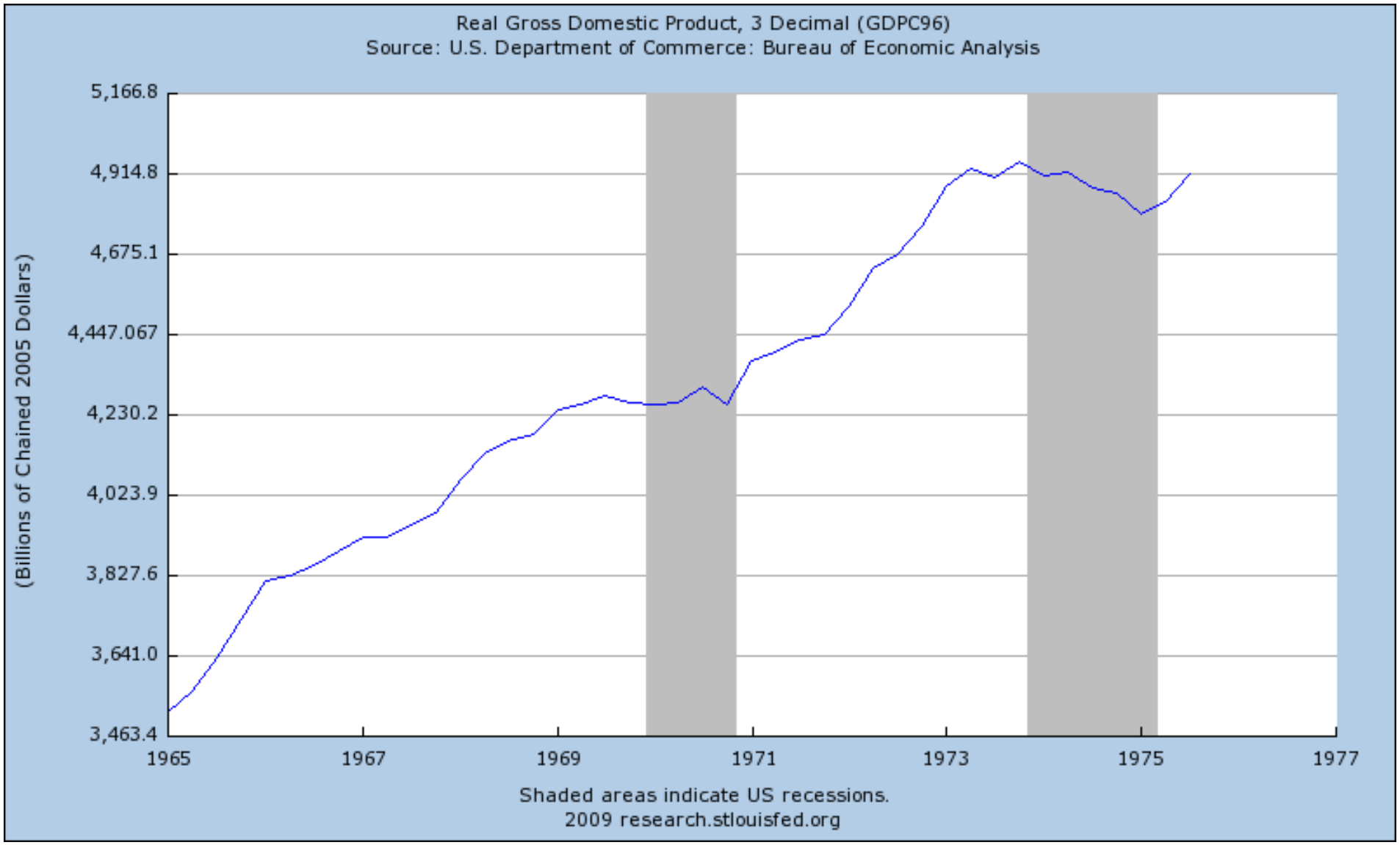
Dating business cycles is easy ….

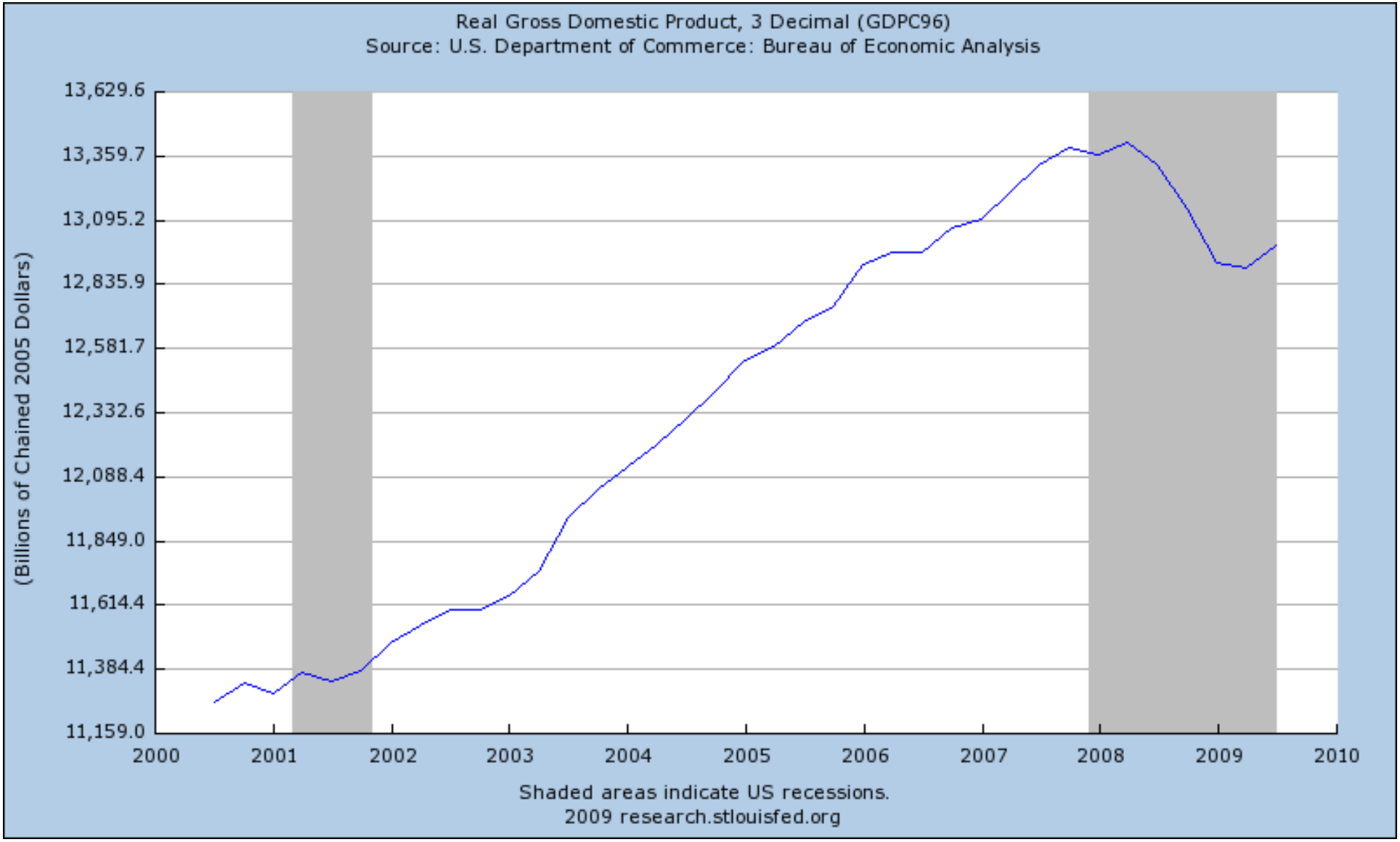
or is it?



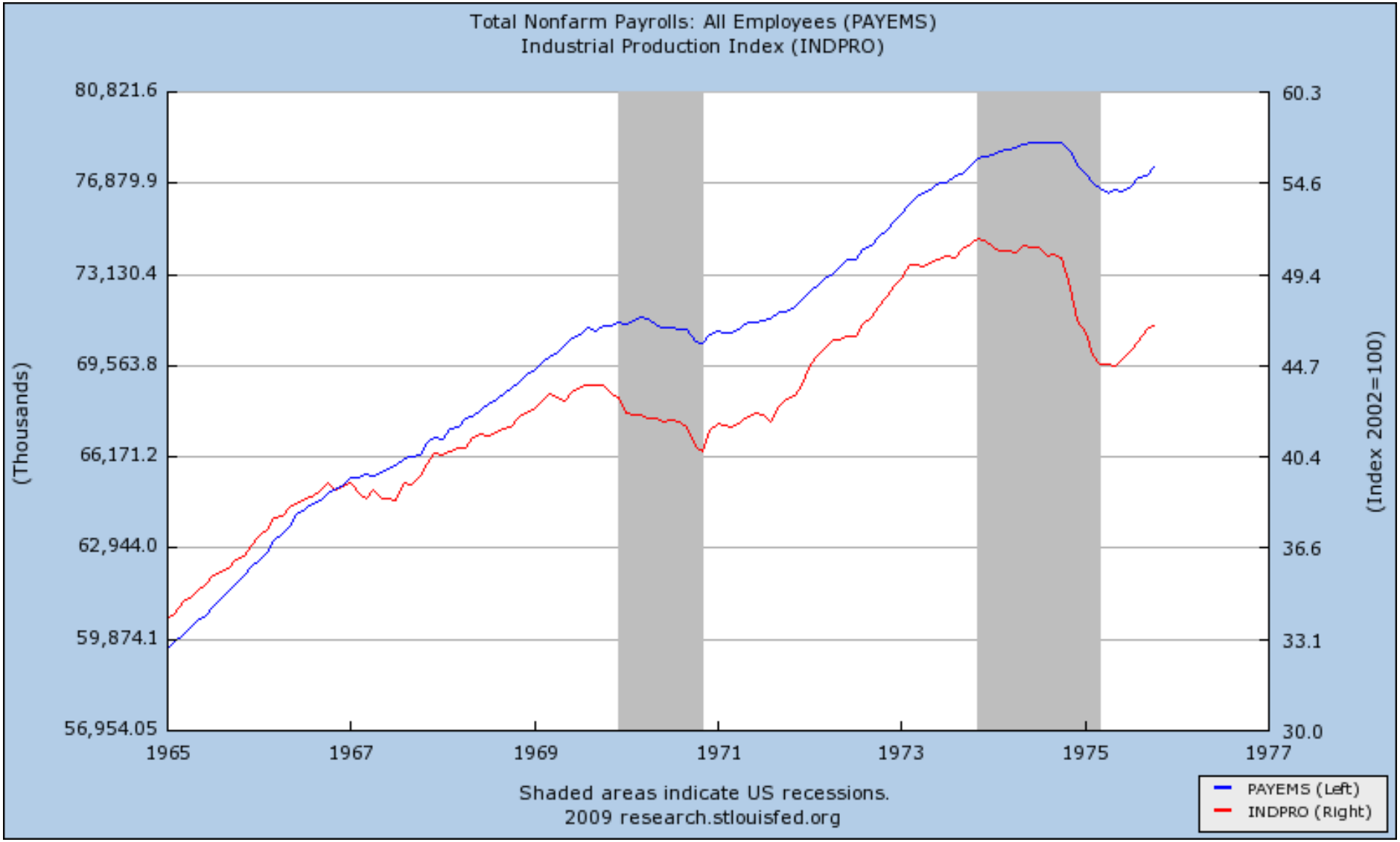
U.S. real GDP (log)



U.S. real GDP (log)



U.S. real GDP (log)



Total Nonfarm Employment & Industrial Production (logs)

What is a turning point?

Burns and Mitchell (1946)

… A reference scale of business cycles must be extracted from the fallible indications provided by time series for **varied** economic activities…. (p. 76)
[more than 1000 in all, with various spans]

In many cases the turning points of different series were bunched so closely that we could not go far astray. But there were cases in which the turning points were widely scattered, and others in which they were concentrated around two separate dates. If there was little else to guide us, we placed the reference turn toward the close of the transition period. (p. 77-80)

NBER Business Cycle Dating Committee (Dec. 2008)

A recession is a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in production, employment, real income, and other indicators. A recession begins when the economy reaches a peak of activity and ends when the economy reaches its trough. Between trough and peak, the economy is in an expansion.

Because a recession is a broad contraction of the economy, not confined to one sector, the committee emphasizes economy-wide measures of economic activity. **The committee believes that domestic production and employment are the primary conceptual measures of economic activity.**

[The release goes on to discuss 6 series: real GDP, real GDI, employment (establishment survey), real personal income less transfers, industrial production, real manufacturing and wholesale-retail trade sales, and employment (household survey).]

http://www.nber.org/cycles/dec2008.html

CEPR Business Cycle Dating Committee

The Committee defines a recession as

> *"a significant decline in the level of economic activity, spread across the economy of the euro area, **usually** visible in two or more consecutive quarters of negative growth in GDP, employment and other measures of aggregate economic activity for the euro area as a whole; and reflecting similar developments in most countries."*

In determining the chronology of the euro area business cycle, the CEPR Committee adopted a definition of a recession similar to that used by the National Bureau of Economic Research (NBER), which has for many years dated the US business cycle. The Committee had to adapt the NBER definition, however, to reflect specific features of the euro area.

http://www.cepr.org/Data/Dating/methodology.asp

Topic of this paper:

Are disaggregated data useful for dating BC turning points (TPs)?

Two ways of using dissaggreated data

1. Average/Aggregate then Date

2. Date then Average/Aggregate

Monthly data set:

- 270 disaggregates (total) of employment, IP, personal income, & sales, U.S.
- Monthly, focus on 1959:1 – 2009:7
- Lots of missing data (blocks)

IP: Industry

Manufacturing		
	Durable	
		IP: Wood product NAICS=321, SA
		IP: Nonmetallic mineral product NAICS=327, SA
		IP: Primary metal NAICS=331, SA
		IP: Fabricated metal product NAICS=332, SA
		IP: Machinery NAICS=333, SA
		IP: Computer and electronic product NAICS=334, SA
		IP: Electrical equipment, appliance, and component NAICS=335, SA
		IP: Transportation equipment NAICS=336, SA
		IP: Furniture and related product NAICS=337, SA
		IP: Miscellaneous NAICS=339, SA
	NonDurable	
		IP: Food NAICS=311, SA
		IP: Beverage NAICS=3121, SA
		IP: Tobacco NAICS=3122, SA
		IP: Textile mills NAICS=313, SA
		IP: Textile product mills NAICS=314, SA
		IP: Apparel NAICS=315, SA
		IP: Leather and allied product NAICS=316, SA
		IP: Paper NAICS=322, SA
		IP: Printing and related support activities NAICS=323, SA
		IP: Petroleum and coal products NAICS=324, SA
		IP: Chemical NAICS=325, SA
		IP: Plastics and rubber products NAICS=326, SA
Mining		
		IP: Oil and gas extraction NAICS=211, SA
		IP: Mining (except oil and gas) NAICS=212, SA
		IP: Support activities for mining NAICS=213, SA
Utilities		
		IP: Electric power generation, transmission and distribution NAICS=2211, SA
		IP: Natural gas distribution NAICS=2212, SA

IP: Markets

Manufacturing		
	Durable	
		IP: Wood product NAICS=321, SA
		IP: Nonmetallic mineral product NAICS=327, SA
		IP: Primary metal NAICS=331, SA
		IP: Fabricated metal product NAICS=332, SA
		IP: Machinery NAICS=333, SA
		IP: Computer and electronic product NAICS=334, SA
		IP: Electrical equipment, appliance, and component NAICS=335, SA
		IP: Transportation equipment NAICS=336, SA
		IP: Furniture and related product NAICS=337, SA
		IP: Miscellaneous NAICS=339, SA
	NonDurable	
		IP: Food NAICS=311, SA
		IP: Beverage NAICS=3121, SA
		IP: Tobacco NAICS=3122, SA
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		IP: Textile product mills NAICS=314, SA
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		IP: Support activities for mining NAICS=213, SA
Utilities		
		IP: Electric power generation, transmission and distribution NAICS=2211, SA
		IP: Natural gas distribution NAICS=2212, SA
Consumer Goods		

	Durables	
		IP: Automotive products, SA
		IP: Autos and trucks, consumer, SA
		IP: Auto parts and allied goods, SA
		IP: Other durable goods, SA
		IP: Computers, video and audio equipment, SA
		IP: Appliances, furniture, and carpeting, SA
		IP: Miscellaneous durable goods, SA
	NonDurables	
		IP: Foods and tobacco, SA
		IP: Clothing, SA
		IP: Chemical products, SA
		IP: Paper products, SA
		IP: Miscellaneous nondurable goods, SA
		IP: Consumer energy products, SA
		IP: Fuels, SA
		IP: Residential utilities, SA
Equipment		
		IP: Transit equipment, SA
		IP: Information processing and related equipment, SA
		IP: Industrial and other equipment, SA
		IP: Industrial equipment, SA
		IP: Other equipment, SA
		IP: Oil and gas well drilling and manufactured homes, SA
		IP: Defense and space equipment, SA
Materials		
	Durable Goods	
		IP: Consumer parts, SA
		IP: Equipment parts, SA
		IP: Computer and other board assemblies and parts, SA
		IP: Semiconductors, printed circuit boards, and other, SA
		IP: Other equipment parts, SA
		IP: Other durable materials, SA
		IP: Basic metals, SA
		IP: Miscellaneous durable materials, SA
	NonDurable Goods	
		IP: Textile materials, SA

		IP: Paper materials, SA
		IP: Chemical materials, SA
		IP: Other nondurable materials, SA
		IP: Containers, SA
		IP: Miscellaneous nondurable materials, SA
	Energy	
		IP: Primary energy, SA
		IP: Converted fuel, SA
NonIndustrial Supplies		
		IP: Construction supplies, SA
		IP: Business supplies, SA
		IP: General business supplies, SA
		IP: Commercial energy products, SA

Employment – Dissagregated

Mining and Logging		
		Logging
		Oil and gas extraction
		Mining except oil and gas
		Support activities for mining
Construction		
		Construction of Buildings
		Heavy and civil engineering construction
		Specialty trade contractors
Manufacturing		
	Durables	
		Wood Products
		Nonmetallic mineral products
		Primary Metals
		Fabricated metal products
		Machinery
		Computer and electronic products
		Electrical equipment and appliances
		Transportation equipment
		Furniture and related products
		Miscellaneous manufacturing
	NonDurables	
		Food Manufacturing
		Beverages and tobacco products
		Textile Mills
		Textile Product Mills
		Apparel
		Leather and allied products
		Paper and paper products
		Printing and related support activities
		Petroleum and coal products
		Chemicals
		Plastics and Rubber Products
Wholesale Trade		

		Durable Goods
		NonDurable Goods
		Electronic markets and agents and brokers
Retail Trade		
		Motor vehicle and parts dealers
		Furniture and home furnishings stores
		Electronics and appliance stores
		Building material and garden supply stores
		Food and beverage stores
		Health and personal care stores
		Gasoline stations
		Clothing and clothing accessories stores
		Sporting goods, hobby, boo, and music stores
		General merchandise stores
		Miscellaneous store retailers
		Nonstore retailers
Transportation and warehousing		
		Air transportation
		Rail transportation
		Water transportation
		Truck transportation
		Transit and ground passenger transportation
		Pipeline transportation
		Scenic and sightseeing transportation
		Support activities for transportation
		Couriers and messengers
		Warehousing and storage
Utilities		
		Utilities
Informatio		
		Publishing industries
		Motion picture and sound recording industries

		Broadcasting except internet
		Telecommuincations
		Data Processing, hosting and related activities
		Other Information Services
Financial Activities		
		Monetary authorities - central bank
		Credit intermediation and related activities
		Securities, Commidities, Investments
		Insurance carriers and related activities
		Funds, Trusts, and other Financial Vehicles
		Real Estate
		Rental and Leasing Services
		Lessors of nonfinancial intangible assets
Professional and Business Services		
		Professional and technical services
		Management of companies and enterprises
		Administrative and waste services
Educationand Health Services		
		Education Services
		Health Care
		Social Assistance
Leisure and Hospitality		
		Arts/Entertaiment/Recreation
		Accomodation
		Food services and drinking places
		Other services
Government		
		Federal
		State
		local

Employment – Major Subaggregates

Manufacturing		
		Durables
		NonDurables
		Construction
Services		
		Education and Health
		Financial Activities
		Government
Services		
		Information
		Leisure and Hospitality
		Nat. Resources and Mining
Services		
		Professional and Bus Services
		Other Services
Trade		
		Retail
		Wholesale
Trade		
		Trans/Utilities (USTPU-USTRADE-USWTRADE)

Manufacturing and Trade Sales: SIC

Manufacturing		
	Durable goods	
		Lumber and wood products
		Furniture and fixtures
		Stone, clay, and glass products
		Primary metals
		Fabricated metals
		Industrial machinery
		Electronic machinery
		Transportation equipment
		Instruments
		Other manufacturing
	Nondurable goods	
		Food and kindred products
		Tobacco products
		Textile mill products
		Apparel products
		Paper and allied products
		Printing and publishing
		Chemical and allied products
		Petroleum products
		Rubber and plastic products
		Leather and leather products
Merchant wholesale		
	Durable goods	
		Motor vehicles
		Furniture and furnishings
		Lumber and construction
		Professional and commercial
		Metals and minerals
		Electrical goods
		Hardware and plumbing
		Machinery, equipment, and supplies
		Other durable goods

	Nondurable goods	
		Paper products
		Drugs and sundries
		Apparel and piece goods
		Groceries
		Farm products
		Chemical and allied products
		Petroleum products
		Alcoholic beverages
		Other nondurable goods
Retail trade		
	Durable goods	
		Automotives
		Lumber and building stores
		Furniture and furnishings
		Other durable goods
	Nondurable goods	
		Food stores
		Apparel stores
		Department stores
		Other general merchandise stores

Manufacturing and Trade Sales: NAICS

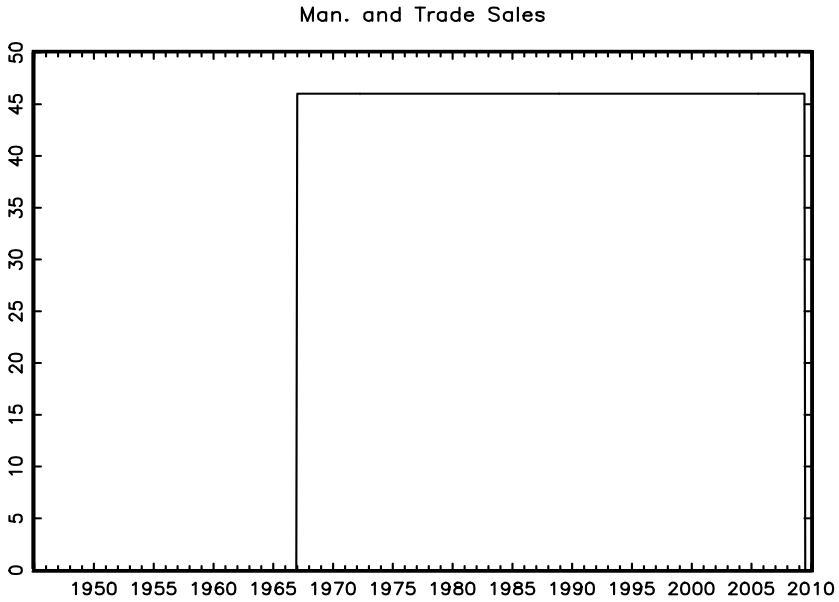
Manufacturing industries		
	Durable goods manufacturing industries	
		Wood product manufacturing
		Nonmetallic mineral product manufacturing
		Primary metal manufacturing
		Fabricated metal product manufacturing
		Machinery manufacturing
		Computer and electronic product manufacturing
		Electrical equipment, appliance, and component manufacturing
		Transportation equipment manufacturing
		Furniture and related product manufacturing
		Miscellaneous durable goods manufacturing
	Nondurable goods manufacturing industries	
		Food manufacturing
		Beverage and tobacco product manufacturing
		Textile mills
		Textile product mills
		Apparel manufacturing
		Leather and allied product manufacturing
		Paper manufacturing
		Printing and related support activities
		Petroleum and coal product manufacturing
		Chemical manufacturing
		Plastics and rubber product manufacturing
Merchant wholesale industries		
	Durable goods merchant wholesale industries	
		Motor vehicles, parts, and supplies wholesalers
		Furniture and home furnishings wholesalers
		Lumber and other construction materials wholesalers
		Professional and commercial equipment wholesalers
		Metal and mineral (except petroleum) wholesalers
		Electrical goods wholesalers

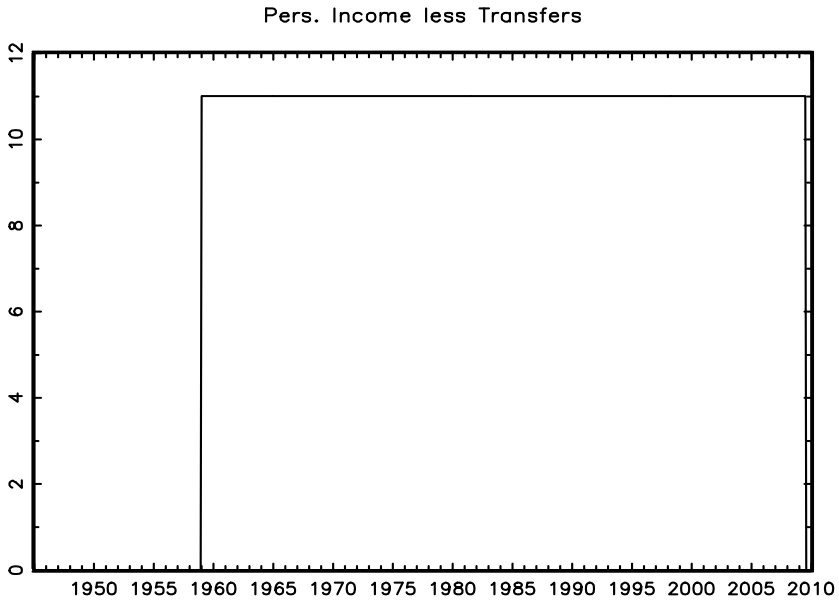
		Hardware and plumbing and heating equipment wholesalers
		Machinery, equipment, and supplies wholesalers
		Miscellaneous durable goods wholesalers
	Nondurable goods merchant wholesale industries	
		Paper and paper products wholesalers
		Drugs and druggists' sundries wholesalers
		Apparel, piece goods, and notions wholesalers
		Grocery and related products wholesalers
		Farm product raw material wholesalers
		Chemical and allied products wholesalers
		Petroleum and petroleum products wholesalers
		Beer, wine, and distilled alcoholic beverages wholesalers
		Miscellaneous nondurable goods wholesalers
Retail trade industries		
		Motor vehicle and parts dealers
		Furniture, furnishings, electronics, and appliance stores
		Building material and garden equipment and supplies dealers
		Food and beverage stores
		Clothing and clothing accessories stores
		General merchandise stores
		Other retail stores

Personal Income

Wages and Salaries		
		Manufacturing(SIC)
		Distributive industries (SIC)
		Service Industries (SIC)
		Manufacturing (NAICS)
		Trade, transportation, and utilities (NAICS)
		Other services-producing industries (NAICS)
		Government
		Supplements to wages and salaries
Prop. Income		
		Farm
		NonFarm
		Rental Income
Personal income receipts on assets		
		Interest
		Dividend
		Personal current taxes

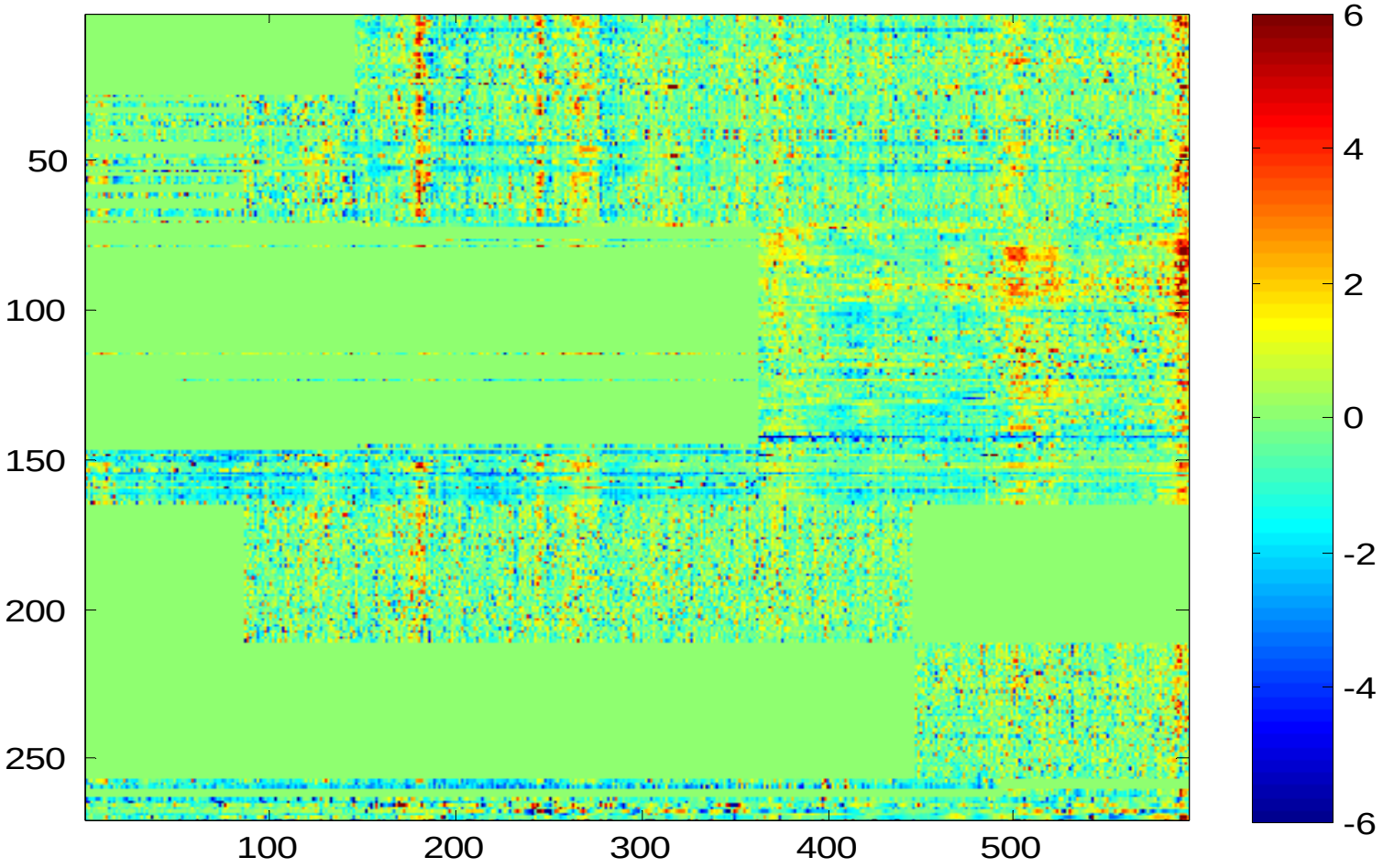
Number of Dissagregated Series by Category



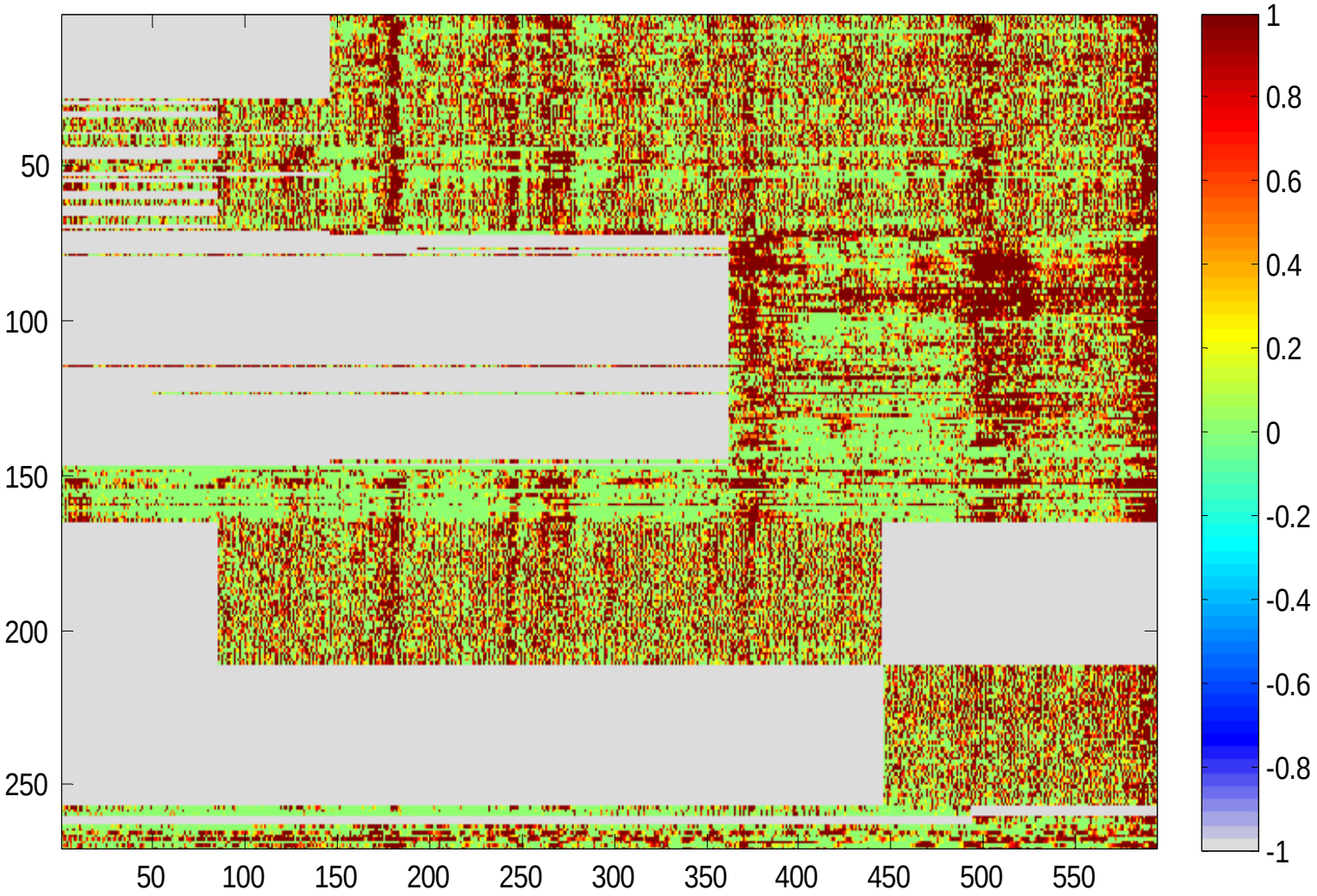


A first look at the data

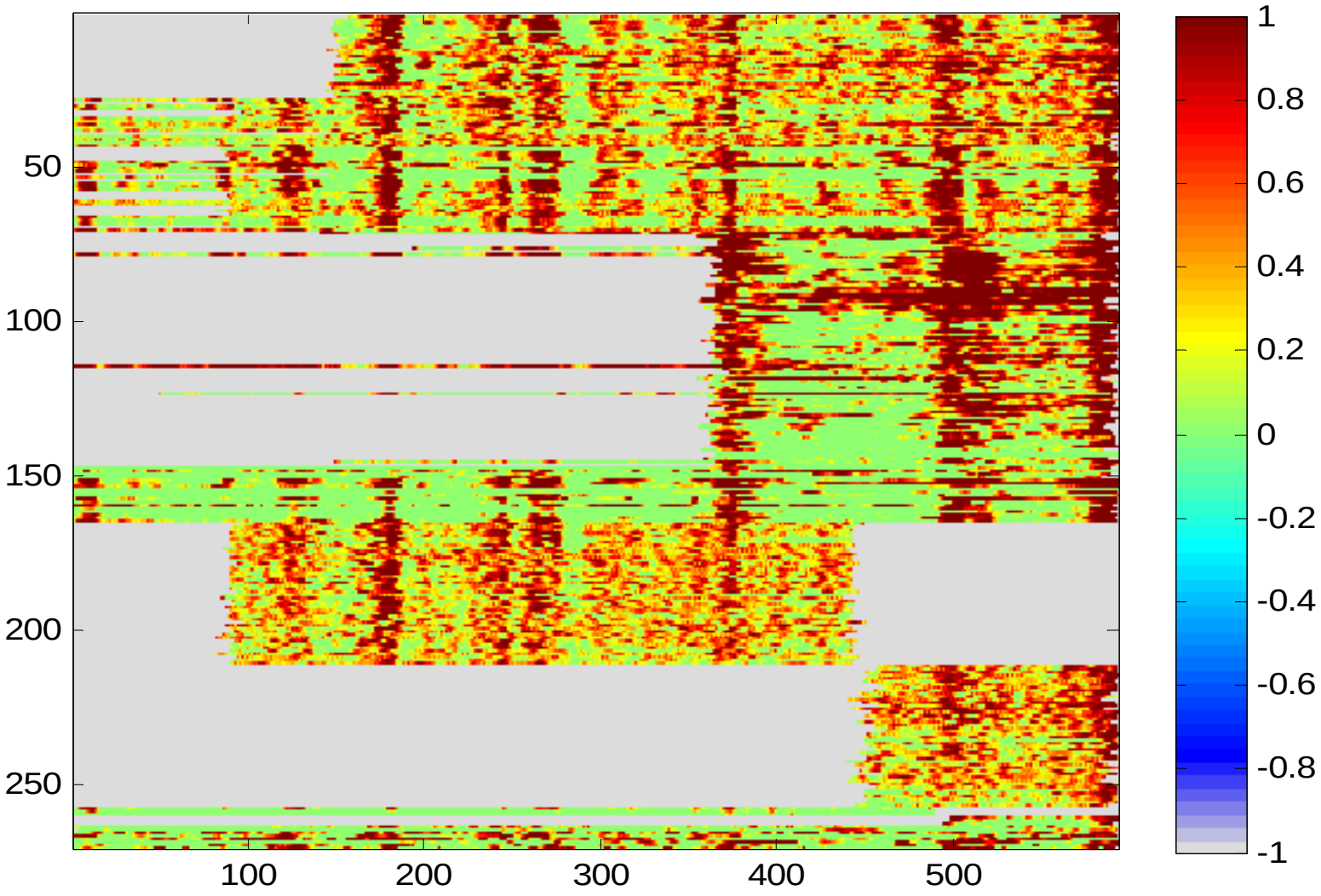
Data: Adjusted for outliers, standardized growth rates (red = negative growth)



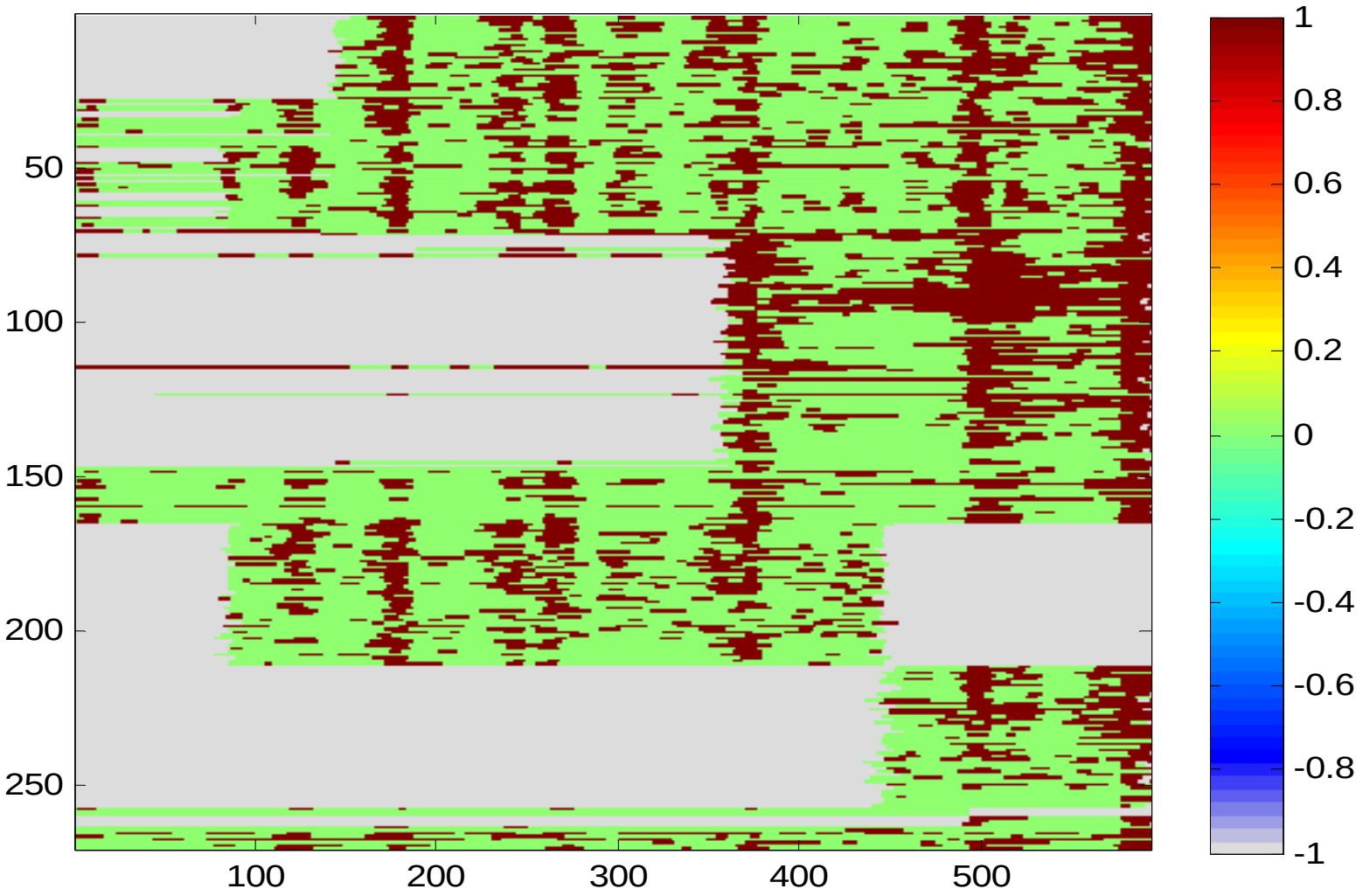
Temperature plot, normal CDF transformation (red = negative growth)



Temperature plot, lag adjusted



Binary Bry-Boschan specific-series recessions, lag-adjusted



Outline

1) Literature review (brief)
2) Econometric theory I: Specific cycles
3) Econometric theory II: Reference cycles
4) Empirical results I: Aggregates
5) Empirical results II: Disaggregates
6) Conclusions

1) Literature review (brief, incomplete)

Early literature

Burns and Mitchell (1946), Zarnowitz (1972), Zarnowitz and Moore (1991), Vaccara and Zarnowitz (1977), Bry and Boschan (1971)

Nonparametric

Wecker (1979), Canova (1994), Zellner and Hong (1991), Harding and Pagan (2002, 2003, 2006, 2009), Watson (1994)

Parametric/filtering

Stock-Watson (1989, 1991), Hamilton (1989), Kim and Nelson (1999), Chauvet and Hamilton (2005), Kauppi and Saikkonen (2008), Chauvet and Piger (2003, 2008), Startz (2008), Berge and Jordà (2009), Morley and Piger (2009), Hamilton and Owyang (2009)

2) Econometric theory I: Specific cycles

Some econometric theory questions:

- What is the estimand
- What are good estimators?
- How to quantify (sampling) uncertainty?
- Does the theory of optimal estimation entail the use of disaggregated data?

Empirical questions:

- Is there a trivial model for the NBER estimand?
- How do methods based on the aggregates perform?
- How do methods based on disaggregates perform?
- Do disaggregates help in estimating TPs?

Estimand – specific cycles

Latent process/measurement error framework:

$$y_t = \mu_t + u_t$$

where

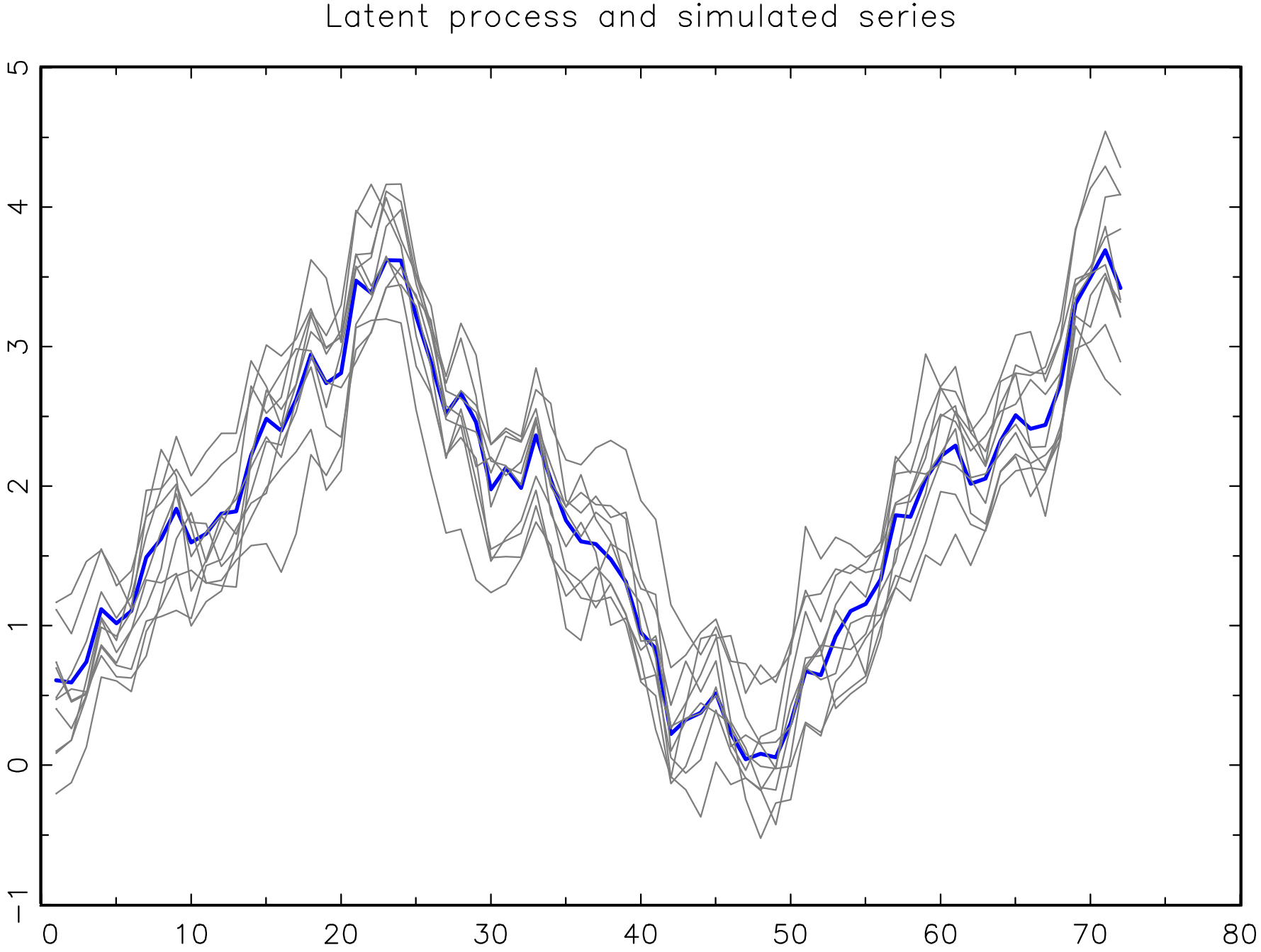
μ_t = latent process (true employment in construction)

u_t = measurement error (survey sampling)

Estimand: turning point in latent process

$P(\ldots, \mu_{t-1}, \mu_t, \mu_{t+1}, \ldots) = (\tau, \pi_\tau)$ = (date, 1/-1 peak/trough indicator)

- P is definitional – $P(\ldots, \mu_{t-1}, \mu_t, \mu_{t+1}, \ldots)$ is definitional
- Here we adopt P to be the Bry-Boschan algorithm (B&M as oracle)
- Measurement error introduces sampling uncertainty
- Recession events v. turning points


Latent process and simulated series
5
4
3
2
1
0
−1
0
10
20
30
40
50
60
70
80

Estimators – specific cycles

Bayes estimators by optimal filtering given model

$$y_t = \mu_t + u_t$$

Let: $Y = (y_1, \ldots, y_T)$, $\mu = (\mu_1, \ldots, \mu_T)$

Latent process model (prior): $f_\mu(\mu)$

ME model: $Y \mid \mu$

Smoother (posterior): $\mu \mid Y$

Posterior for TP: $P[\tau(\mu)] \mid Y \rightarrow$ posterior mean or mode

Leading models (priors) for μ_t:

- Gaussian
- Binary/Markov switching. *note*: MS: $P(\mu)$ reduces to 0/1 (or 00/11) transition

Estimators – specific cycles, ctd.

$$y_t = \mu_t + u_t$$

Frequentist estimators: Treat (τ, π_τ) as nonrandom parameters where $\tau = P(\ldots, \mu_{t-1}, \mu_t, \mu_{t+1}, \ldots)$ where $\{\mu_t\}$ are unknown.

- Nonparametric (or ML): $\hat{\tau} = P(y_{t-p}, \ldots, y_{t+p})$

- Properties of estimators:

$$f_{\hat{\tau}} = f\left(\{\mu_t\}_{t=\tau-k}^{\tau+k}, g(u)\right)$$

Work underway

3) Econometric theory II: Reference cycles

Estimand – Reference cycles

Problems with defining TPs in terms of functions of observable series

- B&M, BCDCs don't use that approach
- definitions like "2 consecutive quarters of GDP decline" are too rigid
- No room for sampling uncertainty; data revision conundrum

Two estimand concepts:

1. "Average then Date": TP of a single latent factor (DFM) or latent monthly GDP (e.g., EuroCoin)
2. "Date then Average": Property of the distribution of (unobserved) TPs of specific series

Estimators – Reference cycles

(a) Estimators based on single aggregate (monthly coincident index), using various weighting schemes

1. BB
2. MS

(b) Estimators based on disaggregates

1. estimators based on distribution of BB estimators
   - unweighted or weighted
   - lag adjusted or not
2. average of MS estimators
   - unweighted or weighted
   - lag adjusted or not

4) Empirical results I: Aggregates

Aggregate data

- Monthly, U.S., 1959:1 – 2009:7

- Aggregates are coincident economic indexes –wtd averages of logs of:

1. Index of industrial production
2. Nonfarm employment
3. Real manufacturing and wholesale/retail trade sales
4. Real personal income less transfers

Aggregation methods

- Simple and weighted averages (including The Conference Board)
- DFM : $\Delta X_t = \lambda \Delta C_t + U_t, \quad \Delta C_t \sim \text{AR}(2), U_t \sim \text{AR}(2)$

(Factor normalized so that weight on ΔX_t (with leads and lags) = 1)

	Average	**Inverse Std Dev**	**TCB**	**DFM**
Mean (×1200)	2.54	2.33	2.28	2.61
SD (×1200)	6.07	4.29	4.54	6.76
Weights				
IP	0.25	0.14	0.14	0.62
EMP	0.25	0.49	0.57	0.09
MT	0.25	0.11	0.12	0.19
PI	0.25	0.26	0.17	0.11

Estimators

BB: Bry-Boschan algorithm

Markov Switching filter

$$x_t = (1 - s_t)\mu_0 + s_t\mu_1 + u_t; \quad u_t = \rho u_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim \text{iidN}(0, \sigma^2)$$

s_t binary, Markov (Hamilton model)

Parameterization: match postwar recession/exp lengths and probabilities

x_t = series standardized using *rolling* window (±8 years)

$p_{11} = 0.913$ (recession)

$p_{00} = 0.983$ (expansion)

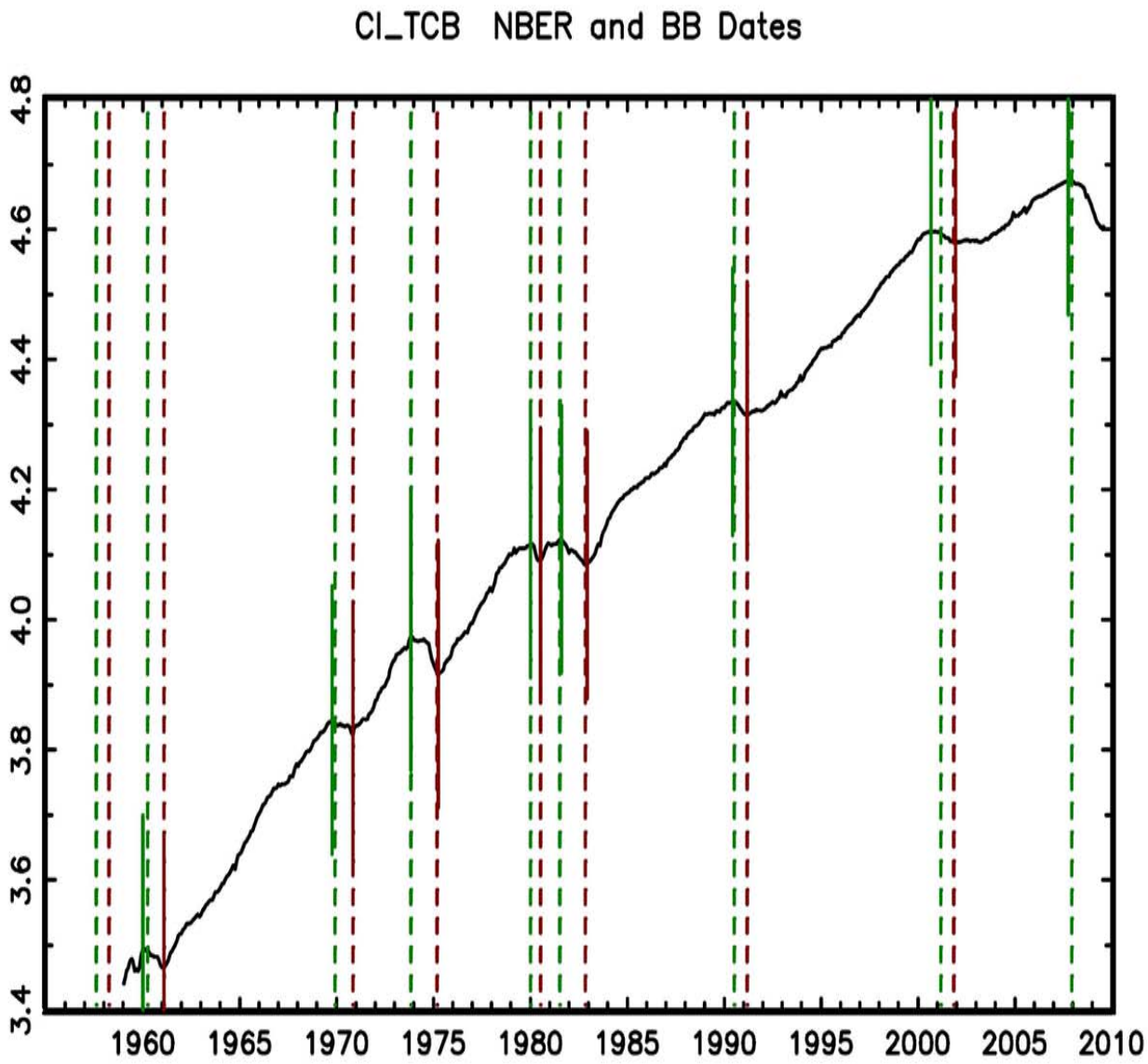
Independent priors on other coefficients:

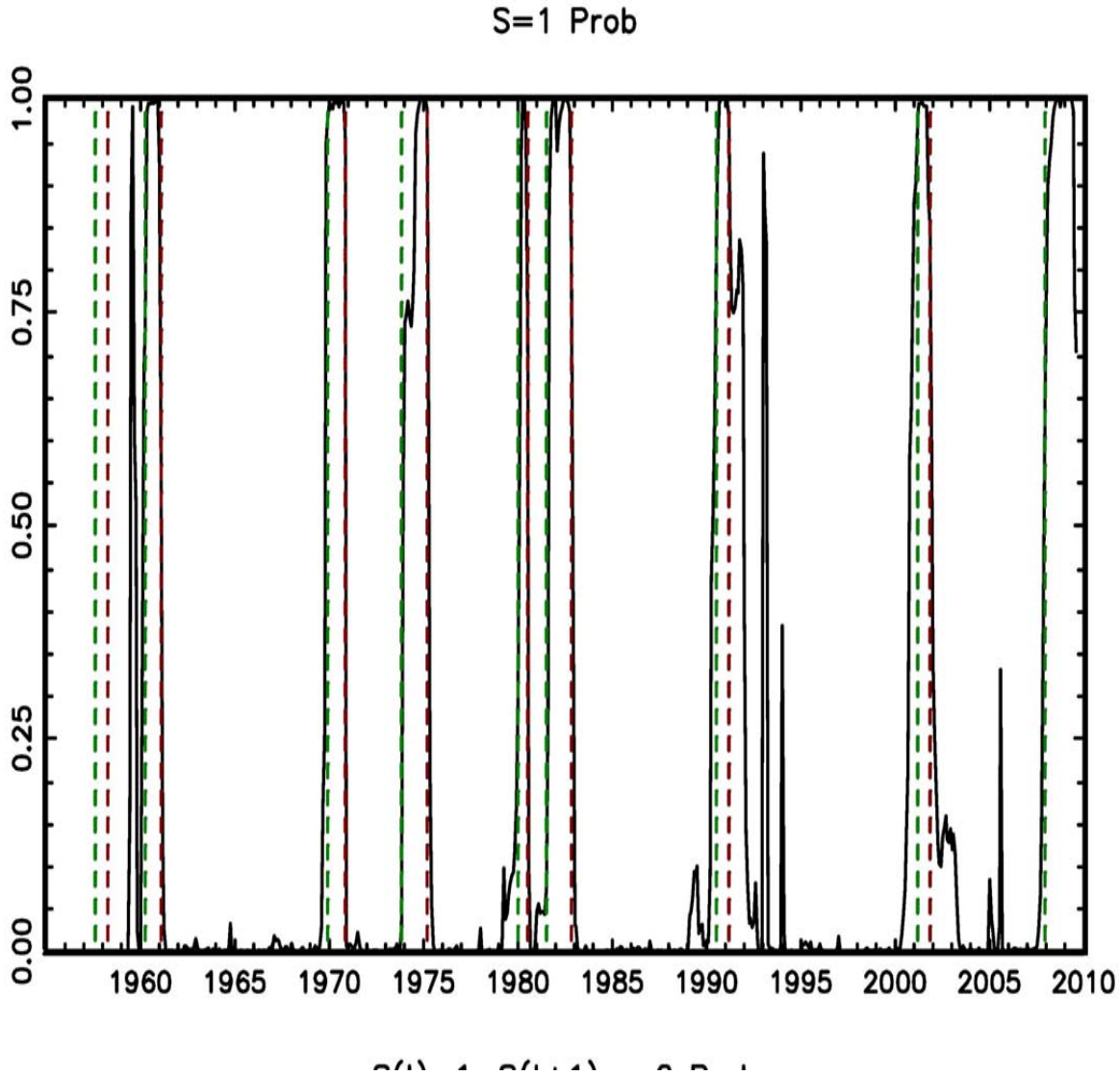
μ_0 uniform on [0 to 0.7] (8 grid points)

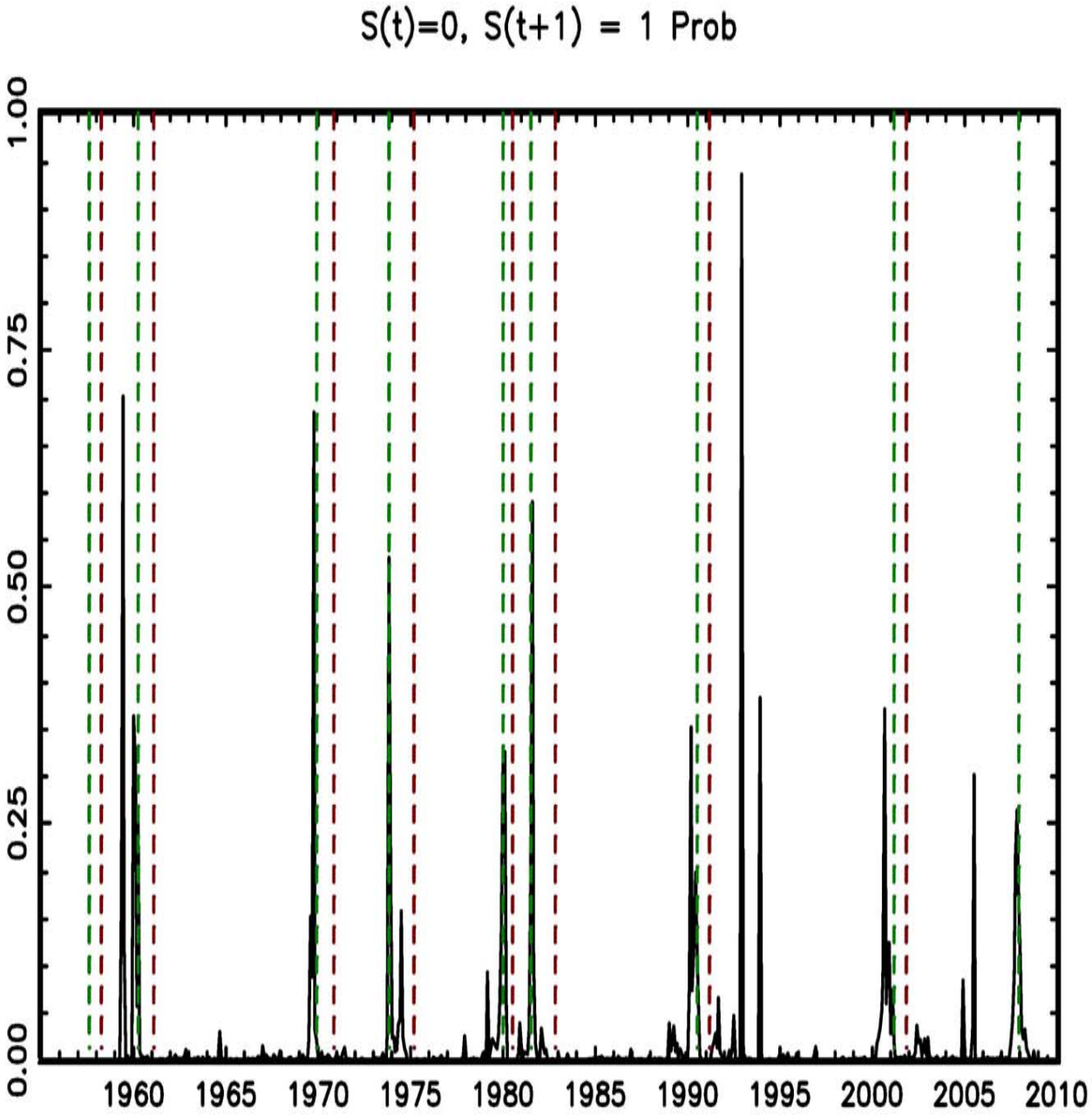
μ_1 uniform on [−1.5 to −0.1] (8 grid points)

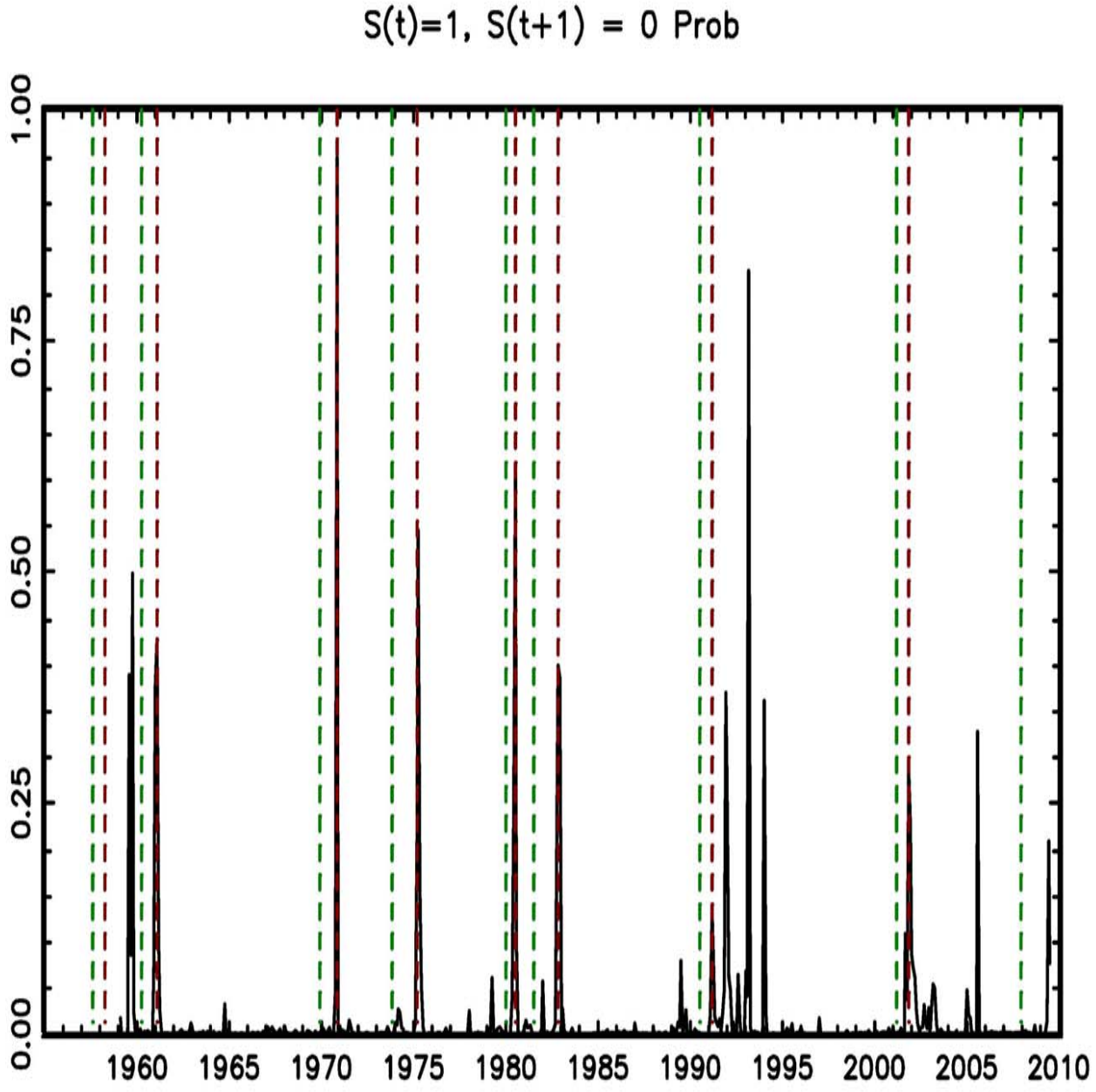
ρ uniform on [−0.8 to 0.8] (5 grid points)

σ uniform on [0.2 to 1.2] (6 grid points)


CI_TCB NBER and BB Dates
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010


S=1 Prob
1.00
0.75
0.50
0.25
0.00
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010


S(t)=0, S(t+1) = 1 Prob
1.00
0.75
0.50
0.25
0.00
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010


S(t)=1, S(t+1) = 0 Prob
1.00
0.75
0.50
0.25
0.00
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

4) Empirical results I: Disaggregates

(1) Exact DFM estimated using subaggregates:

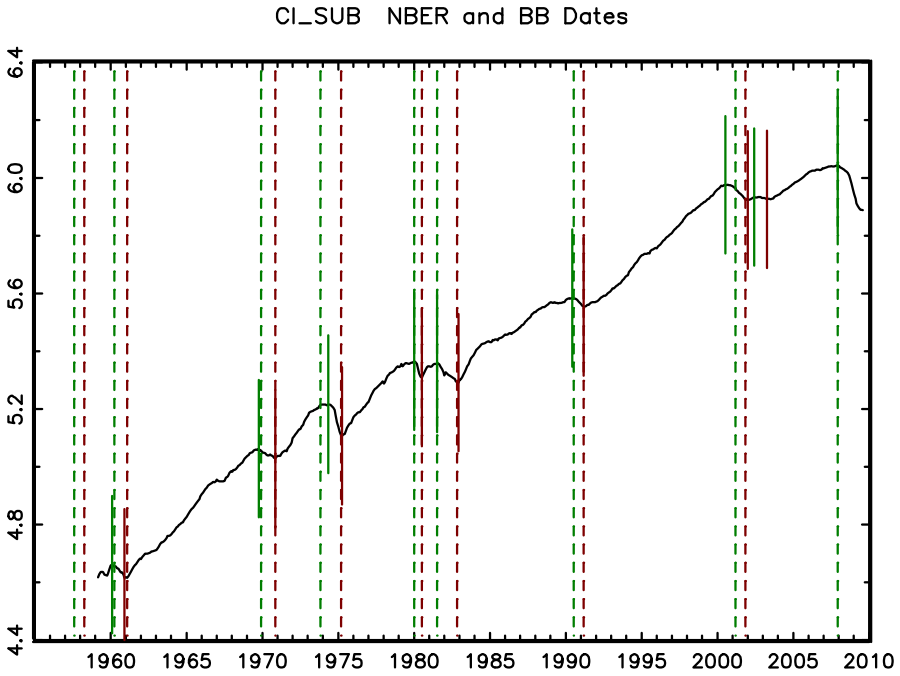
$$\Delta X_{it} = \lambda_i f_t + u_{it},$$

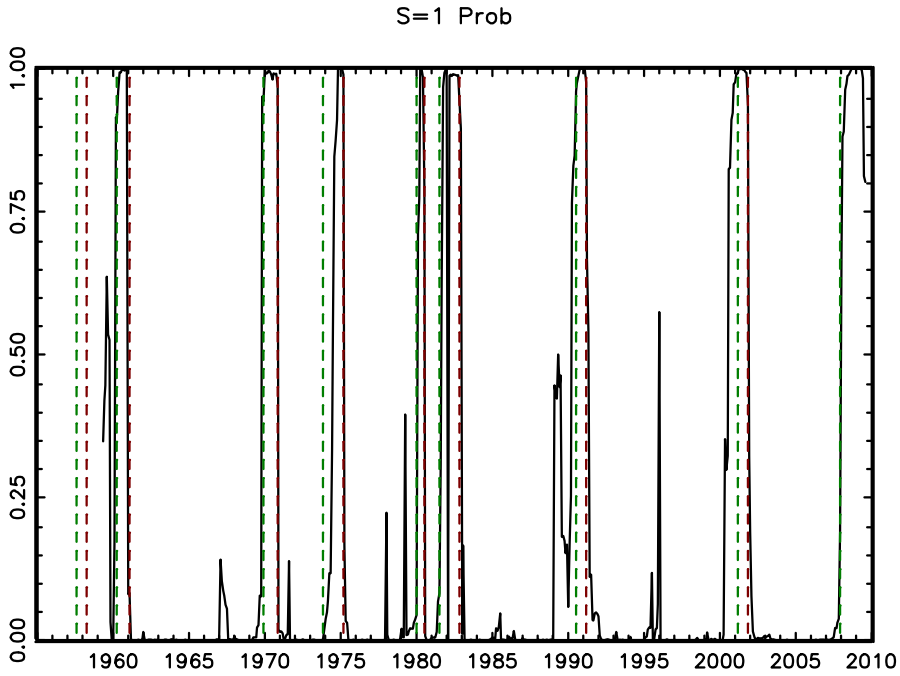
$$u_{it} = \rho_i u_{it-1} + \varepsilon_{it}$$

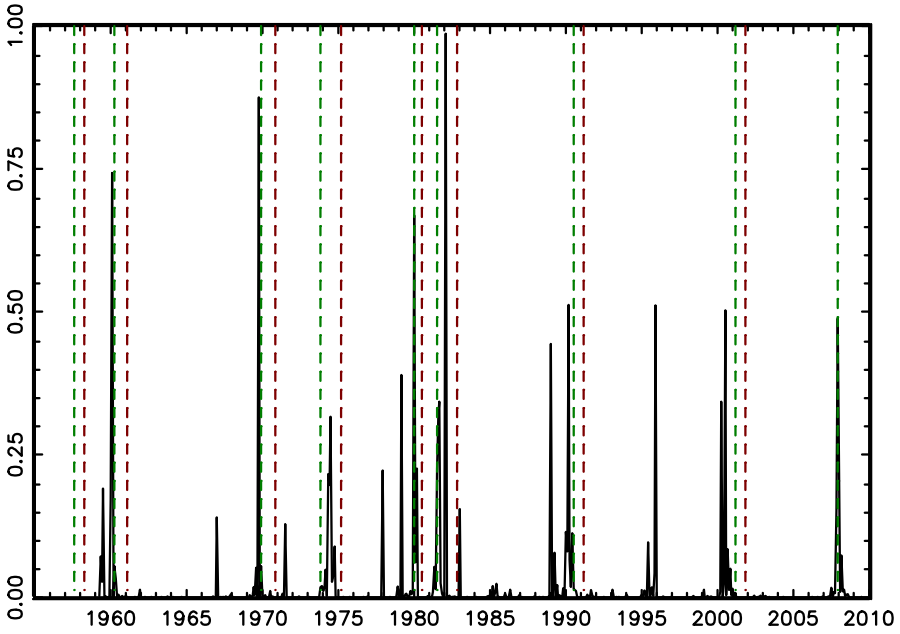
$$f_t = \phi f_{t-1} + e_t$$

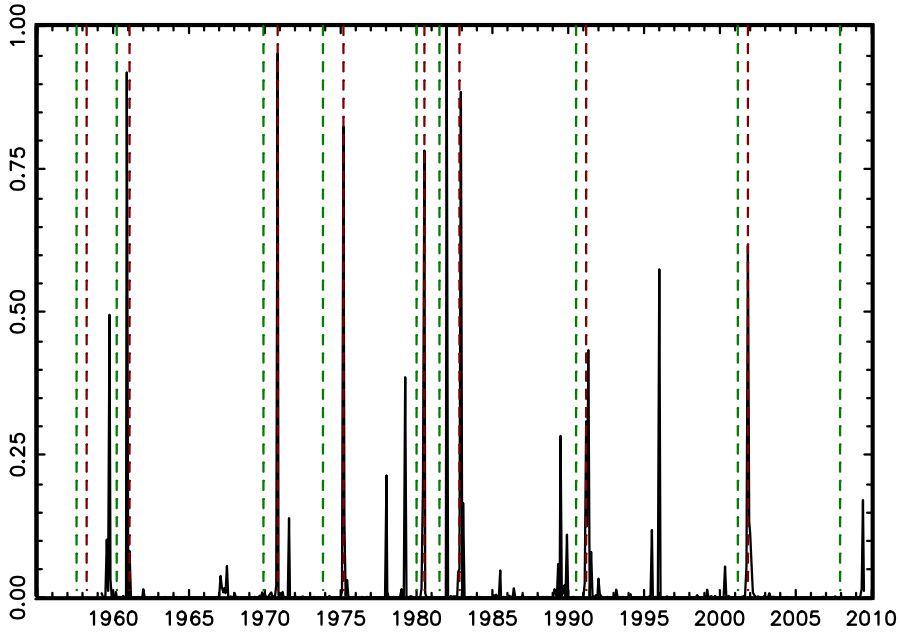
ML, missing data handled within KF; EM algorithm

$\Delta ci\_sub = \sigma f_{t/T} + \mu$, where σ and μ are chosen to match the simple average of ΔIP, ΔPI, ΔMT, ΔEMP.


CI_SUB NBER and BB Dates
6.4
6.0
5.6
5.2
4.8
4.4
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010


S=1 Prob
1.00
0.75
0.50
0.25
0.00
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010


S(t)=0, S(t+1) = 1 Prob
1.00
0.75
0.50
0.25
0.00
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010


S(t)=1, S(t+1) = 0 Prob
1.00
0.75
0.50
0.25
0.00
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

(2) BB on subaggregates: "Date then average"

1. Divide data into episodes: NBER TP ± 12 months (19 episodes)

2. Consider a peak episode, j:

   Let τ_{ij} = peak date of specific series i in episode j

   = $P(Y_j)$, Y_j = 24-month time series on Y in episode j

   (= missing if no peak in episode j)

3. ANOVA-type model for TPs:

$$\tau_{ij} = D_j + k_i + \eta_{ij}$$

where D_j = reference cycle TP in episode j

k_i = specific cycle lead-lag

BB on subaggregates, ctd

$$\tau_{ij} = D_j + k_i + \eta_{ij}$$

Estimators of $\{\tau_j, k_i\}$:

(a) OLS (ANOVA/unbalanced design)

(b) WLS, var(η_{ij}) varies over series *i* (some series more useful than others)

(c) median/median (unweighted)

ideally: $\min_{\{D_j, k_i\}} \sum_{i=1}^{n} \omega_i \sum_{j=1}^{19} \left| \tau_{ij} - D_j - k_i \right|$

actually: solve by iterating

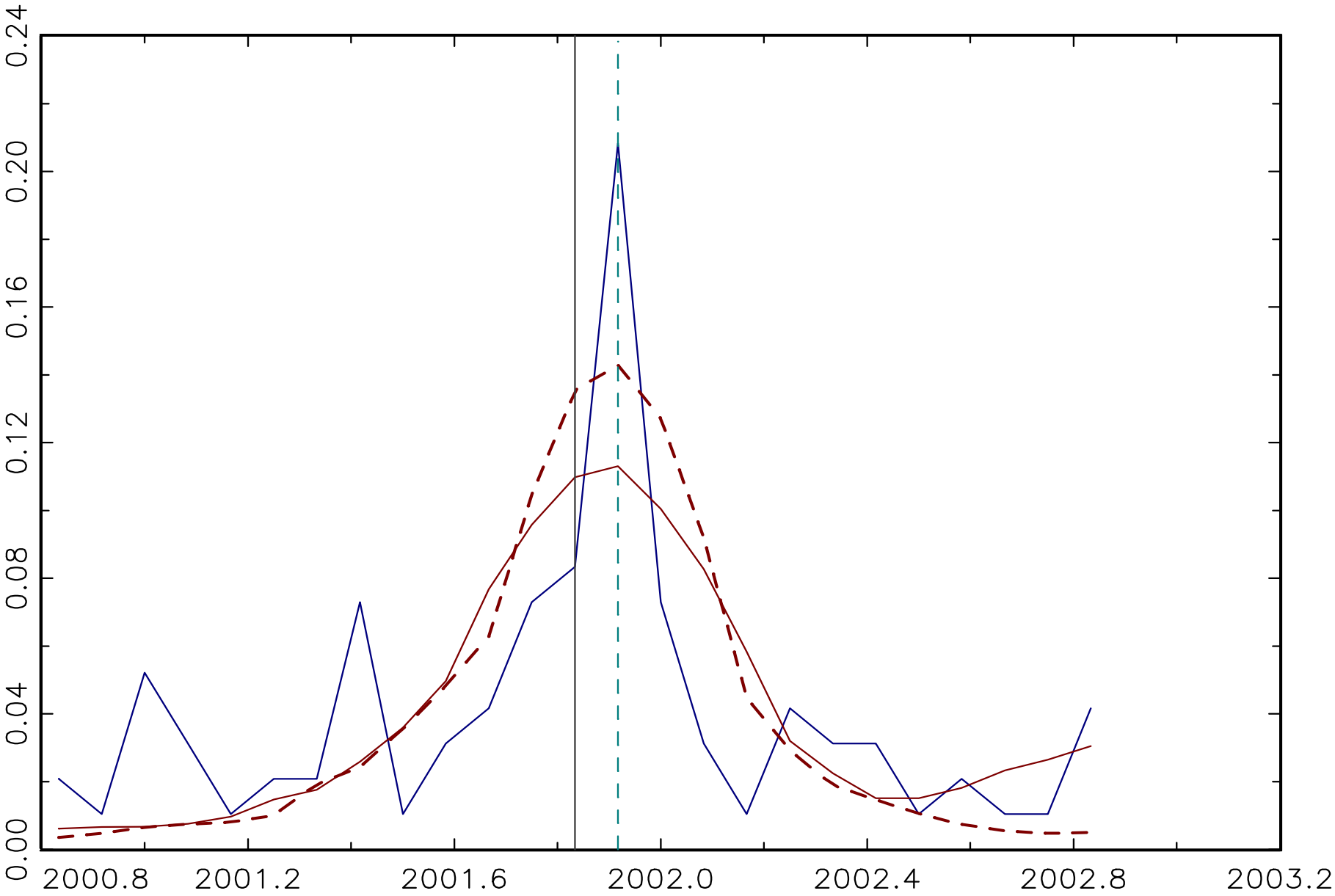
(d) median/median (weighted), inverse MAE weights by series

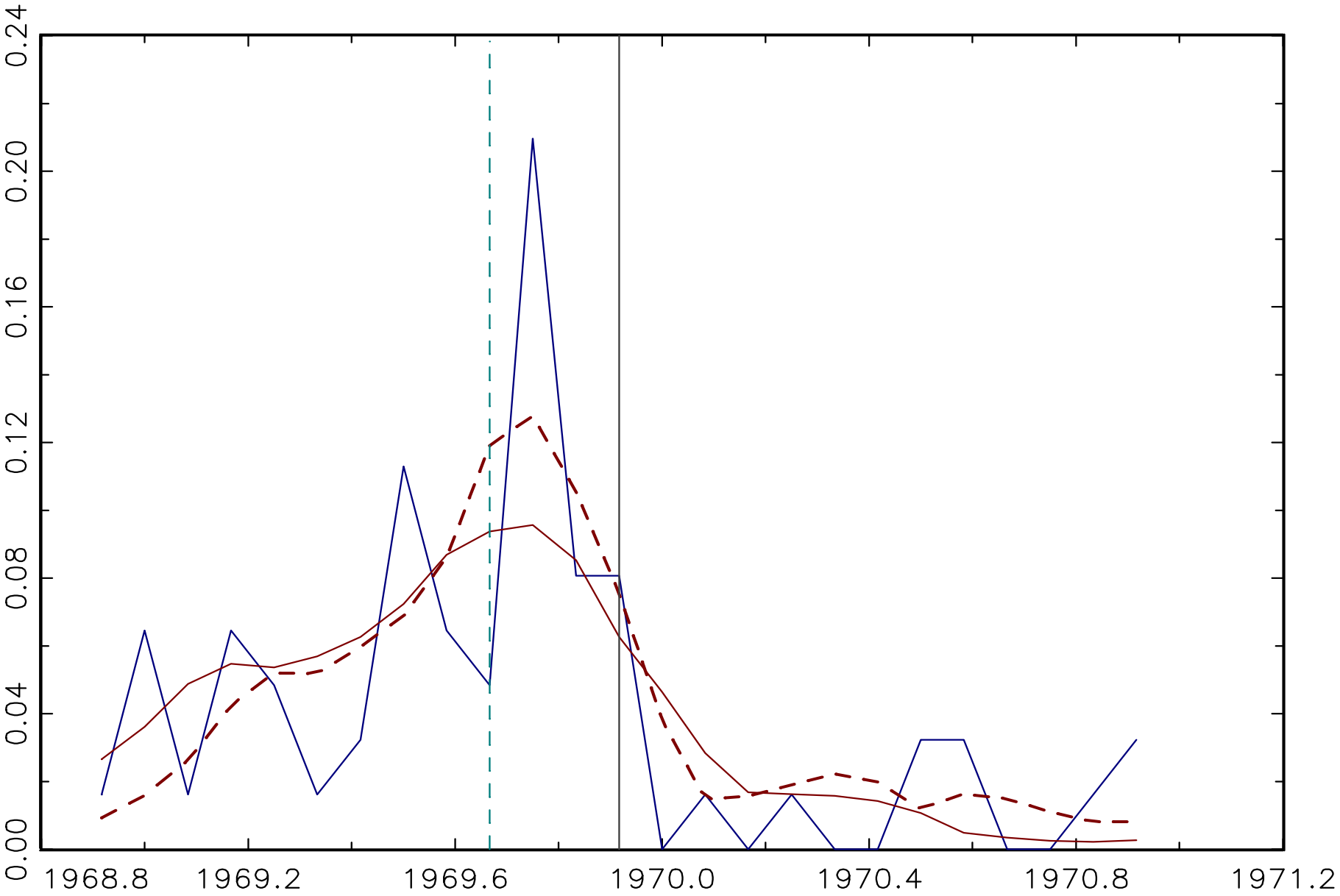
(b) mode/median: iterate on…

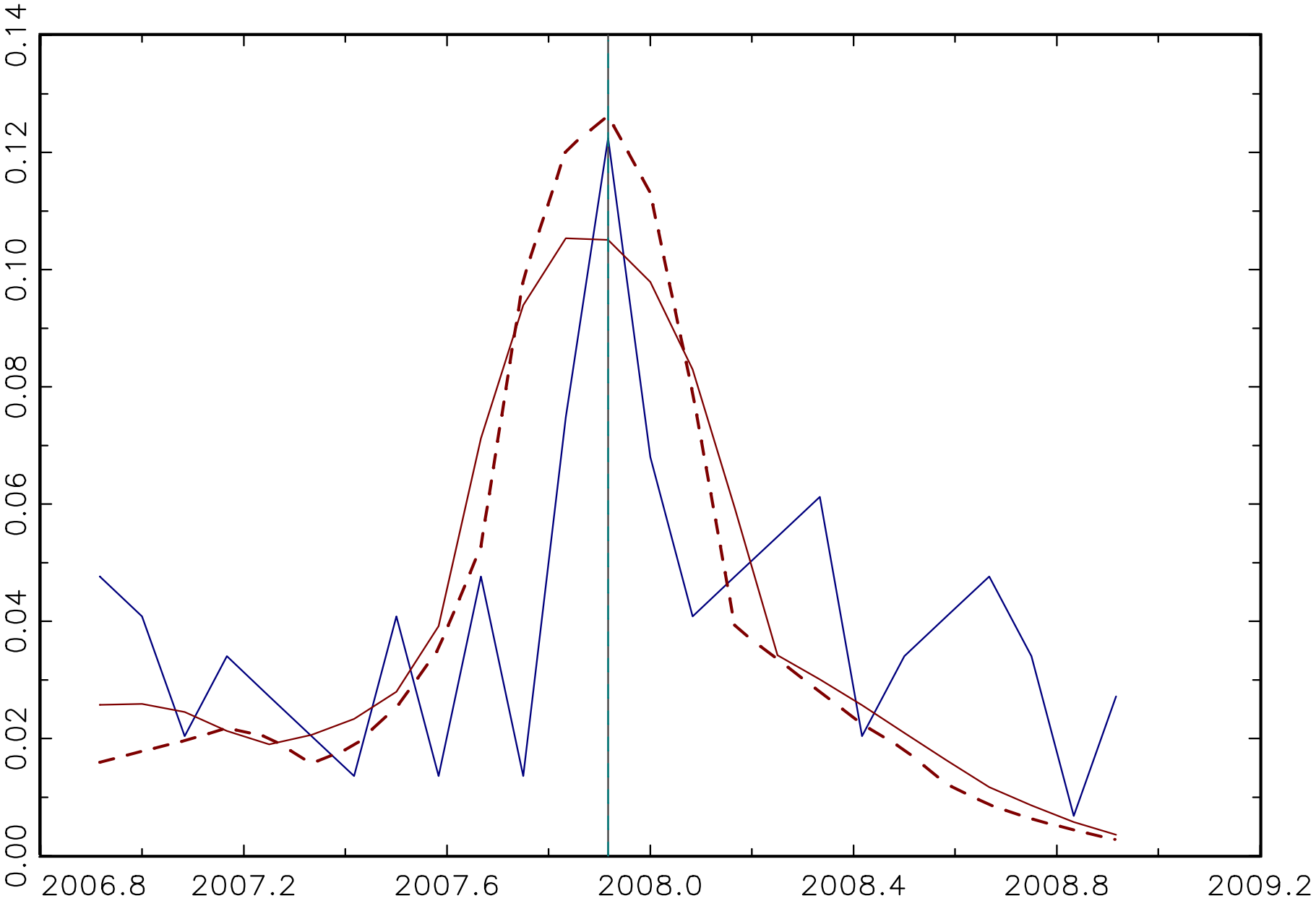
D from mode of (weighted) distribution of ($\tau_{ij} - k_i$)

k from median of distribution of (τ_{ij} - τ_i)

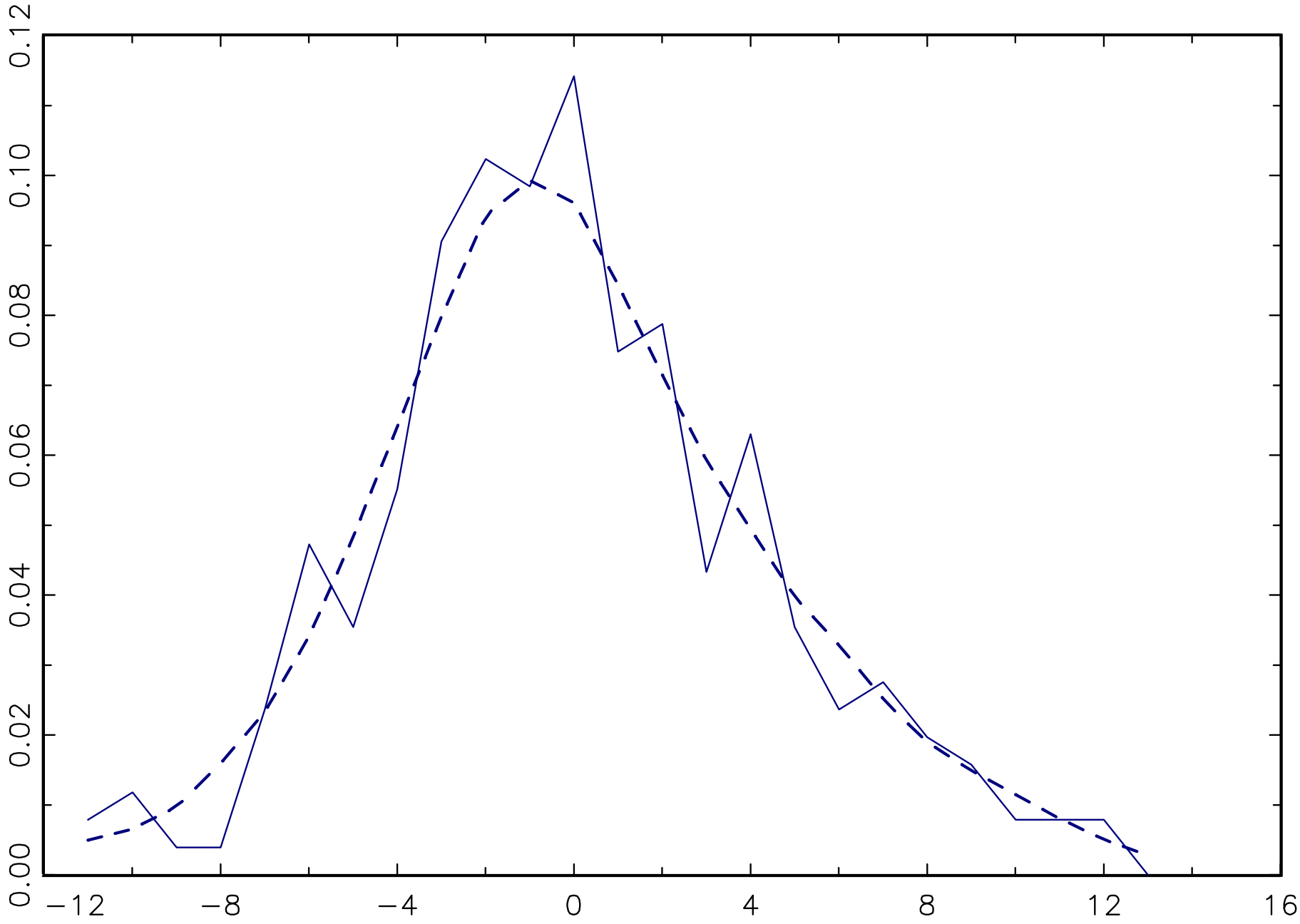
Densities estimated using Epinechnikov kernel


2001:11 Trough
0.24
0.20
0.16
0.12
0.08
0.04
0.00
2000.8
2001.2
2001.6
2002.0
2002.4
2002.8
2003.2


1969:12 Peak
0.24
0.20
0.16
0.12
0.08
0.04
0.00
1968.8
1969.2
1969.6
1970.0
1970.4
1970.8
1971.2


2007:12 Peak
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
2006.8
2007.2
2007.6
2008.0
2008.4
2008.8
2009.2

Episode	NBER	P/T	D-WLS	SE (D-WLS)	D-wtd Med	SE (D-wtdMed)	D-wtd Mode
1	1953:7	P	-0.74	0.56	-2.00	0.71	-1.00
2	1954:5	T	1.31	0.76	1.00	1.02	3.00
3	1957:8	P	-3.97	1.05	-4.00	0.75	-5.00
4	1958:4	T	1.01	0.41	1.00	0.44	1.00
5	1960:4	P	-2.39	0.79	-2.00	0.61	-2.00
6	1961:2	T	0.00	0.53	-1.00	0.48	-1.00
7	1969:12	P	-2.07	0.54	-2.00	0.45	-2.00
8	1970:11	T	2.46	0.64	1.00	0.54	1.00
9	1973:11	P	3.13	0.47	2.00	0.52	3.00
10	1975:3	T	2.95	0.28	2.00	0.28	2.00
11	1980:1	P	-3.36	0.52	-6.00	0.74	-8.00
12	1980:7	T	1.36	0.40	0.00	0.35	0.00
13	1981:7	P	0.18	0.41	0.00	0.37	0.00
14	1982:11	T	0.29	0.41	1.00	0.36	1.00
15	1990:7	P	-0.23	0.35	1.00	0.41	1.00
16	1991:3	T	3.65	0.34	1.00	0.28	1.00
17	2001:3	P	-5.35	0.28	-4.00	0.34	-4.00
18	2001:11	T	-0.09	0.30	1.00	0.32	1.00
19	2007:12	P	-1.08	0.28	0.00	0.27	0.00

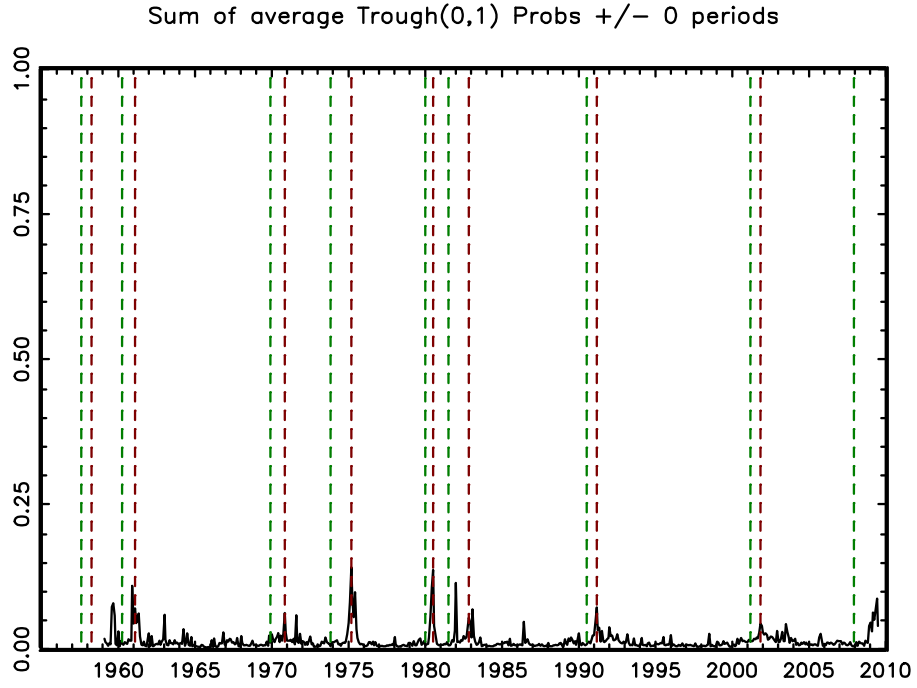

Distribution of WLS lag around WLS dhat
0.12
0.10
0.08
0.06
0.04
0.02
0.00
−12
−8
−4
0
4
8
12
16

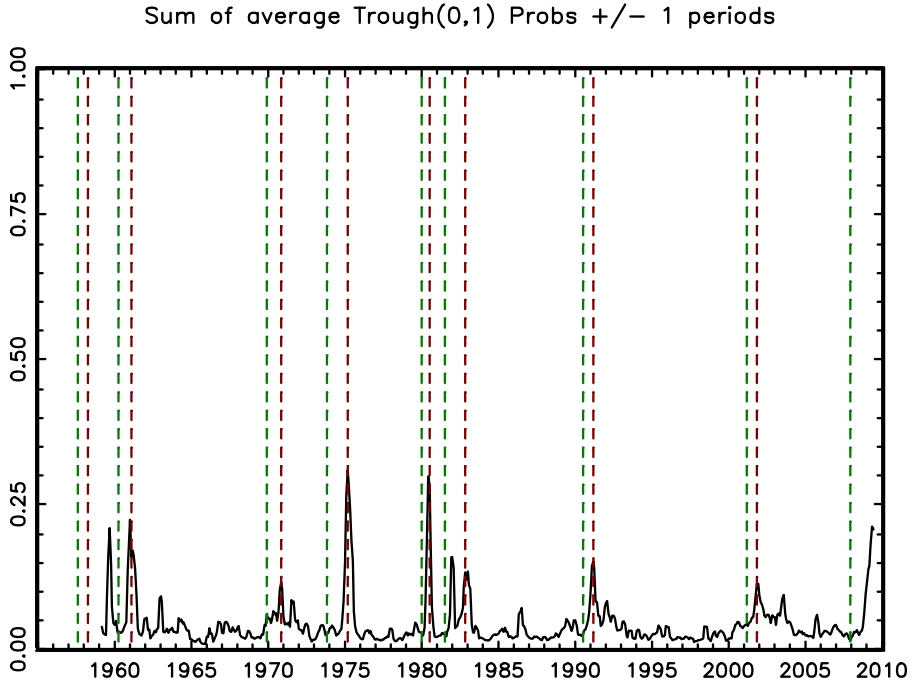
MS on subaggregates

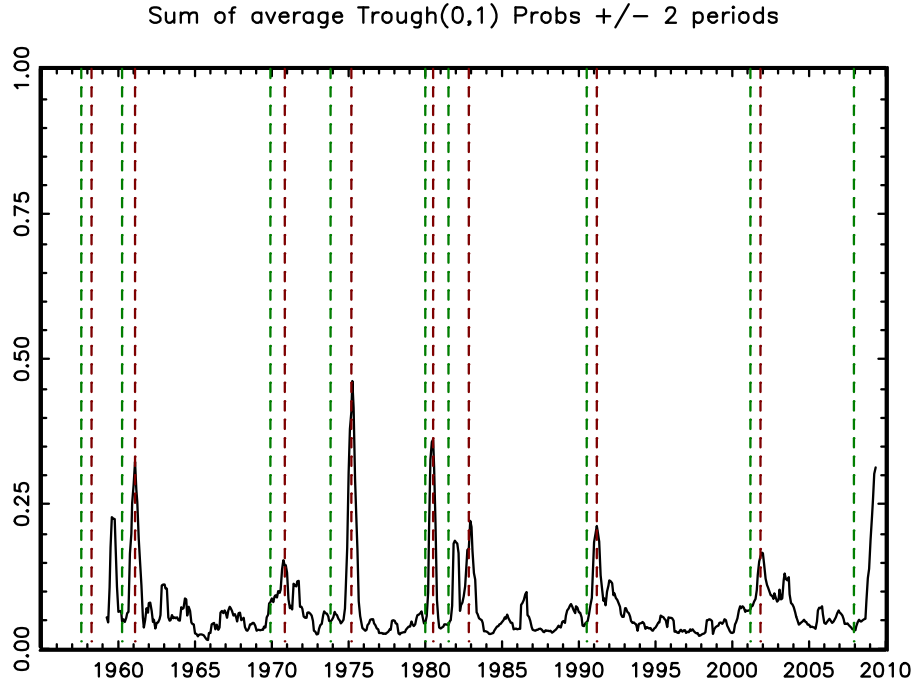
MS filter from above (uniform prior over parameters)

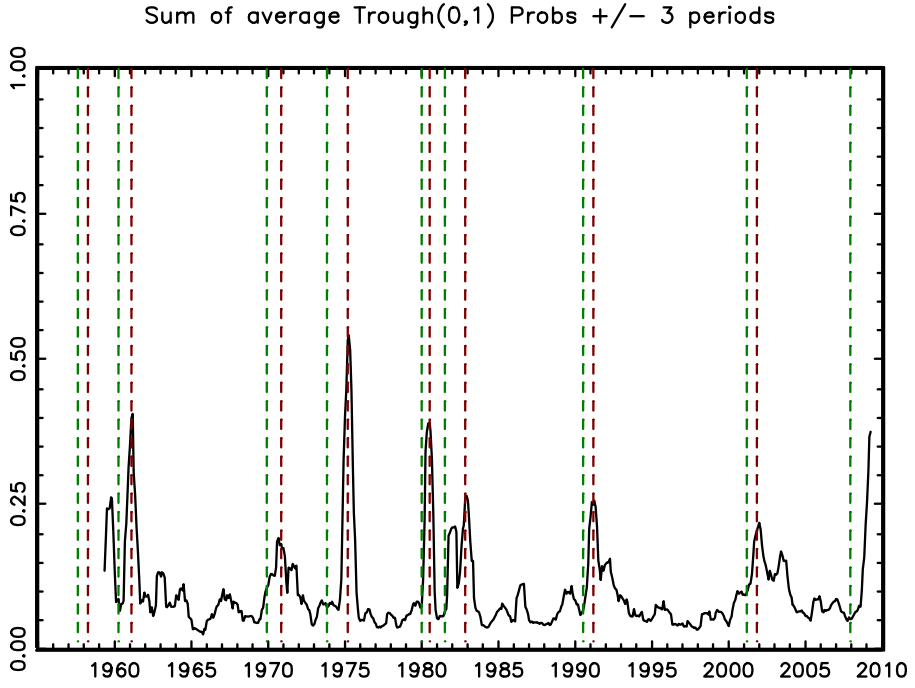
Figures:

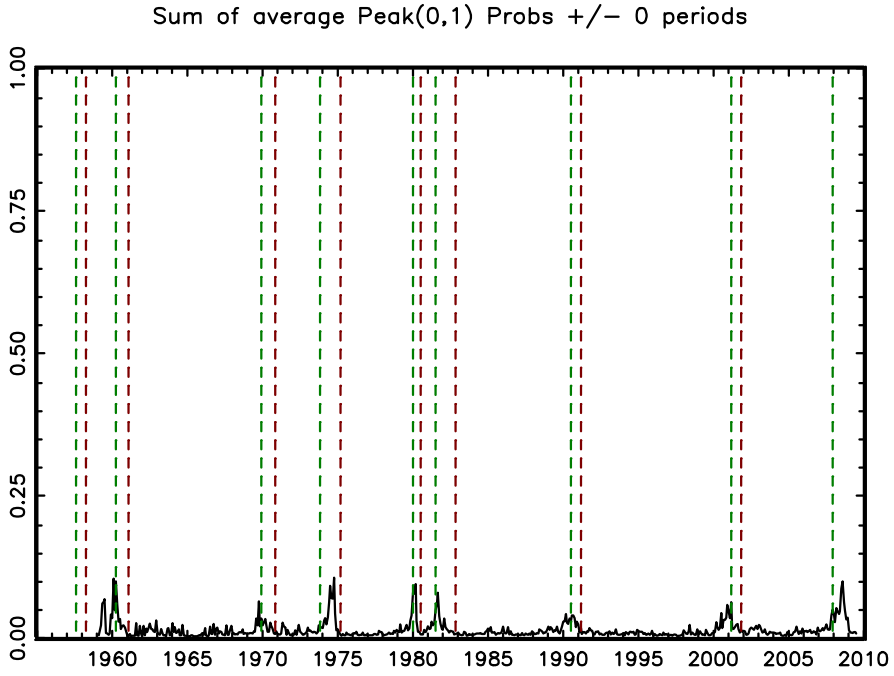
- Trough probabilities, averaged over series, centered k-lag moving average: $k = 0, 1, 2, 3$
- Peak probabilities (same)

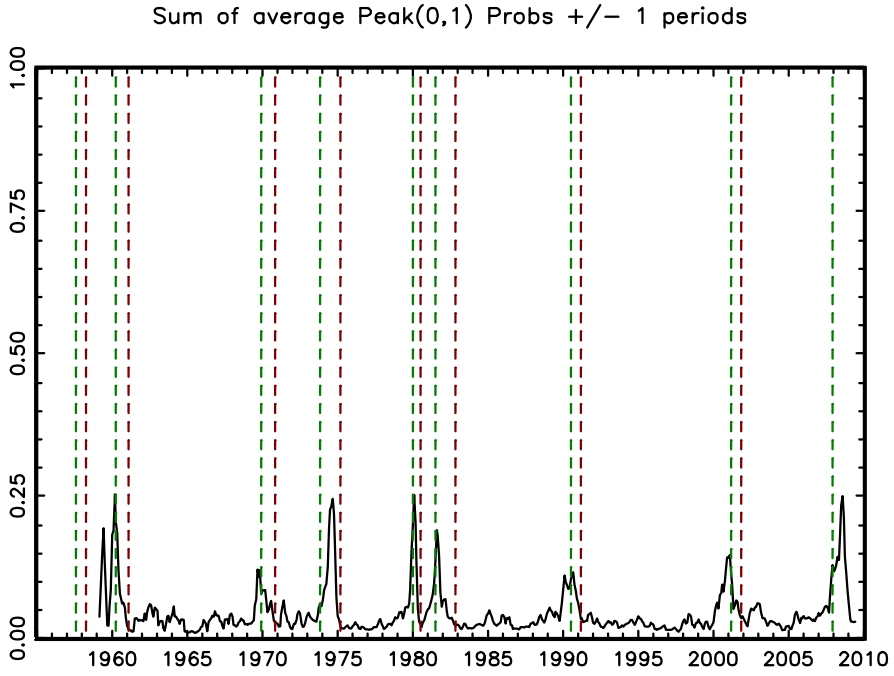

Sum of average Trough(0,1) Probs +/- 0 periods
1.00
0.75
0.50
0.25
0.00
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

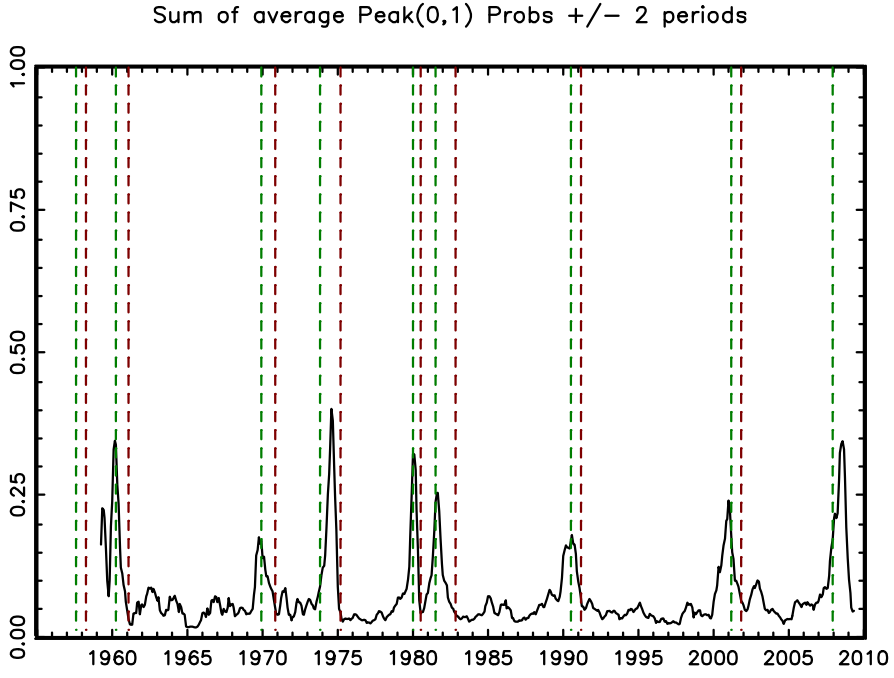

Sum of average Trough(0,1) Probs +/- 1 periods
1.00
0.75
0.50
0.25
0.00
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

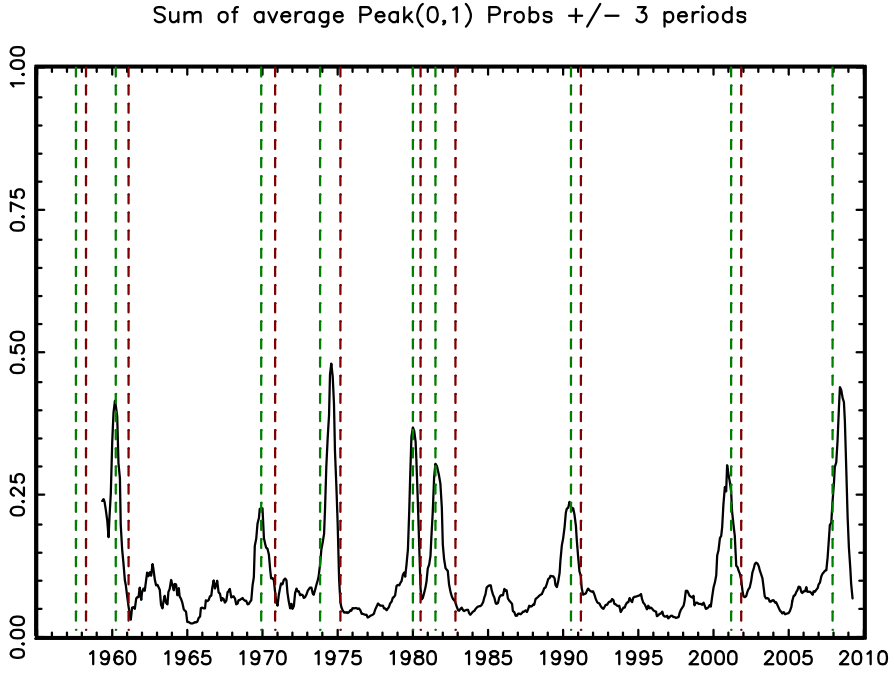

Sum of average Trough(0,1) Probs +/- 2 periods
1.00
0.75
0.50
0.25
0.00
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010


Sum of average Trough(0,1) Probs +/- 3 periods
1.00
0.75
0.50
0.25
0.00
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010


Sum of average Peak(0,1) Probs +/− 0 periods
1.00
0.75
0.50
0.25
0.00
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010


Sum of average Peak(0,1) Probs +/− 1 periods
1.00
0.75
0.50
0.25
0.00
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010


Sum of average Peak(0,1) Probs +/− 2 periods
1.00
0.75
0.50
0.25
0.00
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010


Sum of average Peak(0,1) Probs +/− 3 periods
1.00
0.75
0.50
0.25
0.00
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010

Summary statistics for chronologies

Deviation of estimated chronology from NBER BCDC

Summary statistics I: deviations of PT dates around NBER dates

	P&T	P&T	P&T	P&T	P&T	T	P
Variable	**Mean**	**StdDev**	**RMSE**	**Min**	**Max**	**RMSE**	**RMSE**
OLS	-0.10	2.38	2.38	-4.84	3.40	1.92	2.75
Median	-0.60	2.03	**2.12**	-5.00	2.00	0.90	2.82
Mode	-0.47	2.50	2.55	-7.00	3.00	1.13	3.40
WLS	-0.04	2.55	2.55	-5.35	3.65	2.15	2.90
Med-wtd	-0.40	2.26	2.30	-6.00	2.00	1.19	3.00
Mode-wtd	-0.47	2.72	2.76	-8.00	3.00	1.19	3.70
ms_sub2	1.20	3.08	3.30	-3.00	9.00	1.21	4.50
ms_sub3	1.13	3.25	3.44	-3.00	9.00	0.70	4.78
ci_sub_bb	-0.33	2.89	2.91	-8.00	6.00	1.29	3.93
ci_sub_ms	0.00	3.87	3.87	-8.00	8.00	1.22	5.36
ci_avg_bb	-0.80	1.86	**2.02**	-6.00	1.00	0.99	2.68
ci_avg_ms	-2.07	3.63	4.18	-10.00	1.00	4.12	4.45
ci_sdav_bb	-0.53	1.68	**1.77**	-6.00	1.00	0.40	2.44
ci_sdav_ms	-0.87	4.03	4.13	-10.00	9.00	3.64	4.64
ci_tcb_bb	-0.67	1.91	**2.03**	-6.00	1.00	0.69	2.73
ci_tcb_ms	-0.73	4.08	4.14	-10.00	9.00	3.65	4.66
ci_dfm_bb	-1.40	3.46	3.73	-12.00	1.00	0.40	5.19
ci_dfm_ms	-1.47	5.37	5.57	-11.00	11.00	4.10	6.87

NBER	P/T	D-WLS	DFM - Dissaggrates	TCB CI
1960:4	P	-3 (0.91)	-12	-3
1961:2	T	0 (0.56)	0	0
1969:12	P	-2 (0.65)	-4	-2
1970:11	T	2 (0.60)	0	0
1973:11	P	3 (0.57)	0	0
1975:3	T	3 (0.39)	1	1
1980:1	P	-3 (0.69)	0	0
1980:7	T	1 (0.62)	0	0
1981:7	P	1 (0.49)	0	1
1982:11	T	0 (0.52)	0	1
1990:7	P	0 (0.55)	0	-1
1991:3	T	3 (0.45)	0	0
2001:3	P	-5 (0.45)	-6	-6
2001:11	T	0 (0.56)	0	1
2007:12	P	-1 (0.48)	0	-2

Selected Mincer-Zarnowitz regressions: fitting NBER BCDC

(a) Use only aggregate best CI (no DFM) v. use disaggregates

$$D_j^{NBER} = \alpha + \lambda D_j^{SDwtd-BB} + (1-\lambda) D_j^{disagg}$$

D_j^{disagg}	λ	***t*-stat**
OLS	0.06	0.42
Med-unwtd	0.30	1.09
Mode-unwtd	0.19	1.12
ms_sub2	0.12	1.14

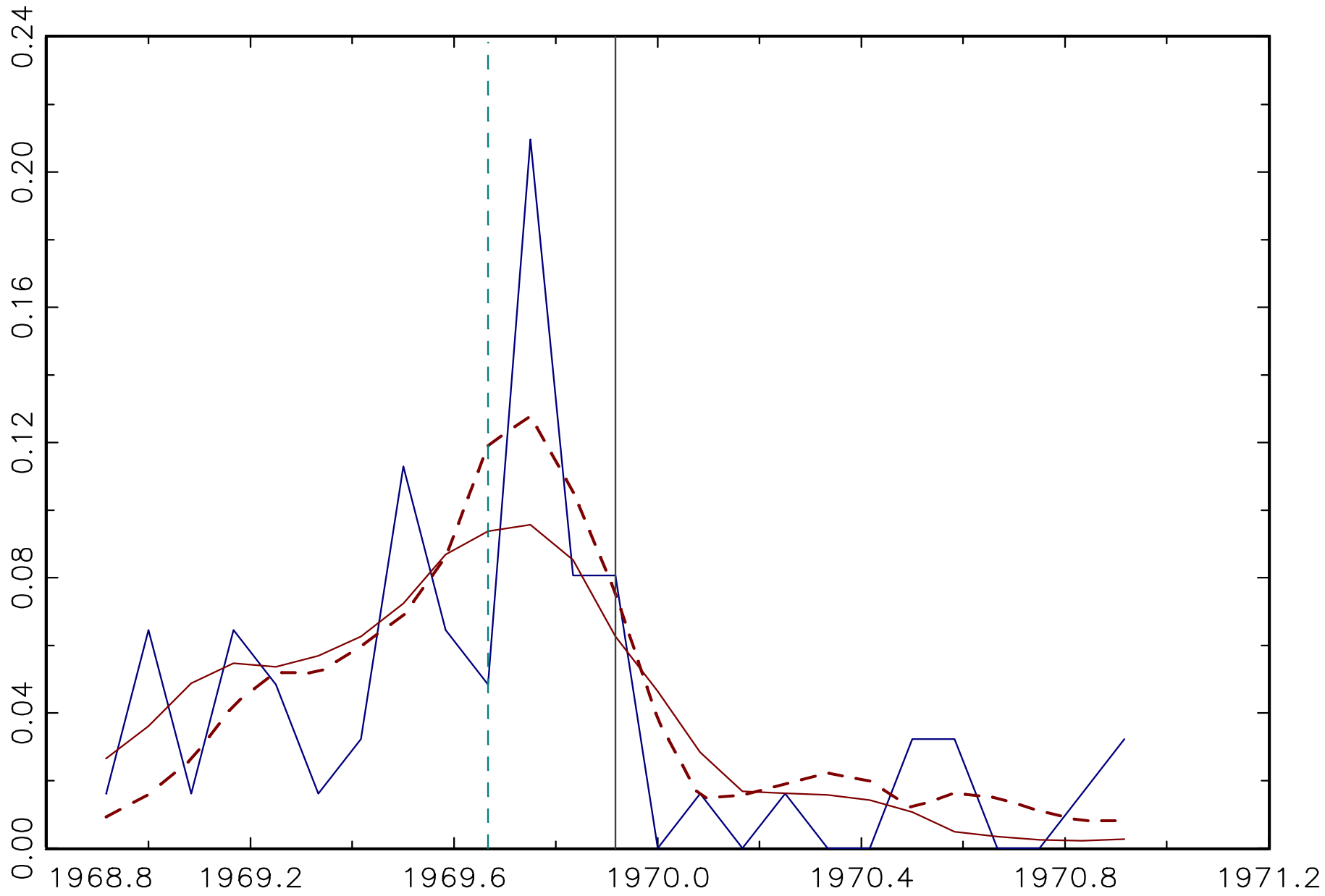
(b) Alternative single aggregate index (DFM on dissagregates)

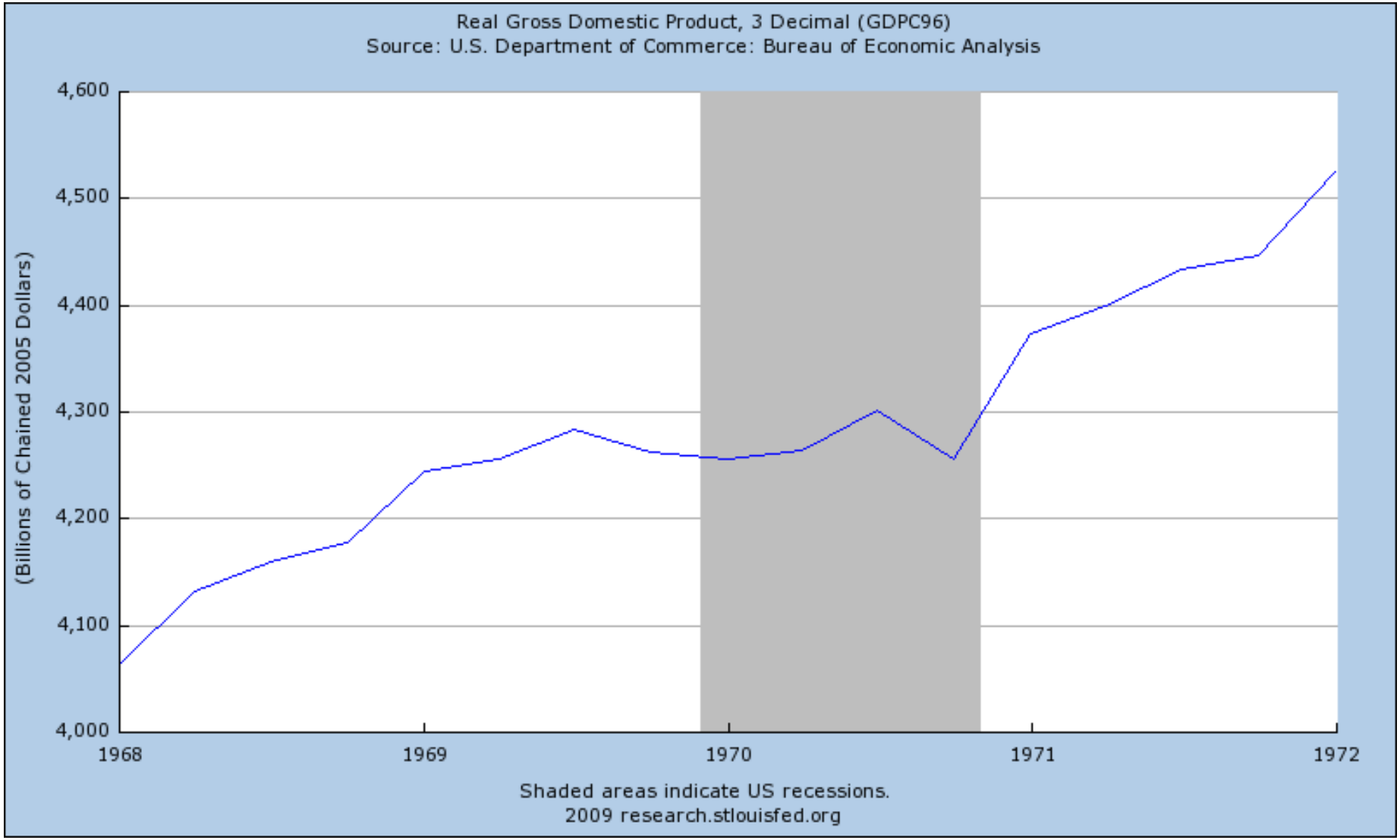
$$D_j^{NBER} = \alpha + \lambda D_j^{DFMall-BB} + (1-\lambda) D_j^{disagg}$$

D_j^{disagg}	λ	***t*-stat**
OLS	0.94	2.97
Med-unwtd	0.93	3.65
Mode-unwtd	0.75	2.20
ms_sub2	0.55	1.67

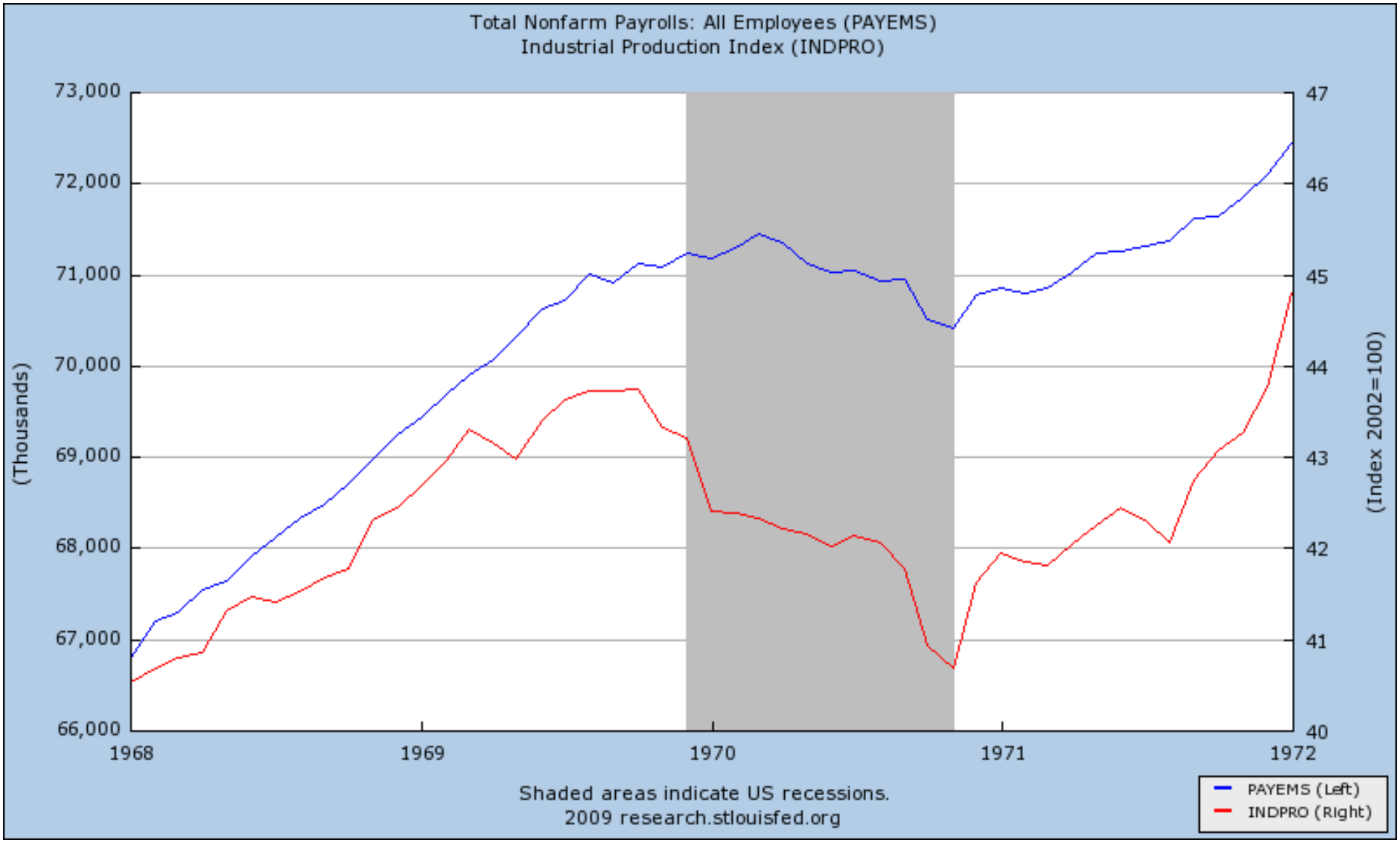
Summary: selected findings:

1. Dispersion is considerably smaller at troughs than peaks
2. "date then average" has lower dispersion than "average then date"
   - OLS "ANOVA" model has low dispersion and is close to mean of all estimators
3. Applying BB to the SD-wtd coincident index comes close to replicating the NBER BCDC (RMSE = 1.77)
4. There are a few large discrepancies (residuals) between the estimated chronologies and the NBER chronology:

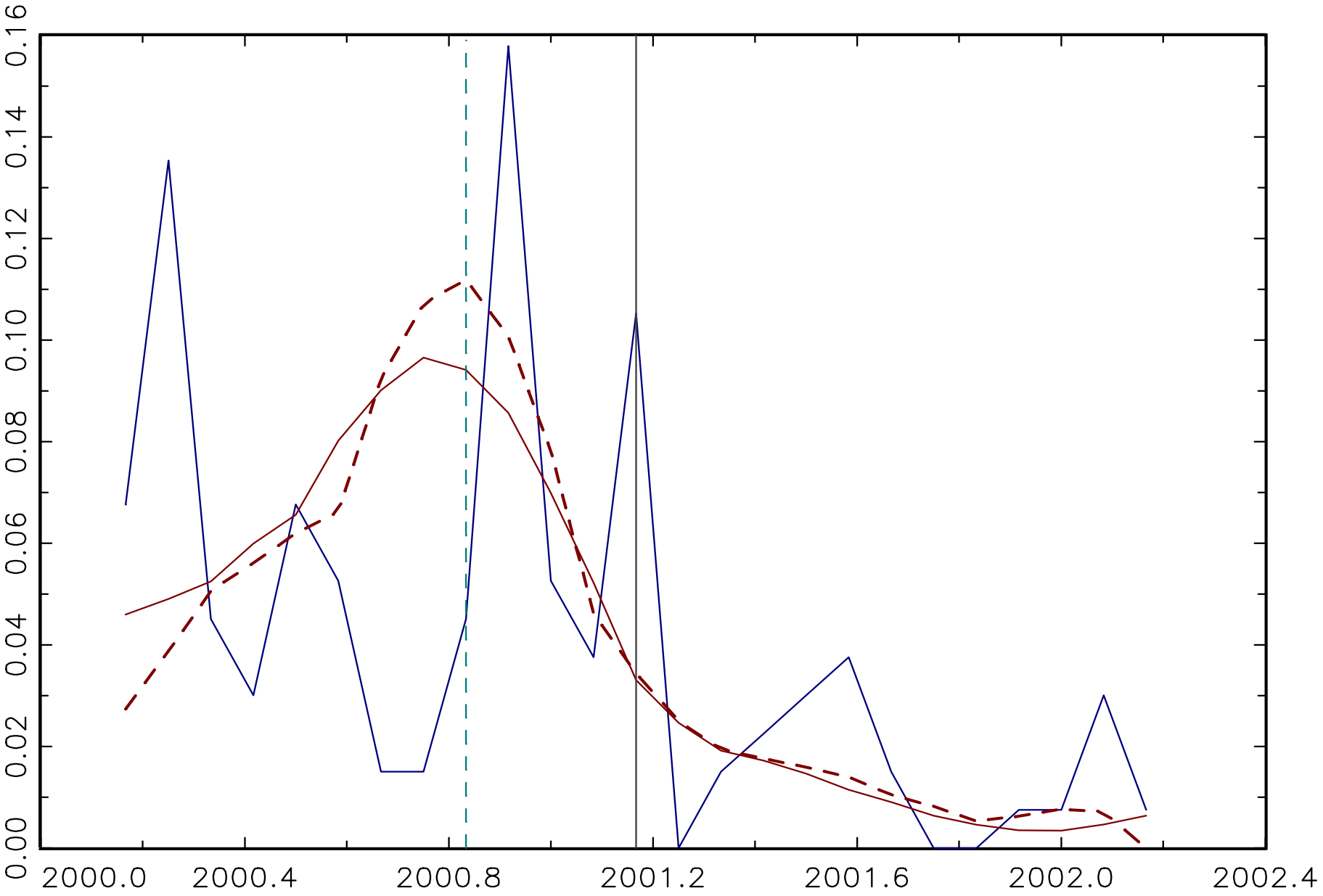

1969:12 Peak
0.24
0.20
0.16
0.12
0.08
0.04
0.00
1968.8
1969.2
1969.6
1970.0
1970.4
1970.8
1971.2

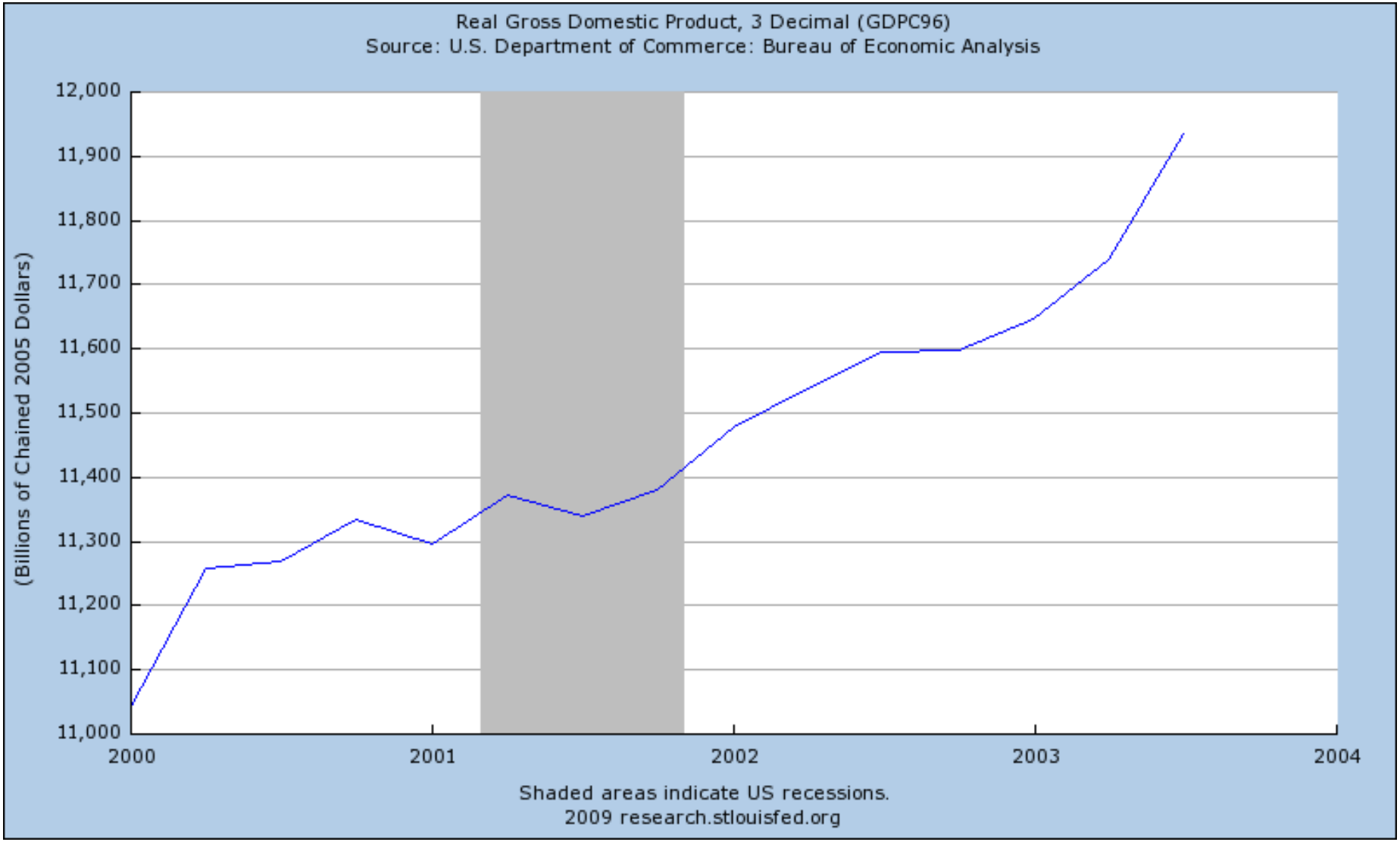


GDP, 1968-1972

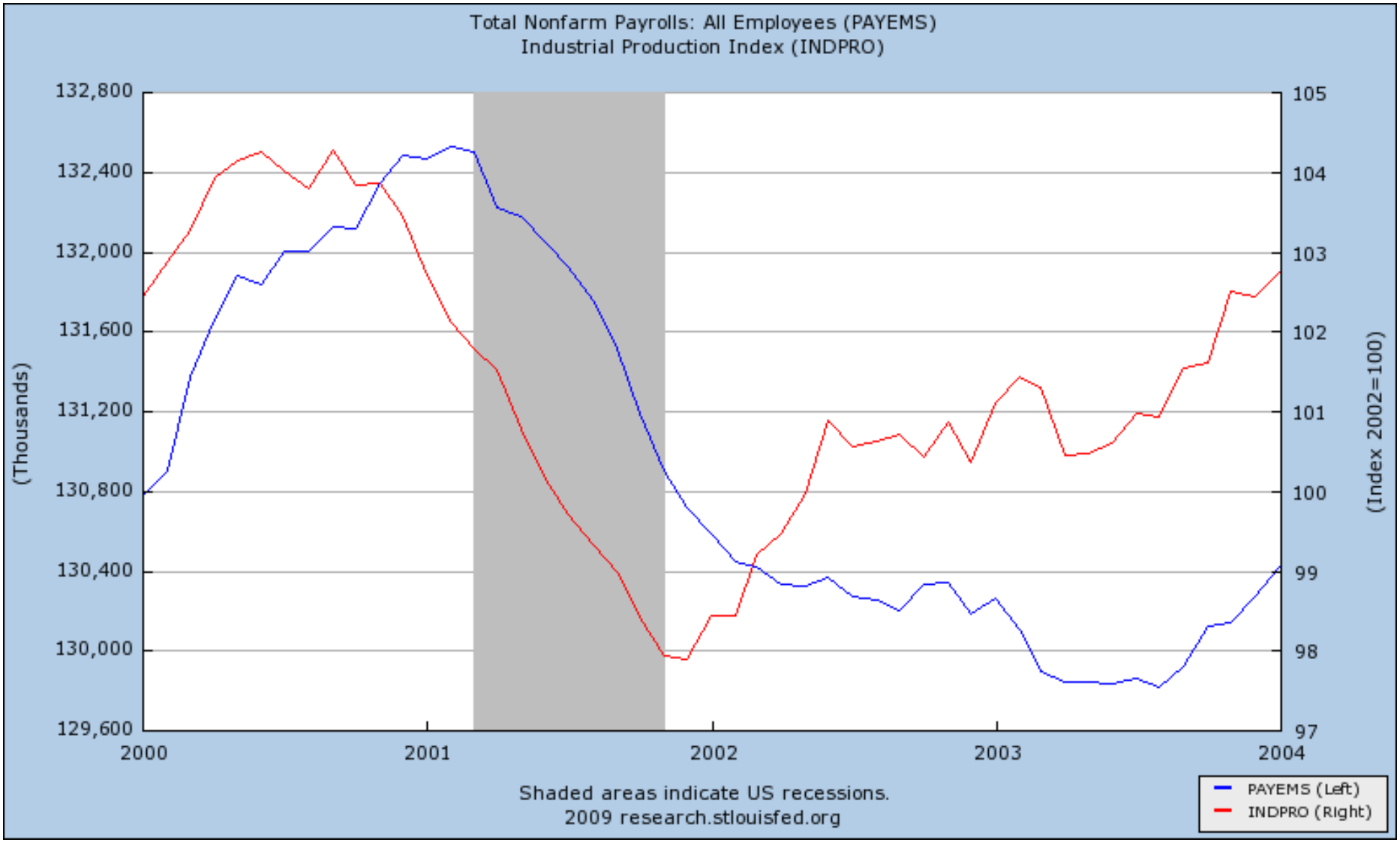


Employment and IP, 1968-1972


2001:03 Peak
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
2000.0
2000.4
2000.8
2001.2
2001.6
2002.0
2002.4



GDP, 2000-2003



Employment and IP, 2000-2003

6) Conclusions

1. Methodology: Specific cycle dating – remaining work:
   - quantifying estimation uncertainty from single episode data
   - theory of optimal estimation
   - robustness
2. Methodology: Reference cycle dating – remaining work:
   - Unresolved ambiguity about the estimand
     - Fix on latent output? latent employment?
     - Or end of cluster episode of (unknown) specific cycle dates?
   - Once estimand problem is solved, the estimation problem can be tackled – a variety of methods have been explored here
3. Empirical findings: It might be appropriate to revisit a few of the historical NBER dates