Forecasting Inflation Using Dynamic Factor Models Subject to Structural Instability

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1. Introduction

U.S. inflation forecasting puzzles and challenges:

Univariate

1. Decrease in persistence of (shock to) inflation
2. Decrease in variability of inflation, and size of RMSFE
3. Instability in univariate inflation models (and Atkeson-Ohanian (2001) puzzle)

Multivariate

4. Decline in marginal R^2 of multivariate inflation forecasts
5. Breakdown of Phillips Curve forecasts

This paper

1. Summarize univariate facts – parsimonious permanent-transitory TV SV model of Stock-Watson (*JMCB*, 2007)
2. Summarize multivariate facts
3. Provide a multivariate parameterization that “explains” (in a mechanical sense) the facts: TV-DFM
   a. common component = univariate permanent component
   b. factor loadings not TV, factor dynamics are TV
   c. TV factor dynamics (constant loadings) “explains” multivariate facts
   d. Implications?

2. Univariate Decomposition

Multistep AR projection: $\pi^h_{t+h} - \pi_t = \mu^h + \alpha^h(\mathrm{B})\Delta\pi_t + v^h_t$

Atkeson-Ohanian (2001) $\pi^h_{t+h|t} = \pi^4_t = \frac{1}{4}(\pi_t + ... + \pi_{t-3})$

Stochastic Volatility-TVP: $\pi_t = \tau_t + \eta_t, \quad \eta_t = \sigma_{\eta,t}\zeta_\eta,$

$$\tau_t = \tau_{t-1} + \varepsilon_t, \quad \varepsilon_t = \sigma_{\varepsilon,t}\zeta_{\varepsilon,t}$$

$$\ln\sigma^2_{\eta,t} = \ln\sigma^2_{\eta,t-1} + \nu_{\eta,t}$$

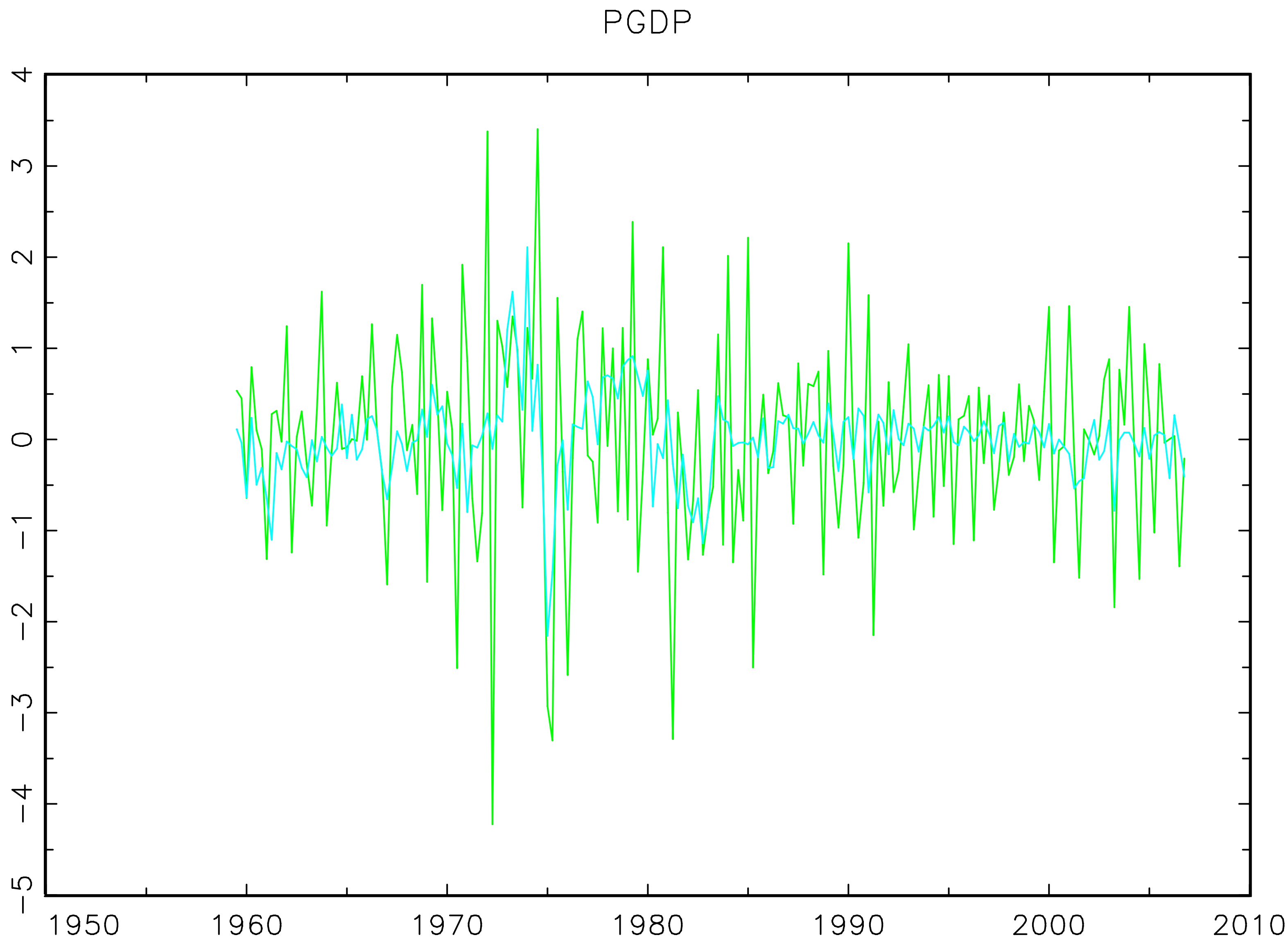
$$\ln\sigma^2_{\varepsilon,t} = \ln\sigma^2_{\varepsilon,t-1} + \nu_{\varepsilon,t}$$

Note: SV-TVP implies TV-IMA(1,1)

Table 1.
Pseudo Out-of-Sample Forecasting Results for GDP Inflation

$$\pi_{t+h}^{h} - \pi_t = \mu^h + \alpha^h(B)\Delta\pi_t + \beta^h xgap_t + \delta^h(B)\Delta x_t + u_t^h$$

	1970:I – 1983:IV				1984:I – 2004:IV				$\frac{RMSFE_{84-04}^{h=4}}{RMSFE_{70-83}^{h=4}}$
	h=1	h=2	h=4	h=8	h=1	h=2	h=4	h=8	
AR RMSFE	1.72	1.75	1.89	2.38	0.78	0.68	0.62	0.73	
Relative MSFEs									
AR(AIC)	.00	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	0.33
AO	1.95	.57	1.06	1.00	1.22	1.10	**0.89**	**0.84**	0.30
PC-*u*	**0.85**	.92	0.88	0.61	**0.95**	1.11	1.48	1.78	0.42
PC-Δu	0.87	**.87**	0.86	0.64	1.06	1.27	1.83	2.21	0.48
PC-$ugap^{1\text{-sided}}$	0.88	.99	0.98	0.87	1.06	1.29	1.84	2.39	0.45
PC-Δy	0.99	1.06	0.93	0.58	1.05	1.06	1.23	1.53	0.37
PC-$ygap^{1\text{-sided}}$	0.94	0.97	0.99	0.78	0.97	0.97	1.25	1.55	0.37
PC-CapUtil	0.85	0.88	**0.79**	**0.55**	0.95	1.01	1.35	1.52	0.43



First difference of GDP price deflator inflation and its SV-TVP permanent component

(a) Standard deviation of permanent innovation, $\sigma_{\varepsilon,t}$

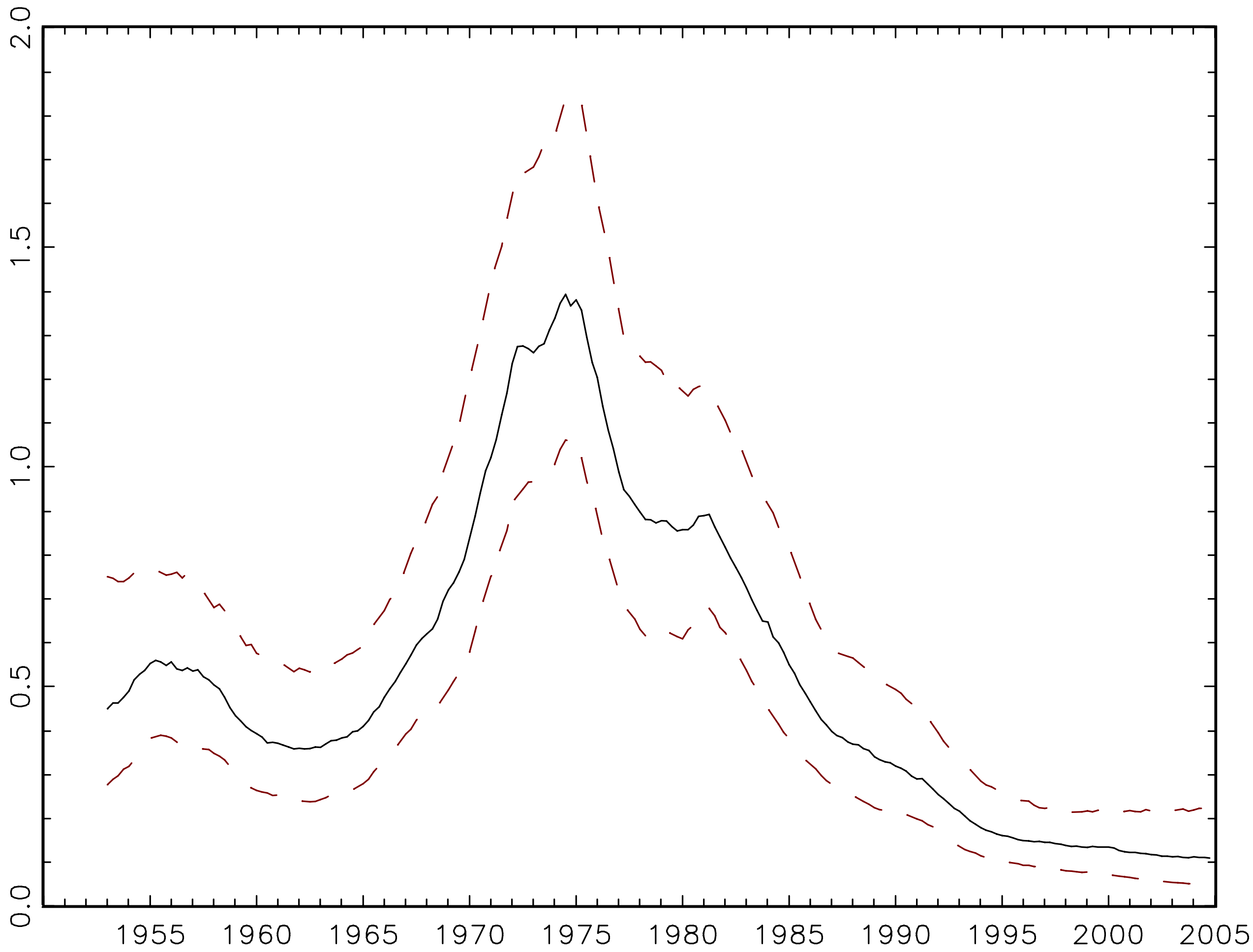


Figure 2. Estimates of the standard deviations of the permanent and transitory innovations, and of the implied IMA(1,1) coefficient, using the UC-SV(.2) model:

(b) Standard deviation of transitory innovation, $\sigma_{\eta,t}$

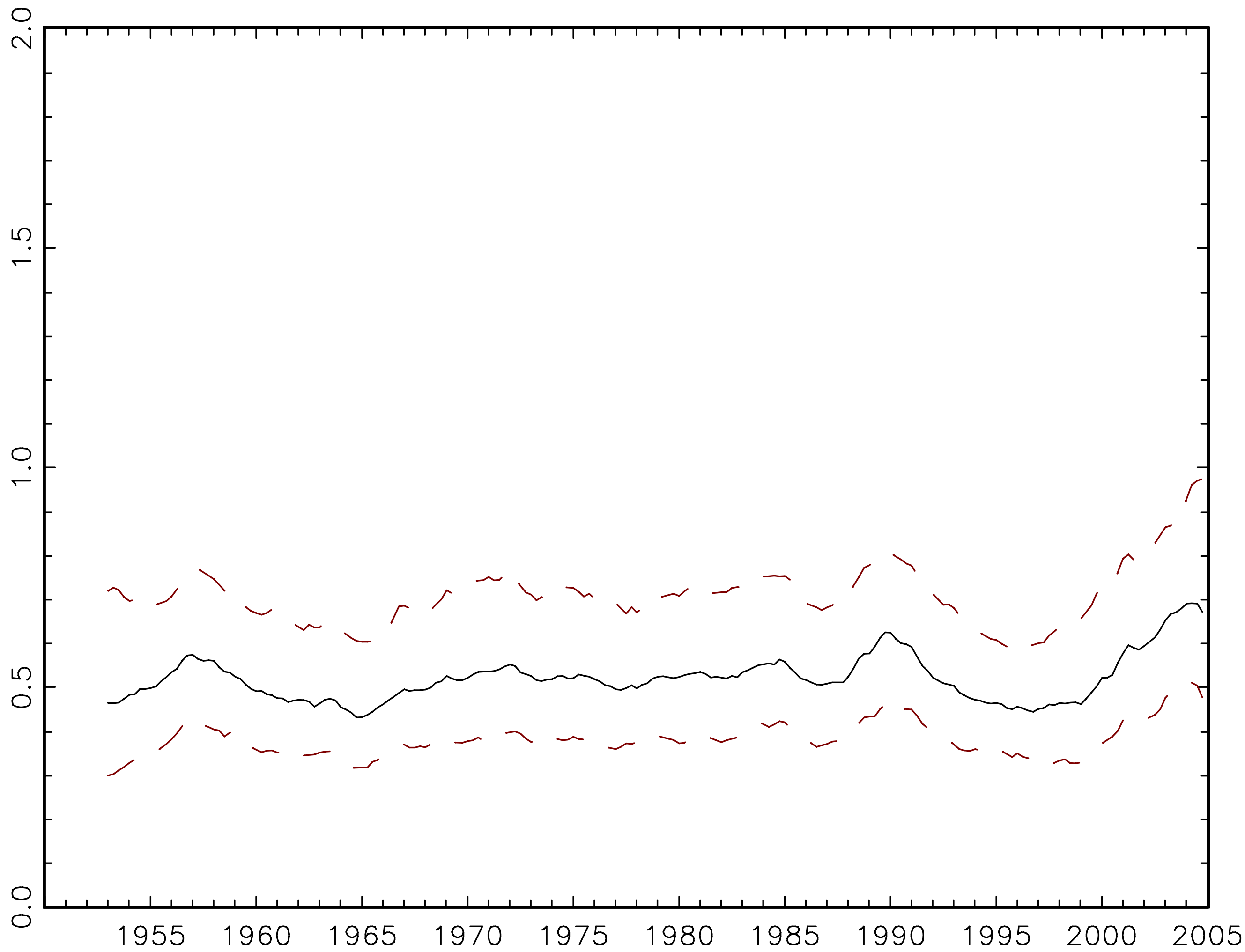


Figure 2. Estimates of the standard deviations of the permanent and transitory innovations, and of the implied IMA(1,1) coefficient, using the UC-SV(.2) model

(c) Implied IMA(1,1) coefficient θ

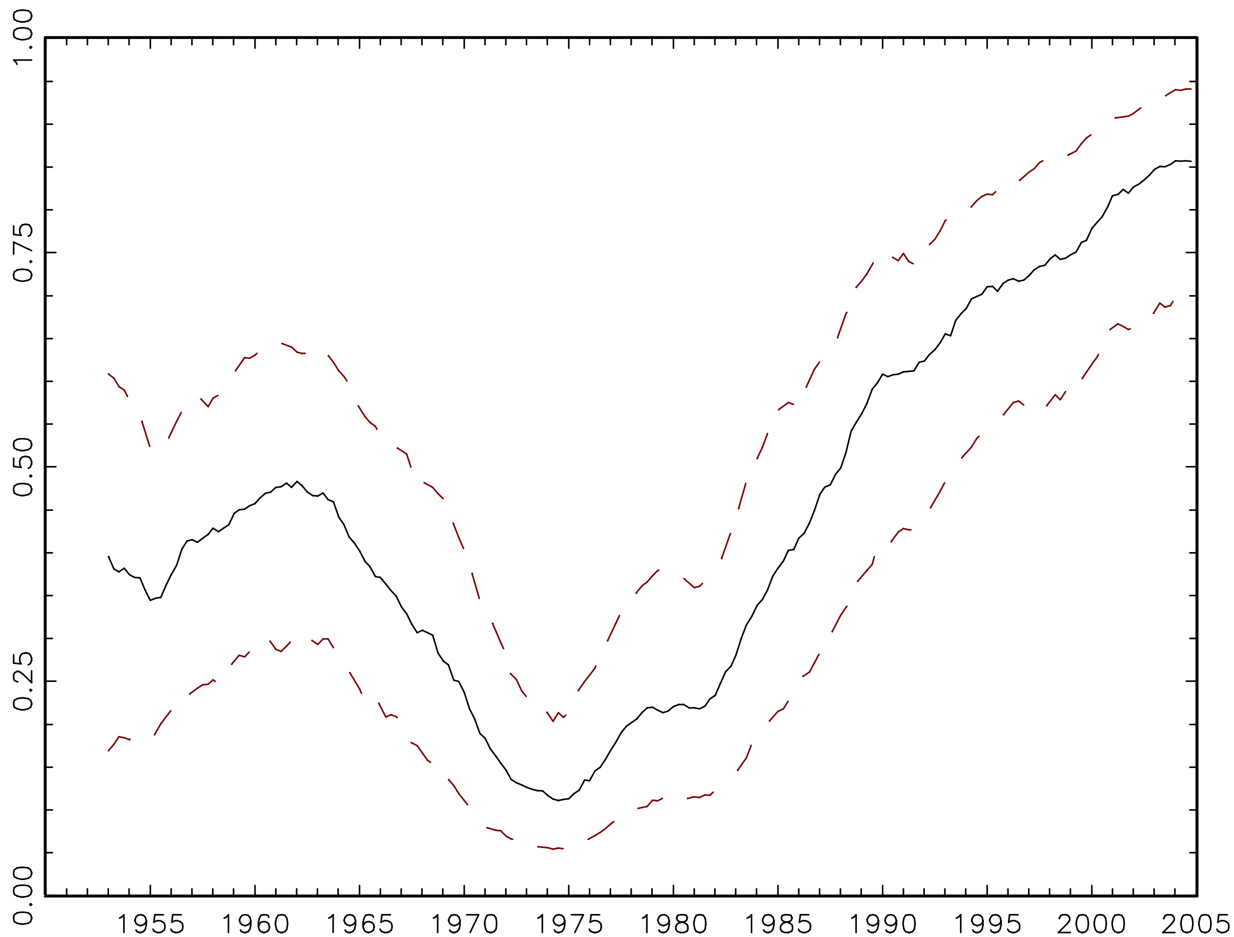


Figure 2. Estimates of the standard deviations of the permanent and transitory innovations, and of the implied IMA(1,1) coefficient, using the UC-SV(.2) model

Table 4. Pseudo Out-of-Sample Forecasting of Additional Univariate Models: MSFEs, Relative to AR(AIC), GDP inflation (SW, *JMCB* 2007)

	1960:I − 1983:IV			1984:I − 2004:IV		
Model	**h = 1**	**h = 4**	**h = 8**	**h = 1**	**h = 4**	**h = 8**
Recursive AR(AIC)	1.00	1.00	1.00	1.00	1.00	1.00
AO	1.95 (.69)	1.06 (.20)	1.00 (.22)	1.22 (.29)	**0.89** (.18)	**0.84** (.23)
Rolling AR(AIC)	0.97 (.06)	0.99 (.09)	**0.83** (.13)	0.95 (.10)	1.17 (.20)	1.18 (.37)
Rolling MA(1)	**0.82** (.06)	**0.86** (.12)	0.88 (.18)	0.99 (.08)	0.93 (.14)	0.87 (.21)
UC-SV, $\gamma = 0.2$	0.77	0.82	0.88	0.96	0.90	0.83

Summary:

The SV-TVP model accounts for (in a mechanical sense) the univariate facts:

1. Decrease in persistence of (shock to) inflation (transitory component more important)
2. Decrease in variability of inflation, and size of RMSFE
3. Instability in univariate inflation models (and Atkeson-Ohanian (2001) puzzle)

But how is this related to the multivariate puzzles?

3. The Time-Varying Factor Model

DFM in static form:

$$X_t = \Lambda_t F_t + e_t,$$

$$F_t = \Phi_t F_{t-1} + \eta_{it}$$

$$e_{it} = a_{it}(\mathrm{L})e_{it\text{-}1} + \varepsilon_{it}$$

We assume η_t, ε_{it} are (joint) mds

<u>Comments</u>

- The usual "dynamic" factor model is

$$X_t = \lambda(\mathrm{L})f_t + e_t,$$

  where f_t are the "dynamic" factors. This can be written in static form if there are finite lags

- The TV-DFM introduces three types of time variation:
  - Λ_t: factor loadings
  - Φ_t: factor dynamics
  - $a_{it}(\mathrm{L})$: idiosyncratic dynamics
- One-step ahead prediction equation, given the factors:

$$X_{it} = \Lambda_{it} F_t + a_{it}(\mathrm{L}) e_{it-1} + \varepsilon_{it}$$

- h-step ahead prediction equation, given the factors:

$$X_{it+h|t} = E(X_{it+h} | F_t, F_{t-1}, \ldots, X_{it}, X_{it-1}, \ldots) = \beta_{it}^{h\prime} F_t + a_{it}^{h}(\mathrm{L}) e_t,$$

where $\beta_{it}^{h\prime} = \Lambda_{it+h} \prod_{s=t+1}^{t+h} \Phi_s$ and

$$a_{it}^{h}(\mathrm{L}) e_t = E[a_{it+\mathrm{h}}(\mathrm{L}) e_{t+h-1} | F_t, F_{t-1}, \ldots, X_{it}, X_{it-1}, \ldots]$$

$$= E[a_{it+\mathrm{h}}(\mathrm{L}) e_{it+h-1} | e_{it}, e_{it-1}, \ldots].$$

Implications of time variation for forecasts: three cases

Consider *h*-step ahead forecasts:

(a) Break in Λ only:

$$\Lambda_{it} = \begin{cases} \Lambda_{i1}, & t < \tau \\ \Lambda_{i2}, & t \geq \tau \end{cases}$$

so

$$X_{it+h|t} = \begin{cases} \Lambda_{i1}\Phi^h F_t + a_i(\mathrm{L})e_{it}, & t < \tau \\ \Lambda_{i2}\Phi^h F_t + a_i(\mathrm{L})e_{it}, & t \geq \tau + h \end{cases}$$

Break in coefficients on F_t*, but not on* e_{it}

(b) Break in Φ only: $\Phi_t = \begin{cases} \Phi_1, & t < \tau \\ \Phi_2, & t \geq \tau \end{cases}$

then

$$X_{it+h|t} = \begin{cases} \Lambda_i \Phi_1^h F_t + a_i(\mathrm{L}) e_{it}, & t < \tau \\ \Lambda_i \Phi_2^h F_t + a_i(\mathrm{L}) e_{it}, & t \geq \tau + h \end{cases}$$

Break in coefficients on F_t, but not on e_{it}

(c) Break in idiosyncratic dynamics: $a_{it}(L) = \begin{cases} a_{i1}(L), & t < \tau \\ a_{i2}(L), & t \geq \tau \end{cases}$

then

$$X_{it+h|t} = \begin{cases} \Lambda_i \Phi^h F_t + a_{i1}(\mathrm{L}) e_{it}, & t < \tau \\ \Lambda_i \Phi^h F_t + a_{i2}(\mathrm{L}) e_{it}, & t \geq \tau + h \end{cases}$$

Break in coefficients on e_{it}, but not on F_t

Comments

- Can have stable factor loadings but unstable forecasts (if Φ changes)
- Observing stable factor loadings and unstable factors suggests instability in Φ
- Instability in idiosyncratic dynamics effects only coefficients on e_{it} and its lags

3. Estimation of the Factors in the Presence of Time Variation

Statistical model of time variation in the factor loadings:

$$X_t = \Lambda_t F_t + e_t,$$
$$\Lambda_t = \Lambda_{t-1} + h_T \zeta_t,$$

Condition TV (time-varying factor loadings). $h_T = \text{diag}(h_{1T},\ldots, h_{NT})$, where h_{iT} is i.i.d. and independent of $\{e_t, \varepsilon_t\}$, and $T\kappa_{4T} = O(1)$, where $\kappa_{qT} = (Eh_{iT}^q)^{1/q}$.

Comment: can have a fraction of large breaks, and/or a fraction of O(1/T) TVP coefficients (this is the Pitman rate)

Additional conditions:

Condition FL. “ubiquity” condition on factor loadings

Condition M. Moments exist; e_t satisfies approximate factor structure.

Theorem 1. Suppose that conditions TV, FL, and M, and that $T \to \infty$ and $\ln(N)/\ln(T) \to \rho > 2$. Then $\delta_{NT} \sup_t \left\| \hat{F}_t - H_{NT} F_T \right\| \to_p 0$, where $\delta_{NT} = T^b$ for any $b <$ $\min(½\rho - 1, 1)$, and H_{NT} is not a function of (i,t).

Proof: Stock and Watson (1998)

Intuition for Theorem 1:

$$X_{it} = \lambda_{it}'F_t + e_{it}$$
$$= \lambda_{i0}'F_t + (\lambda_{it} - \lambda_{i0})'F_t + e_{it}$$
$$= \lambda_{i0}'F_t + \xi_{it} + e_{it}, \text{ where } \xi_{it} = (\lambda_{it} - \lambda_{i0})'F_t$$

or

$$\underline{X}_i = F\lambda_{i0} + \underline{\xi}_i + \underline{e}_i, \text{ where } \underline{X}_i = \begin{pmatrix} X_{i1} \\ \vdots \\ X_{iT} \end{pmatrix}, \underline{\xi}_i = \begin{pmatrix} \xi_{i1} \\ \vdots \\ \xi_{iT} \end{pmatrix}, \underline{e}_i = \begin{pmatrix} e_{i1} \\ \vdots \\ e_{iT} \end{pmatrix}.$$

Principal components: $\hat{F}$ are the eigenvectors corresponding to the r largest eigenvalues of $\frac{1}{NT}\sum_{i=1}^{N} \underline{X}_i \underline{X}_i'$

Now

$$\frac{1}{NT}\sum_{i=1}^{N}\underline{X}_i\underline{X}_i' = \frac{1}{NT}\sum_{i=1}^{N}\left(F\lambda_{i0}+\underline{\xi}_i+\underline{e}_i\right)\left(F\lambda_{i0}+\underline{\xi}_i+\underline{e}_i\right)'$$

$$= \frac{1}{NT}\sum_{i=1}^{N}\left(F\lambda_{i0}+\underline{e}_i\right)\left(F\lambda_{i0}+\underline{e}_i\right)' + o_p(1)$$

under condition TV (plus moment assumptions). So,

$$evec\left[\frac{1}{NT}\sum_{i=1}^{N}\underline{X}_i\underline{X}_i'\right] \approx evec\left[\frac{1}{NT}\sum_{i=1}^{N}\left(F\lambda_{i0}+\underline{e}_i\right)\left(F\lambda_{i0}+\underline{e}_i\right)'\right]$$

$$\approx evec\left[\frac{1}{NT}\sum_{i=1}^{N}\left(F\lambda_{i0}\right)\left(F\lambda_{i0i}\right)'\right]$$

$$= evec\left[\frac{1}{T}\overbrace{F}^{T\times r}\overbrace{\left(\frac{\Lambda_0'\Lambda_0}{N}\right)}^{r\times r}\overbrace{F'}^{r\times T}\right] = F \text{ (up to rotation)}$$

Comments

- Rate condition – two roles for N large:
  - average over time variation in
  - uniform (over t) consistency of the factors
- Unstable factor loadings imply forecast regression instability
- What about:
  - TVP in Φ_t?
  - TVP in a_{it}(L)?
  - neither should matter, within technical (moments exist, etc.) limits
- Implication: factor estimates will be robust to substantial time variation; forecasting regressions (given F_t) will not be.

4. Empirical Results – TV DFM

Data set (*new – replaces quarterly SW* (*2005*))

- 145 quarterly U.S. series, 1959:I – 2006:IV
  - 110 subaggregates (typically NIPA 3rd level)
  - 35 additional variables (e.g. Real GDP)
- Only subaggregates are used for estimation of the factors; factor forecasts are considered for all 145 series
- Categories of series: NIPA real series, sectoral employment, NIPA prices (deflators), misc. activity indexes (housing starts, etc.), interest rates, exchange rates, stock returns
- All series transformed to I(0) using expert judgment

Empirical analysis - methods

- Stability analysis: focus on break in 1984:I (Great Moderation; possibly changes in inflation process)
- All forecasts are 4-quarter, direct
  - (*h*-step flow variable are temporally aggregated, e.g. 4-quarter growth; inflation is four-quarter change in inflation; “levels” and stock variables like interest rates are four quarter ahead)
- “In-sample” statistics: focus on population objects (MSEs, stability tests, R^2s, etc), not pseudo out-of-sample forecasts

Outline of results (factor model)

1. Number of factors (Bai-Ng criteria)
2. Stability (across subsamples) of the estimated factors
3. Stability of factor loadings
4. Stability of 4-quarter ahead forecasts
5. Stability of F dynamics
6. Relative merits of using full/split sample factors, full/split sample estimates of the forecasting regression

1. Number of factors

Number of Factors Estimated Using Bai-Ng (2002) Criteria

Sample	Dates	No. Obs	Estimated Number of factors based on:		
			ICP1	ICP1	
Full	1959:III – 2006:IV	190	4	2	
Pre-84	1959:III – 1983:IV	98	3	2	
Post-84	1984:I – 2006:IV	92	3	2	

Digression: other methods, e.g. Onatski (2006),…

2. Stability of factors: Squared Canonical Correlations, Split- and Full-Sample Estimates of the Factors

No. of factors		Pre-84				
Full sample	Subsample	1	2	3	4	5
3	3	0.999	0.993	0.220		
4	3	0.999	0.994	0.907		
4	4	0.999	0.995	0.947	0.069	
5	4	0.999	0.995	0.947	0.856	
5	5	0.999	0.997	0.952	0.905	0.559

No. of factors		Post-84				
Full sample	Subsample	1	2	3	4	5
3	3	0.992	0.937	0.893		
4	3	0.993	0.945	0.909		
4	4	0.996	0.950	0.932	0.517	
5	4	0.996	0.967	0.932	0.741	
5	5	0.997	0.975	0.936	0.787	0.236

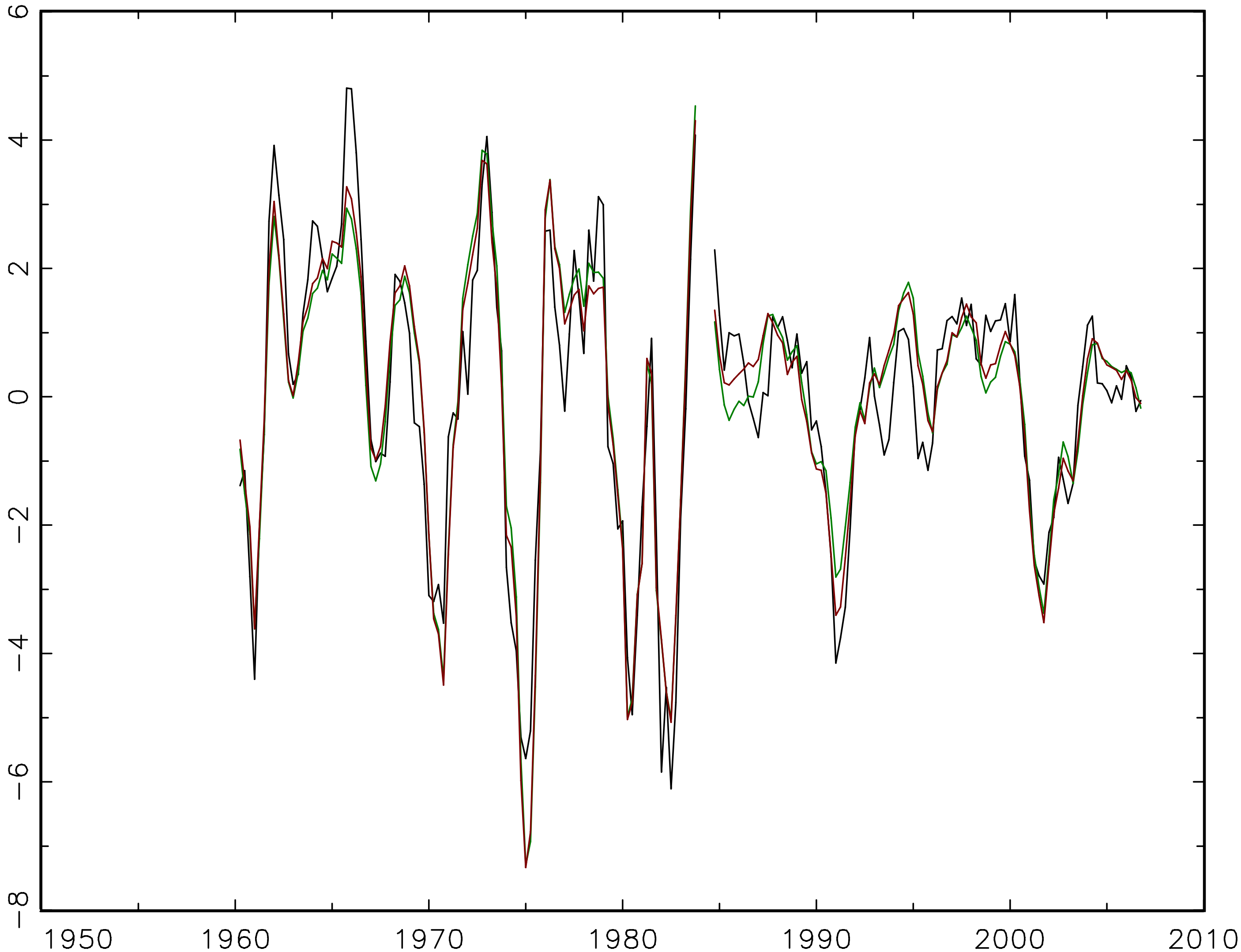


Figure 1. 4-qtr real GDP growth and common component
(a) full sample factors, split sample loadings (red)
split sample factors, split sample loadings (green)

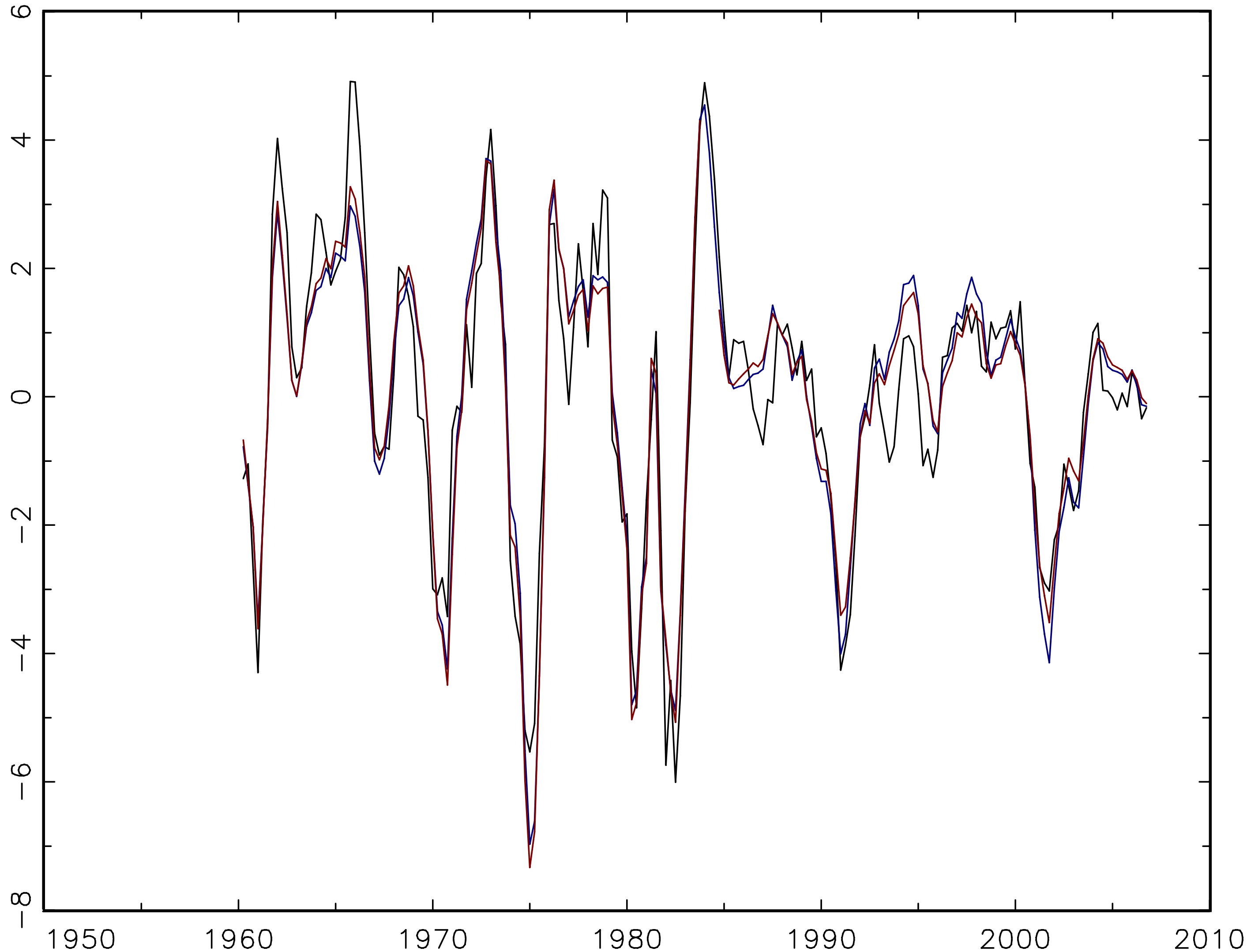


Figure 1. 4-qtr real GDP growth and common component

(b) full sample factors, split sample loadings (red)

full sample factors, full sample loadings (blue)

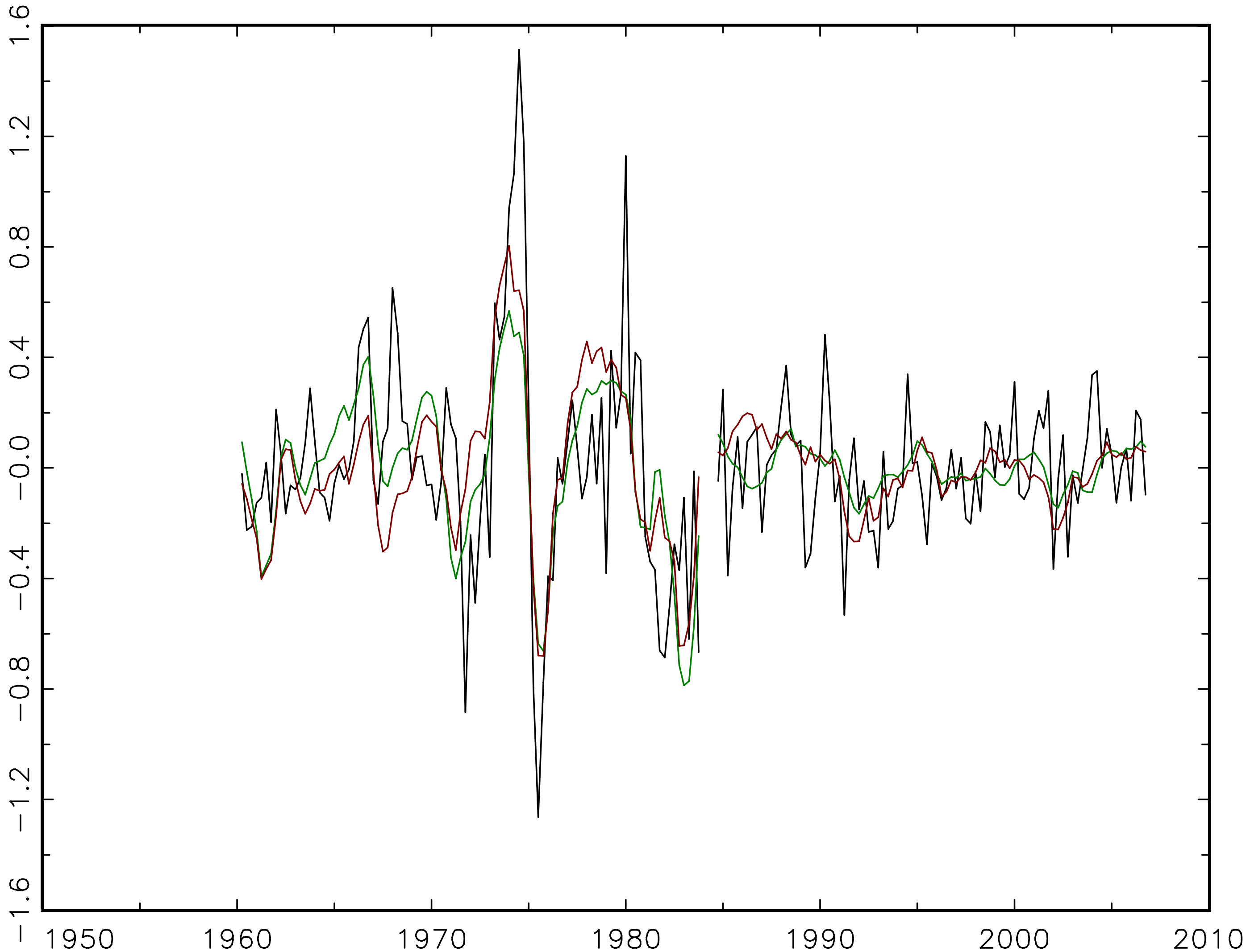


Figure 2. 4-quarter change in core PCE inflation
(a) full sample factors, split sample loadings (red)
split sample factors, split sample loadings (green)

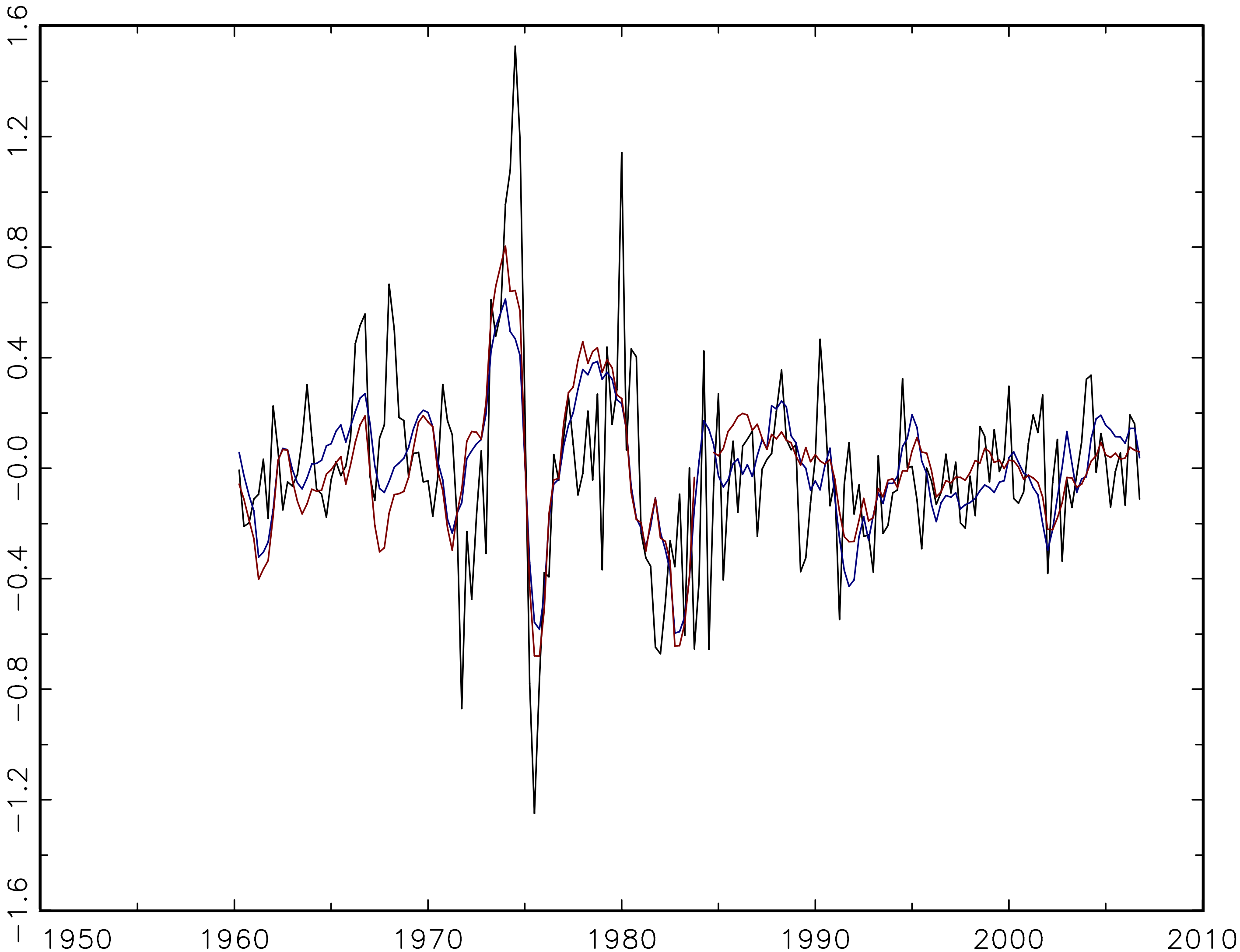


Figure 2. 4-quarter change in core PCE inflation
(b) full sample factors, split sample loadings (red)
full sample factors, full sample loadings (blue)

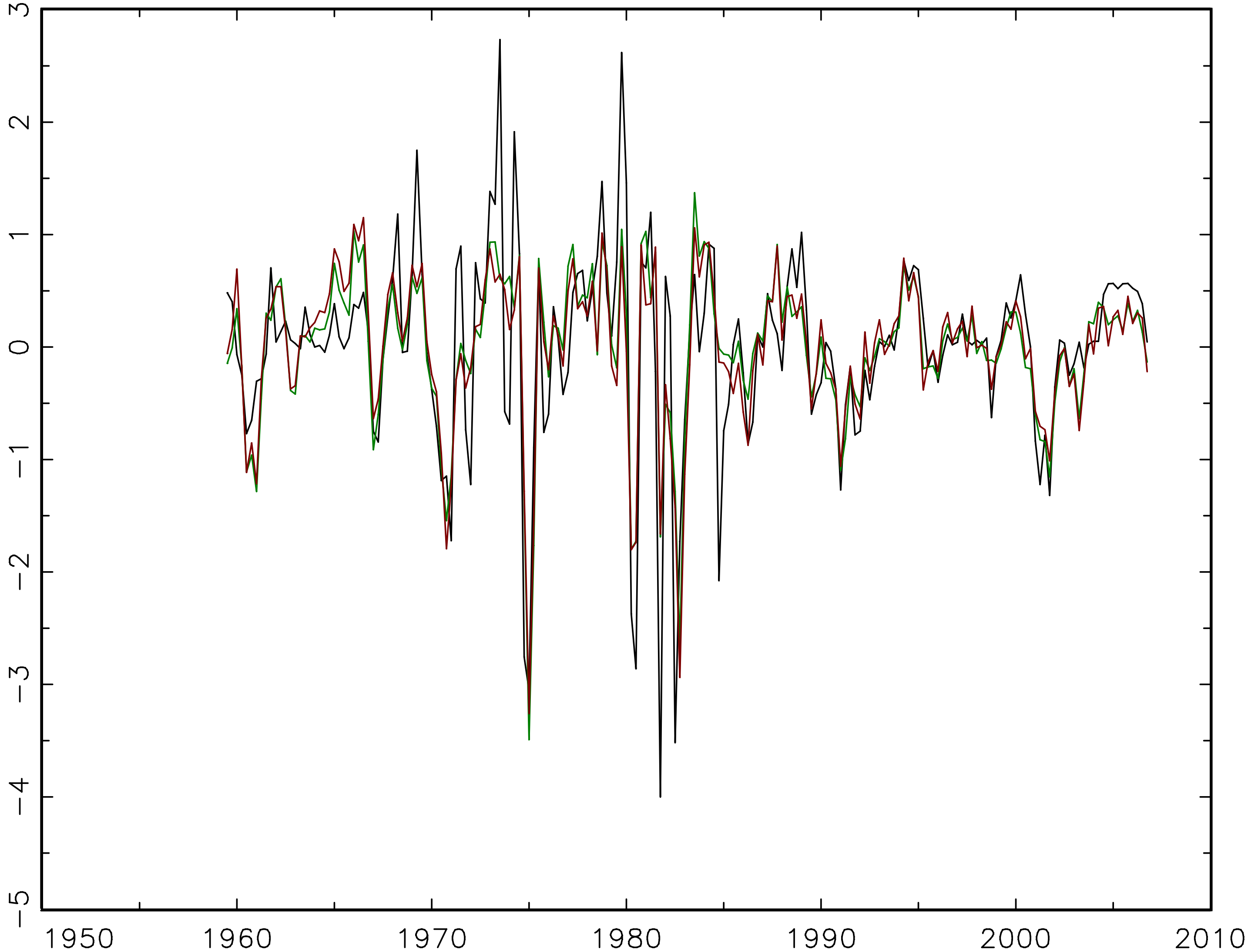


Figure 3. Federal Funds rate and common component
(a) full sample factors, split sample loadings (red)
split sample factors, split sample loadings (green)

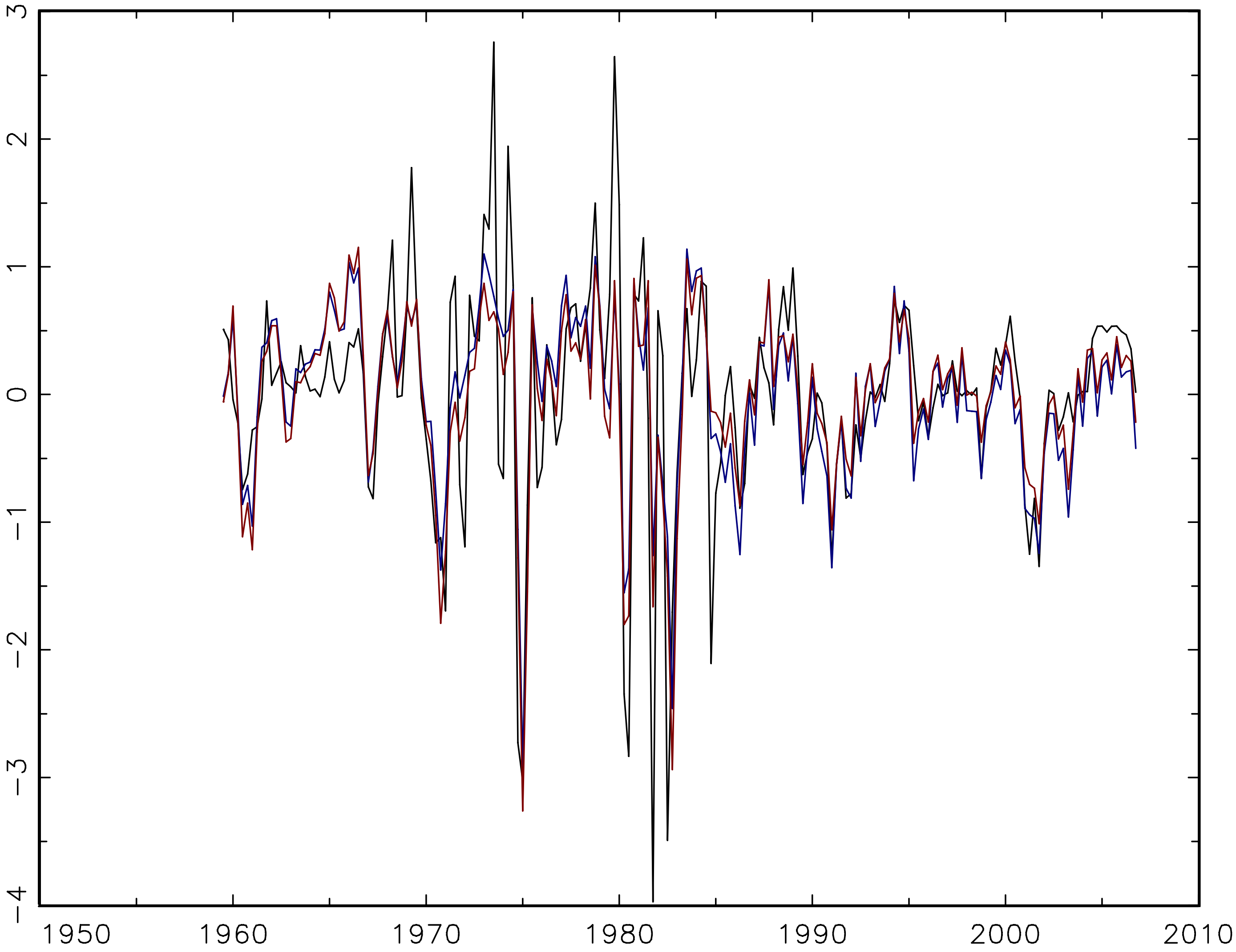


Figure 3. Federal Funds rate and common component
(b) full sample factors, split sample loadings (red)
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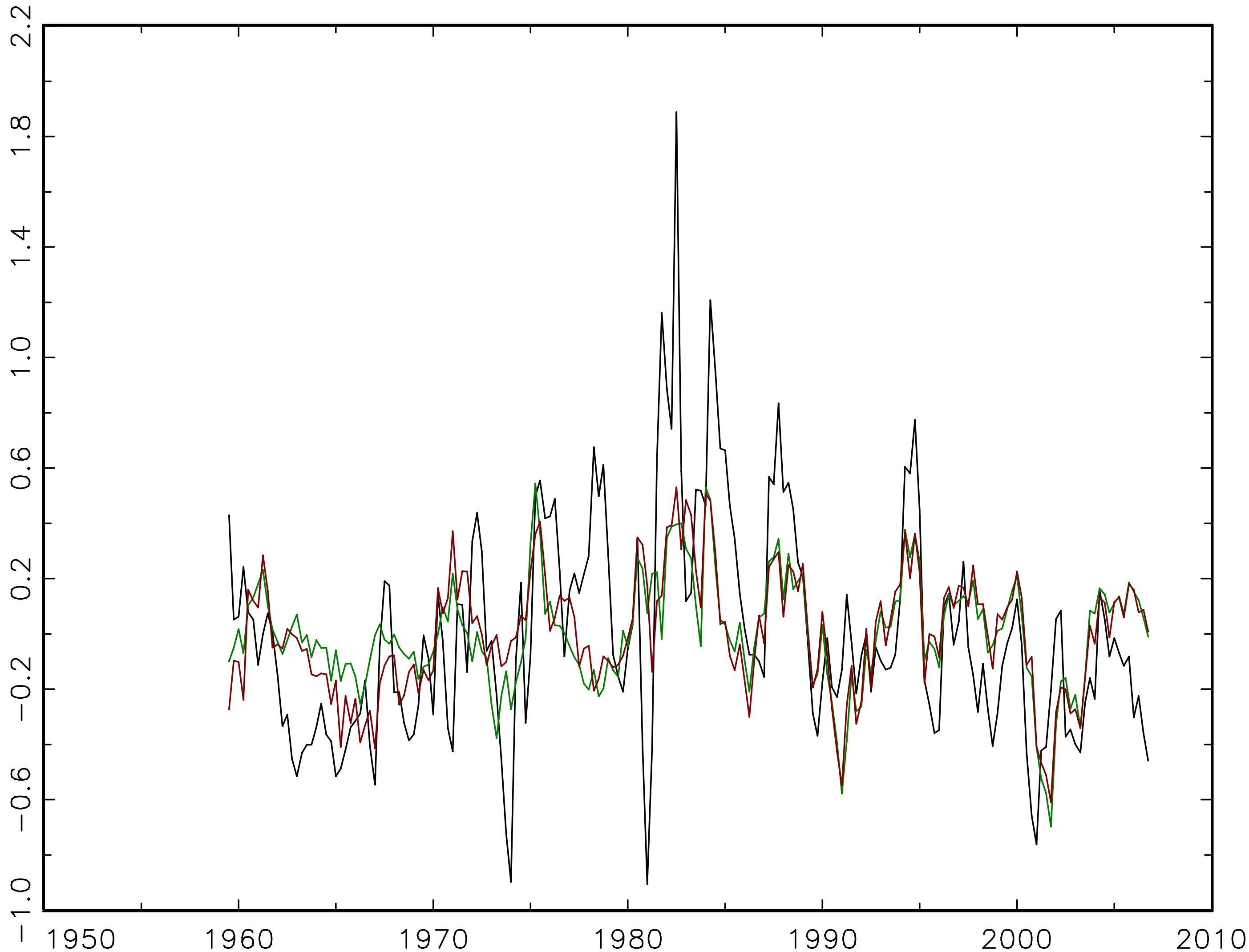


Figure 4. 1 year/1 month Treasury term spread

(a) full sample factors, split sample loadings (red)

split sample factors, split sample loadings (green)

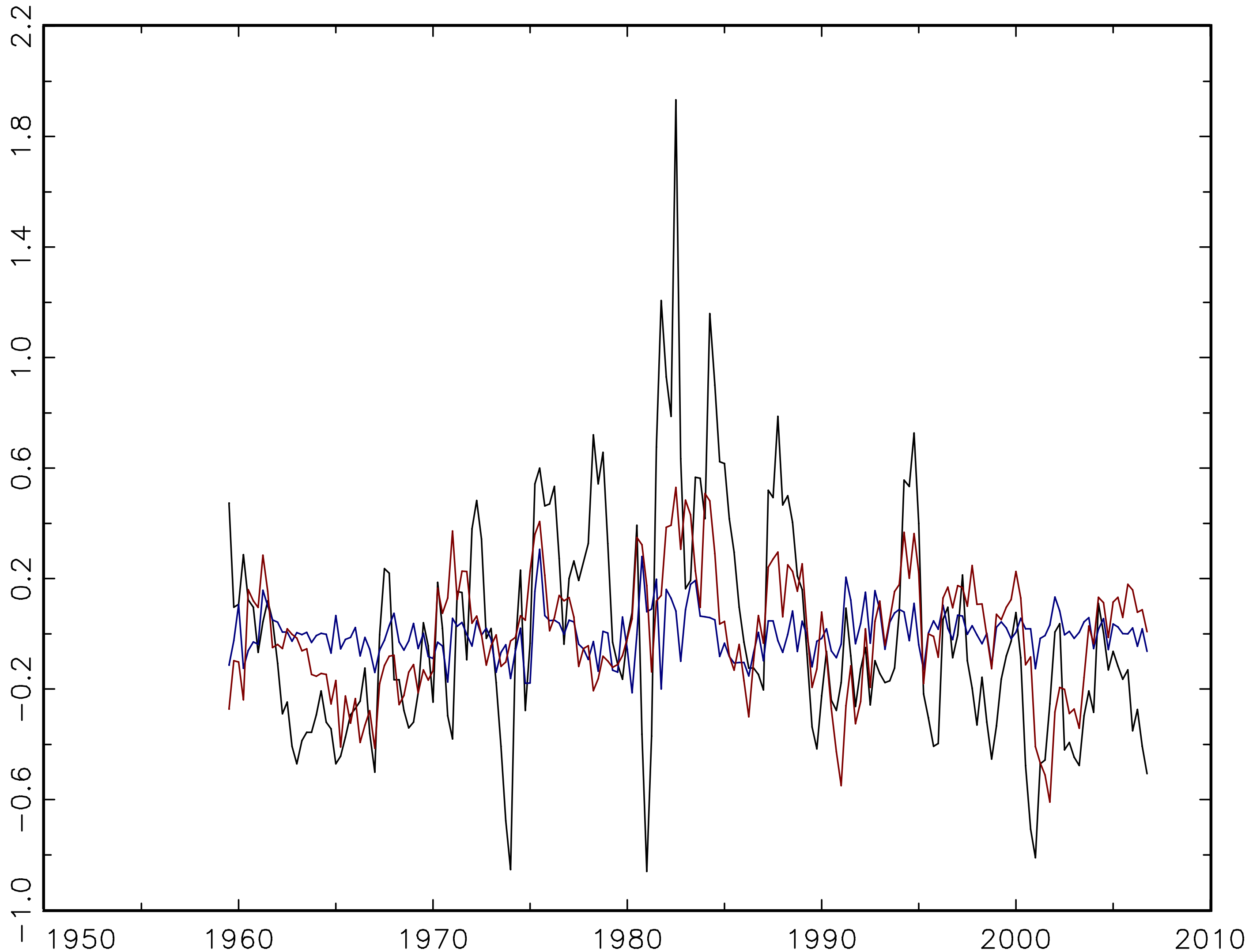


Figure 4. 1 year/1 month Treasury term spread
(b) full sample factors, split sample loadings (red)
full sample factors, full sample loadings (blue)

3. Stability of factor loadings *and*
4. Stability of 4-qtr ahead regressions

Split-sample Chow statistics testing the stability of:

Series	Factor loadings (Λ_i)	4-step ahead forecasting regressions:		
		All coefficients	coefficients on F_t	intercept & coefficients on u_{it-1}
RGDP	5.5	35.8**	9.4	7.0
Cons	10.7*	54.1**	14.4**	3.3
Cons-Dur	9.4	49.9**	18.2**	3.7
Cons-NonDur	9.8*	19.9*	9.0	6.0
Cons-Serv	4.7	58.8**	12.0*	33.6**
GPDInv	2.0	24.8**	8.7	7.2
FixedInv	6.4	43.0**	24.2**	9.0
NonResInv	4.6	25.3**	19.7**	5.1
NonResInv-struct	5.5	17.5*	11.8*	5.4
NonResInv-Bequip	6.5	43.0**	26.1**	11.1
Res.Inv	3.5	65.0**	10.6*	39.3**
Exports	10.7*	25.0**	3.6	18.9**

Imports	3.7	21.5*	11.2*	3.6
Gov	6.6	8.6	4.0	4.2
Gov Fed	10.7*	7.9	3.9	3.7
Gov State/Loc	5.9	13.1	2.6	11.3*
IP: total	9.8*	31.5**	10.7*	4.5
IP: products	6.0	28.8**	9.4	9.5
IP: final prod	5.0	27.7**	10.1*	9.4
IP: cons gds	8.9	57.6**	14.5**	26.1**
IP: cons dble	9.0	18.1*	6.4	2.8
iIP:cons nondble	4.4	68.1**	18.0**	15.8**
IP:bus eqpt	6.2	31.2**	18.4**	1.8
IP: matls	8.5	26.6**	12.2*	7.2
IP: dble mats	8.6	26.9**	13.4**	11.9*
IP:nondble mats	8.7	63.8**	8.3	26.3**
IP: mfg	9.6*	32.5**	10.8*	4.2
IP: fuels	4.0	9.4	3.3	4.1
NAPM prodn	20.3**	29.4**	4.3	14.4*
Capacity Util	12.2*	35.7**	19.0**	10.1
Emp: total	22.6**	44.1**	18.6**	10.0
Emp: gds prod	18.1**	75.3**	20.6**	20.5**
Emp: mining	2.5	18.7*	8.9	9.5
Emp: const	12.9*	57.7**	43.4**	17.1**
Emp: mfg	23.4**	73.2**	18.0**	22.1**
Emp: dble gds	21.7**	80.6**	22.6**	16.5**
Emp: nondbles	6.9	75.7**	9.9*	56.3**

Emp: services	8.2	50.9**	18.0**	15.3**
Emp: TTU	25.2**	82.3**	33.9**	25.3**
Emp: wholesale	27.0**	77.7**	32.9**	22.0**
Emp: retail	10.4*	174.2**	47.6**	57.5**
Emp: FIRE	13.0*	81.7**	28.6**	39.5**
Emp: Govt	26.1**	28.1**	9.3	22.7**
Help wanted indx	13.8**	51.9**	6.1	26.4**
Help wanted/emp	1.4	23.2**	5.5	11.8*
Emp CPS total	9.9*	25.5**	12.7*	13.1*
Emp CPS nonag	5.0	33.4**	9.5	17.8**
Emp. Hours	25.1**	64.7**	28.6**	8.9
Avg hrs	7.6	85.3**	6.9	65.7**
Overtime: mfg	1.3	16.5	1.4	8.2
U: all	11.1*	25.1**	21.1**	2.3
U: mean duration	4.7	52.6**	13.7**	27.5**
U < 5 wks	15.9**	11.3	8.1	2.5
U 5-14 wks	5.2	15.8	13.5**	1.0
U 15+ wks	2.0	24.0**	16.8**	10.1
U 15-26 wks	3.2	27.8**	13.9**	13.5*
U 27+ wks	0.8	29.0**	14.4**	15.9**
HStarts: Total	9.9*	37.5**	8.9	15.0*
BuildPermits	8.6	26.4**	10.0*	6.7
HStarts: ne	2.0	50.1**	13.9**	26.8**
HStarts: MW	21.7**	18.7*	10.2*	6.7
HStarts: South	16.1**	32.5**	21.3**	9.1

HStarts: West	7.1	28.5**	19.2**	4.8
PMI	24.9**	26.5**	5.3	13.7*
NAPM new ordrs	38.7**	25.8**	3.1	16.4**
NAPM vendor del	14.8**	15.1	8.6	6.4
NAPM Invent	18.1**	69.5**	11.9*	45.4**
Orders (ConsGoods)	11.8*	30.6**	9.5*	12.5*
Orders (NDCapGoods)	6.8	29.7**	16.9**	7.9
PGDP	9.6*	42.2**	34.0**	0.9
PCED	2.0	23.1**	19.5**	3.8
CPI-ALL	6.6	29.7**	23.6**	3.7
PCED-Core	5.3	32.4**	25.1**	6.6
CPI-Core	15.0**	16.4	12.1*	6.3
PCED-DUR	2.2	17.2*	11.9*	2.5
PCED-DUR-MOTORVEH	2.4	8.9	6.3	3.4
PCED-DUR-HHEQUIP	10.0*	68.4**	59.8**	13.2*
PCED-DUR-OTH	3.4	26.5**	13.8**	15.9**
PCED-NDUR	3.0	19.0*	11.1*	2.4
PCED-NDUR-FOOD	5.7	33.7**	22.7**	5.7
PCED-NDUR-CLTH	2.1	12.6	6.3	4.4
PCED-NDUR-ENERGY	7.8	43.6**	27.1**	3.5
PCED-NDUR-OTH	5.3	16.5	1.2	14.8*
PCED-SERV	3.5	65.1**	51.2**	5.0
PCED-SERV-HOUS	2.9	5.4	4.0	2.6
PCED-SERV-HOUSOP	3.2	15.8	11.6*	3.9

PCED-SERV-H0-ELGAS	3.2	13.3	6.7	2.9
PCED-SERV-HO-OTH	3.4	11.9	3.2	6.0
PCED-SERV-TRAN	8.6	77.7**	19.3**	46.0**
PCED-SERV-MED	23.7**	35.8**	13.2*	11.6*
PCED-SERV-REC	6.7	16.2	10.4*	8.1
PCED-SERV-OTH	7.6	22.8**	7.5	6.6
PGPDI	8.2	20.7*	16.1**	3.3
PFI	6.2	27.9**	15.4**	8.6
PFI-NRES	3.6	33.1**	12.4*	20.8**
PFI-NRES-STR Price Index	6.9	15.4	6.2	9.7
PFI-NRES-EQP	1.9	14.2	10.5*	2.1
PFI-RES	4.5	58.1**	20.5**	11.5*
PEXP	5.2	23.8**	11.9*	13.1*
PIMP	4.9	27.3**	16.4**	1.4
PGOV	2.3	21.7*	14.8**	6.0
PGOV-FED	1.4	25.0**	7.6	4.8
PGOV-SL	3.0	25.4**	21.8**	4.3
Com: spot price (real)	7.8	29.4**	14.1**	11.6*
OilPrice (Real)	20.2**	23.3**	12.7*	11.5*
NAPM com price	9.7*	113.6**	21.4**	68.9**
Real AHE: goods	4.2	56.2**	10.6*	36.6**
Real AHE: const	11.3*	38.3**	22.1**	6.9
Real AHE: mfg	7.2	49.2**	8.9	26.0**
Labor Prod	10.5*	7.2	4.7	1.1

Real Comp/Hour	11.3*	11.0	6.3	4.8
Unit Labor Cost	17.4**	47.7**	5.7	41.9**
FedFunds	6.0	41.8**	31.1**	13.6*
3 mo T-bill	3.6	40.7**	29.3**	12.9*
6 mo T-bill	10.3*	32.1**	17.5**	14.0*
1 yr T-bond	9.8*	24.0**	13.1*	13.9*
5 yr T-bond	6.2	11.9	2.2	8.7
10 yr T-bond	5.4	15.0	1.5	8.4
Aaabond	7.6	15.0	4.3	7.1
Baa bond	12.2*	17.0*	7.3	5.8
fygm6-fygm3	22.8**	37.7**	6.8	29.7**
fygt1-fygm3	24.5**	60.1**	29.5**	12.9*
fygt10-fygm3	16.7**	28.4**	11.0*	7.6
FYAAAC-Fygt10	4.9	61.2**	11.9*	35.6**
FYBAAC-Fygt10	12.2*	43.5**	23.2**	11.5*
M1	2.3	10.9	3.2	4.0
MZM	5.2	12.6	6.9	3.9
M2	11.3*	53.9**	42.1**	4.9
MB	9.3	26.8**	11.7*	16.5**
Reserves tot	5.2	43.1**	9.8*	19.0**
Reserves nonbor	8.9	15.3	12.3*	6.0
BUSLOANS	2.8	36.2**	13.9**	10.7
Cons credit	4.6	20.3*	15.8**	2.7
Ex rate: avg	27.4**	23.9**	11.6*	4.5
Ex rate: Switz	10.0*	18.7*	9.0	9.7

Ex rate: Japan	6.1	25.0**	8.5	10.4
Ex rate: UK	6.6	41.9**	13.7**	10.4
EX rate: Canada	5.1	27.7**	19.8**	6.6
S&P 500	9.5	20.4*	11.9*	6.2
S&P: indust	9.3	21.4*	12.9*	5.9
S&P div yield	10.2*	21.8**	15.2**	5.9
S&P PE ratio	18.6**	51.6**	36.6**	6.8
DJIA	6.0	31.4**	13.6**	15.3**
S&P DivYld	10.2*	21.8**	15.2**	5.9
Consumer expect	22.5**	37.5**	18.1**	10.0
Summary:				
Pct rejections @ 5%	.38	.81	.68	.41
Pct rejections @ 1%	.19	.71	.45	.26

5. Stability of *F* dynamics

Chow tests on Φ (VAR(1) or VAR(2)) reject at 1% level hypothesis of stability; hypothesis of stability of Σ_F is rejected; joint hypothesis of stability in Φ, Σ_F is rejected.

6. How best to forecast?

(a) full or split sample factors?

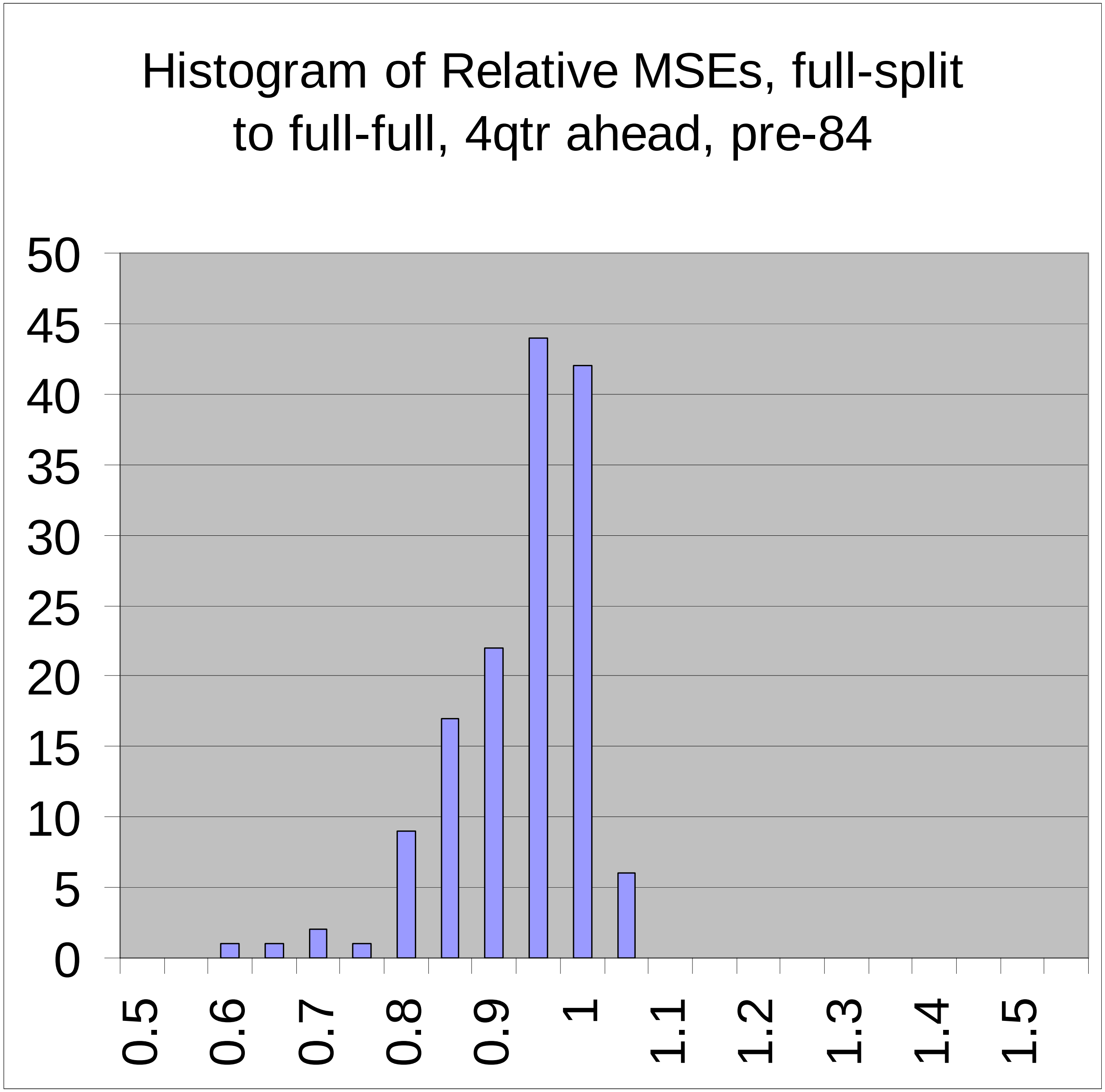
(b) full or split sample forecasting regressions?

MSE comparison, in-sample projections (= MSE of residual in subsample direct 4-qtr ahead regression)

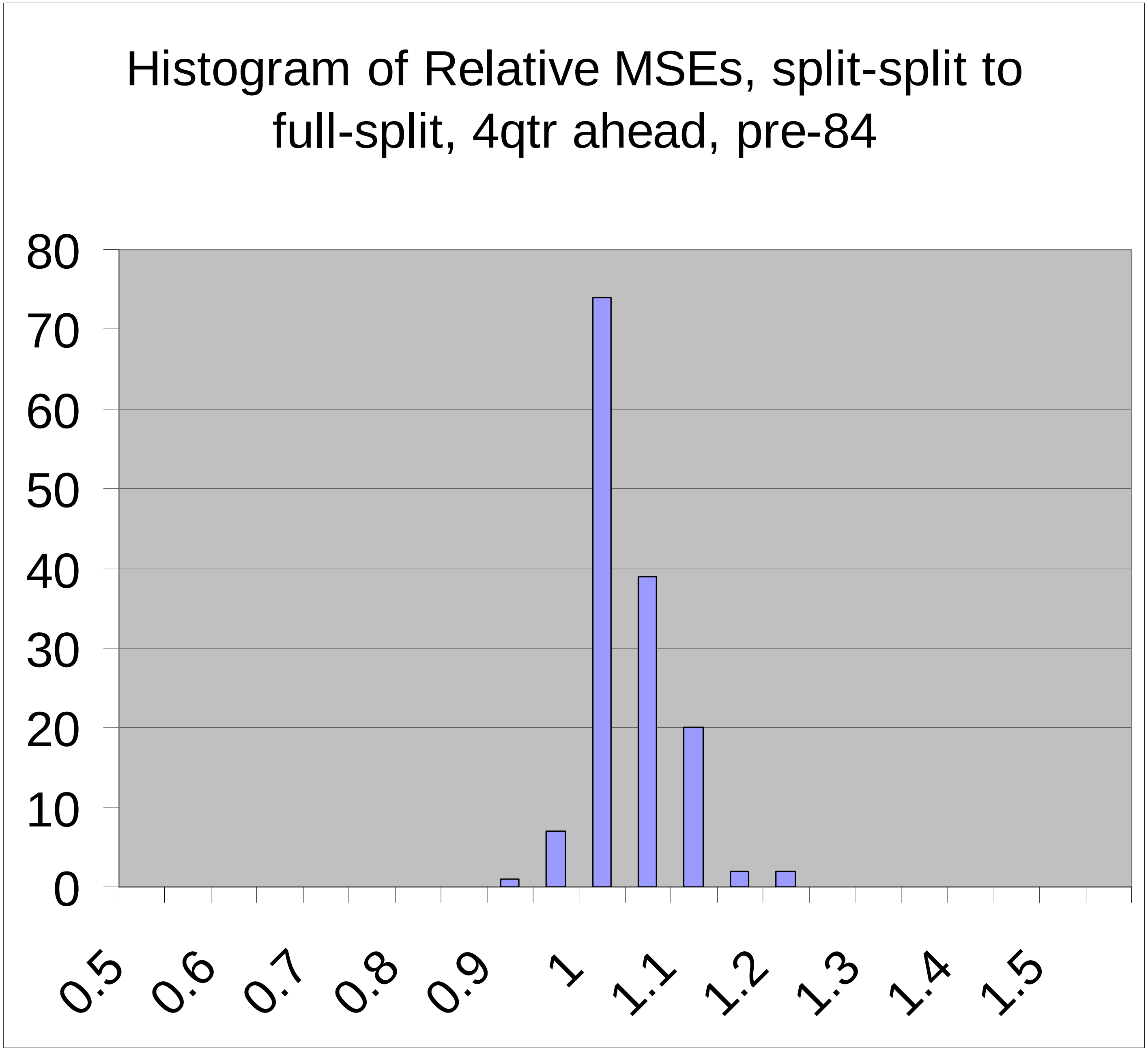
(a) split-split: split sample factors, split sample regression

(b) full-split: full sample factors, split sample regression

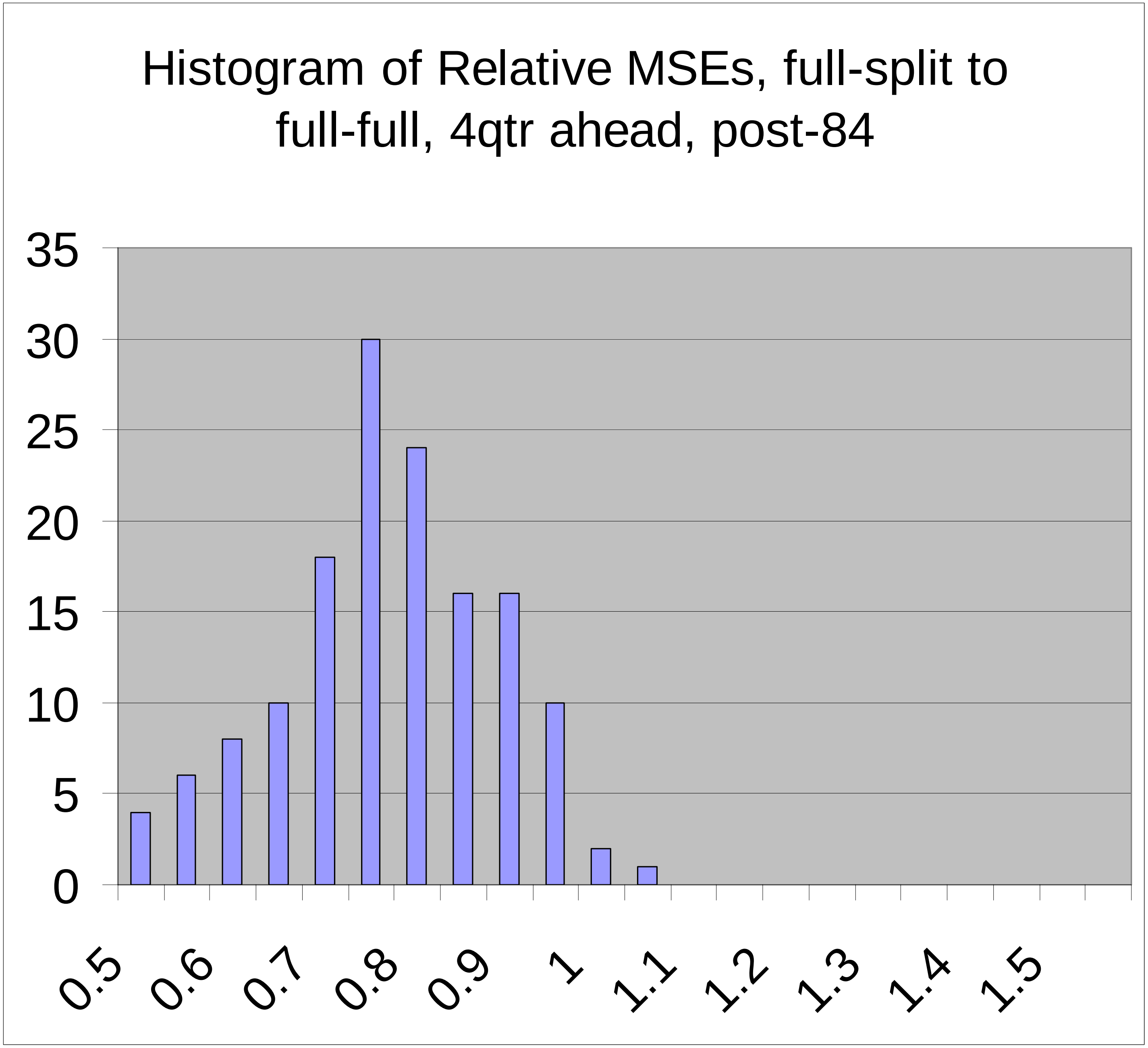
(c) full-full: full sample factors, full sample regression



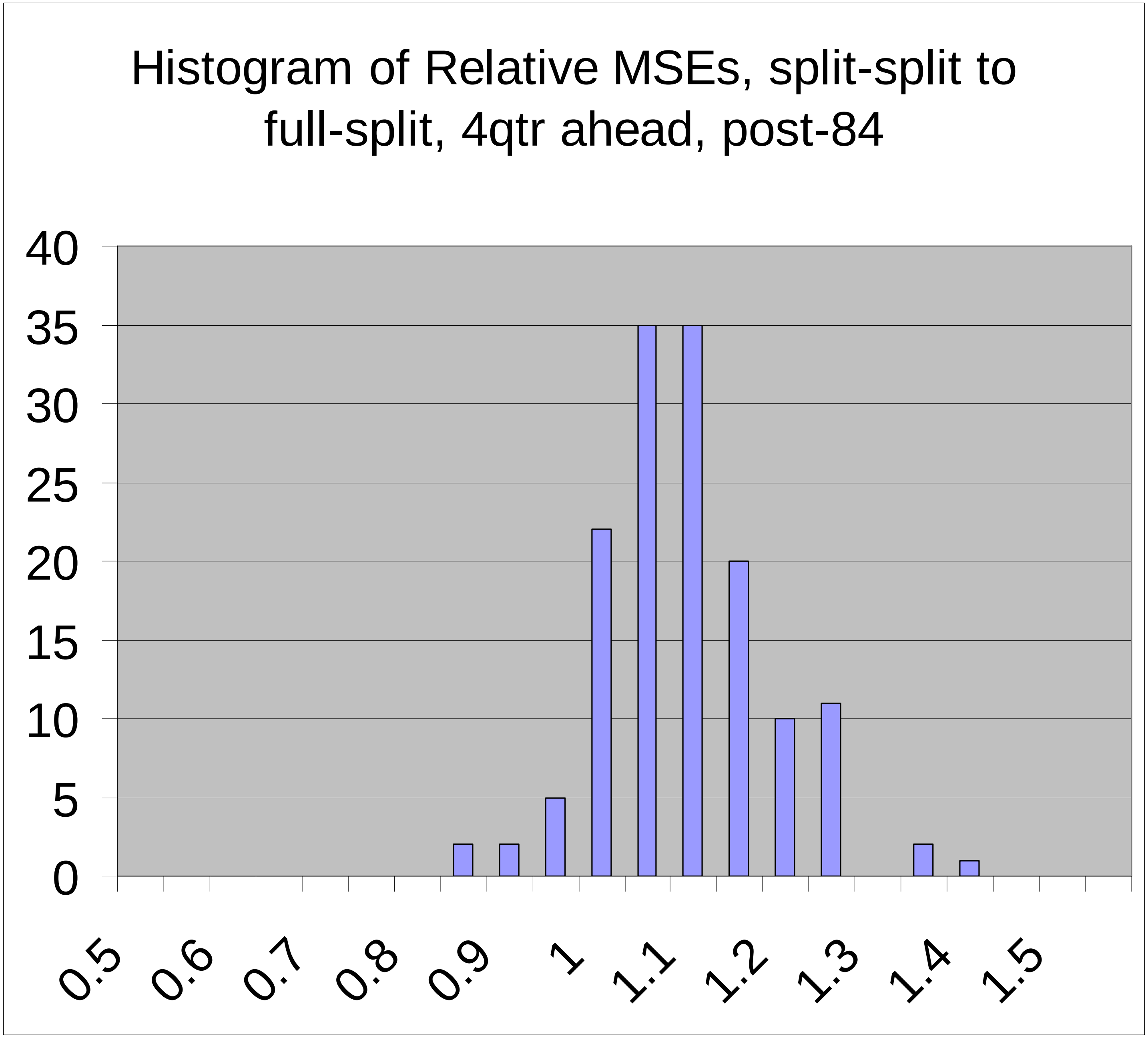
Mean, sd = .905, .074



Mean, sd = 1.008, .043



Mean, sd = .747, .115



Mean, sd = 1.069, .090

5. Implications for Inflation

Return to multivariate inflation puzzles

Univariate

1. Decrease in persistence of (shock to) inflation
2. Decrease in variability of inflation, and size of RMSFE
3. Instability in univariate inflation models (and Atkeson-Ohanian (2001) puzzle)

Multivariate

4. Decline in marginal R^2 of multivariate inflation forecasts
5. Breakdown of Phillips Curve forecasts

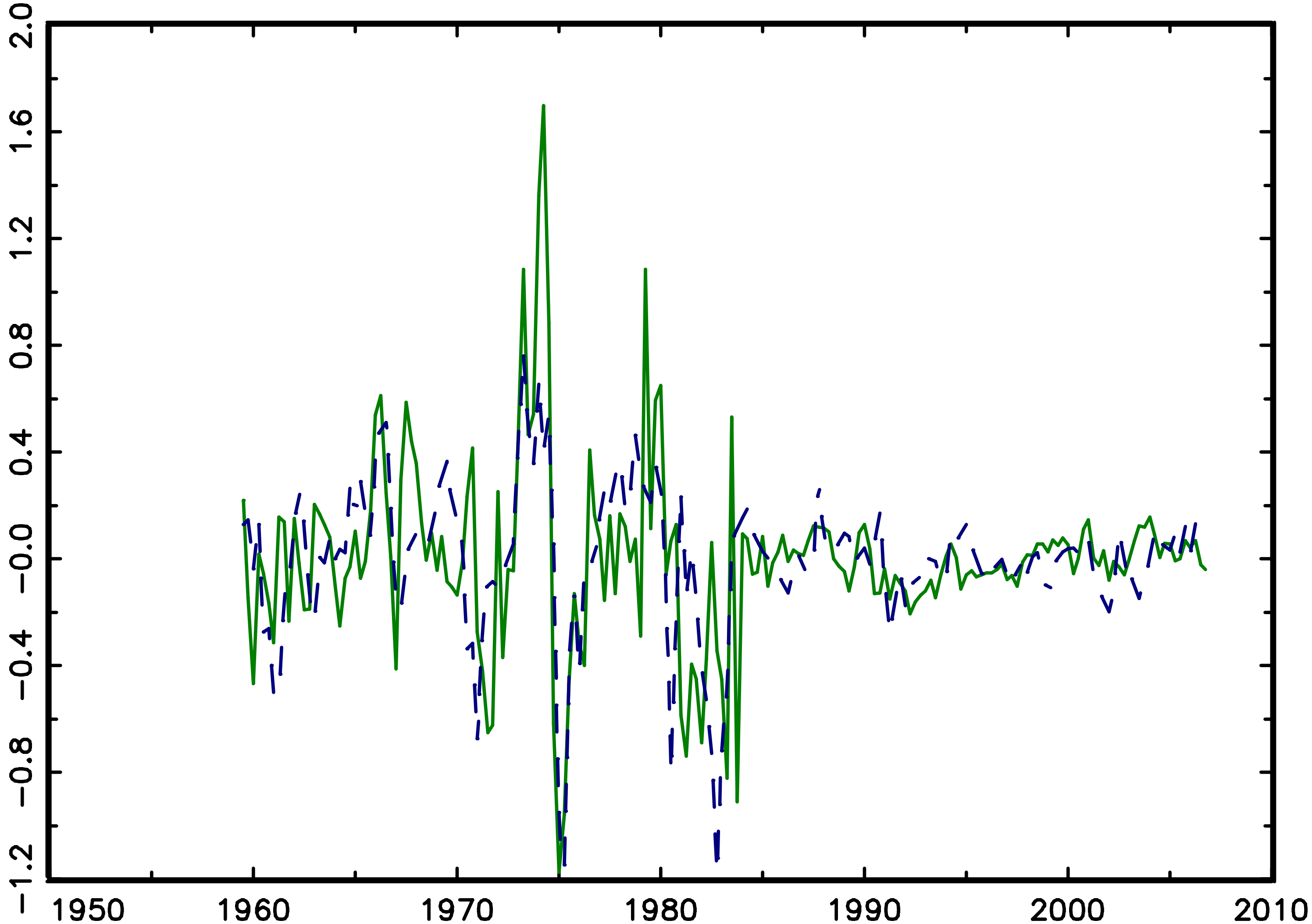
Can these be "explained" by the TV-DFM?

Results (a):

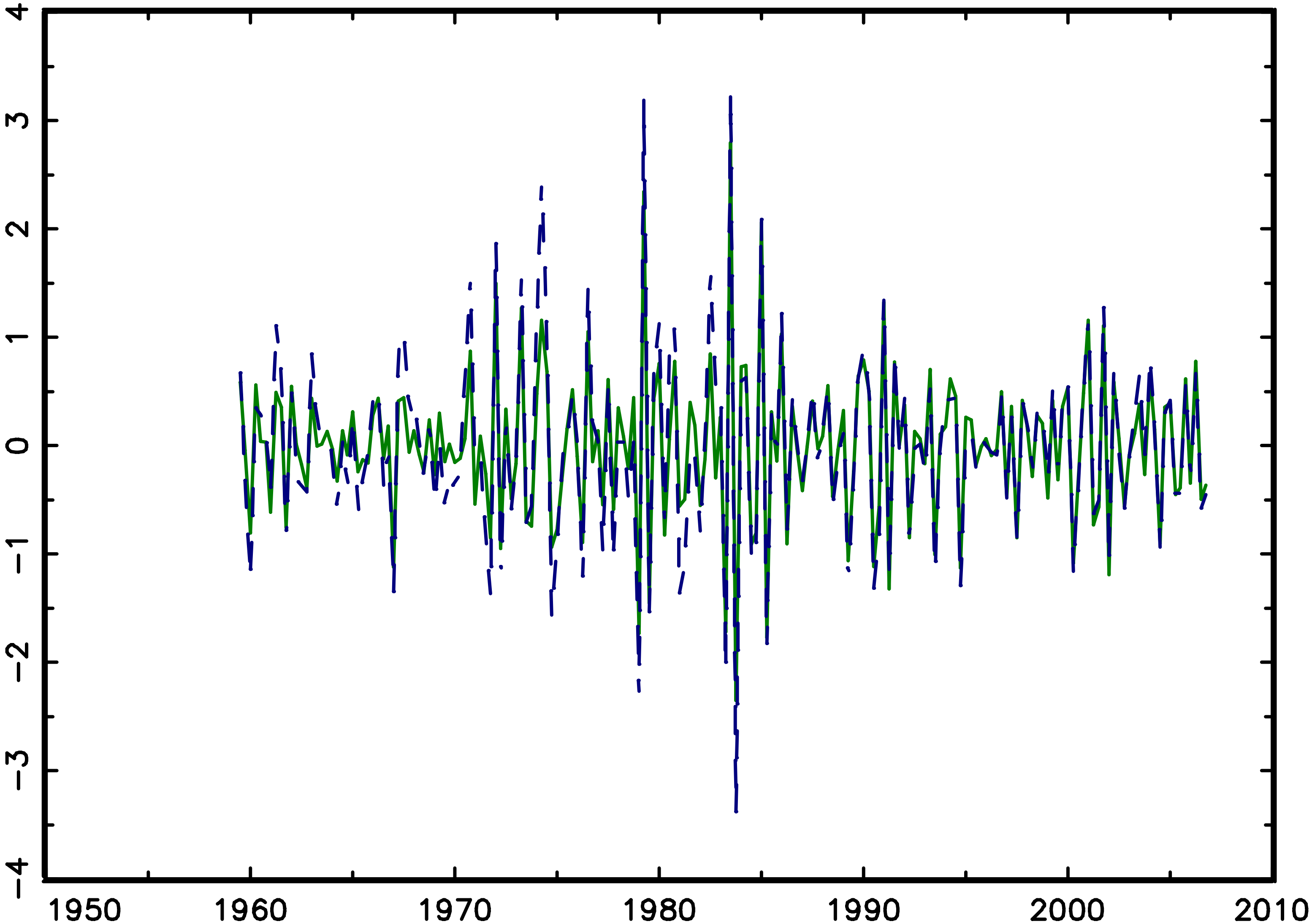
comparison of common component for inflation to the UC-SV permanent component

Note: all statistics are in-sample

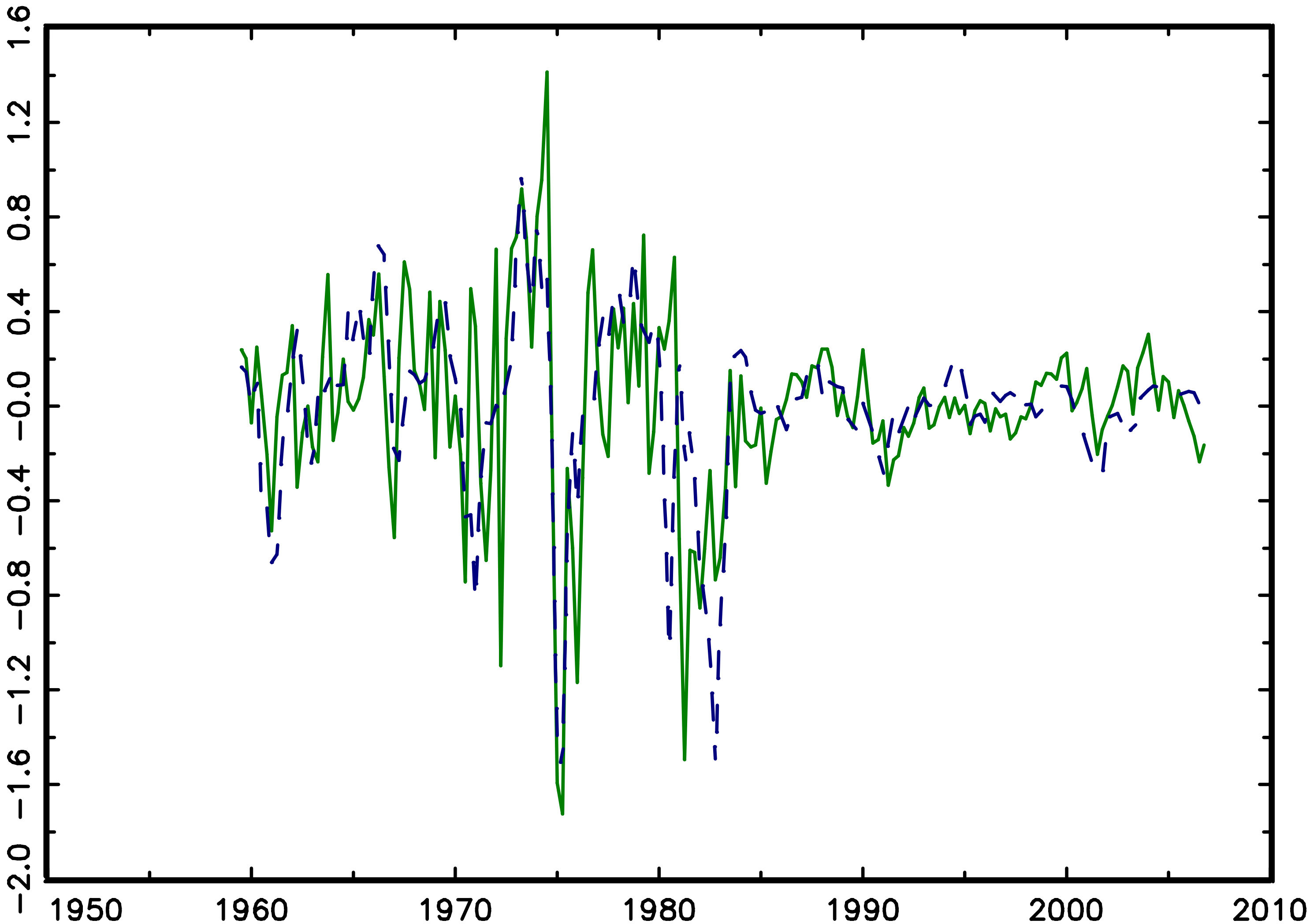
Core PCE: UC Permanent component (green) and common component (blue dashed) (full sample estimates)



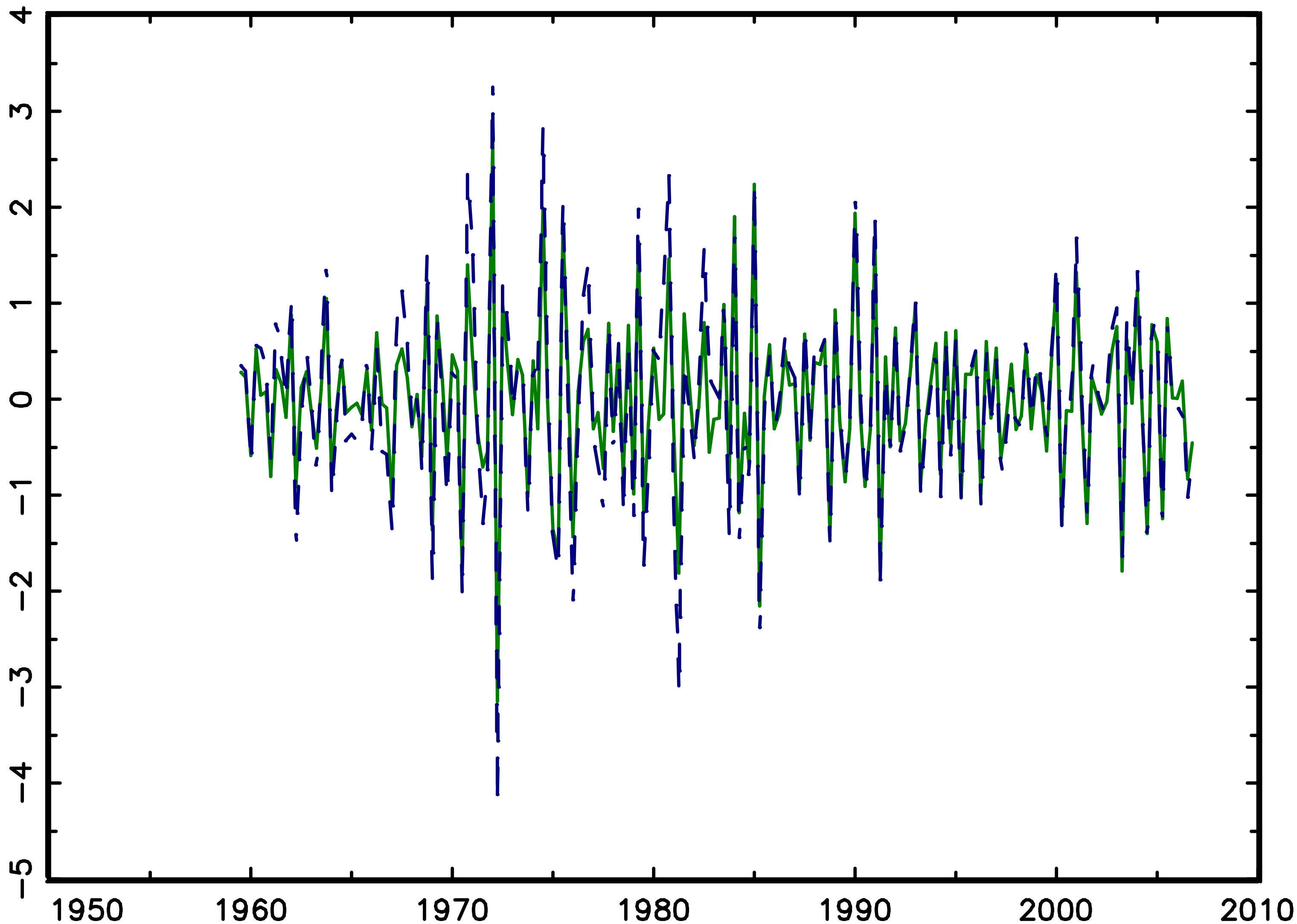
Core PCE : UC transitory component (green) and idiosyncratic component (blue dashed) (full sample estimates)



GDP deflator: UC Permanent component (green) and common component (blue dashed) (full sample estimates)



GDP Deflator: UC transitory component (green) and idiosyncratic component (blue dashed) (full sample estimates)



Implication:

- Reduction in volatility of permanent component can be interpreted as (is implied by) a reduction in volatility of the factors
- Changes aren't a consequence of changing factor loadings – those are constant in this calculation
- Consistent with Φ, Σ_F changing – but Λ staying constant

Results (b):

Marginal R^2s implied by the factor model (is constant Λ, changing Φ, Σ_F view consistent with/explain the Phillips curve breakdown?)

Marginal R^2s from adding predictors: split sample regression estimates and values implied by DFM with full/split sample coefficients

	Pre-84				Post-84		
Estimates of:	**Act**	**C**	**D**		**Act**	**C**	**D**
Λ		full	full			full	full
Φ, Σ_F		split	split			split	split
$a_i(L)$		full	split			full	split
Series							
Factors (4)	0.34	0.34	0.36		0.13	0.17	0.16
RGDP	0.33	0.21	0.23		0.06	0.07	0.05
RGDP (1Sd HP)	0.21	0.19	0.22		0.04	0.05	0.03
IP: total	0.31	0.23	0.25		0.03	0.08	0.07
IP: total (1-sided HP)	0.27	0.20	0.23		0.03	0.07	0.05
Capacity Util	0.29	0.08	0.10		0.07	0.04	0.03
U: all	0.30	0.24	0.26		0.06	0.09	0.07
U: all (1-sided HP)	0.29	0.21	0.22		0.04	0.05	0.04

6. Summary and Conclusions

Many caveats: in-sample statistics; break date chosen because of known breaks, no standard errors on relative MSEs,…

Still, some conclusions:

Theory: some instability in Λ, Φ, a(L)

- shouldn't preclude estimation of the factors
- should result in unstable forecast functions

Empirical work:

- find evidence of unstable Φ, $a(L)$
- factors seem to be stably estimated nevertheless
- forecast functions need subsample (or TVP) methods
- Inflation:
    i. common component = univariate permanent component
    ii. TV-DFM implies the univariate results
    iii. TV-DFM implies the changes in marginal R^2s observed, also the low marginal R^2s in the second period

Future/ongoing work:

1. Asymptotics of Principal Components with TV Λ, Φ, a(L)
2. Characterize nature of change in Φ
3. Can that characterization provide parsimonious model of time variation in many of the forecasting equations (remember case (b) above – only Φ changes…)
4. Loose ends in inflation explanation (some problems in matching univariate R^2's – some specification issue)
5. Does "change in Φ" "explain" various macro phenomena – source of the Great Moderation, breakdown of term structure regressions (SW, *JEL* (2003)), etc?
6. Can "change in Φ" be linked to specific fundamental macro changes?