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Are Commodities Special? Evidence from a Parametric SDF Analysis

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Plan of the Talk

"In the end, I think we can hope for a coherent story that (1) relates the cross-section properties of expected returns to the variation of expected returns through time, and (2) relates the behavior of expected returns to the real economy in a rather detailed way. Or we can hope to convince ourselves that no such story is possible." (Fama (1991, p. 1610))

- Motivation and key research questions
- A parametric SDF
- The choice of factors
- Data
- Model Selection
- Estimates of MS and of Single-Factor Diagonal VAR Model
- Implied Correlations

Motivation

Can we find a stochastic discount factor (SDF) that can jointly price the cross-section of stock, bond, and (spot) commodity returns and reproduce empirically observed correlations?

- Usual difficulty in all the asset pricing literature: can a macro-based SDF be found that precisely prices key asset classes in the absence of arbitrage (e.g., Gorton and Rouwenhorst, 2004, FAJ)?
- What are the priced risk factors and why? Only finance-style factors?
- How difficult is it to jointly price stocks, bonds, and commodities using a unique (under no segmentation) pricing framework?
- Important to understand correlations, that rose dramatically after the debacle of Lehman Brothers (e.g., Tang and Xiong, 2011, FAJ)
- Is the key in the flexibility offered by regimes as in some term structure literature (e.g., Ang, Bekaert, and Wei, 2008, JF)?
- In this paper, we develop an estimated, parametric, macro-factor based SDF that prices stocks, bonds, and commodities

Key Questions

Can a parametric SDF only be found that explains a (simple) cross-section of stocks, bonds, commodities?

Can such an SDF be specified to driven by macroeconomic information only?

Is there evidence of a need of additional parametric flexibility in the SDF in the form of exogenous (non-macro driven) Markov regimes?

Can the best fitting model match the empirical evidence on the hedging properties of commodities, within- and across-asset classes?

Is the resulting SDF a realistic one, reflecting IMRS-like dynamics?

- **First question**: crucial for the existence of arbitrage and/or segmentation in financial markets
- **Second, third & fifth questions**: traditional issue of rationality of asset prices
- **Fourth question**: important for risk and portfolio management (see e.g., Daskalaki and Skiadopoulos (2011, JBF)

The Parametric SDF

- Suppose the SDF has the log-linear structure

$$M_{t+1} = \exp\left(\gamma_0 + \sum_{j=1}^{K} \gamma_j f_{j,t+1}\right) > 0$$

where $f_{1,t+1}, f_{2,t+1}, \ldots, f_{K,t+1}$ are K systematic factors

  - Positivity of $M_{t+1} \Leftrightarrow$ absence of arbitrage opportunities
  - The vector $\gamma \equiv [\gamma_0\ \gamma_1\ \gamma_2 \ldots \gamma_K]'$ restricts the relationship between the prices of all assets and the priced risk factors to be homogeneous across assets according to:

$$E\left[M_{t+1}(1 + R_{i,t+1})|I_t\right] = 1$$

- Standard algebra shows that if the state vector has a stationary multivariate (conditional on the information set Ψ_t) Gaussian distribution, then

$$\boxed{E[r_{i,t+1}|\Psi_t] = -E[m_{t+1}|\Psi_t] - 0.5\sigma_m^2 - 0.5\sigma_i^2 - \sigma_{im}}$$

  - Here $m_{t+1} \equiv \ln M_{t+1}$, σ^2_m is the variance of the log-SDF, σ^2_i is the variance of the continuously compounded return on asset *i*, and σ_{im} is the covariance btw. asset *i* returns and the log-SDF

The Parametric SDF

- As a result, the joint dynamics of the SDF, the factors, and asset returns may be written as:

$$m_{t+1} = \gamma_0 + \sum_{k=1}^{K} \gamma_k f_{k,t+1} + w_{t+1}$$

Auxiliary VAR(P) model for factor dynamics

$$f_{k,t+1} = \varphi_{j0} + \sum_{r=1}^{K} \sum_{j=1}^{P} \varphi_{j,kr} f_{r,t+1-j} + \delta_{k,t+1}, \quad k = 1, ..., K$$

Typical SDF-CAPM covariance factor

$$r_{i,t+1} = \underbrace{(0.5\sigma_m^2 + 0.5\sigma_i^2 + \sigma_{mi})}_{\mu_i} + m_{t+1} + v_{i,t+1}$$

$$= \mu_i + m_{t+1} + v_{i,t+1}, \quad i = 1, ..., n$$

  - The model can be written and estimated by (Q)MLE as a restricted VAR(P) model

- The model can be extended to include Markov states in the coefficients loading the K factors onto the SDF:

$$M_{t+1}(S_{t+1}) = \exp\left(\gamma_{0,S_{t+1}} + \sum_{j=1}^{K} \gamma_{j,S_{t+1}} f_{j,t+1}\right) > 0$$

- S_{t+1} follows a M-state, ergodic and irreducibile Markov chain with constant transition matrix **P**

The Parametric SDF

- By construction the same regimes affect the mapping between all factors and the SDF and are transmitted to all assets (e.g., Nagel and Singleton, 2011, JF)
- Different from simple case in which Markov states in asset return data are simply pinned down on the basis of data
- Using similar algebra and now conditioning on $\{\Psi_t, S_t\}$ one obtains a similar restricted MS-VAR(P) representation that can be estimated by EM algorithm
  - The restrictions create a link between the conditional mean vector and the conditional covariance matrix
  - (Q)MLE/EM estimation not only convenient, but also only feasible way

$$\begin{bmatrix} 1 & \mathbf{0}_K' & \mathbf{0}_n' \\ \mathbf{0}_K & \mathbf{I}_K & \mathbf{O}_{K\times n} \\ \mathbf{0}_n & \mathbf{O}_{n\times k} & \mathbf{I}_n \end{bmatrix} \mathbf{y}_{t+1} = \boldsymbol{\mu}(S_{t+1}) + \sum_{j=0}^{L} \begin{bmatrix} 0 & \ddot{\boldsymbol{\gamma}}_{j,S_{t+1}}' I_{\{j=0\}} & \mathbf{0}_n' \\ 0 & \boldsymbol{\Phi}_j & \mathbf{O}_{K\times n} \\ \boldsymbol{\iota}_n I_{\{j=0\}} & \mathbf{O}_{n\times K} & \mathbf{O}_{n\times n} \end{bmatrix} \mathbf{y}_{t+1-j} + \boldsymbol{\eta}_{t+1}$$

$$\ddot{\boldsymbol{\gamma}}_{j,S_{t+1}} \equiv \begin{bmatrix} \gamma_{1,S_{t+1}} \\ \gamma_{2,S_{t+1}} \\ \vdots \\ \gamma_{K,S_{t+1}} \end{bmatrix} \quad \boldsymbol{\mu}(S_{t+1}) \equiv \begin{bmatrix} \gamma_{0,S_{t+1}} \\ \varphi_0 \\ (0.5\sigma_m^2(\gamma_{S_{t+1}}))\boldsymbol{\iota}_n + 0.5diag(\boldsymbol{\Sigma}(\gamma_{S_{t+1}})) + \boldsymbol{\Sigma}(\gamma_{S_{t+1}})\mathbf{e}_1 \end{bmatrix}$$

The Choice of the Factors

- We follow the same approach as in Ludivgson and Ng (2009, RFS)
- Start from a rich set of 112 U.S. macroeconomic variables, all measured at monthly frequency
- Sample period is Jan. 1983 – Dec. 2011
- Only remove return series

Grouping	Variable	Acronym	Sample period	Notes
GROUP I Labor and Income	Personal Income	PI	1983:01-2011:12	Δln
	Personal Income Less Transfer Payments	PI_LESS_TRANSFERS	1983:01-2011:12	Δln
	Real Consumption	REAL_CONSUMPTION	1983:01-2011:12	Δln
	Manufacturing and Trade Sales	MANUFACTURIN__TRADE_SAL	1983:01-2011:12	Δln
	Sales of Retail Stores	RETAIL_SALES	1983:01-2011:12	Δln
	Industrial Production Index - Total Index	IP__TOTAL	1983:01-2011:12	Δln
	Industrial Production Index - Products, Total	IP__PRODUCTS	1983:01-2011:12	Δln
	Industrial Production Index - Final Products	IP__FINAL_PROD	1983:01-2011:12	Δln
	Industrial Production Index - Consumer Goods	IP__DURABLE_CONSUMER_GOO	1983:01-2011:12	Δln
	Industrial Production Index - Durable Consumer Goods	IP__DURABLE_CONSUMER_GOO	1983:01-2011:12	Δln
	Industrial Production Index - Nondurable Consumer Goods	IP__CONS_NONDBLE	1983:01-2011:12	Δln
	Industrial Production Index - Business Equipment	IP__BUS_EQPT	1983:01-2011:12	Δln
	Industrial Production Index - Materials	IP__MATERIALS	1983:01-2011:12	Δln
	Industrial Production Index - Durable Goods Materials	IP__DURABLE_GOODS_MATERI	1983:01-2011:12	Δln
	Industrial Production Index - Nondurable Goods Materials	IP__NONDURABLE_GOODS_MAT	1983:01-2011:12	Δln
	Industrial Production Index - Manufacturing (Sic)	IP__MANUFACTURING	1983:01-2011:12	Δln
	Industrial Production Index - Residential Utilities	IP__RESIDENTIAL_UTILITIE	1983:01-2011:12	Δln
	Industrial Production Index - Fuels	IP__FUELS	1983:01-2011:12	Δln
	Napm Production Index	NAPM_PRODUCTION_INDEX	1983:01-2011:12	lv
	Capacity Utilization	CAPACITY_UTILIZATION	1983:01-2011:12	Δlv

Grouping	Variable	Acronym	Sample period	Notes
GROUP III Housing	Housing Starts:Nonfarm(1947-58);Total Farm&Nonfarm(1959-)	HOUSING_STARTS_NONFARM_1	1983:01-2011:12	ln
	Housing Starts:Northeast	HOUSING_STARTS_NORTHEAST	1983:01-2011:12	ln
	Housing Starts:Midwest	HOUSING_STARTS_MIDWEST	1983:01-2011:12	ln
	Housing Starts:South	HOUSING_STARTS_SOUTH	1983:01-2011:12	ln
	Housing Starts:West	HOUSING_STARTS_WEST	1983:01-2011:12	ln
	Housing Authorized: Total New Priv Housing Units	HOUSING_AUTHORIZED__TOTA	1983:01-2011:12	ln
	Houses Authorized by Build. Permits:Northeast	HOUSES_AUTHORIZED_BY_BUI	1983:01-2011:12	ln
	Houses Authorized by Build. Permits:Midwest	HOUSES_AUTHORIZED_BY_01	1983:01-2011:12	ln
	Houses Authorized by Build. Permits:South	HOUSES_AUTHORIZED_BY_02	1983:01-2011:12	ln
	Houses Authorized by Build. Permits:West	HOUSES_AUTHORIZED_BY_03	1983:01-2011:12	ln
GROUP IV Consumption, Orders, Inventories	Purchasing Managers' Index	PURCHASING_MANAGERS__IND	1983:01-2011:12	lv
	Napm New Orders Index	NAPM_NEW_ORDERS_INDEX	1983:01-2011:12	lv
	Napm Vendor Deliveries Index	NAPM_VENDOR_DELIVERIES_I	1983:01-2011:12	lv
	Napm Inventories Index	NAPM_INVENTORIES_INDEX	1983:01-2011:12	lv
	Mfrs' New Orders, Consumer Goods and Materials	MFRS__NEW_ORDERS__CONSUM	1983:01-2011:12	Δln
	Mfrs' New Orders, Durable Goods Industries	MFRS__NEW_ORDERS__DURABL	1983:01-2011:12	Δln
	Mfrs' New Orders, Nondefense Capital Goods	MFRS__NEW_ORDERS__NONDEF	1983:01-2011:12	Δln
	Mfrs' Unfilled Orders, Durable Goods Indus.	MFRS__UNFILLED_ORDERS__D	1983:01-2011:12	Δln
	Manufacturing and Trade Inventories	MANUFACTURING_AND_TRADE_	1983:01-2011:12	Δln
	U. of Mich. Index of Consumer Expectations	U__OF_MICH__INDEX_OF_CON	1983:01-2011:12	Δlv
	Ratio, Mfg. and Trade Inventories to Sales	RATIO__MFG__AND_TRADE_IN	1983:01-2011:12	Δlv

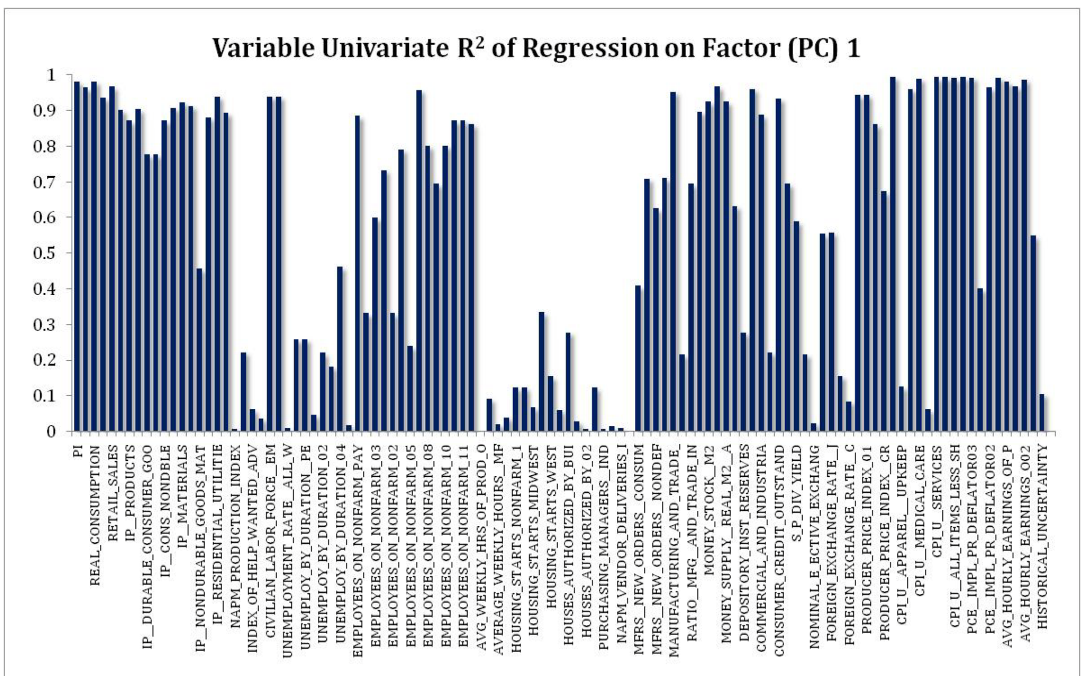
- Only add 3 topical series:

1. Goldman Sachs Financial Conditions Index
2. Historical News-Based Policy Index (Baker, Bloom, Davis, 2012)
3. Liquidity Factor of Pastor and Stambaugh (2003, JPE)

The Choice of the Factors and their Interpretation

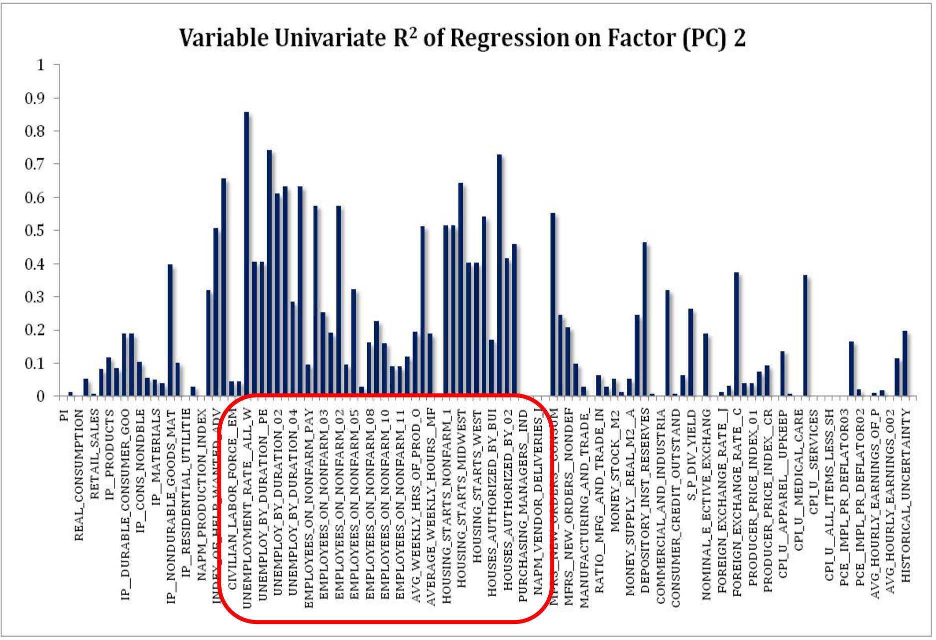
- We summarize covariance structure of the 112 macroeconomic variables using principal component analysis
- Extract 3 and 5 orthogonal factors that summarize 81% and 90% of the total variance, respectively

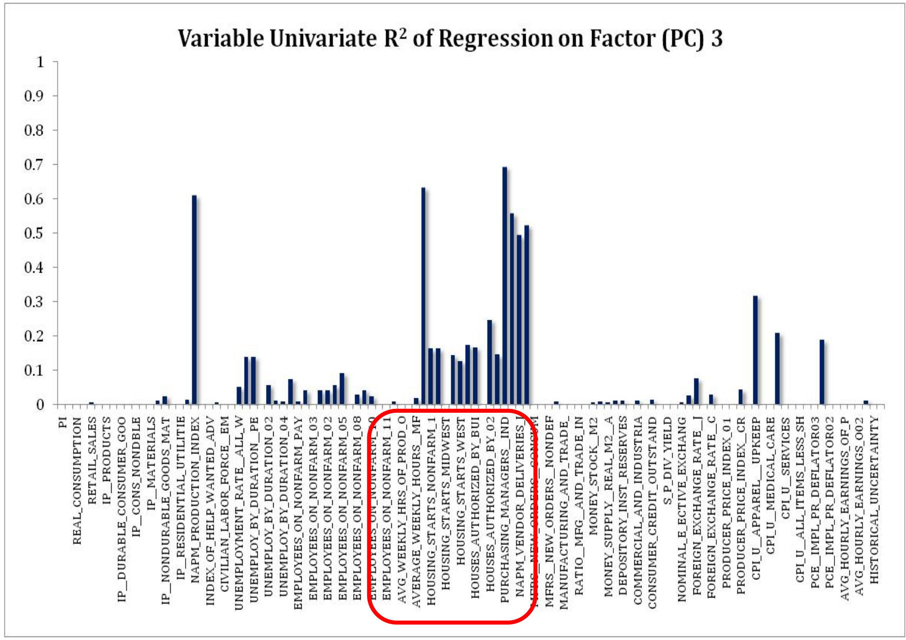
Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	61.8270	40.5546	0.5520	61.827	0.552
2	21.2724	13.7698	0.1899	83.0994	0.742
3	7.5026	0.9345	0.0670	90.60204	0.8089
4	6.5681	2.4623	0.0586	97.17014	0.8676
5	4.1058	1.7682	0.0367	101.276	0.9042
6	2.3376	0.9753	0.0209	103.6136	0.9251
7	1.3623	0.1069	0.0122	104.9759	0.9373
8	1.2554	0.1864	0.0112	106.2313	0.9485
9	1.0690	0.4387	0.0095	107.3003	0.958
10	0.6303	0.0922	0.0056	107.9306	0.9637



- Use univariate regression R2 and sign of factor loadings to provide interpretation
- In what follows: 3 factors
- <u>Factor 1</u>: a business cycle, pro-cyclical factor

The Choice of the Factors and their Interpretation





- <u>Factor 2</u>: a labor markets & housing factor
  - Sensible that factors 1 and 2 may be orthogonal because jobless expansions exist while short recessions have moderate effects on employment

- <u>Factor 3</u>: an inventory and new industrial orders factor
  - Different from factor 1 because anticipatory of business cycle developments

None of the more topical (and less macro-driven) factors appears to affect the first three PCs

Other Data

	Mean	Median	Std. Dev.	Skewness	Excess Kurtosis	Jarque-Bera p-value
Factor 1 (business cycle)	0.0000	0.0389	7.8630	0.0144	-1.1592	0.0001
Factor 2 (labor and housing markets)	0.0000	0.8129	4.6122	-0.7135	-0.1341	0.0000
Factor 3 (inventories and new orders)	0.0000	0.0351	2.7391	-0.0624	-0.0767	0.8399
Agricolture and Livestock	-0.0008	-0.0001	0.0419	-0.0811	1.3465	0.0000
Precious Metals	0.0011	-0.0042	0.0493	0.1040	1.4046	0.0000
Industrial Metals	0.0020	-0.0012	0.0659	0.2815	2.7037	0.0000
Energy	0.0041	0.0036	0.0901	0.3231	1.9378	0.0000
10Y Treasury Bonds	0.0017	0.0014	0.0022	-0.0013	-0.6282	0.0531
Aaa Corporate Bonds	0.0027	0.0024	0.0022	0.0000	-0.6195	0.0574
Baa Corporate Bonds	0.0036	0.0032	0.0022	0.0190	-0.6266	0.0533
Value-weighted Equity CRSP	0.0057	0.0109	0.0456	-0.8264	2.5627	0.0000

- We use a cross section of eight portfolios of stocks, bonds, and (first generation, simple) spot commodity indices
  - Corporate bond returns are approximated as the negative of yield changes for 10Y Moody's portfolios
  - The four commodity index return series are Standard & Poor's/Goldman Sachs spot
  - These series are built using front-end futures, closest to expiry
  - We have verified the correlation of these series with SPGS total return series (that use longer futures maturities) and obtained correlations of 0.97 (energy), 0.99 (precious metals), 0.97 (industrial metals), and 0.94 (agric. & livestock)
  - Total return series have stronger roll and collateral components

Model Selection

Although MS models improved the maximized log-lik, information criteria lean in favor of single-state models; three-factor models are always selected over five-factor ones

		VAR order	Maximized Log-Likelihood	No. Obs.	No. Parameters	Saturation ratio	SIC	AIC	HQIC
SINGLE STATE					**Single-factor models**				
	Hansen-Singleton's consumption based	1	13106.68	3123	12	2082.00	**93.69**	**21.23**	**47.18**
	Hansen-Singleton's consumption based	6	12931.43	3123	57	438.32	455.81	113.32	234.88
					Three-factor models				
	3 factors, 2 states, full VAR model	1	12274.20	3817	40	763.40	327.55	78.53	166.45
	3 factors, 2 states, block Factor VAR	1	12211.04	3817	16	1908.50	**129.63**	**29.82**	**65.19**
	3 factors, 2 states, diagonal Factor VAR	1	12030.50	3817	10	3053.60	**80.18**	**17.76**	**39.90**
					Five-factor models				
	5 factors, 2 states, full VAR model	1	12818.37	4511	76	474.84	637.40	152.55	321.66
	5 factors, 2 states, block Factor VAR	1	12746.06	4511	36	1002.44	300.84	70.52	151.28
	5 factors, 2 states, diagonal Factor VAR	1	12430.42	4511	16	2255.50	132.60	30.09	66.13
2 STATES					**Single-factor models**				
	Hansen-Singleton's consumption based	1	13481.33	3123	26	960.92	206.29	49.53	105.51
	Hansen-Singleton's consumption based	6	13188.77	3123	116	215.38	930.52	238.15	480.90
					Three-factor models				
	3 factors, 2 states, full VAR model	1	12447.58	3817	82	372.39	673.91	165.28	343.66
	3 factors, 2 states, block Factor VAR	1	12382.75	3817	34	898.12	278.05	66.28	141.12
	3 factors, 2 states, diagonal Factor VAR	1	12284.88	3817	22	1388.00	179.10	41.93	90.50
					Five-factor models				
	5 factors, 2 states, full VAR model	1	12965.86	4511	154	234.34	1293.69	316.85	653.91
	5 factors, 2 states, block Factor VAR	1	12865.49	4511	74	487.68	620.56	148.41	313.13
	5 factors, 2 states, diagonal Factor VAR	1	12663.06	4511	34	1061.41	284.02	66.47	142.77
3 STATES					**Single-factor models**				
	Hansen-Singleton's consumption based	1	13642.62	3123	42	594.86	335.01	82.22	172.21
					Three-factor models				
	3 factors, 3 states, full VAR model	1	12663.72	3817	126	242.35	1036.75	258.27	529.29
	3 factors, 2 states, block Factor VAR	1	12455.31	3817	38	86.75	311.03	74.42	157.99
	3 factors, 2 states, diagonal Factor VAR	1	12264.17	3817	26	138.8	212.09	50.04	107.38

Model Estimates: Markov Switching SDF Model

Well defined regime dynamics and state-dependent characterization of conditional means, variances, and covariances; regimes are highly persistent

	Regime 1						Regime 2				Δ Coeff.
	Coefficient	Std. Error	t-Statistic	P-value			Coefficient	Std. Error	t-Statistic	P-value	
	Factor VAR Coefficients and Estimated Transition Matrix										
Factor 1: AR(1) Coeff.	0.9980	0.0012	861.831	0.000	**Transition Matrix**		0.9964	0.0043	231.219	0.000	0.002
Factor 1: AR(1) Intercept	0.0772	0.0082	9.461	0.000	0.992	0.008	0.1173	0.0455	2.577	0.010	-0.040
Factor 2: AR(1) Coeff.	0.9882	0.0054	183.129	0.000	0.013	0.987	0.9899	0.0034	294.603	0.000	-0.002
Factor 2: AR(1) Intercept	0.0666	0.0226	2.946	0.003			-0.2168	0.0263	-8.245	0.000	0.283
Factor 3: AR(1) Coeff.	0.9651	0.0099	97.024	0.000	**Implied Durations**		0.9046	0.0101	89.654	0.000	0.060
Factor 3: AR(1) Intercept	-0.0061	0.0319	-0.190	0.849	Regime 1:	130.6	0.0187	0.0339	0.552	0.581	-0.025
SDF: Loading on Factor 1	0.0004	0.0000	9.346	0.000	Regime 2:	77.0	-0.0009	0.0002	-4.510	0.000	0.001
SDF: Loading on Factor 2	-0.0003	0.0001	-3.638	0.000	**Ergodic Probs.:**		-0.0006	0.0001	-7.560	0.000	0.000
SDF: Loading on Factor 3	0.0002	0.0001	3.179	0.002	Regime 1:	0.629	0.0015	0.0001	11.549	0.000	-0.001
SDF: Intercept	0.0018	0.0002	7.198	0.000	Regime 2:	0.371	0.0109	0.0018	5.938	0.000	-0.009

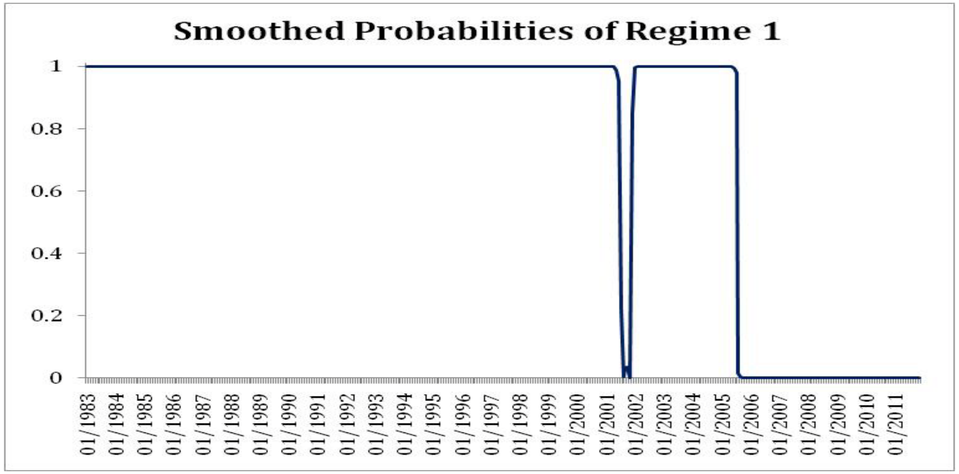
Residual Covariance Matrix of factors and test assets (Regime 1 above; regime 2 below)

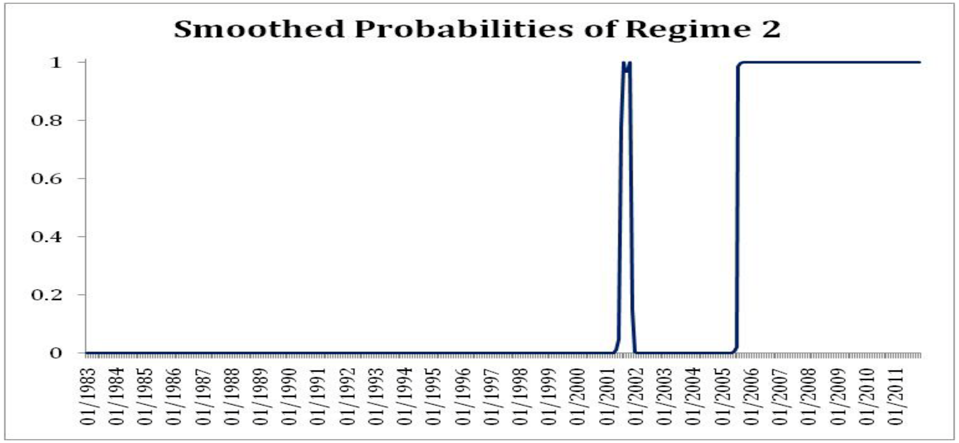
	Factor 1	Factor 2	Factor 3	Agr. & Livestock	Precious	Industrials	Energy	10Y Treasuries	Aaa Corporate	Baa Corporate	VW CRSP
Factor 1	0.019 | 0.043	-0.0143	-0.0208	-0.0001	0.0001	0.0011	0.0019	0.0000	0.0000	0.0000	-0.0002
Factor 2	0.0305	0.173 | 0.276	0.1346	0.0001	0.0014	0.0010	-0.0022	0.0001	0.0001	0.0001	-0.0008
Factor 3	0.0412	0.2593	0.360 | 0.554	0.0011	0.0007	0.0041	0.0035	0.0001	0.0001	0.0001	-0.0001
Agricolture & Livestock	0.0023	0.0045	0.0054	0.001 | 0.004	0.0002	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001
Precious Metals	0.0012	-0.0048	0.0000	0.0016	0.002 | 0.004	0.0006	0.0006	0.0000	0.0000	0.0000	-0.0001
Industrial Metals	0.0043	0.0157	0.0249	0.0022	0.0016	0.004 | 0.006	0.0003	0.0000	0.0000	0.0000	0.0004
Energy	0.0046	0.0106	0.0215	0.0023	0.0019	0.0037	0.008 | 0.008	0.0000	0.0000	0.0000	-0.0004
10Y Treasury Bonds	-0.0003	-0.0012	-0.0016	0.0000	0.0000	-0.0001	0.0000	0.001 | 0.001	0.0000	0.0000	0.0000
Aaa Corporate Bonds	-0.0003	-0.0011	-0.0015	0.0000	0.0000	-0.0001	0.0000	0.0000	0.001 | 0.001	0.0000	0.0000
Baa Corporate Bonds	-0.0003	-0.0011	-0.0015	0.0000	0.0000	-0.0001	0.0000	0.0000	0.0000	0.001 | 0.001	0.0000
VW Equity CRSP	0.0021	0.0084	0.0106	0.0011	0.0003	0.0023	0.0021	0.0000	0.0000	0.0000	0.002 | 0.003

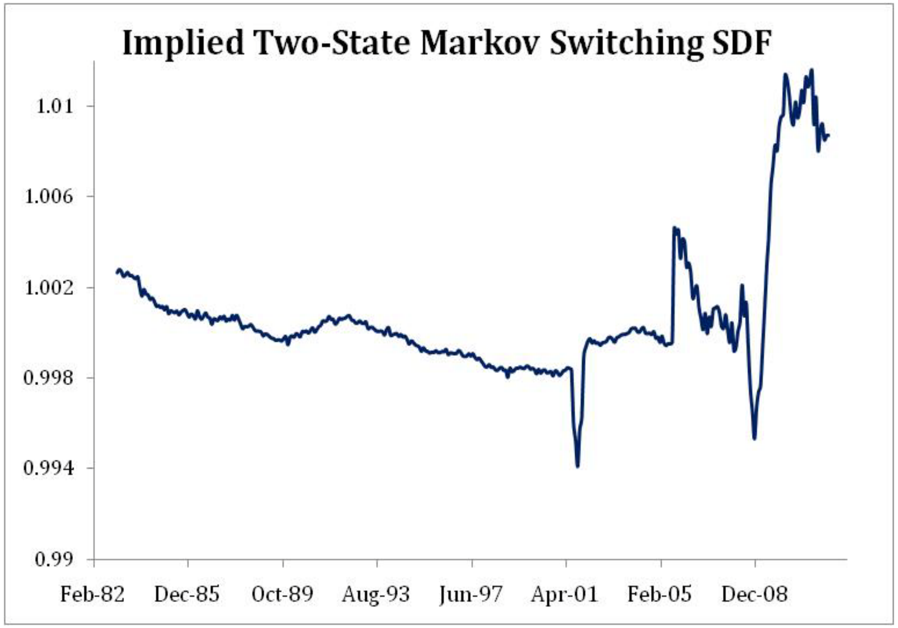
- Regime 2 implies higher variances, correlations and lower mean asset returns
- Regime 2 may be characterized as a state of crisis with a different SDF

Model Estimates: Markov Switching SDF Model

Both the financialization of commodities and the 2007-2009 (11?) seem to be captured by regime 2; the SDF is higher during crisis period consistent with IMRS-type stories







Model Estimates: Single-State Diagonal VAR

The single-state model is highly parsimonious; it yields SDF γ coefficient estimates that are not (probability-weighted) averages of the MS estimates, but signs are identical

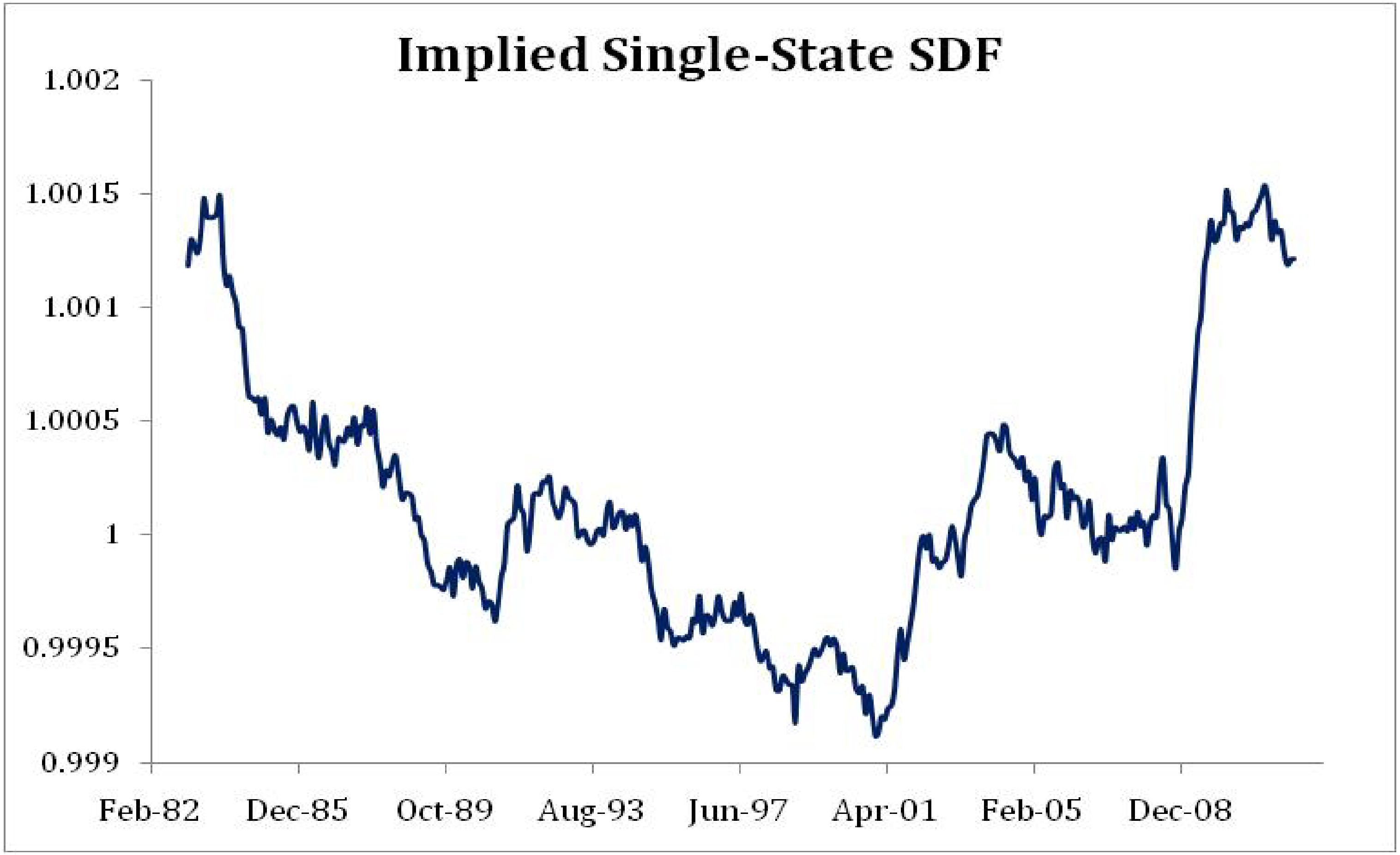
	Regime 1				Regime 2				Δ Coeff.
	Coefficient	Std. Error	t-Statistic	P-value	Coefficient	Std. Error	t-Statistic	P-value	
Factor VAR Coefficients									
Factor 1: AR(1) Coeff.	1.0002	0.0010	976.248	0.000	—	—	—	—	—
Factor 1: AR(1) Intercept	0.0784	0.0082	9.618	0.000	—	—	—	—	—
Factor 2: AR(1) Coeff.	1.0011	0.0045	223.270	0.000	—	—	—	—	—
Factor 2: AR(1) Intercept	-0.0043	0.0241	-0.179	0.858	—	—	—	—	—
Factor 3: AR(1) Coeff.	0.9531	0.0101	94.096	0.000	—	—	—	—	—
Factor 3: AR(1) Intercept	-0.0095	0.0329	-0.289	0.773	—	—	—	—	—
SDF: Loading on Factor 1	0.0002	0.0000	9.006	0.000	—	—	—	—	—
SDF: Loading on Factor 2	-0.0001	0.0000	-2.328	0.020	—	—	—	—	—
SDF: Loading on Factor 3	0.0001	0.0001	1.915	0.056	—	—	—	—	—
SDF: Intercept	0.0014	0.0002	7.003	0.000	—	—	—	—	—

Residual Covariance Matrix of factors and test assets

	Factor 1	Factor 2	Factor 3	Agr. & Livestock	Precious	Industrials	Energy	10Y Treasuries	Aaa Corporate	Baa Corporate	VW CRSP
Factor 1	0.0249	-0.0043	-0.0082	0.0006	0.0004	0.0019	0.0025	0.0000	0.0000	0.0000	0.0004
Factor 2		0.2117	0.1617	0.0010	-0.0007	0.0044	0.0010	0.0000	0.0001	0.0001	0.0021
Factor 3			0.4018	0.0023	0.0008	0.0092	0.0080	0.0000	0.0001	0.0001	0.0025
Agricolture & Livestock				0.0018	0.0005	0.0007	0.0005	0.0000	0.0000	0.0000	0.0004
Precious Metals					0.0024	0.0009	0.0009	0.0000	0.0000	0.0000	0.0000
Industrial Metals						0.0043	0.0011	0.0000	0.0000	0.0000	0.0008
Energy							0.0081	0.0000	0.0000	0.0000	0.0003
10Y Treasury Bonds								0.0000	0.0000	0.0000	0.0000
Aaa Corporate Bonds									0.0000	0.0000	0.0000
Baa Corporate Bonds										0.0000	0.0000
VW Equity CRSP										0.0000	0.0021

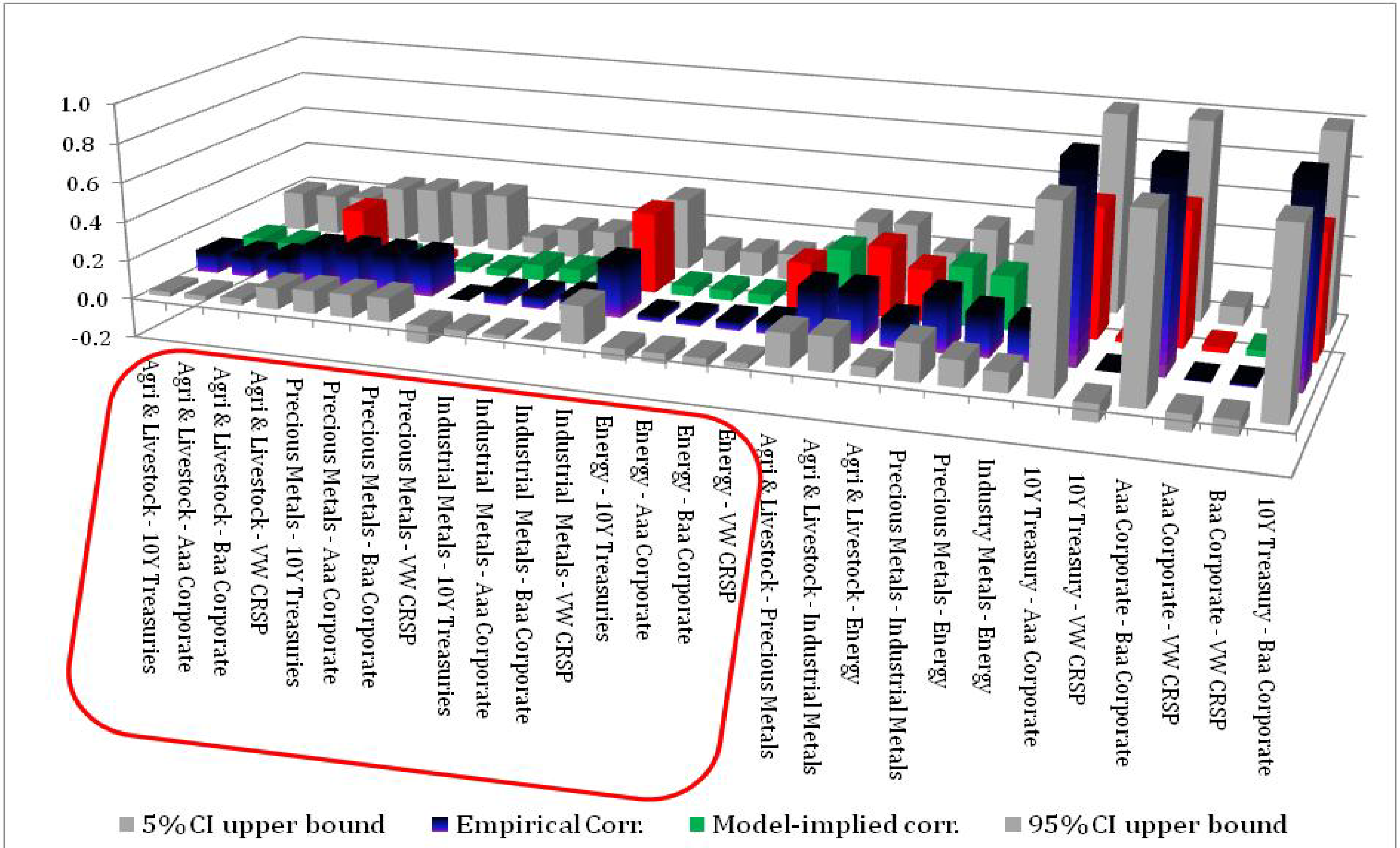
Model Estimates: Single-State Diagonal VAR

The realized time series for the SDF is not as smooth as under MS (because first part of sample is dominated by regime 1); however, the two estimated SDFs behave similarly during the crisis



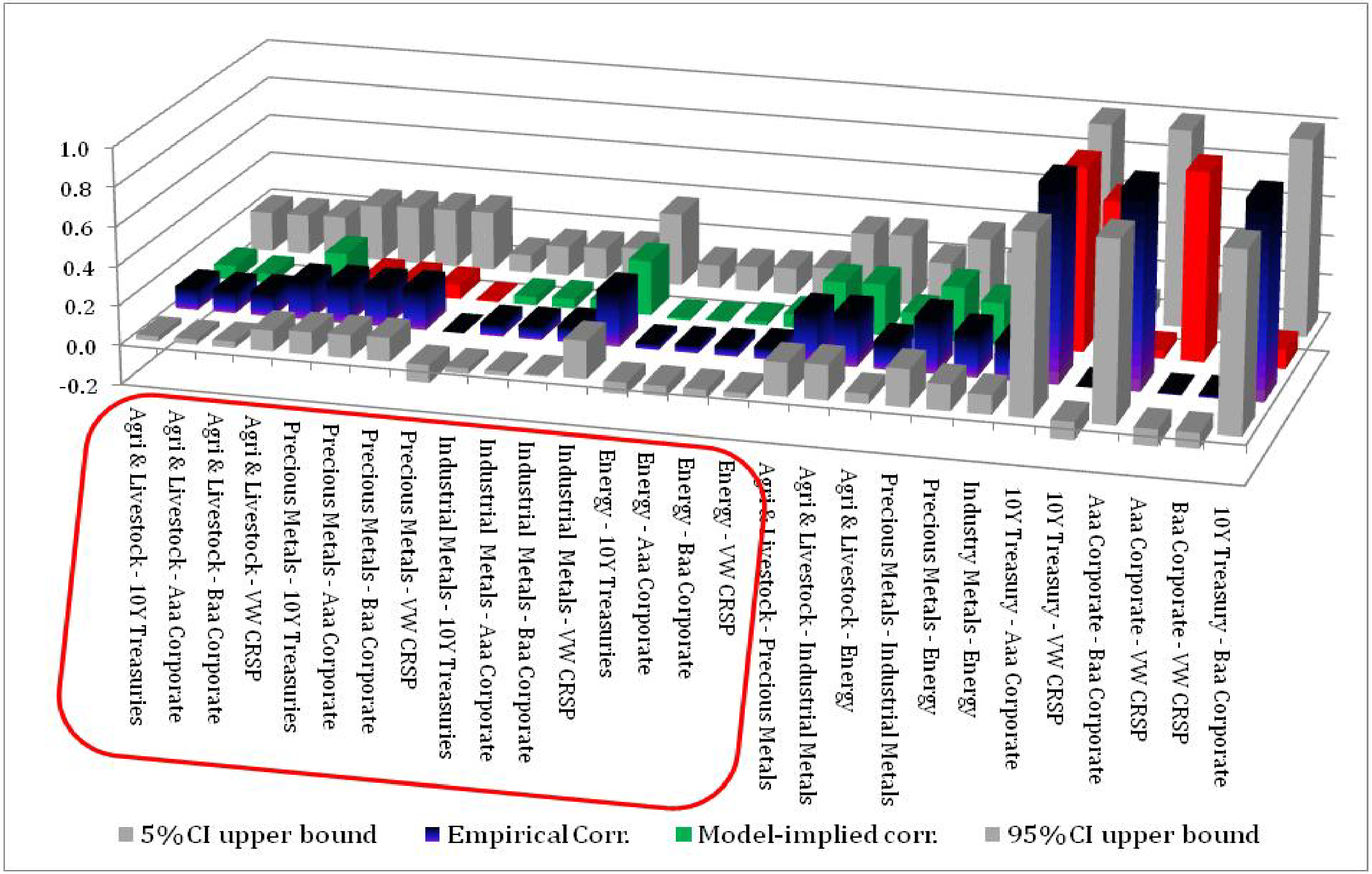
Implied Correlations: MS SDF Model

With only 6 exceptions (out of 22) most commodity-related correlations are matched by a homogeneous SDF model based on macro variables; precision is high for correlations with stocks and bonds



Implied Correlations: Single-State Diagonal VAR

Also the single-state model misses the empirical correlations involving commodities only 6 times, but the most of the correlations involving stocks and bonds are missed out!



Discussion and Concluding Thoughts

Question	Relevance	Answer
1) Can a parametric SDF only be found that explains a (simple) cross-section of stocks, bonds, commodities?	Crucial for the existence of arbitrage and/or segmentation in financial markets	Yes, and the estimated SDF that results possesses sensible IMRS-type properties
2) Can such an SDF be specified to driven by macroeconomic information only?	Traditional issue of rationality of asset prices	Yes, when macroeconomic information is summarized through a set of 3-5 PCs
3)Is there evidence of a need of additional parametric flexibility in the SDF in the form of exogenous (non-macro driven) Markov regimes?		No in a statistical perspec-tive (using information criteria); possibly, as far as matching empirical correlations is concerned
4)Is the resulting SDF a realistic one, reflecting IMRS-like dynamics?		Yes, for instance macro-based discounting ought to have increased during the financial crisis
5)Can the best fitting model match the empirical evidence on the hedging properties of commodities, within- and across-asset classes?	Important for risk and portfolio management (see e.g., Daskalaki and Skiadopoulos, 2011, JBF)	Yes, especially the correlations involving commodities, stocks, and bonds

Discussion and Concluding Thoughts

- Using a parametric SDF that distils into 3-5 orthogonal factors a large set of 112 U.S. macroeconomic variables we have evidence that such a **SDF can price the joint cross-section of stock, bond, and spot commodity returns**
  - In particular, the empirically observed correlations of commodities with stocks and bonds can be reproduced
  - Same applies to most infra-commodity correlations
  - Results important for portfolio and risk managers
  - Some **difficulties** however **in matching correlations among stocks and bonds**
- Adding Markov regimes that do not reflect macroeconomic states does not improve the statistical fit of the model
- However, **MS models produce better correlations across stocks and bonds**
- The implied SDF manifests plausible properties, for instance it climbs up during crisis regimes when real consumption growth is low and marginal utility is high
- In this framework, there is a possibility to develop an asset pricing framework that rationally prices all important asset classes under no arbitrage (i.e., under **no segmentation**)