What Information Drives Asset Prices?

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(joint with Anisha Ghosh, McGill U.)

Overview

- An overload of macroeconomic, business and political news inundates investors. Little is known as to
  - how investors cope with this vast amount of information
  - which macro information they pay the most attention to
- In the macro-finance literature investors focus on a limited number of macro variables (typically only consumption and GDP) and apply a filter to extract information about the economy
- These models fare poorly in explaining the:
  - high equity premium
  - low risk free rate
  - high variability of the *P/D* ratio
  - low corr. between the P/D ratio and consumption growth
  - low predictability of consumption growth by the *P/D* ratio

Expanding the information set to include an additional signal

- Consumption and dividend growth processes have different means in 2 latent regimes
- Each period the investor rationally updates the probability that the economy is in the first regime by observing the updated history of consumption growth and *an additional signal*
- The model explains the equity premium, risk free rate and excess volatility puzzles unlike learning from consumption history alone
- The model explains the:
  - high equity premium
  - low risk free rate
  - high variability of the *P/D* ratio
  - low corr. between the P/D ratio and consumption growth
  - low predictability of consumption growth by the *P/D* ratio

Outline

1. Literature Review
2. What is the Signal?
3. The Model
4. Data Description
5. Results
   - 2nd PC and consumption growth as signals
   - consumption growth alone as signal
6. Interpretation of the Economic Regimes
7. The Real and Nominal Term Structures
8. Conclusion

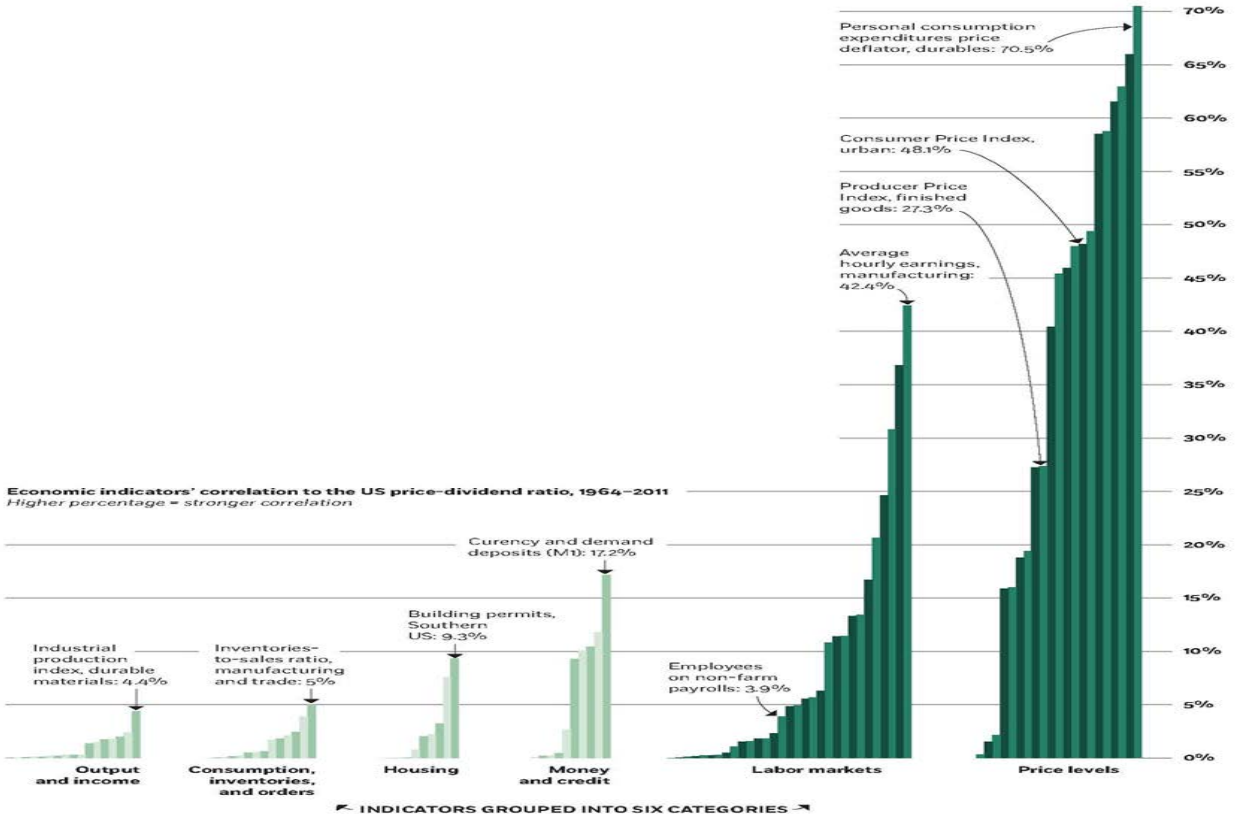
1. Literature review

- **Learning about latent states or a single parameter** Ai (2010), Ai and Bansal (2016), Bansal and Shaliastovich (2011), Croce, Lettau, and Ludvigson (2015), D'Acundo, Hoang, and Weber (2016), David and Veronesi (2013), Li (2005), Nieuwerburgh and Veldkamp (2006), Veronesi (2000), Pastor and Veronesi (2009)...
- **Model and parameter uncertainty**: Collin-Dufresne, Johannes, and Lochstoer (2016), Epstein and Schneider (2003), Hansen & Sargent (2001), Johannes, Lochstoer & Mou (2016), Klibanoff, Marinacci, Mukerji (2005) ...
- **Long run risks:** Bansal and Yaron (2004), Beeler and Campbell (2012), Constantinides and Ghosh (2011), Hansen, Heaton, and Li (2008)…

2. What is the signal?

- Most relevant macro variables :
  - price level: CPI, PPI
  - labor market: hourly earnings, hours of production, and number of employees in different sectors
- Intuition: these macro variables are persistent but consumption growth is not
- These are the 2 classes of macro variables that Bloomberg users pay the most attention to according to FactSet

R-square of univariate regressions of P/D ratio on macro variables 1964-2011



R-square of univariate regressions of P/D ratio on macro variables 1964-2011

- Similar results obtain when the regressions are run in first differences
- High negative correlation of the P/D ratio with inflation across G7 countries, except Italy
- High negative correlation of the P/D ratio with hourly earnings across G7 countries, except Italy and Japan

R-square of univariate regressions of P/D ratio on the PCs of macro variables 1964-2011

- Inflation is an unreliable signal: the negative correlation of the P/D ratio with inflation turns positive in some subperiods
- Thus we consider the principal components of the macro variables
- The R-squares of the P/D ratio on the first six PCs are 0%, **49%**, 0%, 12%, 6%, and 1%
- The 2nd PC loads heavily on price level and labor market variables
- The correlation of the P/D ratio with the 2nd PC is negative in all subperiods
- For our primary results we adopt the 2nd PC as our signal but consider other signals also

3. The Model

- Lucas exchange economy
- Epstein-Zin preferences
- The investors know the model and its parameters but not the current regime
- There are two *latent* regimes, $s(t) = 1, 2$
- Upon observing the signal history $F(t)$ at time t, investors apply Bayes' rule and calculate the probability that $s(t) = 1$

Consumption and dividend growth

- Aggregate consumption and dividend growth rates have different means in two latent regimes, *s(t)* = 1, 2:

$$\Delta c_{t+1} = \mu_{c,s_{t+1}} + \sigma_c e(c, t+1)$$
$$\Delta d_{t+1} = \mu_{d,s_{t+1}} + \sigma_d e(d, t+1)$$

where the shocks *e(c,t*+1) and e(*d,t*+1) are *i.i.d.* normal and correlated with each other

- The volatilities σ_c and σ_d are intentionally set constant across regimes, unlike in Bansal and Yaron (2004)
- *s(t)* is a Markov process with known transition matrix

Model solution

We estimate and solve the model numerically through value function iteration for the mean, variance, autocorrelation and cross-correlations of the

- consumption growth
- dividend growth
- risk free rate
- *P/D* ratio
- market return
- 2^{nd} PC

4. Data Description

- Market proxy is the CRSP value-weighted index of all stocks on the NYSE, AMEX, and NASDAQ
- Risk free rate from T-bills, CPI deflated
- Price-dividend ratio and dividend growth rate are computed from CRSP data
- Annual nominal and real yields from the Federal Reserve Bank of St. Louis website
- US consumption data from BEA
- US macro variables from Ludvigson's web site, based on *Global Insights Basic Economics Database* and *The Conference Board's Indicators Database*
- G7 macro variables from the *Global Financial Database*

5. Results

- The model has 15 parameters
- We target 22 moments:
  - unconditional mean, variance, and 1st-order autocorrelation of consumption growth, dividend growth, 2nd PC, market return, P/D ratio, and risk free rate (18)
  - corr. between consumption and dividend growth rates (1)
  - corr. between consumption growth rate and P/D ratio (1)
  - corr. between dividend growth rate and P/D ratio (1)
  - corr. between 2nd PC and P/D ratio (1)
- We estimate the model with GMM

Table 3: Learning from consumption and 2nd PC 1964-2011

Consumption and Dividends

	$E[\Delta c]$	$\sigma(\Delta c)$	$AC1(\Delta c)$	$E[\Delta d]$	$\sigma(\Delta d)$	$AC1(\Delta d)$	$\rho_{\Delta c,\Delta d}$	$\rho_{\Delta c,p/d}$	$\rho_{\Delta d,p/d}$
Data	.019	.013	.450	.010	.067	.270	.323	-.021	.108
	(.002)	(.002)	(.181)	(.011)	(.010)	(.197)	(.139)	(.156)	(.154)
Model	.014	.015	.022	.025	.142	.038	.345	.153	.194
	[.008	[.012,	[-.293	[-.040	[.111,	[-.286	[.054,	[-.214,	[-.236,
	,.019]	.018]	,.269]	,.075]	.170]	,.276]	.572]	.398]	.425]

Prices

	$E[r_f]$	$\sigma(r_f)$	$AC1(r_f)$	$E[r_m]$	$\sigma(r_m)$	$AC1(r_m)$	$E[p/d]$	$\sigma(p/d)$	$AC1(p/d)$
Data	.015	.018	.639	.046	.183	-.018	3.610	.415	.896
	(.004)	(.002)	(.150)	(.025)	(.023)	(.281)	(.102)	(.048)	(.064)
Model	.018	.001	.610	.040	.202	-.017	4.397	.450	.950
	[.016,	[.000,	[-.103,	[-.022,	[.132,	[-.353,	[3.534,	[.003,	[-.096,
	.018]	.002]	.894]	.095]	.331]	.258]	4.639]	.553]	.943]

2nd PC

	$E[2^{nd}\,PC]$	$\sigma(2^{nd}\,PC)$	$AC1(2^{nd}\,PC)$	$\rho_{2^{nd}\,PC,p/d}$
Data	.000	1.011	.758	.703
	(.231)	(.153)	(.120)	(.065)
Model	-.001	1.712	.646	.836
	[-2.635,.977]	[.800,2.089]	[-.266,.750]	[.367,.905]

Parameter Estimates

γ	ψ	δ	π_1	π_2	$\mu_{c,1}$	$\mu_{c,2}$	ρ
14.570	1.642	.990	.990	.964	.015	.010	.325
(.0004)	(.0003)	(.1012)	(.0344)	(.1107)	(.0034)	(.0096)	(.0187)

$\mu_{d,1}$	$\mu_{d,2}$	$\mu_{2^{nd}\,PC,1}$	$\mu_{2^{nd}\,PC,2}$	σ_c	σ_d	$\sigma_{2^{nd}\,PC}$
.040	-.029	.746	-2.661	.014	.140	.972
(.0279)	(.1007)	(.1893)	(.1769)	(.0418)	(.0459)	(.8325)

Table 3: Consumption and dividends 1964-2011

Consumption and Dividends									
	$E[\Delta c]$	$\sigma(\Delta c)$	$AC1(\Delta c)$	$E[\Delta d]$	$\sigma(\Delta d)$	$AC1(\Delta d)$	$\rho_{\Delta c,\Delta d}$	$\rho_{\Delta c,\mathrm{p/d}}$	$\rho_{\Delta d,\mathrm{p/d}}$
Data	.019	.013	.450	.010	.067	.270	.323	-.021	.108
	(.002)	(.002)	(.181)	(.011)	(.010)	(.197)	(.139)	(.156)	(.154)
Model	.014	.015	.022	.025	.142	.038	.345	.153	.194
	[.008	[.012,	[-.293	[-.040	[.111,	[-.286	[.054,	[-.214,	[-.236,
	,.019]	.018]	,.269]	,.075]	.170]	,.276]	.572]	.398]	.425]

- Matches mean and vol. of consumption growth
- Auto-corr. of cons. growth .475 in data is not credible because higher order auto-corr. are effectively zero
- Matches corr. of consumption and dividend growth
- Matches low corr. of cons. growth and *P/D* ratio
- Matches low corr. of div. growth and *P/D* ratio
- Misses the mean and vol. of dividend growth
- Misses auto-corr. of dividend growth (div. smoothing?)

Table 3: Prices 1964-2011

	Prices								
	$E[r_f]$	$\sigma(r_f)$	$AC1(r_f)$	$E[r_m]$	$\sigma(r_m)$	$AC1(r_m)$	$E[p/d]$	$\sigma(p/d)$	$AC1(p/d)$
Data	.015	.018	.639	.046	.183	-.018	3.610	.415	.896
	(.004)	(.002)	(.150)	(.025)	(.023)	(.281)	(.102)	(.048)	(.064)
Model	.018	.001	.610	.040	.202	-.017	4.397	.450	.950
	[.016, .018]	[.000, .002]	[-.103, .894]	[-.022, .095]	[.132, .331]	[-.353, .258]	[3.534, 4.639]	[.003, .553]	[-.096, .943]

- Matches mean, vol., and auto-corr. of risk free rate
- Matches mean, vol. and auto-corr. of market return
- Matches mean, vol. and auto-corr. of *P/D* ratio

Table 3: 2nd PC 1964-2011

	2nd PC			
	$E[2^{nd}\,PC]$	$\sigma(2^{nd}\,PC)$	$AC1(2^{nd}\,PC)$	$\rho_{2^{nd}\,PC,p/d}$
Data	.000	1.011	.758	.703
	(.231)	(.153)	(.120)	(.065)
Model	-.001	1.712	.646	.836
	[-2.635,.977]	[.800,2.089]	[-.266,.750]	[.367,.905]

- Matches mean, auto-corr., and corr. with P/D ratio
- Overstates vol. of 2nd PC

Table 3: Parameter estimates 1964-2011

Parameter Estimates

γ	ψ	δ	π_1	π_2	$\mu_{c,1}$	$\mu_{c,2}$	ρ
14.570	1.642	.990	.990	.964	.015	.010	.325
(.0004)	(.0003)	(.1012)	(.0344)	(.1107)	(.0034)	(.0096)	(.0187)
$\mu_{d,1}$	$\mu_{d,2}$	$\mu_{2^{nd}PC,1}$	$\mu_{2^{nd}PC,2}$	σ_c	σ_d	$\sigma_{2^{nd}PC}$	
.040	-.029	.746	-2.661	.014	.140	.972	
(.0279)	(.1007)	(.1893)	(.1769)	(.0418)	(.0459)	(.8325)	

- Consumption growth is not a signal: the means of cons. growth in the two regimes are similar relative to volatility
- 2nd PC is very informative: very different means in the two regimes (0, -3.5) relative to volatility (1)
- Higher means of cons. and div. growth in 1st regime
- The regimes are persistent
- Reasonable RRA and IES estimates

Table 5: Learning from consumption history alone 1964-2011

Consumption and Dividends

	$E[\Delta c]$	$\sigma(\Delta c)$	$AC1(\Delta c)$	$E[\Delta d]$	$\sigma(\Delta d)$	$AC1(\Delta d)$	$\rho_{\Delta c,\Delta d}$	$\rho_{\Delta c,\mathrm{p/d}}$	$\rho_{\Delta d,\mathrm{p/d}}$
Data	.020	.013	.513	.016	.072	.269	.253	-.046	.102
	(.002)	(.002)	(.161)	(.012)	(.010)	(.187)	(.171)	(.147)	(.137)
Model	.014	.019	.300	.018	.113	.018	.349	.129	.089
	[.000	[.013,	[-.262	[-.016	[.091,	[-.279	[.075,	[-.553,	[-.265,
	,.020]	.028]	,.645]	,.051]	.136]	,.269]	.576]	.717]	.417]

Prices

	$E[r_f]$	$\sigma(r_f)$	$AC1(r_f)$	$E[r_m]$	$\sigma(r_m)$	$AC1(r_m)$	$E[p/d]$	$\sigma(p/d)$	$AC1(p/d)$
Data	.014	.019	.680	.056	.179	-.013	3.617	.401	.891
	(.004)	(.002)	(.136)	(.023)	(.022)	(.271)	(.095)	(.047)	(.064)
Model	.018	.011	.745	.046	.114	.014	3.567	.003	.161
	[.006,	[.001,	[-.102,	[.012,	[.092,	[-.284,	[3.566,	[.001,	[-.192,
	.021]	.021]	.892]	.079]	.137]	.265]	3.569]	.005]	.558]

Parameter Estimates

γ	ψ	δ	π_1	π_2	ρ
13.536	.849	.990	.988	.801	.329
(.0021)	(.0234)	(.0560)	(.0440)	(.0721)	(.0041)

$\mu_{c,1}$	$\mu_{c,2}$	$\mu_{d,1}$	$\mu_{d,2}$	σ_c	σ_d
.016	-.034	.022	-.052	.015	.112
(.0153)	(.2217)	(.0263)	(.3073)	(.0888)	(.0331)

Table 5 interpretation

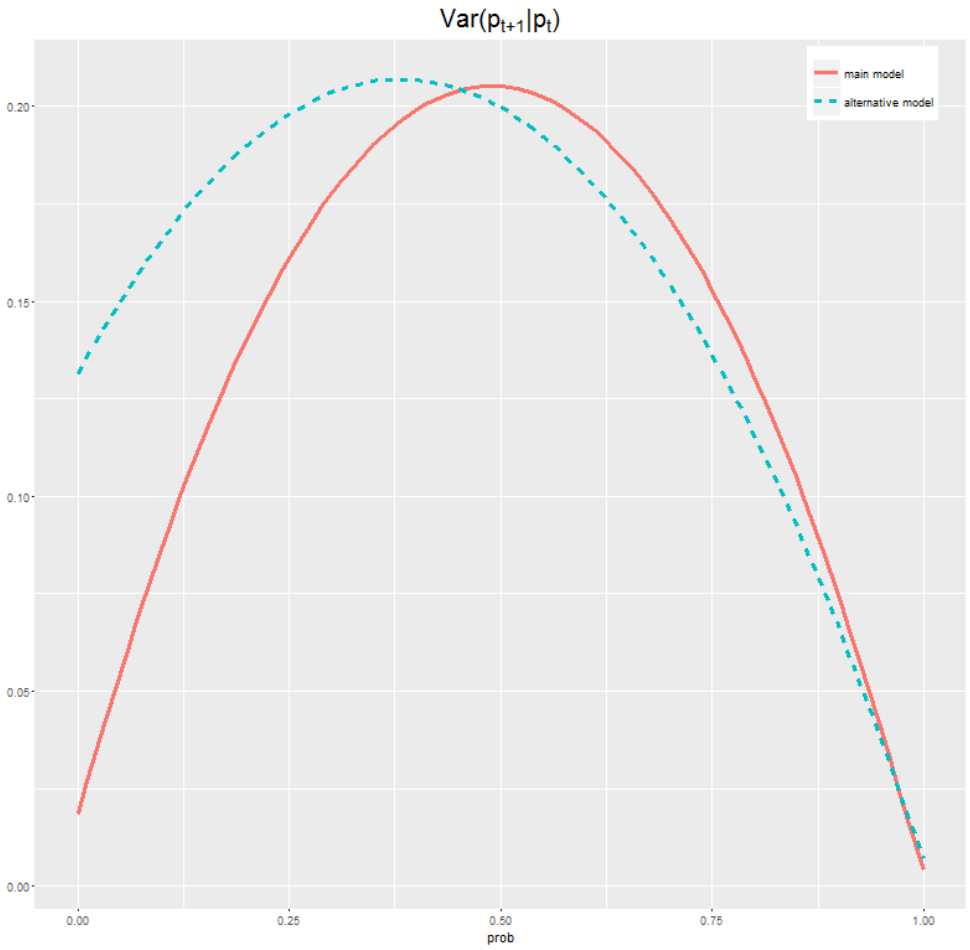
The model fails in key dimensions:

- Essentially zero volatility of the P/D ratio—fails to explain the excess volatility puzzle
- Auto-corr. of P/D ratio 0.208 versus 0.862 in data
- Consumption growth in 2nd regime is -5.7%, a drop in annual consumption that has not been observed in the US history even during the Great Depression
- Pro-cyclical market return (shown later on)

6. Interpretation of the Economic Regimes

- We extract the time series of the beliefs process from the observed P/D ratio and risk free rate
- 2nd PC is an informative signal but is only modestly correlated with the business cycle
- Corr. of beliefs with the business cycle is -24% (and for the alternative model is 0.6%)
- Thus the regimes are loosely matched to recessions and expansions

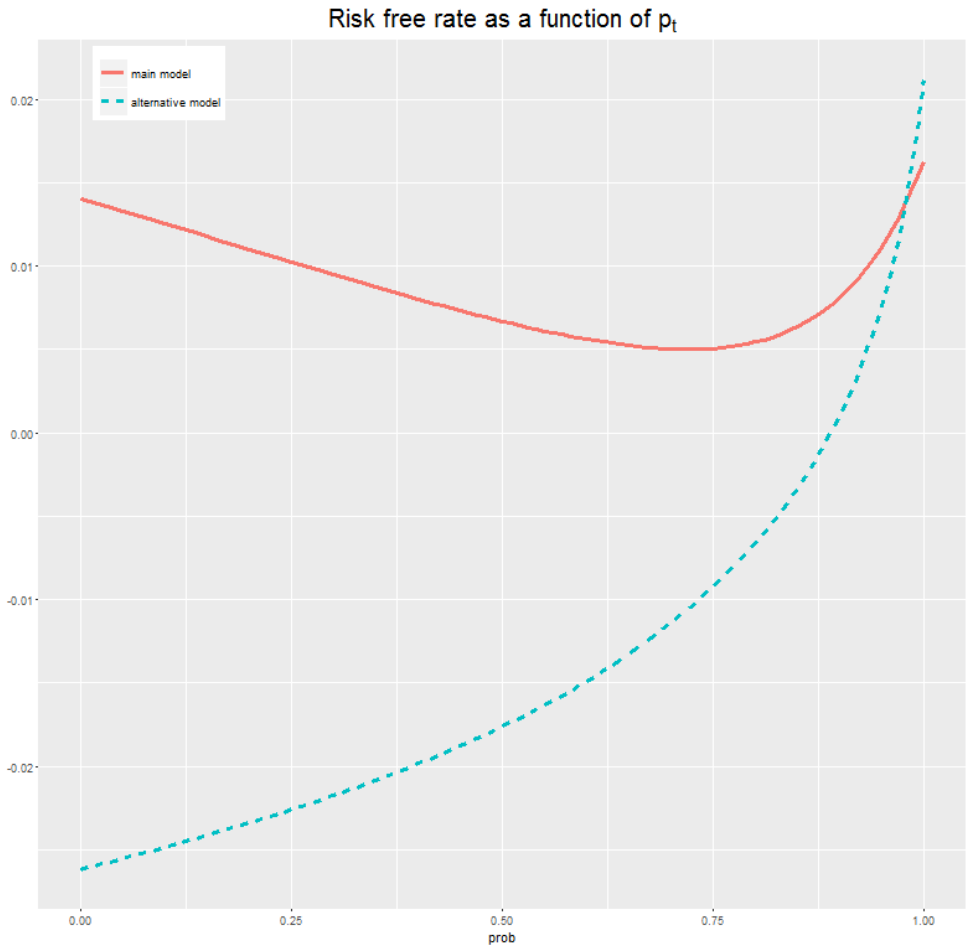
Beliefs process



Beliefs process

- High uncertainty about the future when the probability is around 0.5 that declines as the probability approaches its boundaries
- This generates non-linearities in the price-dividend ratio, expected market return, and conditional variance of the market return

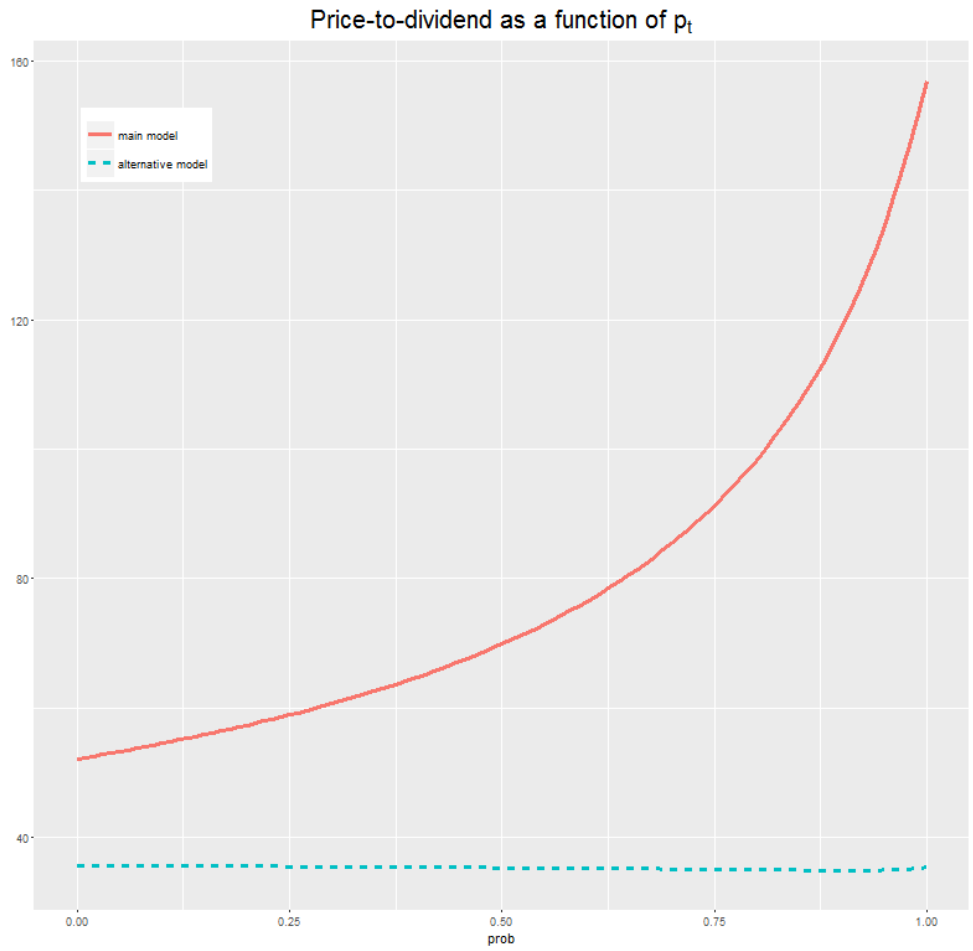
Risk free rate



Risk free rate

- Risk free rate is U-shaped
- At intermediate probabilities the uncertainty is highest and interest rate is low (flight to safety)
- In the alternative model the risk free rate is monotonically increasing

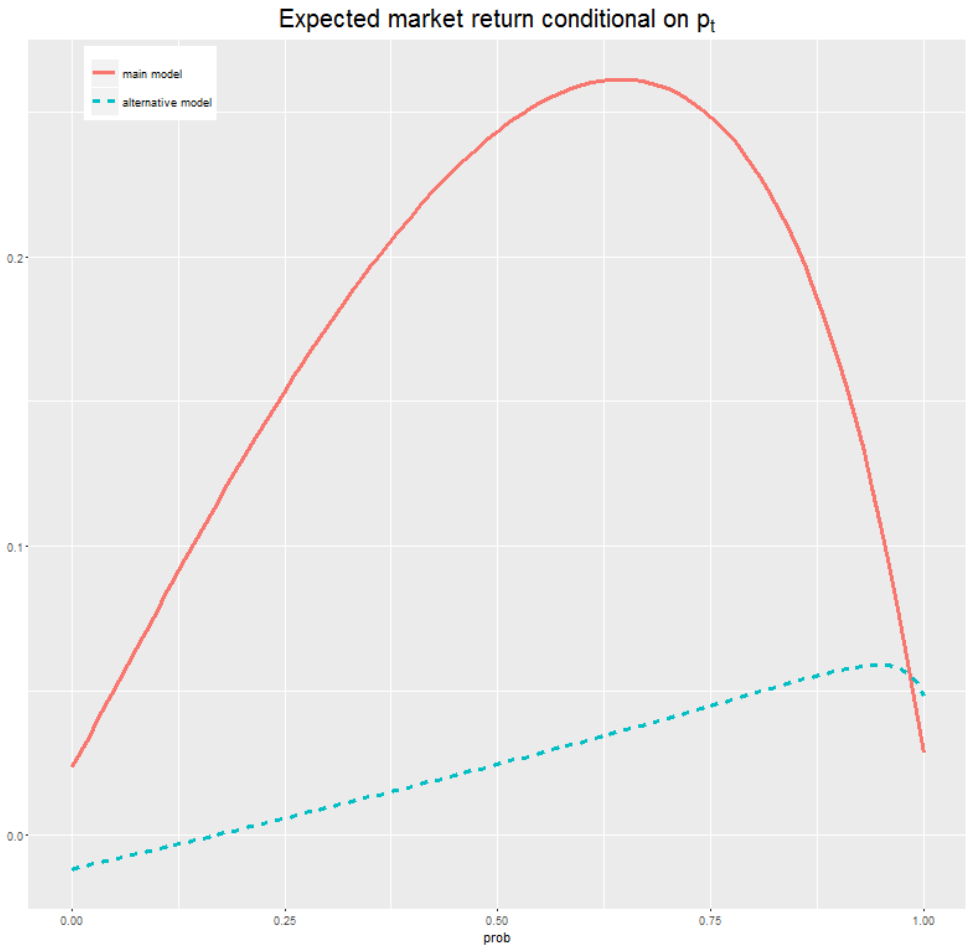
P/D ratio


Price-to-dividend as a function of p_t
160
120
80
40
main model
alternative model
0.00
0.25
0.50
0.75
1.00
prob

P/D ratio

- The P/D ratio is sharply increasing and convex
- In the alternative model the P/D ratio is flat because the current beliefs are not very informative about the future. The model does not generate the observed volatility of the P/D ratio

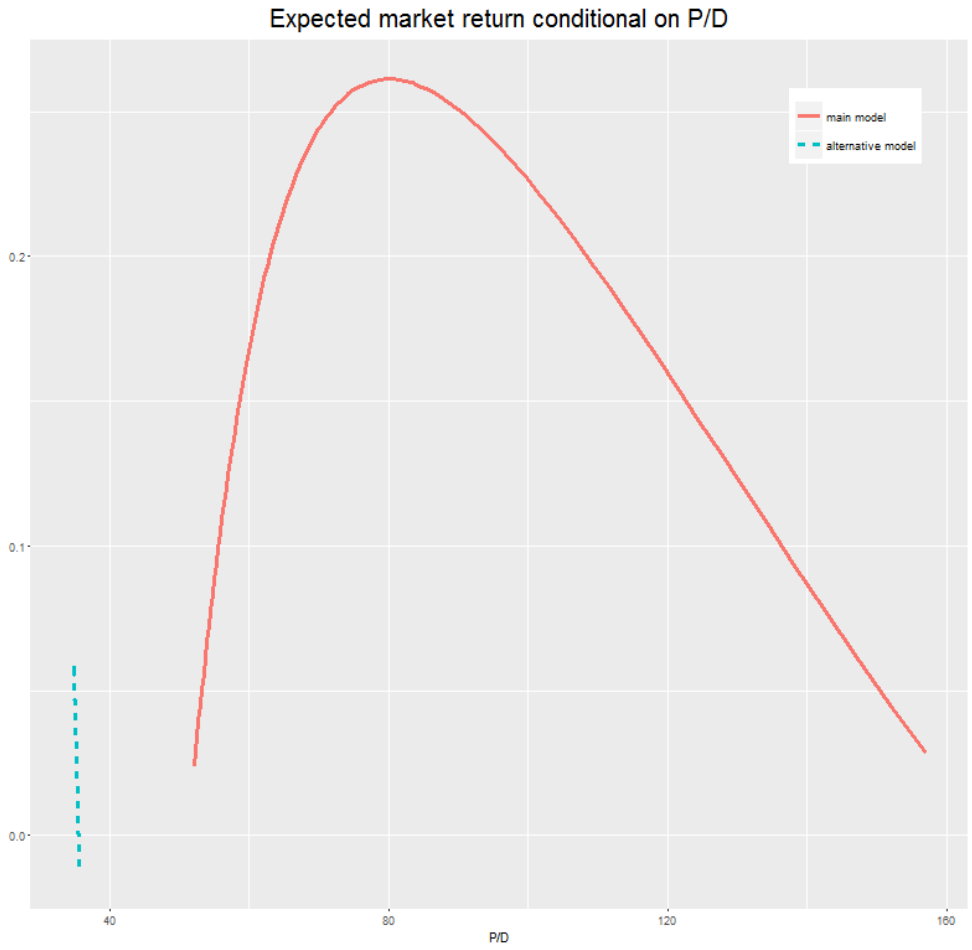
Expected market return



Expected market return

- Uncertainty about the current regime is highest when the probability is away from its boundaries and therefore expected return is highest
- In the alternative model the expected market return is increasing in the probability leading to the counterfactual prediction of procyclical expected market return

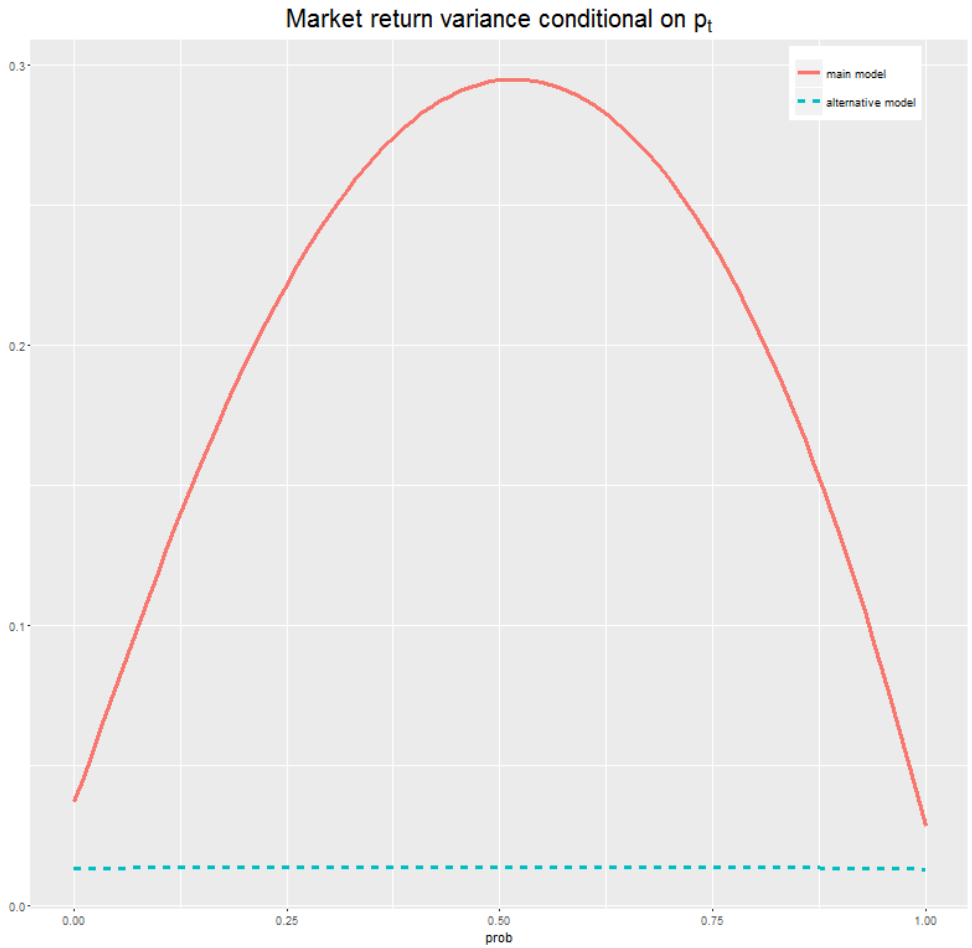
Expected market return as a function of the P/D ratio



Expected market return as a function of the P/D ratio

- The expected market return is strongly concave in the P/D ratio
- This pattern is unlike the common practice of predicting the market return with the price-dividend ratio with a linear regression
- In the alternative model the plot makes no sense because the P/D ratio is insensitive to changes in the probability

Market return variance



Market return variance

- Uncertainty about the current regime is highest when the probability is away from its boundaries and therefore market return variance is highest
- In the alternative model the market return variance is flat in the probability

7. Real and Nominal Term Structures

Average Nominal Yields 1964-2013							
	1-year	2-year	3-year	5-year	7-year	10-year	30-year
Mean	0.055	0.059	0.059	0.061	0.066	0.065	0.073
Vol	0.032	0.035	0.030	0.029	0.029	0.027	0.028

Model-Implied Average Nominal Yields							
	1-year	2-year	3-year	5-year	7-year	10-year	30-year
Mean	0.058	0.058	0.059	0.060	0.062	0.063	0.069
Vol	0.022	0.021	0.021	0.020	0.019	0.018	0.013

Average Real Yields 1964-2013					
	5-year	7-year	10-year	20-year	30-year
Mean	0.008	0.011	0.014	0.017	0.012
Vol	0.012	0.010	0.009	0.007	0.005

Model-Implied Average Real Yields					
	5-year	7-year	10-year	20-year	30-year
Mean	0.015	0.015	0.015	0.015	0.015
Vol	0.001	0.001	0.001	0.001	0.000

Term structure discussion

- This is a challenging test because yields beyond one year are not targets in the estimation
- For all maturities the model-implied nominal yields closely match the data
- More importantly for all maturities the model-implied real yields closely match the data, a feat that eludes many alternative models

8. Conclusion

- The poor performance of some macro-finance learning models may be driven by the stringent assumption that investors learn from the consumption history alone
- We present a model of a real exchange economy with rational learning about the economic regime from the consumption history and the 2nd PC (or CPI growth or earnings per hour growth)

Conclusion continued

The model (unlike the learning from consumption alone model) rationalizes the

- high equity premium
- low risk free rate
- excess volatility of the *P/D* ratio
- dynamic behavior of consumption and dividend growth rates and returns across economic regimes
- low corr. between the P/D ratio and consumption growth
- low predictability of consumption growth by the *P/D* ratio
- The real and nominal term structures

THANK YOU!