Duration-Based Stock Valuation: Reassessing Stock Market Performance and Volatility

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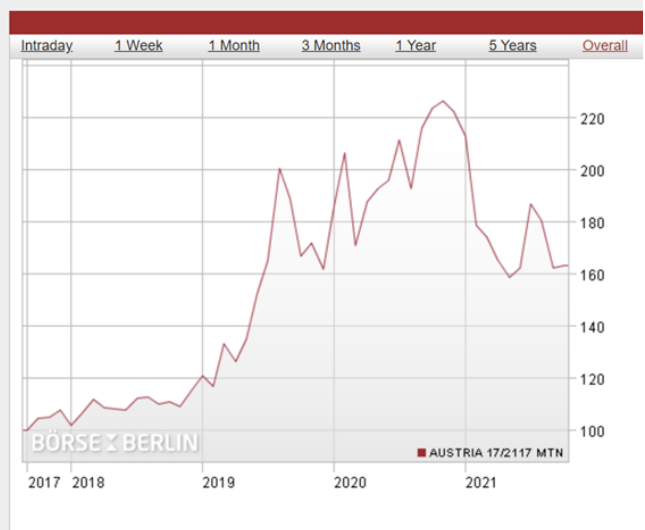
Motivation: What Financial Instrument is This?



Motivation

- On Sep 20th 2017, the Austrian government issued a 100-year par bond with a coupon rate of 2.1% and a duration of 42.5 years.
- Duration profile of this bond is similar to that of a stock index with a dividend yield of 2.1%.
- In 3.5 years time it more than doubled in price and its yield dropped to about 0.5% leading to a duration of 56 years. Today its value is $180 with a yield of 1.1%. Very large price volatility.
- Austrian stock index did not gain value over the same 3.5 year time period.

Bond Price and Duration

- Computing the price of this bond (annual coupons) at issuance using zero coupon yield curve:

$$\begin{aligned} P_t &= \sum_{n=1}^{99} \frac{C}{(1+y_{t,n})^n} + \frac{C+F}{(1+y_{t,n})^{100}} \\ &= \sum_{n=1}^{99} \frac{2.1}{(1+y_{t,n})^n} + \frac{102.1}{(1+y_{t,n})^{100}} \end{aligned}$$

- Price at issuance using yield-to-maturity (bond issued at par):

$$\begin{aligned} P_t &= \sum_{n=1}^{99} \frac{C}{(1+YTM_t)^n} + \frac{C+F}{(1+YTM_t)^{100}} \\ &= \sum_{n=1}^{99} \frac{2.1}{(1.021)^n} + \frac{102.1}{(1.021)^{100}} \\ &= 100 \end{aligned}$$

Bond Price and Duration

- Now define the importance (weight) of each coupon in the price as:

$$w_{t,n} = \frac{\frac{C}{(1+YTM_t)^n}}{P_t} = \frac{0.021}{1.021^n} \text{ for } n < 100.$$

- We can think of a coupon bond as a portfolio of zero coupon bonds, with the portfolio weights equal to $w_{t,n}$.

- The Macaulay duration of the bond is defined as:

$$\text{Dur} = \sum_{n=1}^{100} w_{t,n} n = 42.5.$$

- Duration approximates the change of the bond value for a 1 percentage point change in the YTM (risk management tool).

Weighting Scheme in 100-year Austrian Government Bond

- Weighting scheme $w_{t,n}$ at issuance:

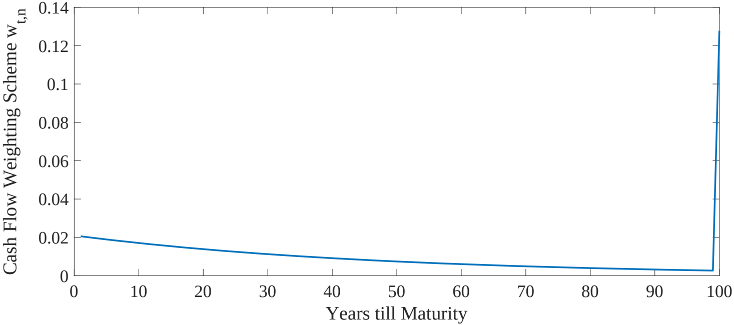


Figure: **Weighting Scheme 100-year Austrian Bond**

Weighting Scheme in 100-year Austrian Government Bond

- Cumulatve weighting scheme $w_{t,n}$ at issuance:

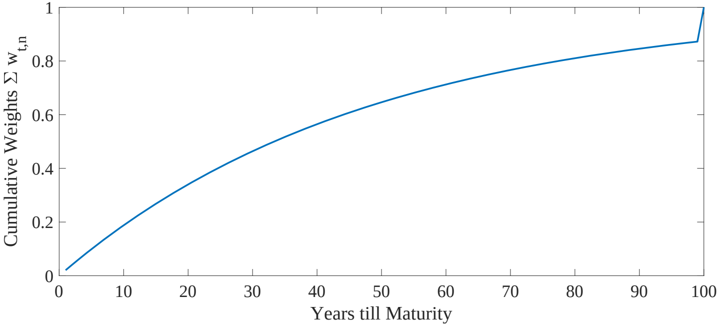


Figure: **Cumulative Weighting Scheme 100-year Austrian Bond**

Summary of Austrian Bond Case

- Main takeaways:
  1. Secular downward trend in interest rates for the past 50 years around the world.
  2. Even very long-maturity bond yields have dropped to very low levels.
  3. Decrease in rates has led to very large realized positive returns on long duration bonds $\Rightarrow$ past realized returns bad proxy for expected returns going forward.
  4. Very volatile returns on long duration bonds (more volatile than stock market): we do not need dividend risk premium variation to generate very volatile returns. Are stocks really excessively volatile?

Main Idea

- Main idea:
  1. Apply Austrian case study more broadly across time and regions.
  2. Construct a set of duration-matched nominal and real bond portfolios for stock market.
  3. How well have those bond portfolios done and with what volatility?

- Where does idea come from?
  1. Dividend futures contracts: exchange variable dividend for fixed nominal amount
  2. Defined Benefit pension plans: exchange risky asset portfolio for fixed pension benefits

- Interest rates have been on a secular decline around the world.

- All else equal, shocks lead to valuation windfalls for all long-duration assets, but all else is never equal...

Not Just Nominal Yields: UK

- Both nominal and real yields have declined.
- UK 20-year inflation-protected bonds:

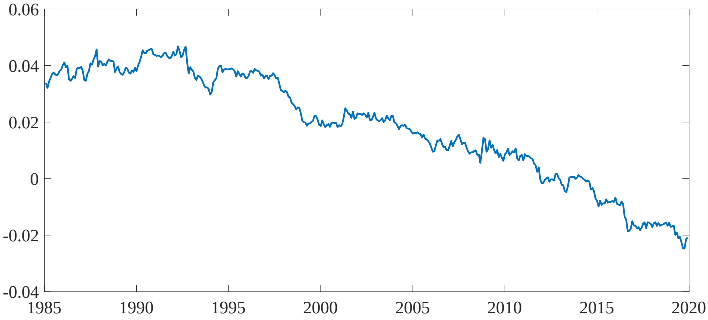


Figure: **20-year inflation-protected bond yield UK**

Motivation III: Typical MBA Bond vs Stock Slide

- Usual MBA bond pricing slide:

$$P_t = \sum_{n=1}^{N-1} \frac{C_{t+n}}{(1+y_{t,n})^n} + \frac{F + C_{t+N}}{(1+y_{t,N})^N}$$

Motivation III: Typical MBA Bond vs Stock Slide

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$$P_t = \sum_{n=1}^{N-1} \frac{C_{t+n}}{(1+y_{t,n})^n} + \frac{F + C_{t+N}}{(1+y_{t,N})^N}$$

- Usual MBA stock pricing slide:

$$P_t = \sum_{n=1}^{N-1} \frac{D_{t+n}}{(1+R)^n} + \frac{P_{t+N} + D_{t+N}}{(1+R)^N}$$

- Subscripts on discount rates have disappeared.
- R is then approximated by CAPM or other model: $y_{t,1} + \beta \times 0.06$.
- Information on term structure often thrown away.

Motivation III: Typical MBA Bond vs Stock Slide

- Instead we could use as the stock pricing slide:

$$P_t = \sum_{n=1}^{\infty} \frac{D_{t+n}}{(1 + y_{t,n} + \theta_{t,n})^n}$$

- Subscripts on discount rates are back.
- Information on term structure of interest rates is preserved.
- Same logic for computing NPV of projects or valuation of other risky projects.

Broader Research Agenda

- AP literature has focused a lot of attention on 4 puzzles:
  1. Equity premium puzzle: stocks have outperformed short-duration fixed income instrument.
  2. Excess volatility: stocks move "too" much relative to subsequent dividends.
  3. Return predictability
  4. CAPM does not work in cross-section of returns
- All four puzzles already emerge when pricing a single short-term dividend strip (BBK2012, BHKV2015, BK2017).
- Models that fix these puzzles only for the market (long duration) but not for strips may not use the right mechanism.
- This paper does not focus on short-term but rather raises additional questions about the puzzles at the long end.

Stripping the Stock Market

- Let $\mathcal{P}_{t,n}$ denote the PV at t of expected dividend paid at $t+n$.

$$\mathcal{P}_{t,n} = \frac{E_t\left[D_{t+n}\right]}{\exp\left(n\left(y_{t,n}+\theta_{t,n}\right)\right)},$$

- Stock index S_t is a portfolio that includes one unit of each div strip:

$$S_t = \sum_{n=1}^{\infty} \mathcal{P}_{t,n}.$$

- Define $w_{t,n}$ as the weight of each strip in this index portfolio:

$$w_{t,n} = \frac{\mathcal{P}_{t,n}}{S_t}.$$

- Return on the stock market is just a portfolio of dividend strip returns with $w_{t,n}$ as the portfolio weights.

Stripping the Stock Market

- The one-period return on a div strip with maturity n is:

$$R^d_{t+1,n} = \frac{\mathcal{P}_{t+1,n-1}}{\mathcal{P}_{t,n}} - 1, \text{ for } n > 1,$$
$$R^d_{t+1,n} = \frac{D_{t+1}}{\mathcal{P}_{t,n}} - 1, \text{ for } n = 1.$$

- The one-period return on the n-year bond is:

$$R^b_{t+1,n} = \frac{\exp\left(-(n-1)y_{t+1,n-1}\right)}{\exp\left(-ny_{t,n}\right)} - 1,$$

for which the conditional expectation is given by:

$$\mu^b_{t,n} = E_t R^b_{t+1,n}.$$

- Define additional expected holding period return $\psi_{t,n}$:

$$\psi_{t,n} \equiv E_t\left[R^d_{t+1,n}\right] - \mu^b_{t,n}.$$

- Note $\psi_{t,n}$ is different from (but related to) $\theta_{t,n}$.

The Long Duration Dividend Premium

- The one-period return on the index is given by:

$$R^s_{t+1} = \frac{S_{t+1} + D_{t+1}}{S_t} - 1.$$

- Return on the index is weighted average of returns on strips:

$$\mu^s_t = E_t\left[R^s_{t+1}\right] = \sum_{n=1}^{\infty} w_{t,n} E_t\left[R^d_{t+1,n}\right].$$

- Main object of interest in this paper:

$$\Psi_0 = E\left[E_t \sum_{n=1}^{\infty} w_{t,n}\psi_{t,n}\right] = E\left[\mu^s_t - E_t \sum_{n=1}^{\infty} w_{t,n}\mu^b_{t,n}\right].$$

- I estimate this quantity through:

$$\hat{\Psi}_0 \approx \frac{1}{T}\left[\sum_{t=1}^{T}\left[\frac{S_{t+1} + D_{t+1}}{S_t}\right] - \sum_{n=1}^{N} w_{t,n} R^b_{t+1,n}\right].$$

Data

- Global Financial Data for S&P500 index returns with and without dividends.
- U.S. zero coupon yield curves by Gurkaynak, Sack, and Wright (2006).
- Japanese zero coupon yield curves by Bank of Japan.
- Vanguard long-term government bond index fund duration (Ameriks).
- Vanguard long-term government bond index fund return data (CRSP).
- Dividend futures data from Goldman Sachs and Bloomberg

Duration of the Stock Market

- Recall formula for duration:

$$\text{Dur} = \sum_{n=1}^{\infty} w_{t,n} n.$$

- Under Gordon growth assumptions the n-th dividend strip value is given by:

$$\mathcal{P}_{t,n} = D_t \left(\frac{1+g}{1+\mu^s} \right)^n$$

implying a weighting scheme equal to:

$$w_{t,n} = \left(\frac{\mu^s - g}{1+\mu^s} \right) \left(\frac{1+g}{1+\mu^s} \right)^{n-1}$$

and a duration equal to:

$$\text{Dur} = \sum_{n=1}^{\infty} w_{t,n} n = \frac{1+\mu^s}{\mu^s - g}.$$

Net Stock Repurchases

	Dividend Yield	Total Net Payout Yield
1970-2020	2.79%	1.09%
1996-2020	1.90%	-0.09%

S&P500 vs Constant Maturity Bonds

Maturity in years	FF	1	2	5	10	15	20	25	30	S&P500
Mean (%)	0.17	0.23	0.28	0.42	0.58	0.68	0.77	0.85	0.96	0.86
St. Dev. (%)	0.17	0.26	0.48	1.30	2.58	3.71	4.67	5.59	6.73	4.41
Mean log (%)	0.17	0.23	0.28	0.41	0.55	0.62	0.67	0.71	0.75	0.75

Table: **Monthly Returns on Constant Maturity Zero Coupon Bonds in Percent Between January 1996-April 2021**

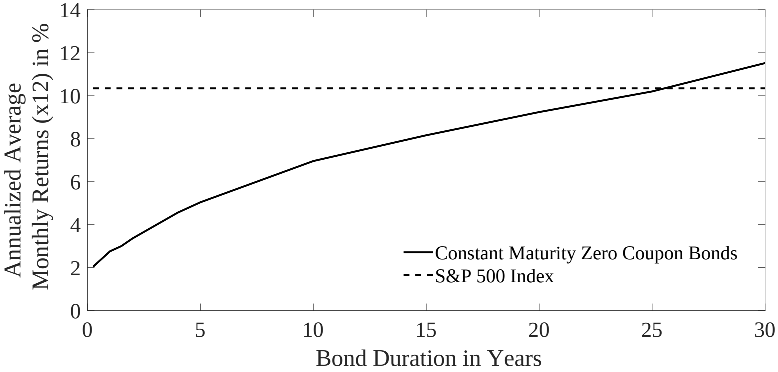


Figure: **Annualized Average Monthly Returns US: 1996-2021**

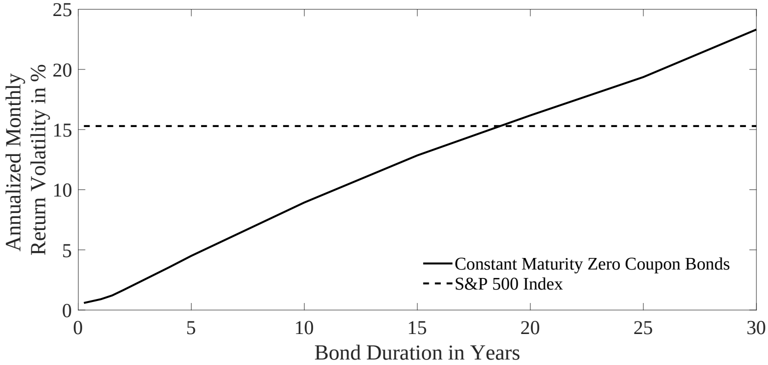


Figure: **Annualized Monthly Return Volatility US: 1996-2021**

S&P500 vs Constant Maturity Bonds

Duration in years	15	20	25	30
$\hat{\mu}^s - \hat{\mu}^b$ (% Monthly)	0.18	0.09	0.01	-0.10
t-stat on difference	0.50	0.23	0.02	-0.19
$12(\hat{\mu}^s - \hat{\mu}^b)$ (% Annual))	2.16	1.14	0.09	-1.20
Annualized difference in mean log returns (%)	1.59	0.99	0.48	-0.03

Table: **Monthly Return Differences between the S&P500 and Constant Maturity Zero Coupon Bonds January 1996-February 2021.**

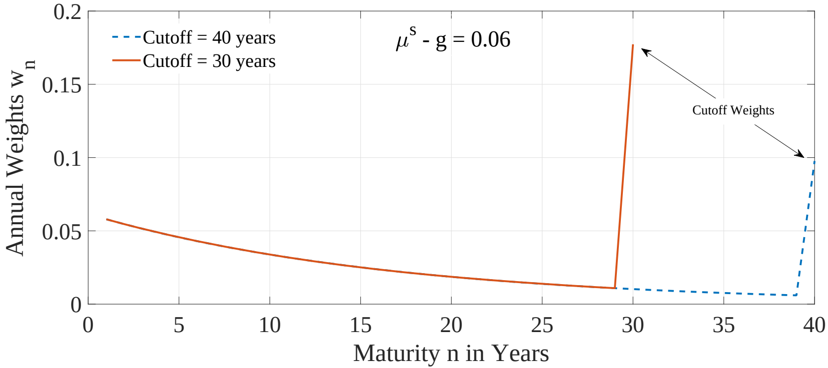


Figure: **Gordon Growth Strip Weights by Year: High Dividend Yield**

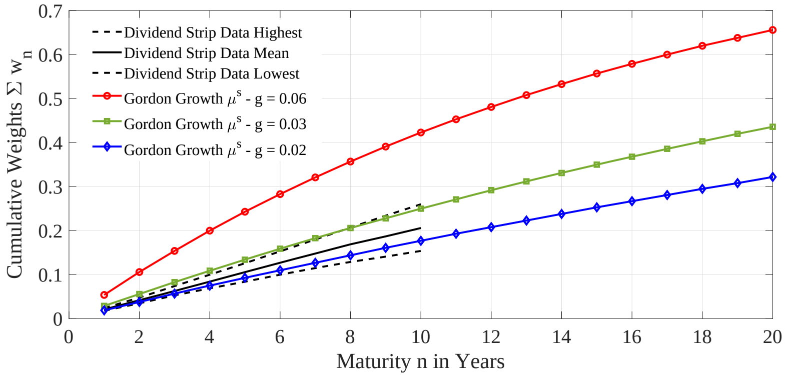


Figure: **Cumulative Strip Weights by Maturity: Data vs Models**

Evaluating 8 Counterfactuals

Counterfactual	I	II	III	IV	V	VI	VII	VIII
$\mu^s - g$	0.06	0.06	0.03	0.03	0.02	0.02	D_t/S_t	D_t/S_t
Cutoff month	360	480	360	480	360	480	360	480
Duration (Dur)	14.0	15.3	19.9	23.4	22.6	27.6	TV	TV
$\sum w_{t,n}\mu^b_{t,n}$ (% Monthly)	0.62	0.67	0.75	0.89	0.81	1.00	0.81	1.01
Std. Dev.	3.13	3.45	4.42	5.54	5.05	6.78	5.04	6.84
$12\hat{\Psi}_0$ (% Annual)	2.96	2.38	1.39	-0.27	0.68	-1.69	0.67	-1.73
Annual mean diff log rets	2.22	1.78	1.23	0.27	0.86	-0.27	0.84	-0.26

Table: **Strip-Replicating Portfolios 1996-2020.**

Long Sample

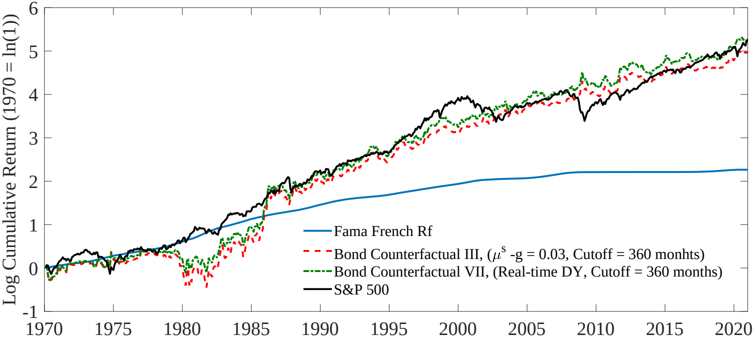
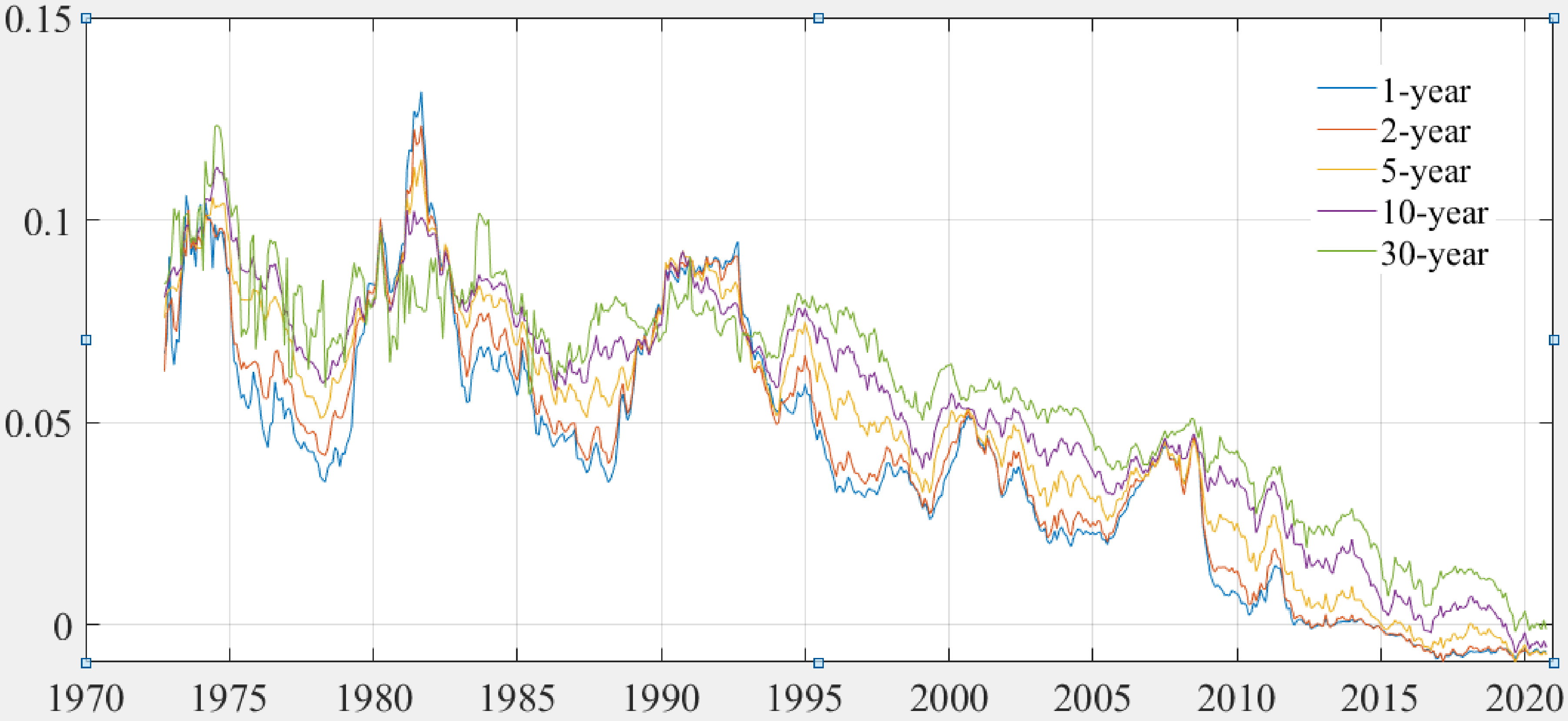


Figure: **S&P500 versus Bond-Replicating Portfolio and FF: Log Scale**

European (German) Bond Yields



Mat. in years	1	2	5	10	15	20	25	30	Eurostoxx
Sample: 1996-2021									
Mean (%)	0.16	0.21	0.36	0.57	0.73	0.87	1.05	1.21	0.67
St. Dev. (%)	0.22	0.40	0.98	1.89	2.88	3.91	5.00	6.25	5.28
Mean log (%)	0.16	0.21	0.36	0.55	0.69	0.80	0.91	1.02	0.53
Sample: 1972-2021									
Mean (%)	0.37	0.42	0.54	0.67	0.81	1.03	-	-	0.83
St. Dev. (%)	0.43	0.64	1.26	2.34	4.15	7.14	-	-	4.86
Mean log (%)	0.36	0.42	0.53	0.65	0.72	0.79	-	-	0.70

Duration Vanguard's LT Government Bond Index Fund

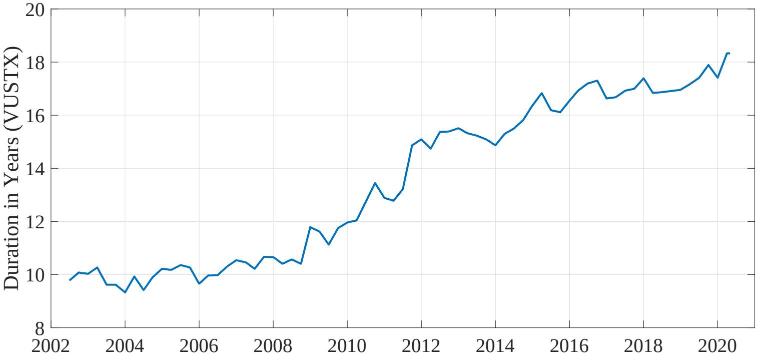


Figure: **Vanguard Long-Term Government Bond Index Fund** The graph plots the effective duration of the Vanguard Long-Term Government Bond Index Fund (VUSTX).

Replicated Returns Vanguard LT Gov Bond Index Fund

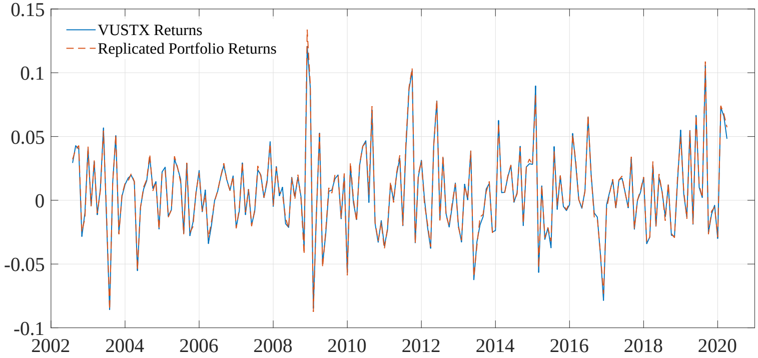


Figure: **Vanguard Long-Term Government Bond Returns (VUSTX) vs Replicated Returns**

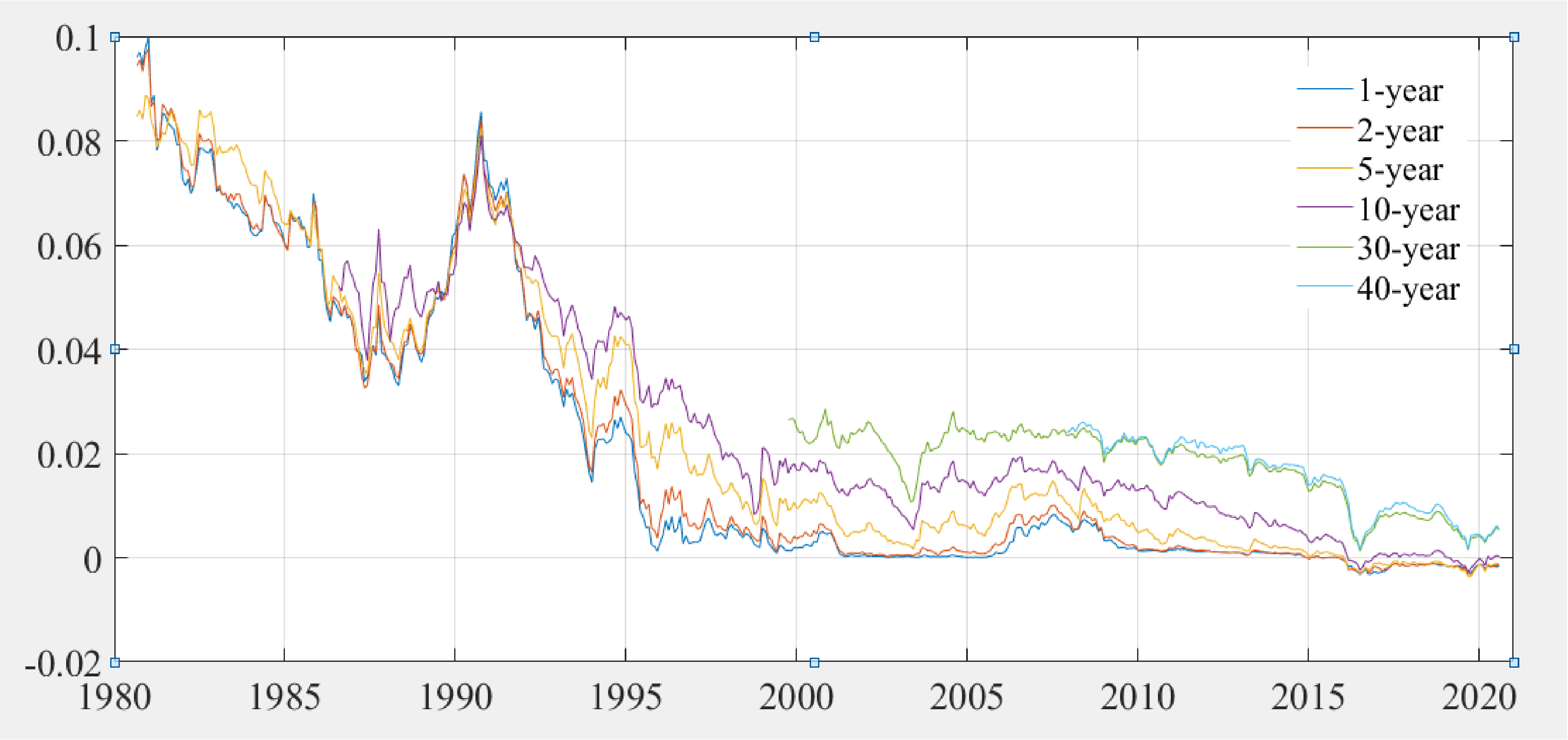
Four Explanations

- Long-duration dividends diversify against each other. While short-duration dividends can be hit by rare disaster (COVID, Great Recession), mean reversion makes long duration dividends less risky.
- Dividends protect against inflation and are therefore less risky than long-term bonds. So dividend risk adds to risk premium relative to government bonds, but inflation risk premium is lower than government bonds, and the two effects roughly cancel leading to similar performance.
- Secular downward trend in expected growth rates: stock market has structurally underperformed due to a series of negative shocks to future expected growth. This means we have poor growth ahead of us.
- Secular upward trend in risk premia: stock market has underperformed because the risk premium going forward keeps going up. This means we have stock market outperformance relative to bonds ahead of us.

Corporate Finance

- Results have potentially important implications for Corporate Finance.
- In capital structure we teach students that risk is distributed between debt and equity.
- Equity earns a premium over debt.
- As leverage is increased, equity expected return goes up.
- What if risk premium is close to 0?

Japanese Bond Yields



Japan

Mat. in years	1	2	3	4	5	10	15	Topix	Nikkei 225
Sample: 1996-2021									
Mean (%)	0.02	0.04	0.07	0.10	0.14	0.30	0.41	0.31	0.40
St. Dev. (%)	0.07	0.16	0.29	0.43	0.58	1.32	2.02	5.05	5.55
Mean log (%)	0.02	0.04	0.07	0.10	0.14	0.29	0.39	0.18	0.23
Sample: 1985-2021									
Mean (%)	0.14	0.17	0.21	0.25	0.29	0.45	0.57	0.42	0.46
St. Dev. (%)	0.25	0.42	0.62	0.82	1.01	1.89	2.85	5.47	5.90
Mean log (%)	0.13	0.17	0.21	0.24	0.28	0.43	0.53	0.27	0.29

Conclusion

- Comparing apples to apples: evaluate performance of stock market against other long duration assets.
- In this paper I have picked one choice for such a counterfactual: maturity-matched nominal bonds. Other counterfactuals are certainly possible.
- Long-duration bonds have gained in value a lot in the past 5 decades.
- Relative to these duration-matched fixed income portfolios, stocks have not done too well.
- Raises at least 4 important questions:
  1. How should long duration risky cash flows be discounted?
  2. Can we maintain usual stationarity assumptions in asset pricing? How long should sample be?
  3. How does this affect our view on the equity premium puzzle?
  4. How does this affect our view on the excess volatility puzzle?