INFLATION RISK AND YIELD SPREAD CHANGES

Diego Bonelli

Norwegian School of Economics

MOTIVATION: MISSING PIECE

- **U.S. corporate bond yield changes are only partially explained by variables implied by structural models:** (Collin-Dufresne, Goldstein, and Martin (CDGM) (CDGM)):
  - Regressions of yield spread changes on credit risk variables (Leverage, RF, etc.)
  - R^2 of 20-30%

- **Residuals exhibit large systematic variation**
  - Leverage-Maturity averaged residuals show large variation
  - PC1 of group-averaged residuals explains $\sim$ 80% of remaining variation
  - Indicating potential unidentified factors alongside standard fundamental variables

- **This paper: Inflation risk is a significant determinant of yields spread changes**

THIS PAPER: INFLATION RISK IS A SIGNIFICANT DETERMINANT OF YIELDS SPREAD CHANGES

- **I develop market-based measures of inflation risk**:
  - Expected inflation (capturing changes in real vs nominal firms' leverage)
  - Inflation uncertainty (capturing changes in cash-flow volatility due to uncertainty in prices)
  - Correlation inflation-cash flow (capturing state-dependent effects of inflation)

- **I empirically show that inflation risk**:
  - Adds $\sim$10pp of explanatory power on top of structural variables
  - Explains $\sim$40% of the systematic unexplained variation of yield spread changes
  - Explains $\sim$22% of the variation of the latent factor of yield spread changes

- **Interpretation: structural model of default with inflation and sticky cash-flow**:
  - Rationalize findings above
  - Develop new tests on: default risk, cash-flow flexibility and non-linearity

LITERATURE

- **Credit risk literature**
  - **Theoretical:** Merton (1974), Leland and Toft (1996), David (2008), Chen (2010), Bhamra, Fisher, and Kuehn (2011), Kang and Pflueger (2015), Gomes, Jermann, and Schmid (2016) Bhamra, Dorion, Jeanneret, and Weber (2022)
  - **Empirical:** Collin-Dufresne, Goldstein, and Martin (CDGM), Huang and Huang (2012), Friewald and Nagler (2019), He, Khorrami, and Song (2022), Eisfeldt, Herskovic, and Liu (2022)
- **Empirical literature linking inflation to asset prices**

  Fama (1981), Chen, Roll, and Ross (1986), Weber (2014), Kang and Pflueger (2015), Eraker, Shaliastovich, and Wang (2016), Fleckenstein, Longstaff, and Lustig (2017), Boons, Duarte, de Roon, and Szymanowska (2020)
- **Inflation linked securities and their application**

  Pflueger and Viceira (2011), Haubrich, Pennacchi, and Ritchken (2012), Fleming and Sporn (2013), Fleckenstein, Longstaff, and Lustig (2014), Christensen, Lopez, and Rudebusch (2016), Fleckenstein, Longstaff, and Lustig (2017), D'Amico, Kim, and Wei (2018), Diercks, Campbell, Sharpe, and Soques (2023)

Determinants of Yield Spread Changes in Collin-Dufresne, Goldstein, and Martin (CDGM)

DATA

Bond Datasets

- Enhanced TRACE: CUSIP-level trades, from 2004-2021
- Mergent FISD: bond characteristics
- CRSP and Compustat: equity prices and accounting data
- CBOE: VIX and SP options
- FED: Treasury rates, Zero-coupon TIPS yields, and break-even rates
- Bloomberg: Inflation swap rates
- BLS: Industry PPI

Bond Sample

- Keep publicly-traded, non-financial, non-utility firms' bonds with dollar denominations, no embedded options, constant coupon rates, credit rated, ≥ $10m issuance
- Drop trades with when-issued, lock-in, special trades, P1 flag, or time-to-maturity < 1m or >30yr
- Resulting in a sample of 6534 bonds from 2004 to 2021

DETERMINANTS OF YIELD SPREAD CHANGES IN CDGM

- $YS_{i,t}$:= yield spread for bond i in month t

$$\Delta YS_{i,t} = \alpha_i + \beta_i^T \mathbf{\Delta S_{i,t}} + \epsilon_{i,t},$$

where $\mathbf{\Delta S_{i,t}} := [\Delta Lev_{i,t},\ \Delta RF_t,\ \Delta RF_t^2,\ \Delta Slope_t,\ \Delta VIX_t,\ RM_t,\ \Delta Jump_t]$

Structural variables based on Merton (1974):

- $\Delta Lev_{i,t}$ as the change in firm leverage
- ΔRF_t the change in 10-year Treasury interest rate
- ΔRF_t^2 the squared change in the 10-year Treasury interest rate
- $\Delta Slope_t$ the change in the slope of the term structure
- ΔVIX_t the change in VIX index
- RM_t the S&P 500 return
- $\Delta Jump_t$ the change in a jump factor based on S&P 500 index options

CDGM REGRESSION

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	<15%	15%–25%	25%–35%	35%–45%	45%–55%	>55%	All
Intercept	0.012	0.012	0.029	0.038	0.070	0.108	0.037
	(4.890)	(4.540)	(9.212)	(8.486)	(8.357)	(10.580)	(17.991)
$\Delta Lev_{i,t}$	0.015	0.006	0.013	0.016	0.026	0.061	0.020
	(3.878)	(5.016)	(10.175)	(10.621)	(8.029)	(16.096)	(18.451)
ΔRF_t	-0.309	-0.430	-0.561	-0.837	-0.868	-1.167	-0.624
	(-23.651)	(-30.953)	(-25.495)	(-20.694)	(-12.205)	(-16.914)	(-43.505)
ΔRF_t^2	0.031	0.087	-0.030	-0.046	-0.115	0.053	0.017
	(0.782)	(2.160)	(-0.670)	(-0.692)	(-1.060)	(0.425)	(0.648)
$\Delta Slope_t$	0.343	0.467	0.571	0.908	0.856	0.961	0.620
	(17.095)	(23.293)	(17.114)	(14.614)	(8.184)	(9.376)	(29.658)
ΔVIX_t	0.003	0.005	0.007	0.008	0.006	0.005	0.006
	(1.456)	(5.541)	(5.041)	(4.376)	(1.745)	(1.437)	(6.712)
RM_t	-0.019	-0.024	-0.039	-0.062	-0.087	-0.124	-0.050
	(-12.135)	(-19.353)	(-21.968)	(-22.082)	(-18.006)	(-24.624)	(-43.690)
$\Delta Jump_t$	0.002	0.004	0.007	0.013	0.011	0.026	0.009
	(2.934)	(5.087)	(6.650)	(7.712)	(3.470)	(7.482)	(13.316)
Mean R^2	0.303	0.324	0.341	0.387	0.391	0.349	0.340
Median R^2	0.310	0.342	0.347	0.416	0.413	0.372	0.359
Obs.	77352	114979	94561	51903	30156	54889	423840
Bonds	1224	1783	1275	823	475	954	6534

Bond level time series regressions

- At least 25 months of obs
- Aggregated in leverage buckets

Key Takeaway:

- Very low mean R^2 of 31.7%

PRINCIPAL COMPONENT ANALYSIS

Leverage	Maturity	Bonds	Observations	PC1	PC2	Exp
1	1	878	35080	0.088	0.018	0.010
1	2	616	15640	0.091	-0.051	0.009
1	3	678	26632	0.064	-0.067	0.006
2	1	1256	48366	0.125	-0.005	0.018
2	2	989	24348	0.128	-0.113	0.016
2	3	1069	42265	0.087	-0.102	0.009
3	1	856	32002	0.182	0.054	0.034
3	2	762	19489	0.159	-0.126	0.024
3	3	813	43070	0.131	-0.084	0.018
4	1	592	19750	0.267	0.170	0.070
4	2	567	14168	0.253	-0.282	0.060
4	3	488	17985	0.181	-0.213	0.037
5	1	373	12311	0.330	0.602	0.115
5	2	351	8916	0.307	-0.310	0.091
5	3	241	8929	0.204	-0.038	0.044
6	1	773	24843	0.414	0.367	0.163
6	2	710	16975	0.408	0.042	0.156
6	3	383	13071	0.336	-0.440	0.120
Proportion of Variance				0.795	0.048	
Unexplained Variance					1.337	

PCA Procedure

- Take residuals from CDGM regression ($\epsilon_{i,t}$), divide in Leverage - Maturity buckets, create an average residual and compute PCA
- The reported PC1 and PC2 are the loadings
- Exp is ratio of residual variation to total residual variation (Exp$= \sigma_{\epsilon g} / \sum_{g}^{18} \sigma_{\epsilon g}$)

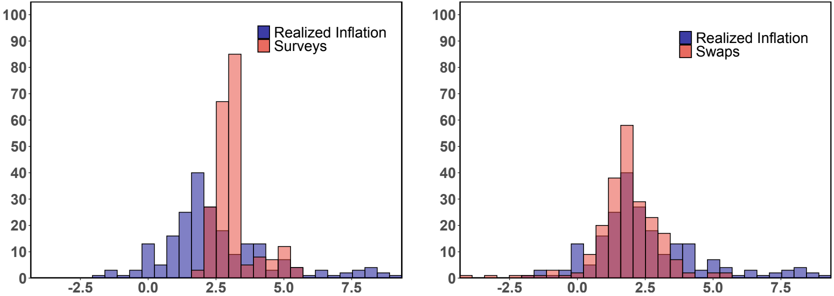
Key Takeaway:

- PC1 explanatory power $\sim$80%
- PC1 load largely on high leverage firms
- High leverage firms account for 50+% of residual variation

Main Empirical Results

INFLATION RISK MEASURES: ZERO COUPON SWAP RATES

- Zero coupon swap rates
  - Available with tenor from 1 to 30 years, and quoted daily
  - On average, more precise than surveys (Diercks, Campbell, Sharpe, and Soques (2023))
  - Seasonally adjust the swap rates and match swaps' tenor with the bonds' duration



Forecast or realized inflation in percentage points

INFLATION RISK MEASURES: ZERO COUPON SWAP RATES

- Zero coupon swap rates
  - Available with tenor from 1 to 30 years, and quoted daily
  - On average, more precise than surveys (Diercks, Campbell, Sharpe, and Soques (2023))
  - Seasonally adjust the swap rates and match swaps' tenor with the bonds' duration

- 3 proxies:
  - $\Delta Swap_{i,t}$: Stickiness of leverage makes real values of debt coupons a function of inflation

    $\uparrow$ E[inflation] $\downarrow$ real value of debt $\downarrow$ default risk $\downarrow$ yield spreads
  - $\Delta\sigma^S_{i,t}$: Cash-flow volatility increases with inflation volatility

    $\uparrow$ inflation volatility $\uparrow$ Cash-flow volatility $\uparrow$ default risk $\uparrow$ yield spreads
  - ΔCor^S_t: Risk of low inflation recession

    $\downarrow$ E[inflation], real cash-flow $\uparrow$ default risk $\uparrow$ yield spreads (Proxy is negative)

BASELINE RESULTS: EMPIRICAL STRATEGY

- For each industrial bond i with at least 25 monthly observations of $\Delta YS_{i,t}$, estimate the model:

$$\Delta YS_{i,t} = \alpha_i + \boldsymbol{\beta}_i^T \boldsymbol{\Delta S}_{i,t} + \boldsymbol{\Gamma}_i^T \boldsymbol{\Delta C}_{i,t} + \boldsymbol{\theta}_i^T \boldsymbol{\Delta I}_{i,t} + \nu_{i,t},$$

- $\boldsymbol{\Delta S}_{i,t} := [\Delta Lev_{i,t},\ \Delta RF_t,\ \Delta RF_t^2,\ \Delta Slope_t,\ \Delta VIX_t,\ RM_t,\ \Delta Jump_t]$: structural model variables
- $\boldsymbol{\Delta C}_{i,t}$: additional control proxies (Friewald and Nagler (2019), He, Khorrami, and Song (2022) and Eisfeldt, Herskovic, and Liu (2022))
- $\boldsymbol{\Delta I}_{i,t} := [\Delta Swap_{i,t},\ \Delta \sigma_{i,t}^S,\ \Delta Cor_t^S]$: inflation risk variables

- We are interested in:
  - **Incremental R^2 contribution**
  - **Fraction of variance explained** ($FVE = 1 - \frac{\sum_g^{18} \sigma_{\nu g}}{\sum_g^{18} \sigma_{\epsilon g}}$)
  - **PC1 explanatory power**

INFLATION RISK AND YIELD SPREAD CHANGES

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Individual Bond Regressions								
$\Delta Swap_{i,t}$		-0.707			-0.562	-0.427	-0.427	-0.358
		(-37.765)			(-34.261)	(-24.993)	(-23.906)	(-21.056)
$\Delta\sigma^S_{i,t}$			1.915		1.444	0.756	0.860	0.407
			(36.979)		(31.021)	(13.171)	(14.578)	(6.323)
ΔCor^S_t				-0.289	-0.172	-0.112	-0.136	-0.141
				(-19.251)	(-12.333)	(-5.495)	(-6.548)	(-6.377)
CDGM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FN	No	No	No	No	No	Yes	Yes	Yes
HKS	No	No	No	No	No	No	Yes	Yes
EHL	No	No	No	No	No	No	No	Yes
Mean R^2	0.340	0.382	0.403	0.340	0.427	0.496	0.503	0.516
Median R^2	0.359	0.397	0.412	0.360	0.437	0.521	0.534	0.551
Obs.	423840	423840	423840	423840	423840	423840	423840	423840
Bonds	6534	6534	6534	6534	6534	6534	6534	6534
Panel B: Principal Component Analysis								
FVE		0.249	0.221	0.039	0.402	0.276	0.284	0.261
PC1	0.795	0.732	0.746	0.789	0.700	0.683	0.681	0.658
PC2	0.048	0.080	0.061	0.050	0.085	0.087	0.092	0.095
UV	1.337	1.003	1.042	1.285	0.800	0.513	0.456	0.387

Key Takeaway:

- Each proxy adds on average 3.5 pp to the mean adj. R^2
- All together the mean and median adj. R^2 increase by 8.7 and 7.8 pp

INFLATION RISK AND YIELD SPREAD CHANGES

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Individual Bond Regressions								
$\Delta Swap_{i,t}$		-0.707			-0.562	-0.427	-0.427	-0.358
		(-37.765)			(-34.261)	(-24.993)	(-23.906)	(-21.056)
$\Delta\sigma^S_{i,t}$			1.915		1.444	0.756	0.860	0.407
			(36.979)		(31.021)	(13.171)	(14.578)	(6.323)
ΔCor^S_t				-0.289	-0.172	-0.112	-0.136	-0.141
				(-19.251)	(-12.333)	(-5.495)	(-6.548)	(-6.377)
CDGM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FN	No	No	No	No	No	Yes	Yes	Yes
HKS	No	No	No	No	No	No	Yes	Yes
EHL	No	No	No	No	No	No	No	Yes
Mean R^2	0.340	0.382	0.403	0.340	0.427	0.496	0.503	0.516
Median R^2	0.359	0.397	0.412	0.360	0.437	0.521	0.534	0.551
Obs.	423840	423840	423840	423840	423840	423840	423840	423840
Bonds	6534	6534	6534	6534	6534	6534	6534	6534
Panel B: Principal Component Analysis								
FVE		0.249	0.221	0.039	0.402	0.276	0.284	0.261
PC1	0.795	0.732	0.746	0.789	0.700	0.683	0.681	0.658
PC2	0.048	0.080	0.061	0.050	0.085	0.087	0.092	0.095
UV	1.337	1.003	1.042	1.285	0.800	0.513	0.456	0.387

Key Takeaway:

- All proxies together around $\sim$ 40% of unexplained variation
- Explain $\sim$ 26% of unexplained variation after accounting for all proxies

INFLATION RISK AND YIELD SPREAD CHANGES

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Individual Bond Regressions								
$\Delta Swap_{i,t}$		-0.707			-0.562	-0.427	-0.427	-0.358
		(-37.765)			(-34.261)	(-24.993)	(-23.906)	(-21.056)
$\Delta\sigma^S_{i,t}$			1.915		1.444	0.756	0.860	0.407
			(36.979)		(31.021)	(13.171)	(14.578)	(6.323)
ΔCor^S_t				-0.289	-0.172	-0.112	-0.136	-0.141
				(-19.251)	(-12.333)	(-5.495)	(-6.548)	(-6.377)
CDGM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FN	No	No	No	No	No	Yes	Yes	Yes
HKS	No	No	No	No	No	No	Yes	Yes
EHL	No	No	No	No	No	No	No	Yes
Mean R^2	0.340	0.382	0.403	0.340	0.427	0.496	0.503	0.516
Median R^2	0.359	0.397	0.412	0.360	0.437	0.521	0.534	0.551
Obs.	423840	423840	423840	423840	423840	423840	423840	423840
Bonds	6534	6534	6534	6534	6534	6534	6534	6534
Panel C: Time-Series Regression of PC1 on Inflation Risk Proxies								
Adj. R^2					0.227	0.109	0.097	0.074
R^2		0.150	0.164	0.016	0.238	0.122	0.111	0.088
F-stat		34.684	38.533	3.282	20.353	9.060	8.109	6.245
P-stat		0.000	0.000	0.072	0.000	0.000	0.000	0.000
Obs.		199	199	199	199	199	199	199

Key Takeaway:

- Proxies have large explanatory power when regressed onto the PC1

Motivating Model

MODEL INTUITION

Balance Sheet

Assets x P^{ϕ}	Liabilities
	Equity

$$\text{Real} \xrightarrow{P^{\phi}} \text{Nominal}$$

- Firms earn real cash flows (asset growth) while they issue almost exclusively nominal debt
- Link the two different ”worlds” by converting real to nominal using the price index P
- But allow the conversion to be imperfect, using the price index P^{ϕ} where ϕ is a stickiness parameter

MODEL SETUP

Structural default model in spirit of Leland (1994):

1. Real assets A_t^r and price index P_t are two correlated GBM

$$\frac{dA_t^r}{A_t^r} = \mu_{A^r} d_t + \sigma_{A^r} dW_t^{P,A^r}, \tag{1}$$

$$\frac{dP_t}{P_t} = \mu_P d_t + \sigma_P dW_t^{P,P}, \quad cor(dW_t^{P,A^r}, dW_t^{n,P}) = \rho_{A^r P}. \tag{2}$$

2. The nominal asset is: $A_t^n = A_t^r P_t^{\phi}$ where $\phi \in (0,1)$ is a stickiness parameter
3. Assets are sticky when $\phi < 1$
4. The firm chooses the level of debt, D, (through the constant coupon rate, C) by issuing consol bonds.
5. The incentive to issue debt comes from a tax advantage, ($\tau_{tax} C$).
6. In liquidation debt holders get the whole residual value of the firm after accounting for bankruptcy costs, determined by the recovery rate, R.

- Define A_B^n the level of assets at which default is triggered, and τ the first time the assets hit A_B^n

$$\tau = \inf\left\{t \mid A_t^n \leq A_B^n\right\}. \tag{3}$$

- Let r_n be equal to $r_r + \phi(\mu_P + \frac{1}{2}(\phi - 1)\sigma_P^2)$, and $\sigma_{A^n}^2$ be $\sigma_{A^r}^2 + \phi^2\sigma_P^2 + 2\phi\rho_{A^rP}\sigma_{A^r}\sigma_P$.
- The value of a claim of 1 at the default boundary is

$$P_B(A^n) = \left(\frac{A^n}{A_B^n}\right)^{-\gamma_1} \qquad \gamma_1 = \frac{r_n - \frac{\sigma_{A^n}^2}{2}}{\sigma_{A^n}^2} + \sqrt{\frac{r_n - \sigma_{A^n}^2 + 2\sigma_{A^n}^2 r_n}{\sigma_{A^n}^2}}. \tag{4}$$

DEBT STRUCTURE AND YIELD SPREADS (2)

- The debt value follows

$$D(A^n; A_B^n, C) = \underbrace{\frac{C}{r_n}(1 - P_B(A^n))}_{\text{coupon flow up until time } \tau} + \underbrace{RA_B^n P_B(A^n)}_{\text{recovery value in case of bankruptcy}} \tag{5}$$

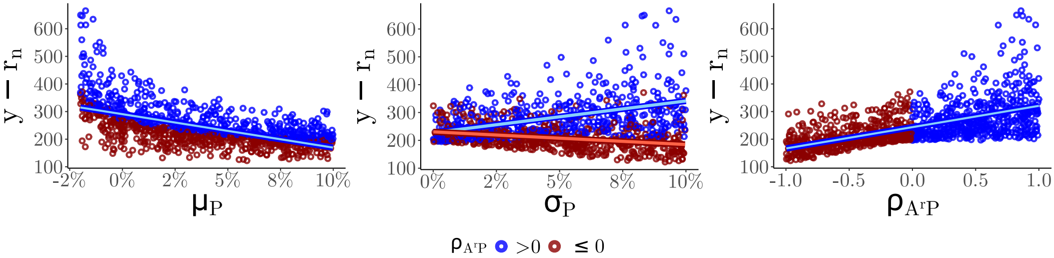
- The yield spreads, $y - r_n$, are given by

$$y - r_n = \frac{C*}{D(A^n; A_B^{n*}, C*)} - r_n, \tag{6}$$

where $C*$ is the optimal coupon found by maximizing the firm value.

MODEL SIMULATION

- Simulate 1000 firms, where all parameters are fixed except μ_p, σ_p and $\rho_{A^r P}$



Model Based Tests

HETEROGENEITY: DEFAULT-RISK

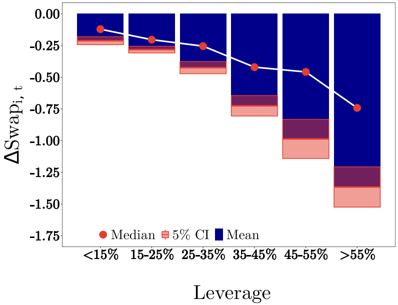


Figure 1: Empirics

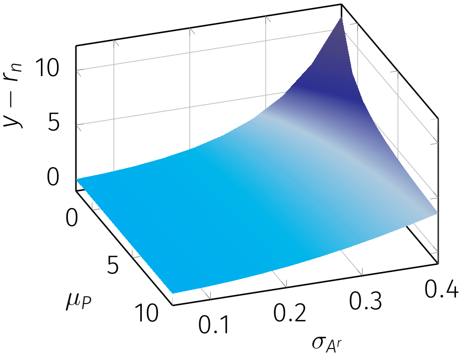


Figure 2: Theory

1 sd increase in $\Delta Swap$:

- $<15\%$ group: 5.2% decrease in average yield spread
- $>55\%$ group: 6.6% decrease in average yield spread

HETEROGENEITY: INDUSTY PPI

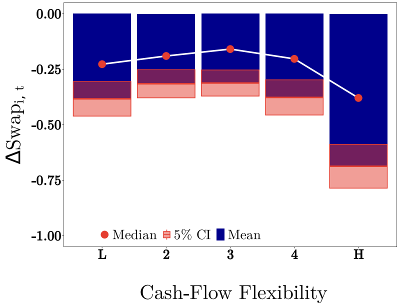


Figure 3: Empirics

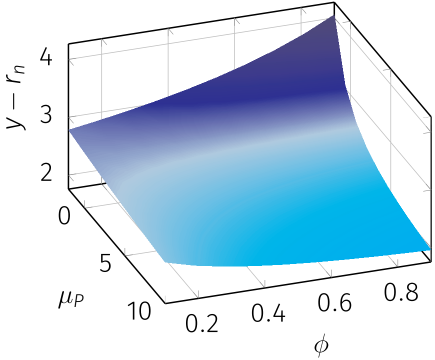


Figure 4: Theory

1 sd increase in $\Delta Swap$:

- Low group: 5.1% decrease in average yield spread
- High group: 6.3% decrease in average yield spread

NONLINEARITY

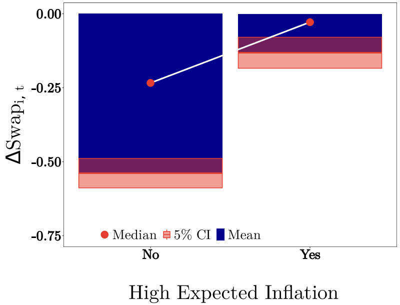


Figure 5: Empirics

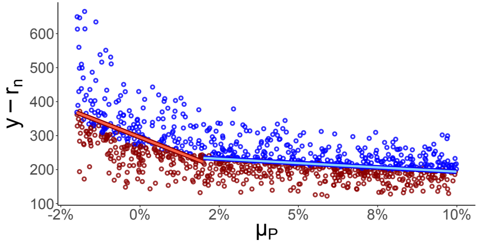


Figure 6: Theory

1 sd increase in Δ*Swap*:

- Low group: 5% decrease in average yield spread
- High group: 3.3% decrease in average yield spread.

ROBUSTNESS

Proxies' Robustness

- Using TIPS rates
- Non-cash-flow matched rates
- ARMA(1,1) CPI

Data Robustness

- End of month
- All bonds (No filters)

Additional Controls

- Different residual groups
- Macro variables
- Monetary policy

CONCLUSION

- **Inflation risk is a significant determinant of yields spread changes**
- **I develop market-based measures of inflation risk and show that**:
  - Explains ∼40% of the unexplained systematic variation of yield spread changes
  - Large explanatory power on top of structural factors
- **The findings can be rationalized with a structural model including inflation and sticky cash-flow**:
  - Matches main findings and
  - Matches increasing in firm default-risk and cash-flow flexibility and decreasing ex-ante inflation rate