Oil Futures Prices, Inflation Expectations, and Bond Risk Premiums

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Motivation: Why oil?

- Modern economies heavily depend on fossil energy
  - Global expenditure on petroleum: 4.5% of the world GDP
- Oil prices affect: inflation, consumption, and production
  - Consumer gasoline expenditure: $3,000/year/household (in 2013)
  - Oil input in firm production: 40% of industrial energy
- Investors & Fed pay close attention to oil price fluctuations
  - Bond Traders Track Oil as Rising Inflation Bets Muddy Fed's Job (Bloomberg, March 4, 2022)
  - "*The surge in prices of crude oil and other commodities that resulted from Russia's invasion of Ukraine is creating additional upward pressure on inflation.*" (Powell, FOMC Press Conference on May 4, 2022)

Research questions

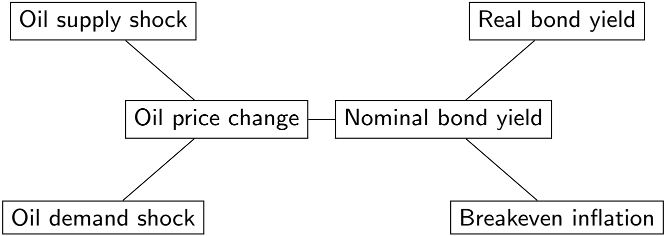
Whether oil futures prices and decomposed oil supply and demand shocks are helpful to predict inflation

The extend to which fluctuations in oil futures prices are related to bond yields and risk premium

- Oil and stock returns: studied by many papers
- Oil and bond returns: examined by few papers
- *Unlike stocks, bonds are more directly affected by oil price changes: inflation component in nominal bond yields*

This paper aims to provide empirical and theoretical analyses

Challenges in analyzing oil prices & bond returns (yields)



1. Oil price changes: oil supply and demand shocks, oil-specific demand shocks

$$g_t^{Oil} \equiv g_t^{Supply\ shock} + g_t^{Demand\ shock} + g_t^{Oil-specific\ Demand\ shock} \tag{1}$$

2. Nominal bond yield: real bond (TIPS) yield and breakeven inflation

$$y_t^n \equiv \underbrace{r_t^n}_{TIPS\ yield} + \underbrace{BE_t^n}_{Breakeven\ inflation} \tag{2}$$

What I do & find

1) Empirical findings:

- Oil supply, global demand, and oil-specific demand shocks have predictive value for forecasting CPI and core CPI inflation.
- Oil futures changes fail to predict nominal bond return premium
- Oil futures changes due to global demand shocks predict negative real bond return premium but predict positive inflation risk premium

2) Theoretically:

- A two-sector New Keynesian model
- Economic links: oil shocks, nominal and real yields, and breakeven inflation
- Nominal and real yields, and breakeven inflation: respond differently to oil shocks
- The model helps to explain the muted impact of 2000s energy crisis on expected inflation and the co-movement of the expected inflation and the oil price surge resulted from Russia's invasion of Ukraine in 2022

Related literature

Oil and inflation forecast

Pasaogullari and Waiwood (2014), Hasenzagl, Pellegrino, Reichlin, and Ricco (2022), Kilian and Zhou (2022a and 2022b), Gagliardone and Gertler (2024), Shapiro (2024)

Oil and bond returns

Baker and Routledge (2015), Kang, Ratti, and Yoon (2014), Demirer, Ferrer, and Shahzad (2020), Mensi, Hamed Al-Yahyaee, Vinh Vo, and Hoon Kang (2021)

Oil and equity returns

Chen, Roll, and Ross (1986), Driesprong, Jacobsen, and Maat (2008), Kilian and Park (2009), Chiang, Hughen, and Sagi (2014), Ready (2014), Jiang, Skoulakis, and Xue (2018)

Decomposition of oil supply and demand shocks

Kilian (2009), Baumeister and Hamilton (2019), Caldara, Cavallo, and Iacoviello (2019), Ready (2017)

Data

- Nominal bonds: U.S. 10-year Treasury bonds; Real bonds: U.S. 10-year inflation-indexed bonds (TIPS)

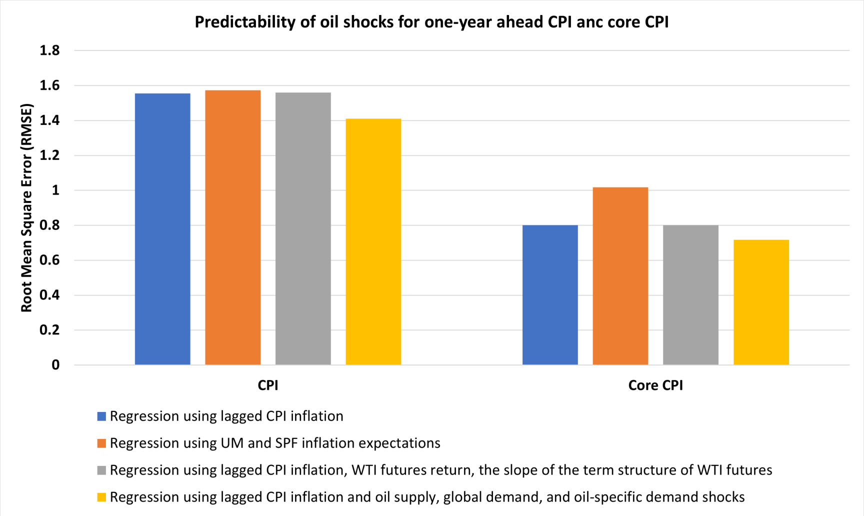
- Breakeven inflation: long 1 nominal bond & short 1 TIPS of the same maturity; CPI data from US BLS; Inflation expectation survey: UM's Survey of Consumers and SPF

- Crude oil futures prices: WTI futures (front-month and forth successive contracts)

- Oil supply shocks, global demand shocks, and oil-specific demand shocks
  - Estimated in a structural VAR framework (Jiang, Skoulakis, and Xue, 2018; Baumeister and Hamilton, 2019; Caldara, Cavallo, and Iacoviello, 2019)
  - Additional data: world oil production and proxies for global economic activities (BDI shipping index, world steel production, and world industrial production) (Kilian (2009), Baumeister and Hamilton (2019))

- Sample period: 1986 - 2024, monthly

Predictive ability for one-year ahead CPI and core CPI



Excess returns and oil price changes: Predictive

$$Y_{t+1} = \alpha + \beta_1 g_t^{Oil} + \beta_2 \, Term\ spread_t + \beta_3 \pi_t^{CPI\ less\ energy} + \varepsilon_{t+1}$$

	(1) Nominal bond $xr_{t+1}^{\$}$	(2) TIPS xr_{t+1}^{TIPS}	(3) Breakeven inflation xr_{t+1}^{BE}
g_t^{Oil}	0.00 (0.01)	-0.03 (0.01)	0.03** (0.01)
Controls	✓	✓	✓
Adj. R^2 (*incl.* g^{Oil})	7.9%	9.0%	27.9%
Adj. R^2 (*excl.* g^{Oil})	7.2%	5.7%	21.4%

- Oil futures changes predict only excess returns on breakeven inflation
- Oil futures price increases predict higher excess return on breakeven inflation (i.e., lower breakeven inflation rate)
- Including g_t^{Oil} increases $Adj.\ R^2$ by 6.5%

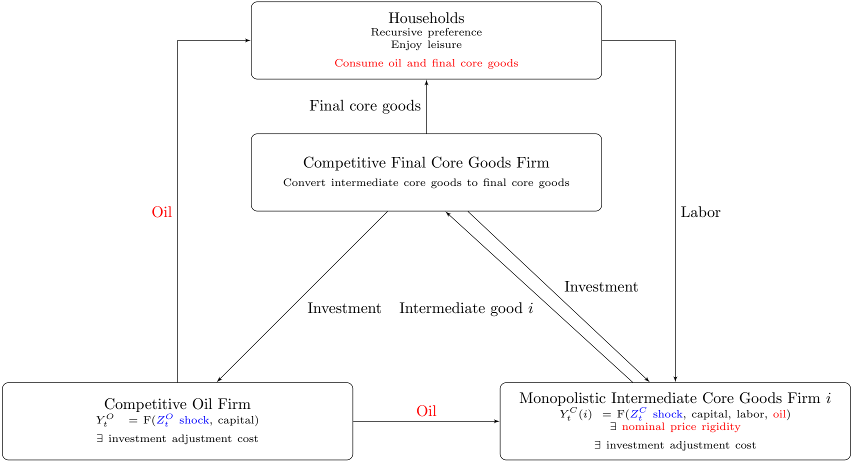
Excess returns and oil supply, global demand, and oil-specific demand shocks: Predictive

$$Y_{t+1} = \alpha + \beta_1 g_t^S + \beta_2 g_t^{GD} + \beta_3 g_t^{OSD} + \beta_4 \, Term\ spread_t + \beta_5 \pi_t^{CPI\ less\ energy} + \varepsilon_t$$

	(1) Nominal bond $xr_{t+1}^{\$}$	(2) TIPS xr_{t+1}^{TIPS}	(3) Breakeven inflation xr_{t+1}^{BE}
g_t^S	0.02	-0.01	0.03
	(0.03)	(0.01)	(0.02)
g_t^{GD}	-0.02	-0.05***	0.03**
	(0.03)	(0.03)	(0.02)
g_t^{OSD}	-0.01	-0.04*	0.04*
	(0.04)	(0.02)	(0.02)
Controls	✓	✓	✓
R^2	8.3%	9.8%	27.9%

- Global demand shocks and oil-specific demand shocks: predict excess returns on TIPS with a negative slope and excess returns on breakeven inflation with a positive slope

A two-sector New Keynesian model: Overview



Oil firm: Competitive

Production function: $Y_t^O = Z_t^O K_{t-1}^O$

Log oil productivity $z_t^o \equiv log Z_t^O$: transitory

- AR(1) process: $z_t^o = \rho_o z_{t-1}^o + \sigma_o \varepsilon_t^o$
- Supply shock in the oil market

Intermediate core goods firm: Monopolistic

Production function: $Y_t^C(i) = [K_{t-1}^C(i)]^{\omega}[Z_t^C N_t(i)]^{\alpha}[O_t^I(i)]^{1-\alpha-\omega}$

Productivity growth rate, $\Delta z_{t+1}^c \equiv log(Z_{t+1}^C / Z_t^C)$:

Transitory and Permanent, as in Croce (2014)

- $\Delta z_{t+1}^c = x_t^c + \sigma_c \varepsilon_{t+1}^c$
- $x_t^c = \rho_{xc} x_{t-1}^c + \sigma_{xc} \varepsilon_t^{xc}$
- Supply shocks in the core goods sector
- Demand shocks in the oil market

Numerical solutions

Symmetric equilibrium

- All intermediate goods firms: identical cost minimization & value maximization problems
- Households maximize the expected utility and firms maximize profits

Solutions

- Perturbation method (Dynare) with the second order approximation at a quarterly frequency

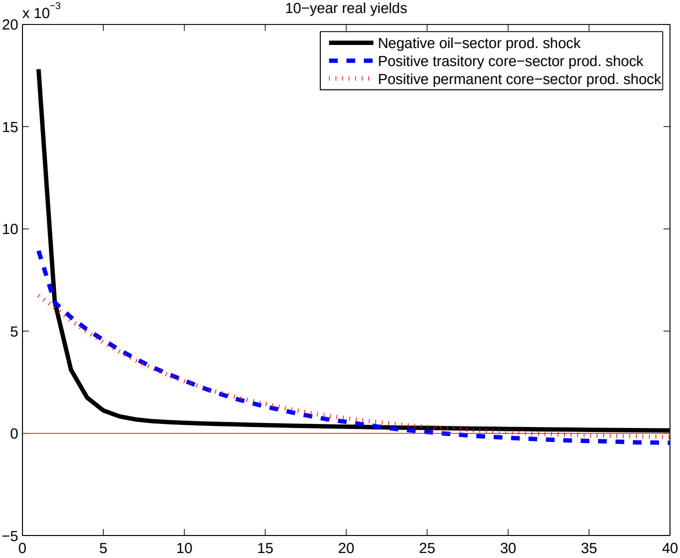
Parameter values

Matched moments

Bond yields and breakeven inflation

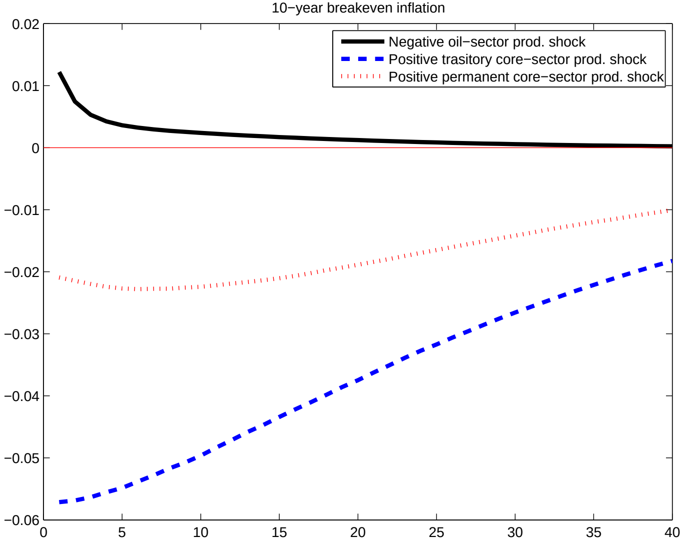
Model prediction 1: Real Yield

Real yields ↑, no matter the cause of oil price changes



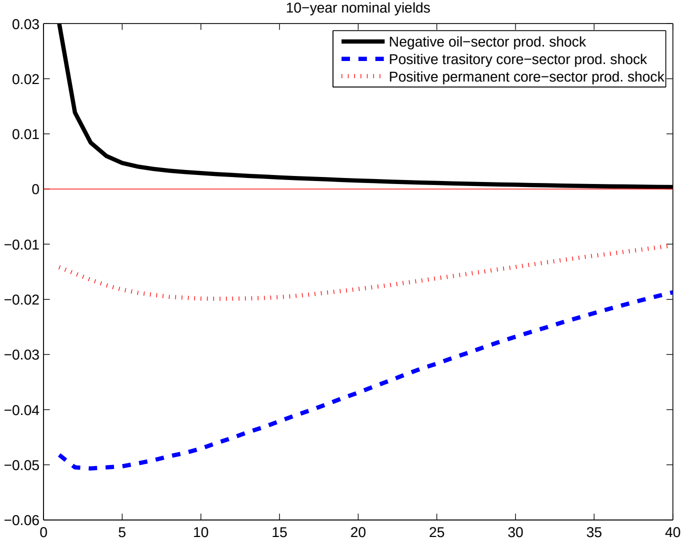
Model prediction 2: Breakeven inflation

Breakeven inflation: ↑ for the negative oil supply shock; ↓ for the positive productivity shocks in the core goods sector



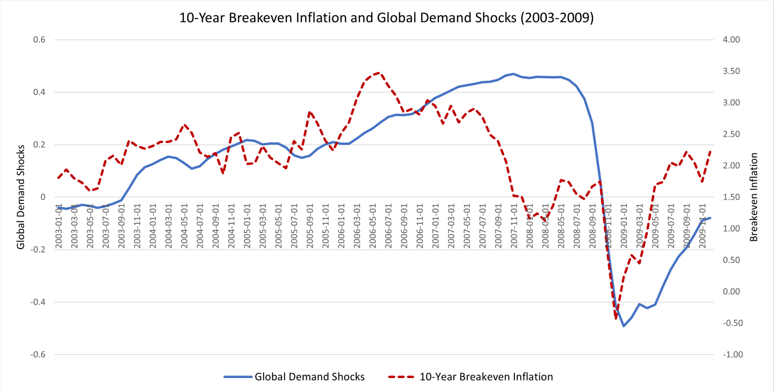
Model prediction 3: Nominal yield

Nominal yield: ↑ for negative oil supply shock; ↓ for the positive productivity shocks in the core sector



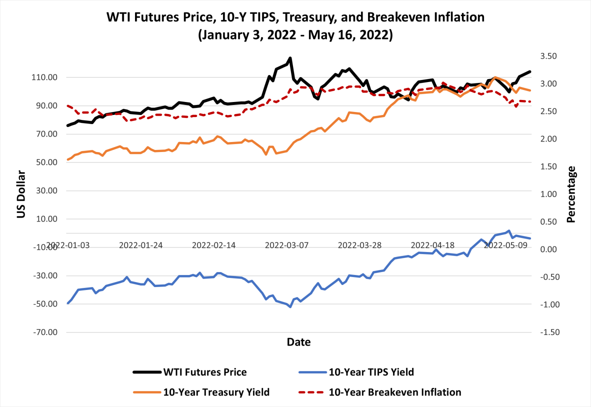
2000s energy crisis and inflation expectations

- Crude oil price had a long-run persistent rise from 2003 to 2008, from about US$30 per barrel to US$60 in 2005 and then to US$147 in 2008.
- Meanwhile, the 10-year breakeven inflation remained at a lower stable level.
- The strong global demand for oil, especially from developing economies, is widely considered as one of major drivers of the 2000s oil price shocks.
- According to the model, breakeven inflation decreases for the oil price rise driven by the strong demand from the consumer sectors.



Recent oil shocks for bond yields and inflation expectations

- The recent surge of oil price that resulted from Russia's invasion of Ukraine is an example of oil supply shock.
- The Russian oil sector was directly targeted by sanctions. WTI and Brent on March 8, 2022 were traded around US$123 per barrel.
- Breakeven inflation increases, real yields increase, and nominal yields increase.



Conclusions

- Decomposed oil futures prices improve CPI and core CPI inflation forecasts.
- Oil futures changes due to global demand shocks and oil-specific demand shocks predict negative real bond return premium but predict positive inflation risk premium.
- Predictions from a two-sector New Keynesian model help to explain:
  - the muted impact of the persistent rising crude oil prices on inflation in 2000s
  - the co-movement of the oil futures surge and expected inflation resulted from Russia's invasion of Ukraine in March 2022.

Parameter values

Group	Description	Symbol	Value
Preferences	Time discount rate	β	0.997
	Relative risk aversion	γ	10
	EIS	$1/\rho$	2
	Coefficient of disutility	ϕ	3.6272
	Frisch elasticity of labor supply	ν	0.2498
	Oil share of the consumption bundle	ξ	0.1
	Elasticity of substitution of oil and core goods	η	0.25
	Index of real wage rigidity	ρ_w	0.965
	Labor supply in the DSS	N	0.33
Production	CES of consumption goods	ε	6
	Degree of price adjustment cost	ϑ	25
	Degree of oil capital adjustment cost	ζ^o	4.8
	Degree of consumption goods capital adjustment cost	ζ^c	4.8
	Depreciation rate of oil capital	δ^o	0.05
	Depreciation rate of consumption goods capital	δ^c	0.02
	Capital share of output	ω	0.33
	Labor share of output	α	0.568
	Oil share of output	$1-\alpha-\omega$	0.102
Shocks	z^o-shock in the DSS	$\bar{z^o}$	0
	AR(1) coefficient of z^o-shock	ρ_o	0.45
	Standard deviation of z^o-shock	σ_o	9.5%
	z^c-shock in the DSS	$\bar{z^c}$	0
	Standard deviation of SRR shock	σ_c	1.2%
	AR(1) coefficient of LRR shock	ρ_{xc}	0.85
	Standard deviation of LRR shock	σ_{xc}	0.07%
Policy	Inflation target	$\bar{\pi}$	1.0092
	Sensitivity of the interest rate to inflation	ϕ_π	1.5
	Sensitivity of the interest rate to output	ϕ_y	0.125

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Matched moments

	Data	Model
Relative oil prices		
$E(\Delta log(P_t^O/P_t^C))$	0.45%	0.03%
$\sigma(\Delta log(P_t^O/P_t^C))$	18.48%	14.39%
$AC1(\Delta log(P_t^O/P_t^C))$	0.01	-0.22
Inflation		
$E(\pi_t^C)$	0.64%	0.64%
$\sigma(\pi_t^C)$	0.29%	0.58%
$AC1(\pi_t^C)$	0.72	0.57
$E(\pi_t^{CPI})$	0.66%	0.64%
$\sigma(\pi_t^{CPI})$	0.62%	0.67%
$AC1(\pi_t^{CPI})$	0.05	0.32
10Y nominal yields		
$E(y^{10Y})$	1.31%	0.94%
$\sigma(y^{10Y})$	1.01%	0.25%
$AC1(y^{10Y})$	0.94	0.89
Correlations		
$Corr(\Delta y_t^{10Y}, g_t^{Oil})$	0.40	0.49
$Corr(\Delta c, \pi^{CPI})$	-0.56	-0.50
Macroeconomic moments		
$\sigma(\Delta c)/\sigma(\Delta y^c)$	0.51	0.76
$\sigma(\Delta w)/\sigma(\Delta y^c)$	0.44	0.42

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Bond yields and breakeven inflation

Zero-coupon nominal bond price:

$$P_t^{\$,n} = e^{-ny_t^n} = E_t[M_{t,t+n}^{\$} \times 1] \tag{3}$$

Nominal yield:

$$y_t^n = -\frac{1}{n} E_t(m_{t,t+n}^{\$}) - \frac{1}{2n} Var_t(m_{t,t+n}^{\$}) \tag{4}$$

Zero-coupon TIPS price:

$$P_t^{TIPS,n} = e^{-nr_t^n} = E_t[M_{t,t+n}^{R,X} \times 1] \tag{5}$$

Real yield:

$$r_t^n = -\frac{1}{n} E_t(m_{t,t+n}^{R,X}) - \frac{1}{2n} Var_t(m_{t,t+n}^{R,X}) \tag{6}$$

Breakeven inflation:

$$s_t^{(n)} = y_t^{(n)} - r_t^{(n)} \tag{7}$$

$$s_t^{(n)} \approx Expected\ inflation_{t,t+n} + Inflation\ risk\ premium_{t,t+n} \tag{8}$$

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