The U.S. Government Debt Valuation Puzzle

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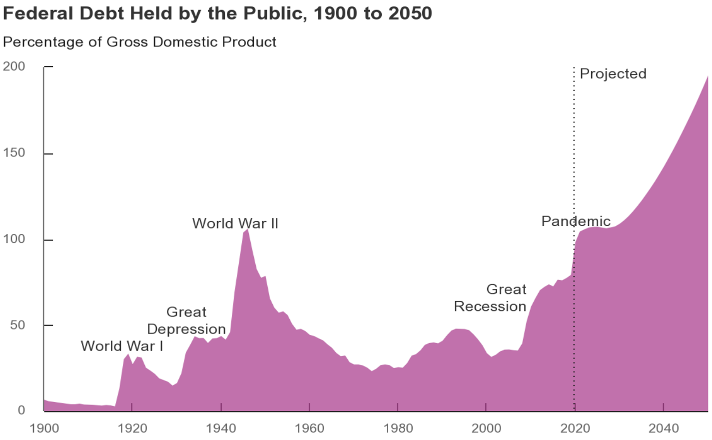
COVID-19: Largest Fiscal Shock since WWII

- estimated U.S. federal gov't deficit for 2020 \$3.3 trillion (about 16% of projected U.S. GDP)
    1. \$1 trillion (original deficit)
    2. \$ 2.2 trillion: Emergency funding: CARES Act & Families First Coronavirus Response Act

- another \$1-2 trillion on the table
- U.S. federal gov't is the largest borrower in the world. The outstanding debt held by the public today is projected at 98% of GDP at end of 2020.
- Doubled from 35% of GDP before the Great Recession to 79% in 2019. CBO/CFRB forecasts it to grow to exceed 200 % of GDP by 2050

U.S. Debt Projected to Surpass WWII record

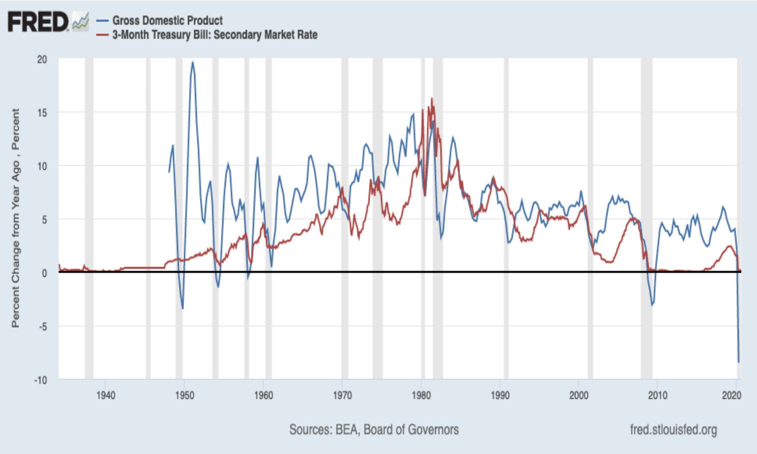


Source: Congressional Budget Office, Sept. 2020.

What is U.S.' Debt-Bearing Capacity?

- Can U.S. federal government borrow trillions more?
  - to fund the private sector's payroll
  - to bail out states
  - to lend to banks
- Or should it reduce the deficit to avoid a debt market crash?
- use standard toolbox of financial economics

Let's roll it over



- "... public debt may have no fiscal cost." (Blanchard's AEA Presidential address; 2019)

Pricing Gov't Bond Portfolio

- gov't debt is backed by current and future primary surpluses.
  - gov't budget constraint:

$$G_t + Q_{t-1}^1 = \sum_{h=1}^{H} \left(Q_t^h - Q_{t-1}^{h+1} \right) P_t^h + T_t$$

  - No arbitrage bond pricing: $P_t^h = \mathbb{E}_t \left[M_{t,t+1} P_{t+1}^{h-1} \right]$
  - Iterate forward on the budget constraint
  - The market value of outstanding gov't debt, D_t, must equal the expected PDV of future primary surpluses S_{t+j}:

$$D_t = \sum_{h=0}^{H} Q_{t-1}^{h+1} P_t^h = \mathbb{E}_t \left[\sum_{j=0}^{T} M_{t,t+j} (T_{t+j} - G_{t+j}) \right] + E_t \left[M_{t,t+T} D_{t+T} \right]$$

  - impose a TVC: $E_t \left[M_{t,t+T} D_{t+T} \right] \to 0$ as $T \to \infty$ TVC

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- gov't debt is backed by current and future primary surpluses.
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$$G_t + Q^1_{t-1} = \sum_{h=1}^{H} \left(Q^h_t - Q^{h+1}_{t-1} \right) P^h_t + T_t$$

  - No arbitrage bond pricing: $P^h_t = \mathbb{E}_t \left[M_{t,t+1} P^{h-1}_{t+1} \right]$
  - Iterate forward on the budget constraint + impose a TVC

$$D_t \quad = \quad \sum_{h=0}^{H} Q^{h+1}_{t-1} P^h_t = \mathbb{E}_t \left[\sum_{j=0}^{\infty} M_{t,t+j} (T_{t+j} - G_{t+j}) \right].$$

- Assumes existence of SDF (*not* complete markets), no arbitrage in Treasury market, no bubbles, and no convenience yield on Treasuries.

Miller-Modigliani for Treasury

- gov't debt is backed by current and future primary surpluses.
  - Intertemporal gov't budget constraint:

$$D_t = \sum_{h=0}^{H} Q_{t-1}^{h+1} P_t^h = \mathbb{E}_t \left[\sum_{j=0}^{\infty} M_{t,t+j} (T_{t+j} - G_{t+j}) \right] = P_t^T - P_t^G.$$

  - holds ex ante in nominal and real terms
    - ex post, surprise inflation can erode real value of debt
  - allowing for default only changes left hand side, not right hand side

Treasury Balance Sheet

Tax Revenue P_t^T	Spending P_t^G
	Debt D_t

Return Evidence

Treasury Balance Sheet

Tax Revenue $P_t^{T,ex}$	Spending $P_t^{G,ex}$
	Debt $B = D_t - S_t$

- Risk Premium on Treasury Portfolio:

$$\mathbb{E}_t\left[R_{t+1}^D - R_t^f\right] = \frac{B_t + P_t^{G,ex}}{B_t}\mathbb{E}_t\left[R_{t+1}^T - R_t^f\right] - \frac{P_t^{G,ex}}{B_t}\mathbb{E}_t\left[R_{t+1}^G - R_t^f\right],$$

$$\beta_t^D = \frac{B_t + P_t^{G,ex}}{B_t}\beta_t^T - \frac{P_t^{G,ex}}{B_t}\beta_t^G, \beta_t^i = \frac{-cov\left(M_{t+1}, R_{t+1}^i\right)}{var_t(M_{t+1})},$$

  - in U.S. data: $\mathbb{E}_t\left[R_{t+1}^D - R_t^f\right]$ is 100 bps per annum.
  - Risk-free Treasury portfolio: need safer revenue claim.

$$\beta_t^T = \frac{P_t^{G,ex}}{B_t + P_t^{G,ex}}\beta_t^G << \beta_t^G,$$

Manufacturing Risk-free Debt, JLVNX (2020)

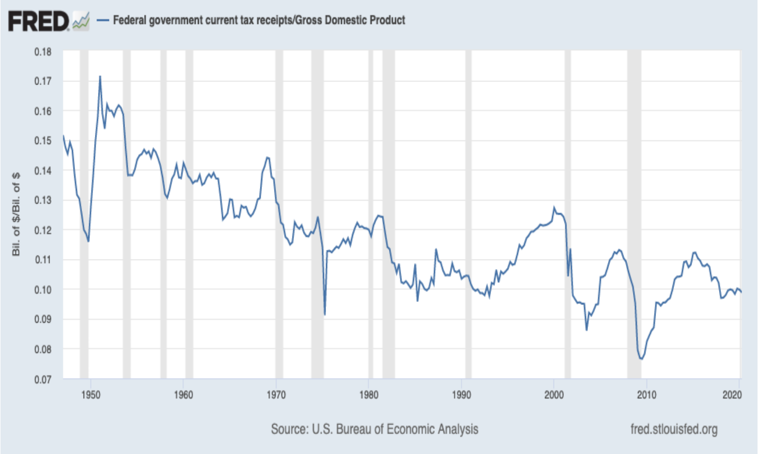
Cash Flow Evidence

$$D_t \quad = \quad \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j} S_{t+j}\right] = \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j} - G_{t+j})\right]$$

- stand-in investor who buys all gov't debt issuances and receives all redemptions has a claim to future primary surpluses $\{S_{t+j}\}$. Surpluses are the **cash flows on this investment strategy**.
- Surpluses are highly pro-cyclical: $\beta_t^T >> \beta_t^G$?

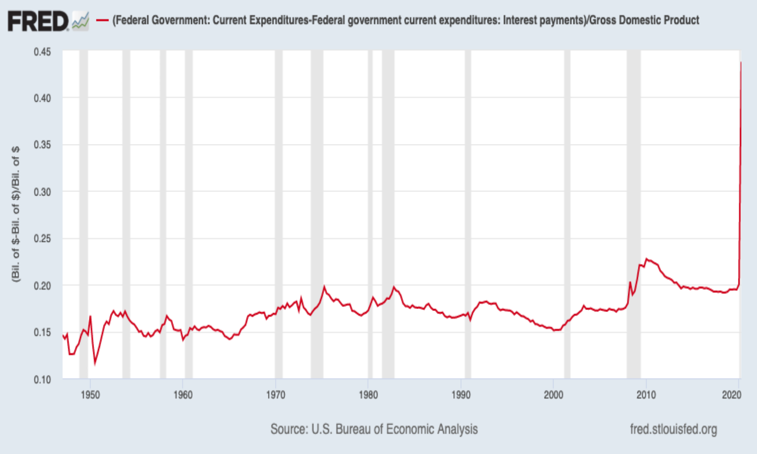
Cash Flow Evidence: Tax Receipts

- $\beta_t^T >> \beta_t^G$



Cash Flow Evidence: Government Spending

- $\beta_t^T >> \beta_t^G$



Gov't Debt Valuation Puzzle

- This logic poses a puzzle: gov't debt is positive while surplus claim has negative value when measured in the data

$$
\begin{aligned}
\underbrace{\sum_{h=0}^{H} Q_{t-1}^{h+1} P_t^h}_{>0} &= \mathbb{E}_t \left[\sum_{j=0}^{\infty} M_{t,t+j} (T_{t+j} - G_{t+j}) \right] \\
&= \sum_{j=0}^{\infty} \mathbb{E}_t \left[M_{t,t+j} \right] \underbrace{\mathbb{E}_t \left[T_{t+j} - G_{t+j} \right]}_{\approx 0} \\
&+ \underbrace{\sum_{j=0}^{\infty} cov_t \left(M_{t,t+j}, T_{t+j} \right)}_{<0} - \underbrace{\sum_{j=0}^{\infty} cov_t \left(M_{t,t+j}, G_{t+j} \right)}_{>0} .
\end{aligned}
$$

- For a given amount of debt that the gov't wants to issue, the presence of covariance terms raises the required future surpluses substantially.

Gov't Debt Valuation Puzzle

- This logic poses a puzzle: gov't debt is positive while surplus claim has negative value when measured in the data
- The gov't bond portfolio is more valuable than the surplus claim:

$$\sum_{h=0}^{H} Q_{t-1}^{h+1} P_t^h > 0 > \mathbb{E}_t \left[\sum_{j=0}^{\infty} M_{t,t+j} (T_{t+j} - G_{t+j}) \right]$$

- Equivalently, interest rates on the gov't bond portfolio in data are much lower than the risk-adjusted "interest rate" on the surplus claim. Risk premium equivalence also violated.

puzzle

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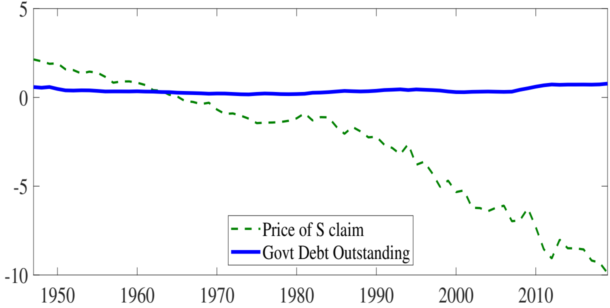
- Equivalently, interest rates on the gov't bond portfolio in data are much lower than the risk-adjusted "interest rate" on the surplus claim. Risk premium equivalence also violated.
- This puzzle is much deeper in a realistic model of risk and risk premia (SDF M);
  - most of the macro-fiscal policy literature ignores risk premia and ignores CF dynamics (except: Liu, Schmid, and Yaron, 2019)

puzzle

Size of the U.S. Treasury Valuation Puzzle

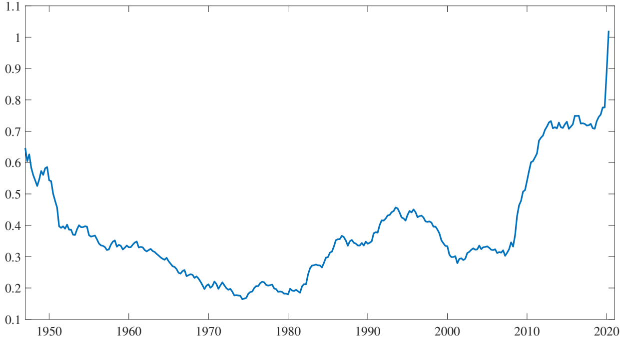
$$D_t = \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j} - G_{t+j})\right]$$



Related Literature

- **Affine no-arbitrage asset pricing models**: Campbell (91, 93, 96); Duffie and Kan (96); Dai and Singleton (00); Ang and Piazzesi (03); Lustig, Van Nieuwerburgh, and Verdelhan (13)
- **Fiscal policy** literature in macro: Hansen and Sargent (80); Lucas and Stokey (83); Hansen, Sargent, and Roberds (91); Angeletos (02); Buera and Nicolini (04); Hall and Sargent (11); Sargent (12); Karantounias (18); Bandhari, Golosov, Evans, and Sargent (17, 19); Blanchard (19), Cochrane (19, 20)
- **Specialness of U.S. bonds**: Longstaff (04); Krishnamurthy and Vissing-Jorgensen (12, 15); Greenwood, Hanson, and Stein (15); Nagel (16); Farhi and Maggiori (18) Du, Im, and Schreger (18); Binsbergen, Diamond, Grotteria (19); Jiang, Krishnamurthy, and Lustig (19)
- **Fiscal policy risk**: Croce, Nguyen, Schmid (12), Croce, Kung, Nguyen, and Schmid (19), Chernov, Schmid, and Schneider (19), Liu, Schmid, and Yaron (20)

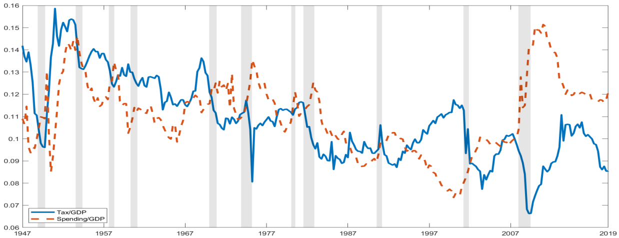
The Market Value of Outstanding Debt to GDP



- Build up market value of government debt, cusip by cusip, stripped across horizons
- Follows Hall and Sargent (2011), extended to 2020
- Portfolio has low excess return over the T-bill rate: 1.11% per year

Key Ingredients

1. Cash flow risk in $\{T, G\}$
   1.1 Business cycle-frequency risk
   - Tax revenues and revenues/GDP strongly pro-cyclical
   - Government spending and spending/GDP are strongly counter-cyclical



Key Ingredients

1. Cash flow risk in $\{T, G\}$
   1.1 Business cycle-frequency risk
   - $\Rightarrow$ Primary surplus is strongly pro-cyclical
   - Primary surplus is the cash flow of an investment strategy that buys all Treasury debt (net) issuance
   - In recessions, Treasury is net issuer of debt = investor has negative cash flows
   - Cash flow has wrong-way business cycle risk $\Rightarrow$ surplus claim carries business-cycle risk premium

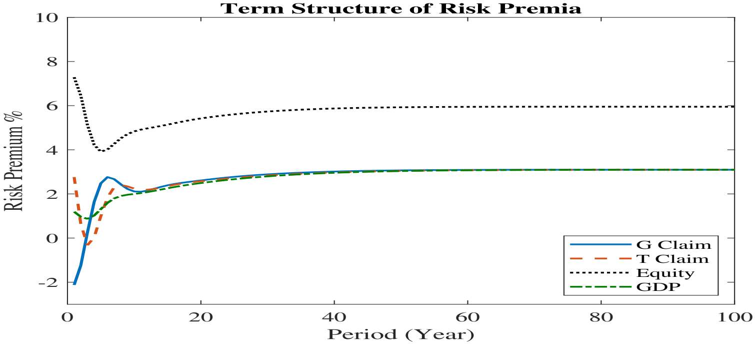
Key Ingredients

1. Cash flow risk in $\{T, G\}$
   1.1 Business cycle-frequency risk
   1.2 Long-run risk
      - Tax revenue and government spending are cointegrated with GDP $\Rightarrow$ same long-run risk
      - The expected return on a long-dated revenue or spending strip = expected return on long-dated GDP strip
      - Investor who is net long govt debt portfolio faces substantial long-run risk

Key Ingredients

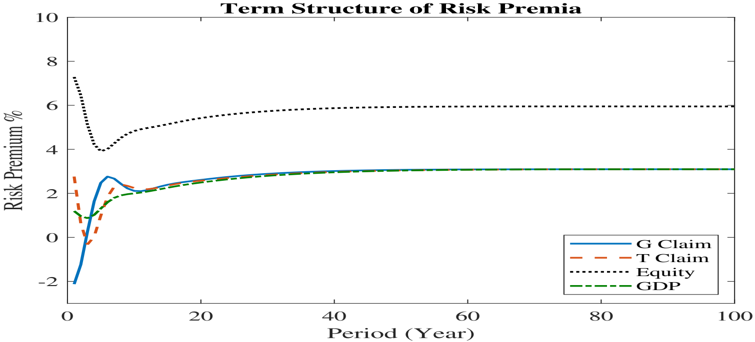
1. Cash flow risk in $\{T, G\}$
2. Realistic SDF M
   - Fits individual bond yields, nominal and real, of various maturities
   - Prices stocks (price levels, and risk premia)
   - Has a sufficiently large permanent component (Alvarez and Jermann, Borovicka, Hansen, Scheinkman)
   - Long-dated GDP claim (unlevered equity claim) has high risk premium $>$ long bond yield
   - Surplus claim has substantial long-run risk premium

Government Debt Risk Premium Puzzle



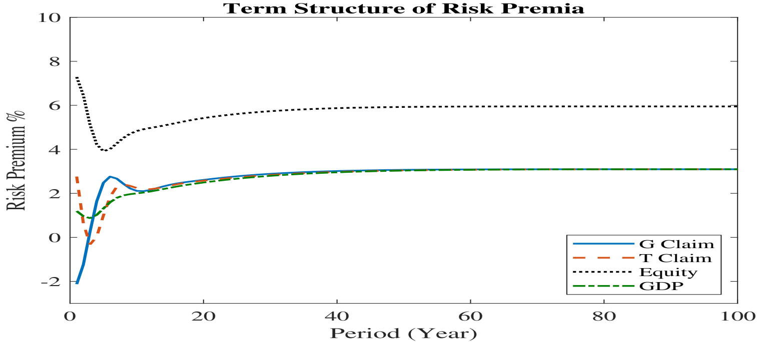
- Short-run: G claim is recession hedge, T claim is exposed

Government Debt Risk Premium Puzzle



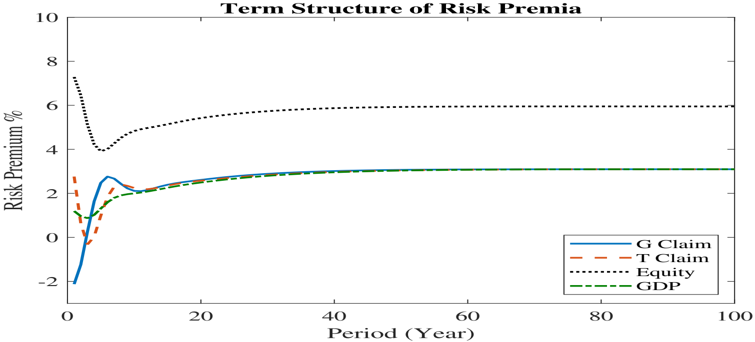
- With cointegration, long-run expected return on T- and on G-claim equals long-run expected return on GDP claim
- High long-run expected return on GDP strip, b/c permanent component in SDF

Government Debt Risk Premium Puzzle



- Short- and long-run risk premia imply that correct discount rate for surplus claim = debt portfolio is **not** the risk-free bond yield
- Expected excess return on surplus claim much higher than average observed excess return on Treasury portfolio of 1.1%

Government Debt Risk Premium Puzzle



- For surplus claim to be risk-free, the T-claim would need to be safer than the G-claim (JLVNX, 2020)

$$\mathbb{E}_t\left[R^T_{t+1} - R^f_t\right] = \underbrace{\frac{P^G_t - G_t}{D_t + P^G_t - G_t}}_{\text{less than 1}} \mathbb{E}_t\left[R^G_{t+1} - R^f_t\right]$$

Cash Flow Dynamics

- Define $\tau_t = \log(T_t/GDP_t)$, and $g_t = \log(G_t/GDP_t)$
- We let $\Delta\tau_{t+1}$ and Δg_{t+1} depend on lagged macro variables in VAR
  - Real GDP growth, inflation, short interest rate, slope of YC, price-dividend ratio on stock market, aggregate dividend growth, $\Delta\tau_{t+1}$, and Δg_{t+1}
  - Annual data 1947-2019, estimated by OLS
- Tax revenue and spending are cointegrated with GDP
- Model delivers reasonable impulse-responses of fiscal variables
- Results robust to

Cash Flow Dynamics

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- Tax revenue and spending are cointegrated with GDP
  - $\Delta\tau_{t+1}$ and Δg_{t+1} depend on lagged cointegration variables τ_t and g_t.
  - Cointegration indicates (long-run) automatic stabilizers (Bohn, 98)
  - Fiscal shocks temporarily affect the level of τ_t and g_t
- Model delivers reasonable impulse-responses of fiscal variables
- Results robust to

Cash Flow Dynamics

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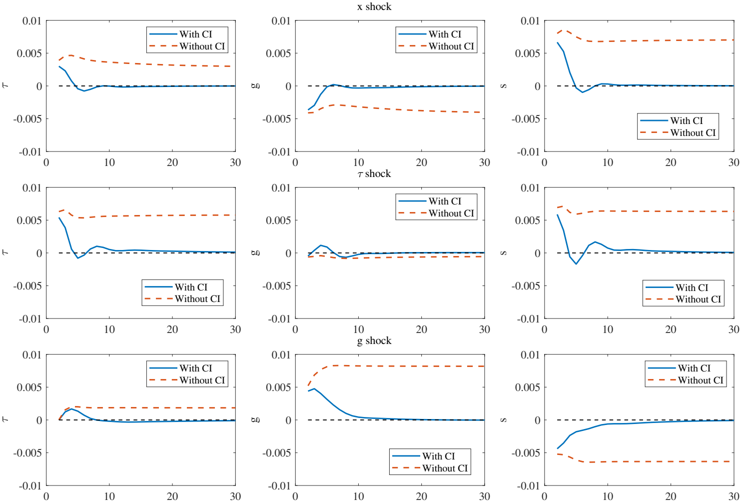
- Results robust to
  - Zeroing out insignificant elements in VAR companion matrix
  - Using quarterly instead of annual VAR
  - Starting sample in 1970
  - **Adding debt/gdp as a predictor in the VAR** (see appendix G) debt in VAR restrictions debt in VAR gap

Dynamic Asset Pricing Model

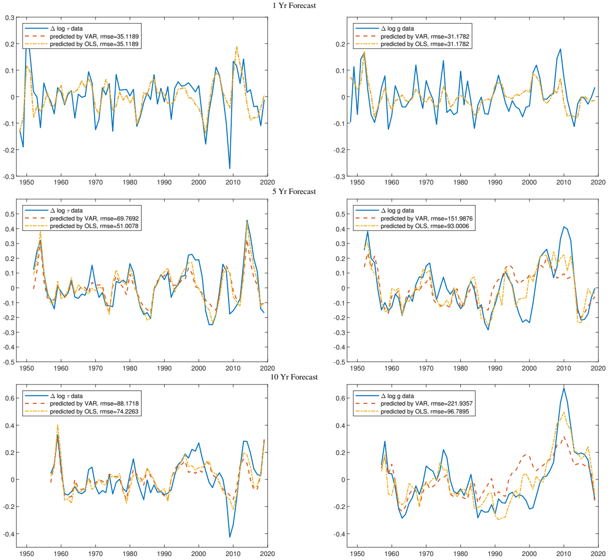
Table: State Variables

Position	Variable	Mean	Description
1	π_t	π_0	Log Inflation
2	x_t	x_0	Log Real GDP Growth
3	$y_t^{\$}(1)$	$y_0^{\$}(1)$	Log 1-Year Nominal Yield
4	$yspr_t^{\$}$	$yspr_0^{\$}$	Log 5-Year Minus 1-Year Nominal Yield Spread
5	pd_t	$\overline{pd}$	Log Stock Price-to-Dividend Ratio
6	Δd_t	μ_d	Log Stock Dividend Growth
7	$\Delta \log \tau_t$	μ_τ	Log Tax Revenue-to-GDP Growth
8	$\log \tau_t$	$\log \tau_0$	Log Tax Revenue-to-GDP Level
9	$\Delta \log g_t$	μ_g	Log Spending-to-GDP Growth
10	$\log g_t$	$\log g_0$	Log Spending-to-GDP Level
11	$\Delta \log d_t$	μ_d	Log Debt-to-GDP Growth
12	$\log d_t$	$\log d_0$	Log Debt-to-GDP Level

Responses of Tax and Spending



Forecasts of Revenue and Spending Growth



Some Details on Asset Pricing Model

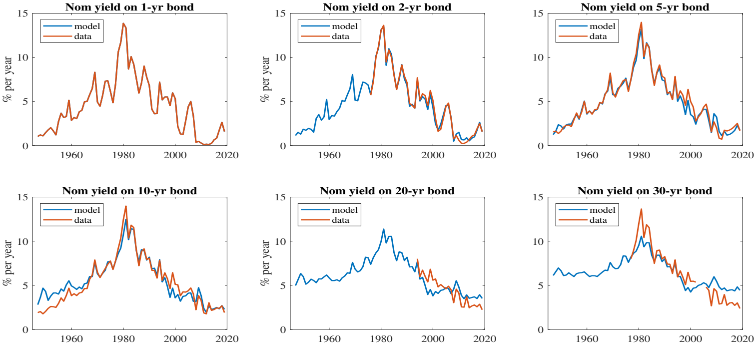
- Takes a stance on the priced sources of aggregate risk in the economy
  - Level & slope factor in the bond term structure
  - Dividend growth on the stock market
- Affine log SDF with market prices of risk Λ_t (Ang and Piazzesi, 2003)

$$
\begin{aligned}
m^{\$}_{t+1} &= -y^{\$}_t(1) - \frac{1}{2}\boldsymbol{\Lambda}_t'\boldsymbol{\Lambda}_t - \boldsymbol{\Lambda}_t'\boldsymbol{\varepsilon}_{t+1} \\
\boldsymbol{\Lambda}_t &= \boldsymbol{\Lambda}_0 + \boldsymbol{\Lambda}_1 z_t
\end{aligned}
$$

- Bond yields, price-dividend ratios on stock strips, expected (excess) returns on bonds and stocks are all affine in z_t
- Estimate $(\boldsymbol{\Lambda}_0, \boldsymbol{\Lambda}_1)$ to closely match: nominal and real bond yields of various maturities, nominal bond risk premia, stock price-dividend ratios, equity risk premia

Estimation

- Estimate $\widehat{\Lambda}_0, \widehat{\Lambda}_1$ to match observed interest rates for bonds at various horizons, expected excess return on 5-year nominal bond (BRP), and observed stock valuation ratio and expected excess stock returns.



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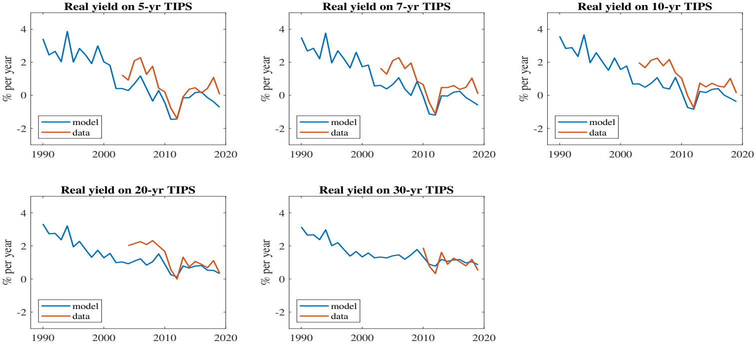

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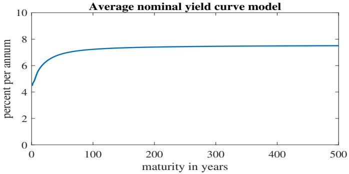

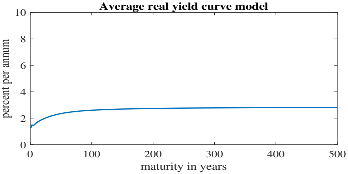

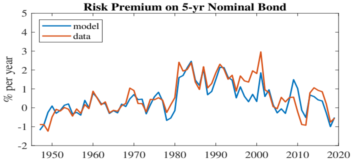

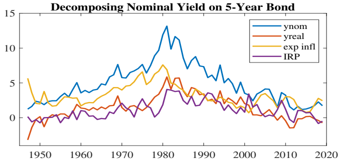

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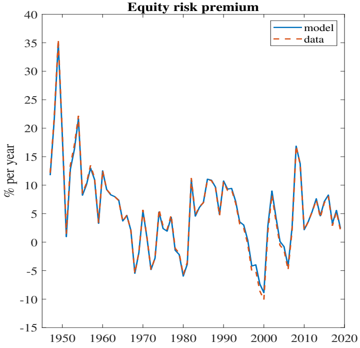
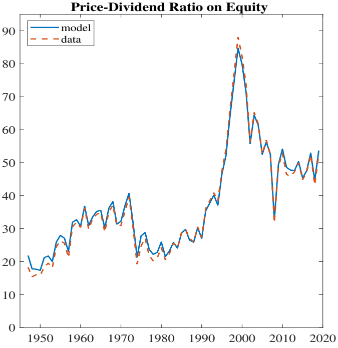




Pricing Claims to Revenue T and Spending G

- With VAR dynamics and the SDF in hand, we can value T and G claims

$$
\begin{aligned}
P_t^T &= \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j} T_{t+j}\right] \\
P_t^G &= \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j} G_{t+j}\right].
\end{aligned}
$$

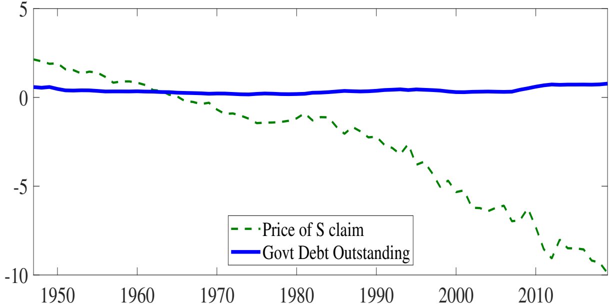
- The price-dividend ratios $PD_t^T = P_t^T / T_t$ and $PD_t^G = P_t^G / G_t$ are affine in the state z_t.

- Value of the surplus claim is $P_t^T - P_t^G = T_t PD_t^T - G_t PD_t^G$
- Scale by GDP for easier comparison to debt/GDP

$$
\frac{T_t}{GDP_t} PD_t^T - \frac{G_t}{GDP} PD_t^G
$$

And we get the Government Bond Valuation Puzzle

$$D_t = \mathbb{E}_t \left[\sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j} - G_{t+j}) \right]$$



Potential Resolution 1: Convenience Yield

- Convenience yield $\lambda_t \Leftrightarrow$ Treasury bonds paying lower yields than implied from SDF:

$$\begin{aligned} E_t[M_{t+1}] &= P_t^1 e^{-\lambda_t}, \\ E_t[M_{t+1}P_{t+1}^1] &= P_t^2 e^{-\lambda_t}, \\ E_t[M_{t+1}P_{t+1}^K] &= P_t^{K+1} e^{-\lambda_t}. \end{aligned}$$

- Debt now also backed by convenience services that Treasuries offers investors:

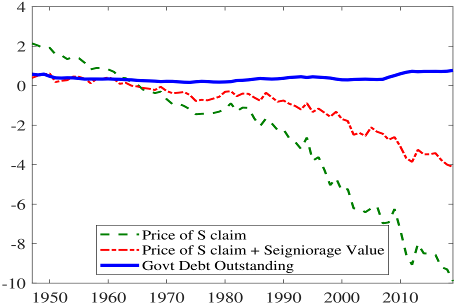
$$D_t = E_t\left[\sum_{j=0}^{\infty} M_{t,t+j}\left(T_{t+j} - G_{t+j} + (1 - e^{-\lambda_{t+j}})D_{t+j}\right)\right]$$

Can Convenience Yields Close the Gap?

- Measure λ_t as the weighted average of CP–T-bill spread and AAA–T-bond spread (Krishnamurthy and Vissing-Jorgensen, 2012).
  - Avg. λ_t is 60 bps p.a.; Avg. conv. revenue is 0.2% of GDP
  - Lines up with measure of Binsbergen et al. (19) BDG
  - Is strongly counter-cyclical
- Reduces puzzle but does not resolve it
- How Large a Convenience Yield to Close the Gap?
- Leaves open possibility that convenience yields are much larger and counter-cyclical than conventionally thought

Can Convenience Yields Close the Gap?

- Measure λ_t as the weighted average of CP–T-bill spread and AAA–T-bond spread (Krishnamurthy and Vissing-Jorgensen, 2012).
- Reduces puzzle but does not resolve it
  - PDV of convenience services averages 122% of GDP, closes about half of the gap
  - Higher convenience revenue offset by higher discounting because true risk-free rate higher with convenience



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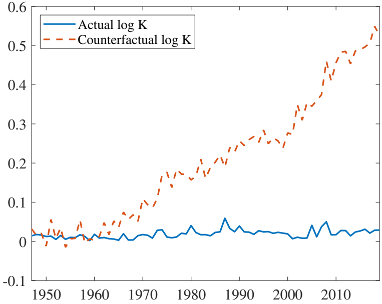
  - Convenience service revenues would need to be 22% of tax revenue, and 42% in last 20 years
  - They are only 1.9% in the data.



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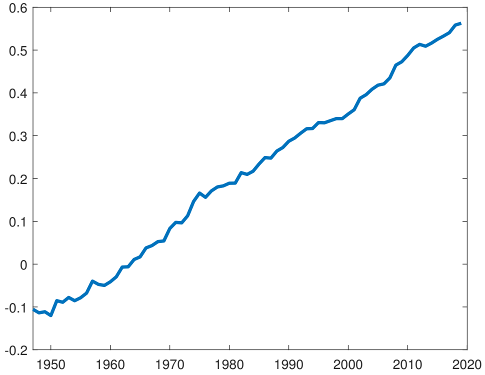
- How Large a Convenience Yield to Close the Gap?
- Leaves open possibility that convenience yields are much larger and counter-cyclical than conventionally thought
  - Other dollar-denominated assets also earn convenience yield
  - Krishnamurthy, Jiang, and Lustig (2019) find convenience yields for foreigners between 2 and 3%; Koijen and Yogo (2020) find 2.15% for U.S. long-term bonds
  - U.S. is world's designated supplier of dollar-denominated safe assets, *but that could change*; see Farhi and Maggiori (18)

Potential Resolution 2: Peso Problem

- Hypothesize that probability ϕ_t of a significant, **permanent** spending cut is priced in the surplus claim
- Such a spending cut "disaster" never realizes in post-war U.S. era, a peso event
- Spending cut of 8% of U.S. GDP = 2$\times$stdev of spending shock. Average spending is 11.5% of GDP in sample.
- How large should this spending cut probability ϕ_t be in order to equate the market value of the government debt to the present value of surpluses, period-by-period?

Potential Resolution 2: Peso Problem

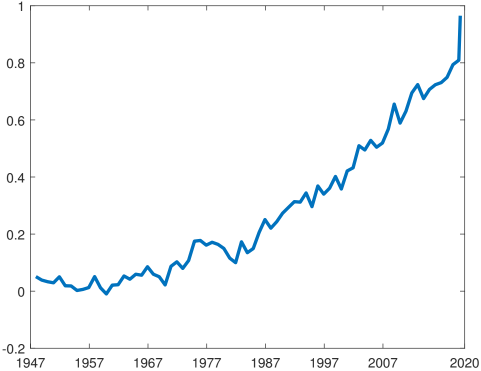
- Large! 23% on average



- Implied probability ϕ_t at odds with notion of peso event
- Suggests a restatement of the puzzle

Potential Resolution 2: Peso Problem

- Find similar results for probability of major increase in **tax revenues**



- Covid-19 update: implied probability of future tax ↑ from 81% in 2019.Q4 to 96% in 2020.Q1

Potential Resolution 3: Bubble in Treasuries

- Bond markets are not enforcing TVC
  - Bubble = value of outstanding debt − value of surplus claim
  - We quantify the size of the bubble at 260% of GDP unconditionally
- But, TVC may very well hold given large risk premium on debt; $r^f < g$ is not the relevant condition (even if debt is risk-free); $r^f + rp > g$
- TVC violations are hard to sustain in the presence of long-lived investors (Santos and Woodford, 97)
- If Treasury can run Ponzi scheme, why not AAA-rated corporates?
- Rise in sovereign CDS spread after GFC (Chernov et al. 16) seems inconsistent with rational bubble in Treasuries

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Potential Resolutions 4: Pure Fiscal Risk is Priced

- Model assumes that fiscal shocks that are orthogonal to macro-economic and financial sources of risk are not priced
- Mechanically, one can close the wedge by changing this assumption. Allow for non-zero mpr on tax shock and let it depend on the debt/gdp ratio.
- Would need orthogonal tax revenue shocks to have a very large negative risk price to close the wedge
  - That would make the tax claim safer and increase its value, and hence the value of the surplus claim
  - Violates Cochrane and Saa-Requejo (2000) good-deal bound: adds 6.3 to the model's maximum Sharpe ratio.
  - Implausible that positive (orthogonal) tax revenues/GDP shocks occur in bad times
- Similarly, would need very large positive risk price to orthogonal govt spending/gdp shock

Potential Resolutions 5: Government Assets

- Assets lower **net** government debt held by the public from 77.8% to 69.1% of the GDP; makes little difference for the puzzle
  - Outstanding student loans and other credit transactions, cash balances, and various financial instruments
  - Based on CBO data, total value of these government assets is 8.8% of GDP as of 2018.
- Other assets (national park land, defense assets, critical infrastructure, etc.) arguably off limits for political and military-strategic reasons
- If anything, massive off-balance sheet **liabilities** (Medicare, Social Security) will further **deepen** the puzzle in the future

Potential Resolutions 6: Financial Repression

- markets anticipate that at some future data, bond prices will no longer be determined by market forces. (e.g. Japan)

Conclusion

- A portfolio strategy that buys all outstanding Treasuries produces risky cash flows.
- When sources of aggregate risk reflected in bond and stock prices are adequately quantified, substantial risk premium on debt portfolio results.
- Implies that bond yields are puzzlingly low, especially recently.
- Interpretations:
  1. Bond market investors fail to enforce the TVC.
  2. Convenience yields may be much larger than we think.
  3. Investors hold optimistic beliefs about future fiscal rectitude.

Where have all the bond market vigilantes gone?