

# A Fiscal Decomposition of Unexpected Inflation: Cross-Country Estimates and Theory

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# Introduction: The Fiscal Sources of Unexpected Inflation

## ■ The Valuation Equation of Public Debt

$$\frac{\text{Market Value of Debt (**Bond Prices**)}}{\text{Price Level}} = \text{Intrinsic Value (**Discounting, Surpluses**)}.$$

## ■ Unexpected inflation $\Delta E_t \Pi_t$ must accompany news about:

- Bond prices  $Q_t$
- Real surpluses  $\{s_{t+k}\}$
- Real discounting  $\{R_{t+k}\}$

$$\Delta E_t \Pi_t = \Delta E_t \left[ Q_t - \{s_{t+k}\} + \{R_{t+k}\} \right]$$

- If unexpected inflation exists, it must nowcast/forecast some of these variables
- What are these forecasts? How do they change across countries? How can theory explain them?

# Introduction: Exercises, Motivation, Results

## ■ This paper.

1. Estimate a Bayesian-VAR to measure the decomposition for 25 countries
  - Variance decomposition:  $\text{var} [\Delta E \Pi] = \text{cov} [\Delta E \Pi, \quad Q + \{-s\} + \{R\}]$
  - "Aggregate demand" shock: recession + low inflation
2. Estimate a New-Keynesian model to reproduce B-VAR decompositions

## ■ Motivation. How do you read Debt/Price = Discounted Surpluses?

- Active fiscal: *"How does inflation react to changes in discounted surpluses?"*
  - Surpluses x Inflation in a given economy
  - Surpluses x Inflation across countries
  - Role of monetary policy?
  - Theory: which shocks cause inflation surprises?
- Active monetary: *"How should discounted surpluses adjust to unexpected inflation?"*

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## Introduction: Preview of Key Results

- The variance of unexpected inflation is accounted for by discounted surpluses (all countries)

$$\underset{> 0}{\text{var} [\Delta E \pi]} = \underset{< 0}{\text{cov} [\Delta E \pi, Q]} + \underset{> 0}{\text{cov} [\Delta E \pi, \{-s\} + \{R\}]}$$

- Most relevant terms (Surplus-to-GDP, GDP growth and Real discounting) vary
  - Monetary policy trades current for future unexpected inflation
- Lower inflation in recessions: low discounting + higher subsequent surpluses
- Productivity shocks reproduce findings in NK model
  - Policy shocks do not
- Different policy rules explain differences in variance decomposition across countries

### ■ **Fiscal Theory of the Price Level.** Cochrane (2022a) and Cochrane (2022b).

- Analysis of multiple countries + more general debt instruments
- NK model estimated to reproduce decompositions + Productivity shocks

Leeper (1991), Sims (1994), Cochrane (1998), Cochrane (2005), Sims (2011), Leeper and Leith (2016), Bassetto and Cui (2018), Cochrane (2022c), Brunnermeier et al. (2022).

### ■ **Monetary-Fiscal Interaction.**

Cagan (1956), Sargent and Wallace (1981), Hall and Sargent (1997), Hall and Sargent (2011), Jiang et al. (2019), Corsetti et al. (2019), Sunder-Plassmann (2020), Du et al. (2020), Akhmadieva (2022)

### ■ **Empirical Finance** (Decomposition of Returns)

Campbell and Shiller (1988), Cochrane (1992), Campbell and Ammer (1993), Chen and Zhao (2009).

# Introduction: A Map of the Road

## 1. Fiscal Decomposition Derivation

- Simple environment + General decomposition

## 2. Bayesian-VAR

- Empirical model + Variance decomposition + "Aggregate demand" recession

## 3. Theory

- Closed economy + Productivity shocks + Policy rules + Open economy

## Fiscal Decomposition: The Valuation Equation

- Environment with discrete time + single good (price  $P_t$ ) + households and government
- One-period nominal public bonds (price  $Q_t$ )
- **In the morning**, the government:
  - redeems bonds  $B_{t-1}$  for currency
  - announces real taxes  $s_t$  (payable in currency)
  - announces sale of  $B_t$  new bonds (payable in currency)
- **In the afternoon**, households trade goods, purchase bonds, pay taxes
- Market clearing + No Money Holding  $M = 0$ :

$$B_{t-1} = P_t s_t + Q_t B_t$$



## Fiscal Decomposition: The Valuation Equation

$$B_{t-1} = P_t s_t + Q_t B_t$$

- *Ex-post* real discounting  $\beta_t = Q_t(P_{t+1}/P_t)$   $\beta_{t,t+k} = \prod_{\tau=t}^{t+k} \beta_\tau$
- Iterate law of motion forward:

$$\frac{B_{t-1}}{P_t} = \sum_{k=0}^p \beta_{t,t+k-1} s_{t+k} + \beta_{t,t+p} \frac{B_{t+p}}{P_{t+p+1}}$$

- **Key Assumption:**  $\lim_{\tau \rightarrow \infty} \beta_{t,\tau} \frac{B_\tau}{P_{\tau+1}} = 0$  almost surely (**No bubbles**)
  - In Macro models: transversality conditions + no Ponzi
- The valuation equation of public debt

$$\frac{B_{t-1}}{P_t} = \sum_{k=0}^{\infty} E_t [\beta_{t,t+k-1} s_{t+k}]$$

## Fiscal Decomposition: In the Simplest Environment

- Nominal rate  $1 + i_t = 1/Q_t$  and real interest  $r_t = i_t - E_t\pi_{t+1}$
- End-of-period real debt  $v_t$

$$\underbrace{\frac{1}{\beta}v_{t-1} + \frac{v}{\beta}(i_{t-1} - \pi_t)}_{B_{t-1}/P_t} = s_t + v_t = \sum_{k=0}^{\infty} \beta^k E_t s_{t+k} - \frac{v}{\beta} \sum_{k=1}^{\infty} \beta^k E_t r_{t+k}$$

Linearized valuation equation (all variable in deviations from their mean)

- Innovations  $\Delta E_t = E_t - E_{t-1}$  decomposition:

$$\Delta E_t \pi_t = -\frac{\beta}{v} \sum_{k=0}^{\infty} \beta^k \Delta E_t s_{t+k} + \sum_{k=0}^{\infty} \beta^k \Delta E_t r_{t+k}$$

- Variance decomposition:

$$\text{var} [\Delta E_t \pi_t] = -\text{cov}_{\pi} \left[ \frac{\beta}{v} \sum_{k=0}^{\infty} \beta^k \Delta E_t s_{t+k} \right] + \text{cov}_{\pi} \left[ \sum_{k=0}^{\infty} \beta^k \Delta E_t r_{t+k} \right]$$

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## Fiscal Decomposition: Currency and Term Structures + Growth

- Real **market value** debt-to-GDP  $v_t$ , surplus-to-GDP  $s_t$  and GDP growth  $g_t$  (stationarity!)
- Bonds  $(j, n)$  promises one unit of currency  $j$  after  $n$  periods Currencies
  - Nominal bonds
  - Real bonds (currency denomination = final goods)
  - US Dollar bonds

Constant structure  $\{\delta_j\}, \{\omega_j^n\}$

- Bond price  $Q_{j,t}^n$ , excess return  $rx_{j,t}$   $1 + \text{return}_{j,t} = 1 + rx_{j,t} + i_{j,t-1} = \frac{\sum_n Q_{j,t}^{n-1} B_{j,t-1}^n}{\sum_n Q_{j,t-1}^n B_{j,t-1}^n}$   
(one-period bonds  $\implies rx = 0$ )
- Debt law of motion:

$$\frac{v_{t-1}}{\beta} + \frac{v}{\beta} \left[ -g_t + \sum_j \delta_j (rx_{j,t} + i_{j,t-1} + \Delta h_{j,t} - \pi_{j,t}) \right] = v_t + s_t$$

# Fiscal Decomposition of Unexpected Inflation

- Ex-post real return  $r_{j,t} = rx_{j,t} + i_{j,t-1} + \Delta h_{j,t} - \pi_{j,t}$

$$\Delta E_t \pi_t = \underbrace{\left[ \Delta E_t rx_t + \sum_{j \neq N} \frac{\delta_j}{\delta} \Delta E_t r_{j,t} \right]}_{\text{Innovation to Bond Prices}} - \frac{\beta}{\delta v} \underbrace{\left[ \sum_{k=0}^{\infty} \beta^k \Delta E_t s_{t+k} + \frac{v}{\beta} \sum_{k=0}^{\infty} \beta^k \Delta E_t g_{t+k} - \frac{v}{\beta} \sum_{k=1}^{\infty} \sum_j \delta_j \beta^k \Delta E_t r_{j,t+k} \right]}_{\text{Innovation to the Intrinsic Value of Debt}}$$

$$\equiv d_1(rx) + d_1(r_0) - d_1(s) - d_1(g) + d_1(r)$$

- Variance decomposition.

$$\text{var} [\Delta E_t \pi_t] = \text{cov}_{\pi} [d_1(rx)] + \text{cov}_{\pi} [d_1(r_0)] - \text{cov}_{\pi} [d_1(s)] - \text{cov}_{\pi} [d_1(g)] + \text{cov}_{\pi} [d_1(r)]$$

## Bayesian-VAR: Data and Model

- Annual data on **observables**  $\tilde{x}_t$

$$x_t^{OBS} = \begin{bmatrix} i_t & \text{(Nominal Interest)} \\ \pi_t & \text{(CPI Inflation)} \\ v_t^b & \text{(Par-Value Debt-to-GDP)} \\ g_t & \text{(GDP growth)} \\ \Delta h_t & \text{(Chg. Real Exchange Rate)} \end{bmatrix}$$

- 25 countries (samples starting at 1945, 1960, 1975, 1998)
- General VAR

$$X_t = AX_{t-1} + Ke_t$$

- Decompose  $X_t' = [x_t^{OBS'} \ x_t^{NOT'}]$

$$X_t = \begin{bmatrix} x_t^{OBS} \\ x_t^{NOT} \end{bmatrix} = \begin{bmatrix} a & 0 \\ b & c \end{bmatrix} \begin{bmatrix} x_{t-1}^{OBS} \\ x_{t-1}^{NOT} \end{bmatrix} + \begin{bmatrix} I \\ k \end{bmatrix} e_t$$

# Bayesian-VAR: Empirical Challenges and Solutions

## 1. Explosive debt dynamics in 1960-2020 implies unstable OLS VARs

$$\tilde{x}_t = \tilde{a} \tilde{x}_{t-1} + \tilde{b} \tilde{u}_{t-1} + \varepsilon_t$$

$$\tilde{u}_t = \tilde{a}_u \tilde{u}_{t-1} + \varepsilon_{u,t}$$

- Estimate US model ( $\tilde{a}_u$ ) by OLS (stable!)
- Estimate ( $\tilde{a}, \tilde{b}$ ) with a Bayesian-Regression

$$\tilde{a}^{BAY} = (X'X + \lambda^{-1})^{-1}(X'X \tilde{a}^{OLS} + \lambda^{-1} \tilde{a}^{PRIOR})$$

$\lambda$  maximizes the marginal distribution  $p(\text{data})$  and **ensures stability**

## 2. Public finance data do not respect law of motion of public debt

- Define surplus from the law of motion:  $s_t = \frac{v_{t-1}}{\beta} - v_t + \frac{v}{\beta} \left[ -g_t + \sum_j \delta_j (rx_{j,t} + i_{j,t-1} + \Delta h_{j,t} - \pi_{j,t}) \right]$

## 3. No data on the **market** value of debt, only its **par** value ( $v_t^b$ )

- Model for market vs par value (Cox (1985)):  $v_t = v_t^b + \frac{v}{\beta} \sum_j \delta_j (rx_{j,t} + i_{j,t-1} - i_{j,t-1}^b)$

## 4. No data on bond returns Geometric Term Structure

- Geometric maturity structure:  $rx_{j,t} + i_{j,t-1} = (\omega_j \beta) q_{j,t} - q_{j,t-1}$



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## Bayesian-VAR: Variance Decomposition

- **Proposition.** The variance decomposition

$$1 = \frac{\text{cov}_\pi \left[ d_1(rx) \right]}{\text{var} [\Delta E_t \pi_t]} + \frac{\text{cov}_\pi \left[ d_1(r_0) \right]}{\text{var} [\Delta E_t \pi_t]} - \frac{\text{cov}_\pi \left[ d_1(s) \right]}{\text{var} [\Delta E_t \pi_t]} - \frac{\text{cov}_\pi \left[ d_1(g) \right]}{\text{var} [\Delta E_t \pi_t]} + \frac{\text{cov}_\pi \left[ d_1(r) \right]}{\text{var} [\Delta E_t \pi_t]}$$

is equivalent to the innovations decomposition applied to VAR shock  $\text{Proj}(e \mid \Delta E_t \pi_t = 1)$

$$1 = \Delta E_t \pi_t \equiv d_1(rx) + d_1(r_0) - d_1(s) - d_1(g) + d_1(r)$$

- *"Given 1% unexpected inflation, how do we change our nowcast/forecast of the surplus, discounting and bond prices?"*

# Bayesian-VAR: Variance Decomposition

Country	$\Delta E_t \pi_t =$	$\Delta E_t(\text{Bond Prices})$		$-\Delta E_t(\text{Intrinsic Value of Debt})$		
		$d_1(r_0)$	$d_1(rx)$	$-d_1(s)$	$-d_1(g)$	$d_1(r)$
United States	1	<b>*0.03</b>	<b>*-0.78</b>	<b>0.57</b>	0.23	<b>0.96</b>
<i>Advanced - 1960 Sample</i>						
Canada	1	<b>*-0.11</b>	<b>*-1.59</b>	0.62	<b>*1.22</b>	0.86
Denmark	1	<b>*-0.29</b>	<b>-0.30</b>	0.42	-0.04	<b>1.21</b>
Japan	1	0	<b>*-0.52</b>	<b>*1.60</b>	-0.38	0.30
Norway	1	<b>*-0.01</b>	<b>*-0.36</b>	<b>0.60</b>	<b>0.47</b>	0.30
Sweden	1	<b>-0.15</b>	<b>*-0.93</b>	-0.34	<b>*0.98</b>	<b>*1.42</b>
United Kingdom	1	<b>*0.52</b>	<b>*-0.73</b>	<b>*2.89</b>	<b>*0.97</b>	<b>*-2.65</b>
<i>Advanced - 1973 Sample</i>						
Australia	1	<b>*0.07</b>	<b>*-0.76</b>	<b>*2.09</b>	<b>0.66</b>	<b>-1.06</b>
New Zealand	1	<b>-0.10</b>	<b>*-0.86</b>	0.40	<b>*0.87</b>	0.68
South Korea	1	-0.01	<b>*-0.45</b>	<b>*1.91</b>	0.17	<b>-0.62</b>
Switzerland	1	0	<b>*-0.69</b>	<b>0.90</b>	<b>*0.91</b>	-0.12

(a) Advanced Economies

Country	$\Delta E_t \pi_t =$	$\Delta E_t(\text{Bond Prices})$		$-\Delta E_t(\text{Intrinsic Value of Debt})$		
		$d_1(r_0)$	$d_1(rx)$	$-d_1(s)$	$-d_1(g)$	$d_1(r)$
<i>Emerging - 1998 Sample</i>						
Brazil	1	<b>-0.26</b>	<b>*-0.22</b>	<b>-1.46</b>	<b>1.05</b>	<b>1.89</b>
Chile	1	-3.80	<b>-1.33</b>	8.95	-5.71	2.88
Colombia	1	<b>1.51</b>	<b>*-0.96</b>	1.39	-1.09	0.15
Czech Republic	1	<b>*-0.16</b>	<b>*-0.37</b>	-2.31	<b>2.42</b>	<b>1.42</b>
Hungary	1	<b>*-0.57</b>	<b>*-0.93</b>	-0.98	1.60	1.88
India	1	<b>*0.17</b>	<b>*-0.46</b>	<b>1.54</b>	0.05	-0.30
Indonesia	1	<b>*-2.59</b>	<b>*-1.07</b>	1.69	<b>*2.61</b>	0.35
Israel	1	-0.06	<b>*-0.78</b>	-0.55	<b>*1.51</b>	0.88
Mexico	1	-0.02	<b>*-0.74</b>	<b>1.41</b>	0.03	0.32
Poland	1	<b>*-0.45</b>	<b>*-1.15</b>	0.87	-0.39	<b>*2.11</b>
Romania	1	-0.40	<b>*-0.96</b>	2.24	0.42	-0.31
South Africa	1	<b>0.36</b>	<b>*-0.51</b>	1.58	0.25	-0.68
Turkey	1	<b>0.37</b>	<b>*-0.37</b>	-1.18	-0.15	<b>*2.33</b>
Ukraine	1	0	<b>*-0.77</b>	<b>0.65</b>	<b>0.41</b>	<b>*0.70</b>

(b) Emerging Economies

## Bayesian-VAR: Variance Decomposition - Takeaways

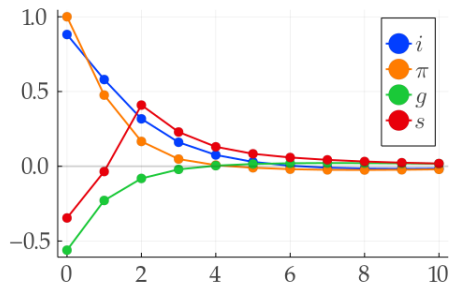


Figure: IRF - Brazil

- Unexpected inflation accounted for by variation in the intrinsic value of debt
- Surplus-to-GDP, GDP growth and real discounting...
  - ...account for unexpected inflation alone in 0/25
  - ...have a positive contribution in 8+/25
- Fiscal roots of inflation do not imply connection between fiscal policy and unexpected inflation
- Nominal bond price dynamics reduce unexpected inflation variance 25/25
  - Effects of monetary policy!

## Bayesian-VAR: "Aggregate Demand" Recession

- "Aggregate demand" recessions (Great Recession in 2008) feature:
  - Low inflation
  - Low growth
  - Fiscal deficits (often)
- Does that deny the fiscal sources of inflation?
- Where does unexpected (dis)inflation come from?
- Scenario:

$$\Delta E_t g_t = -1 \quad \Delta E_t \pi_t = -0.5$$

VAR Shock:  $\text{Proj}(e \mid \Delta E_t g_t = -1, \Delta E_t \pi_t = -0.5)$

# Bayesian-VAR: "Aggregate Demand" Recession

Country	$\Delta E_t \pi_t =$	$\Delta E_t(\text{Bond Prices})$		$-\Delta E_t(\text{Intrinsic Value of Debt})$		
		$d_1(r_0)$	$d_1(rx)$	$-d_1(s)$	$-d_1(g)$	$d_1(r)$
United States	-0.50	*0.03	*1.00	-0.65	*1.32	*-2.21
<i>Advanced - 1960 Sample</i>						
Canada	-0.50	*0.14	*2.21	-0.45	0.30	*-2.70
Denmark	-0.50	*0.20	*0.86	-2.64	*2.75	-1.67
Japan	-0.50	0	*0.83	*-1.51	*1.64	*-1.46
Norway	-0.50	0	*0.63	-1.36	*1.72	-1.49
Sweden	-0.50	*0.41	*1.22	-0.65	0.87	*-2.35
United Kingdom	-0.50	0.11	*2.54	-2.20	0.73	-1.68
<i>Advanced - 1973 Sample</i>						
Australia	-0.50	0.06	*1.54	-1.46	0.66	-1.31
New Zealand	-0.50	*0.26	*0.87	-0.84	0.63	-1.42
South Korea	-0.50	*0.10	*0.70	*-3.17	*1.74	0.14
Switzerland	-0.50	0	*1.18	*-0.93	-0.07	-0.67

(a) Advanced Economies

Country	$\Delta E_t \pi_t =$	$\Delta E_t(\text{Bond Prices})$		$-\Delta E_t(\text{Intrinsic Value of Debt})$		
		$d_1(r_0)$	$d_1(rx)$	$-d_1(s)$	$-d_1(g)$	$d_1(r)$
<i>Emerging - 1998 Sample</i>						
Brazil	-0.50	*0.37	0.06	1.87	0.13	-2.39
Chile	-0.50	*15.78	*2.94	-30.50	30.54	-19.26
Colombia	-0.50	1.86	*0.67	-10.90	*7.57	0.31
Czech Republic	-0.50	*0.37	*0.61	-0.07	0.25	-1.65
Hungary	-0.50	*0.99	*0.60	10.82	-5.29	-7.63
India	-0.50	-0.03	0.13	-1.16	0.71	-0.15
Indonesia	-0.50	*8.23	-0.55	*-11.24	1.42	1.64
Israel	-0.50	*1.79	0.37	-3.18	1.17	-0.65
Mexico	-0.50	*1.69	*0.81	*-4.56	*1.94	-0.38
Poland	-0.50	*0.87	*1.00	-0.14	1.30	*-3.53
Romania	-0.50	*2.08	0.21	*-8.16	2.05	3.31
South Africa	-0.50	-0.10	0.35	*-30.02	*11.15	*18.13
Turkey	-0.50	*0.99	*0.23	0.64	0.52	*-2.88
Ukraine	-0.50	0	-0.68	-3.22	*1.92	1.48

(b) Emerging Economies



## Bayesian-VAR: "Aggregate Demand" Recession - Takeaways

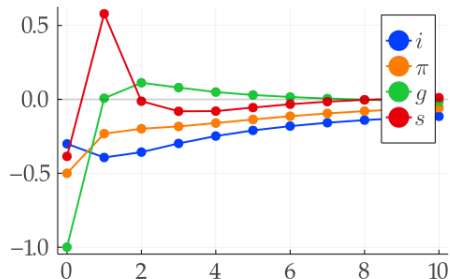


Figure: IRF - United States

- Lower inflation follows from...
  - lower discounting (monetary policy)
  - larger surplus-GDP ratios, current or in the future
- COVID: what if governments reacted to a recession by credibly reducing  $\{s\}$  permanently?



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## Appendix: Public Debt Currency Denomination

Return

Symbol	Description	Nominal Debt	Real Debt	Dollar Debt
$j$	Index Symbol Notation	$N$ $\delta, \omega$	$R$ $\delta_R, \omega_R$	$D$ $\delta_D, \omega_D$
$P_j$	Price per Good	$P$	1	$P_t^{US}$
$\mathcal{E}_j$	Nominal Exchange Rate	1	$P$	Dollar NER
$H_j$	Real Exchange Rate	1	1	Dollar RER
$\pi_j$	Log Variation in Price	$\pi$	0	$\pi_t^{US}$
$\Delta h_j$	Log Real Depreciation	0	0	$\Delta h_t$

Table: Public Debt Denomination

## Appendix: Geometric Term Structure

### Return

- To each currency portfolio  $j$ , fixed geometric maturity structure:

$$B_{j,t}^n = \omega_j B_{j,t}^{n-1}$$

- Total return on currency- $j$  portfolio:

$$1 + rx_{j,t} + i_{j,t-1} = \frac{1 + \omega_j Q_{j,t}}{Q_{j,t-1}} \implies \boxed{rx_{j,t} + i_{j,t-1} = (\omega_j \beta) q_{j,t} - q_{j,t-1}}$$

- Assume **constant risk premia**  $E_t rx_{j,t+1} = 0$

$$\boxed{q_{j,t} = (\omega_j \beta) E_t q_{j,t+1} - i_{j,t}} = - \sum_{k=0}^{\infty} (\omega_j \beta)^k E_t i_{j,t+k}$$