The Municipal Bond Valuation Puzzle: Evidence from U.S. States

by

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Abstract

This paper seeks to elucidate the mechanisms that generate Jiang et al. (2020)'s "government debt valuation puzzle" by adapting their approach to the setting of state-level municipal debt. The main motivation in doing so is that states do not issue their own currencies, and are therefore precluded from monetizing the value of their debt through inflation. I find that, contrary to Jiang et al. (2020), the market value of outstanding state-level government debt is typically smaller than the present discounted value of current and future primary surpluses. For example, the gap between these two quantities is equal to 86.61 percent of GDP for the state of California from 1979 to 2019. This gap may be attributed to a number of factors: (i) expectations of federal bailouts and transfers during recessionary periods; (ii) balanced-budget amendments (BBAs) and statutory debt limits that constrain countercyclical fiscal spending; and (iii) mismeasurement of surpluses due to the omission of state-contingent liabilities for underfunded pensions and insolvent local governments.

1 Introduction

The government's intertemporal budget constraint has been referred to as "the least controversial equation in macroeconomics."[1] While that may be true, the asset-pricing implications of the equation have recently been a matter of dispute.

In an unpublished paper, Jiang et al. (2020) find that, under realistic models of the quantities and prices of risk for fiscal cash flows, the market value of outstanding U.S. Treasury debt exceeds the present discounted value of current and future primary surpluses. As *de rigueur* for financial economists, the authors label the resulting gap a "puzzle," and suggest that a violation of the transversality condition is afoot. In response, Cochrane (2020) suggests that the "puzzle" is driven by the usage of an inappropriate VAR to forecast primary

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[1]See Hall and Sargent (2011), pg. 193.

surpluses, one that crucially excludes the value of government debt as a state variable.

This paper seeks to elucidate the mechanisms that generate Jiang et al. (2020)'s valuation puzzle by adapting their approach to the setting of state-level municipal debt. The main motivation in doing so is that states do not issue their own currencies, and are therefore precluded from monetizing the value of their debt through inflation. Thus, state governments must either run surpluses to repay their debts, or default—the price level in the United States does not adjust in response to an individual state government's debts. Other potential explanations for the puzzle—including non-zero money demand by the representative consumer, the existence of a convenience yield and accompanying seigniorage revenue, and investor expectations of "peso events" that precipitate a debt roll-over crisis—are unlikely to be material for state governments.

In order to facilitate comparison between the federal and state contexts, I deploy the same state variables, lag order structure, and stochastic discount factor (SDF) as in Jiang et al. (2020) when computing the quantities and prices of risk in fiscal cash flows. I find that, contrary to what has been documented at the federal level, the market value of outstanding state government debt is typically *smaller* than the present discounted value of current and future primary surpluses. For example, the gap between these two quantities is equal to 86.61 percent of GDP for the state of California from 1979 to 2019, and it is considerably larger in the post-2000 subsample. For state governments, this gap can be attributed to a number of factors: (i) expectations of federal bailouts and transfers during recessionary periods; (ii) balanced-budget amendments (BBAs) and statutory debt limits that constrain countercyclical fiscal spending; and (iii) mismeasurement of surpluses due to the omission of state-contingent liabilities for underfunded pensions and insolvent local governments.

2 Theoretical Background

To cement intuition, a derivation and discussion of the government's intertemporal budget constraint is warranted. I follow the inchoate textbook treatment of Cochrane (2020), emphasizing how the standard fiscal theory of the price level (FTPL) equations are modified in the case of monetary unions like the United States.

2.1 Single-Period Model

Let T_t denote nominal government revenue and G_t denote nominal government spending excluding interest payments on existing debt, both at time period t. The difference between these two quantities, $S_t \equiv T_t - G_t$, is the government's primary surplus. The government faces the one-period budget constraint

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

where Q_t^h is the number of nominal zero-coupon bonds of maturity h outstanding in period t, and P_t^h is the price in period t of an h-period zero-coupon bond. Intuitively, the LHS of Equation (1) captures the government's financing needs in the current period arising from primary deficits (i.e., negative primary surpluses) and any maturing one-period debt from the previous period. The RHS shows that the required financing is raised by issuing new bonds of various maturities. Since state governments frequently issue coupon-bearing bonds, Equation (1) can be rewritten in such a way that P_t^h represents the price of a bond that pays a series of coupon payments until maturity.

As alluded to in Section 1, Equation (1) is considered by some to be uncontroversial, and it is frequently invoked without proof or discussion. It is important, however, to address which interpretations of Equation (1) are justified in the setting of a monetary union like the United States, and which are not.

First, while Equation (1) is commonly referred to as the government's "budget constraint," it is more precisely an equilibrium condition. Colloquially, budget constraints limit quantities given prices. Since Equation (1) is in nominal terms, how is the price level determined?

In the case of a currency-issuing sovereign like the U.S. federal government, the actual budget constraint is a slightly modified form of Equation (1) that includes money:

$$Q_{t-1}^{1} - S_t + M_{t-1} = \sum_{h=1}^{H} \left(Q_t^h - Q_{t-1}^{h+1} \right) P_t^h + M_t \tag{2}$$

where M_t denotes the stock of non-interest-paying money at period t. In a frictionless setting, when the interest rate on government bonds is greater than zero, consumer money demand implies that $M_t = 0$. When the interest rate is zero, money and bonds are perfect substitutes, so Q_t can represent their sum. (In this simple example, the interest rate on government debt cannot be less than zero.) Thus, money balances cancel from both sides of Equation (2), leading to Equation (1).

In other words, Equation (1) is a *flow equilibrium condition* resulting from the optimizing behavior of a hypothetical representative consumer. As such, there is no guarantee that Equation (1) will hold at off-equilibrium prices for a currency-issuing sovereign. In the case of the federal government, nominal debt is akin to equity, whose relative price adjusts in order for a valuation equation—in this analogy, the dividend discount model—to hold.

For state governments, however, Equation (1) is a *bona fide* budget constraint, given that states do not issue debt in their own currencies. Nominal debt issued by state governments is like debt issued by a corporation, which must be repaid at the prevailing price level or defaulted upon. In the terminology of Leeper (1991), state fiscal policies are "passive," insofar as the government must adjust surpluses such that Equation (1) holds for any price level. "Active" fiscal policy, on the other hand, allows the government to adjust the price level so that Equation (1) holds for any sequence of surpluses. A regime in which the government can inflate away its debt is an active one, although such a possibility requires close coordination between fiscal and monetary authorities.

2.2 Intertemporal Model

I now derive the intertemporal version of the government's budget constraint. The derivation is a modified version of that found in Appendix A of Jiang et al. (2020). Reorganize Equation (1) as:

$$\begin{aligned} S_t =& Q_{t-1}^1 - Q_t^1 P_t^1 + Q_{t-1}^2 P_t^1 - Q_t^2 P_t^2 + Q_{t-1}^3 P_t^2 - Q_t^3 P_t^3 \\ &+ \cdots - Q_t^H P_t^H + Q_{t-1}^{H+1} P_t^H . \end{aligned} \tag{3}$$

Assume there exists a nominal multi-period SDF $M_{t,t+h} = \prod_{k=0}^{h} M_{t+k}$ that is the product of adjacent one-period SDFs, M_{t+k}. Note that this assumption relies only on the absence of arbitrage, not on market completeness, which is required for the SDF to be unique. Iterate Equation (3) forward one period, multiply both sides by M_{t+1}, and take expectations conditional on time t:

$$\begin{aligned} \mathbb{E}_t\left[M_{t+1}S_{t+1}\right] =& Q_t^1 P_t^1 - \mathbb{E}_t\left[Q_{t+1}^1 M_{t+1} P_{t+1}^1\right] + Q_t^2 P_t^2 - \mathbb{E}_t\left[Q_{t+1}^2 M_{t+1} P_{t+1}^2\right] + Q_t^3 P_t^3 \\ &- \mathbb{E}_t\left[Q_{t+1}^3 M_{t+1} P_{t+1}^3\right] + \cdots + Q_t^H P_t^H \\ &- \mathbb{E}_t\left[Q_{t+1}^H M_{t+1} P_{t+1}^H\right] + Q_t^{H+1} P_t^{H+1} \end{aligned}$$

where $\mathbb{E}_t\left[M_{t+1}\right] = P_t^1, \mathbb{E}_t\left[M_{t+1}P_{t+1}^1\right] = P_t^2, \cdots, \mathbb{E}_t\left[M_{t+1}P_{t+1}^{H-1}\right] = P_t^H$, and $\mathbb{E}_t\left[M_{t+1}P_{t+1}^H\right] = P_t^{H+1}$.

Now consider the period $t+2$ constraint, multiplied by $M_{t+1}M_{t+2}$, and take time-t expectations:

$$\begin{aligned} \mathbb{E}_t\left[M_{t+1}M_{t+2}S_{t+2}\right] =& \mathbb{E}_t\left[Q_{t+1}^1 M_{t+1} P_{t+1}^1\right] - \mathbb{E}_t\left[Q_{t+2}^1 M_{t+1} M_{t+2} P_{t+2}^1\right] + \mathbb{E}_t\left[Q_{t+1}^2 M_{t+1} P_{t+1}^2\right] \\ &- \mathbb{E}_t\left[Q_{t+2}^2 M_{t+1} M_{t+2} P_{t+2}^2\right] + \mathbb{E}_t\left[Q_{t+1}^3 M_{t+1} P_{t+1}^3\right] - \cdots \\ &+ \mathbb{E}_t\left[Q_{t+1}^H M_{t+1} P_{t+1}^H\right] - \mathbb{E}_t\left[Q_{t+2}^H M_{t+1} M_{t+2} P_{t+2}^H\right] + \mathbb{E}_t\left[Q_{t+1}^{H+1} M_{t+1} P_{t+1}^{H+1}\right], \end{aligned}$$

where by the law of iterated expectations $\mathbb{E}_{t+1}\left[M_{t+2}\right] = P_{t+1}^1, \mathbb{E}_{t+1}\left[M_{t+2}P_{t+2}^1\right] = P_{t+1}^2$, etc.

Adding up the expected discounted surpluses at $t, t+1$, and $t+2$, we get that:

$$S_t + \mathbb{E}_t\left[M_{t+1}S_{t+1}\right] + \mathbb{E}_t\left[M_{t+1}M_{t+2}S_{t+2}\right] = \textstyle\sum_{h=0}^{H} Q_{t-1}^{h+1}P_t^h$$
$$-\mathbb{E}_t\left[Q_{t+2}^{1}M_{t+1}M_{t+2}P_{t+2}^{1}\right] - \mathbb{E}_t\left[Q_{t+2}^{2}M_{t+1}M_{t+2}P_{t+2}^{2}\right] - \cdots - -\mathbb{E}_t\left[Q_{t+2}^{H}M_{t+1}M_{t+2}P_{t+2}^{H}\right].$$

Similarly, consider the one-period government budget constraints at times $t+3, t+4$, etc. Adding up all the one-period budget constraints until horizon $t+J$, we get that:

$$\sum_{h=0}^{H} Q_{t-1}^{h+1}P_t^h = \mathbb{E}_t\left[\sum_{j=0}^{J} M_{t,t+j}S_{t+j}\right] + \mathbb{E}_t\left[M_{t,t+J}\sum_{h=1}^{H} Q_{t+J}^{h}P_{t+J}^{h}\right] \tag{4}$$

where, by convention, $M_{t,t} = M_t = 1$ and $P_t^0 = 1$.

Equation (4) says that the market value of outstanding government debt is equal to the present discounted value of expected surpluses over the next J years plus the present discounted value of government debt outstanding at time $t+J$. We now take the limit as $J \to \infty$:

$$\sum_{h=0}^{H} Q_{t-1}^{h+1}p_t^h = \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}S_{t+j}\right] + \lim_{J\to\infty}\mathbb{E}_t\left[M_{t,t+J}\sum_{h=1}^{H} Q_{t+J}^{h}P_{t+J}^{h}\right].$$

We obtain that the market value of outstanding debt inherited from the previous period is equal to the present discounted value of the expected primary surplus stream $\left\{S_{t+j}\right\}$ plus the discounted market value of debt outstanding in the infinite future. Consider the transversality condition (TVC):

$$\lim_{J\to\infty}\mathbb{E}_t\left[M_{t,t+J}\sum_{h=1}^{H} Q_{t+J}^{h}P_{t+J}^{h}\right] = 0$$

which says that while the market value of outstanding debt may grow over time, it cannot grow at a rate faster than the SDF. Otherwise, there exists a "rational bubble" in government debt.

If the TVC is satisfied, then outstanding debt today, D_t, reflects the present discounted value of current and future primary surpluses:

$$D_t = \sum_{h=0}^{H} Q_{t-1}^{h+1}P_t^h = \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}S_{t+j}\right]. \tag{5}$$

2.3 Discussion

Equation (5) is typically referred to as the government's intertemporal budget constraint. Again, in light of the discussion in Section 2.1, for a currency-issuing sovereign, it is more accurately described as an equilibrium relationship, which is the product of three distinct consumer optimality conditions: zero money demand, intertemporal allocation, and a TVC. Thus, any divergence between the LHS and RHS of Equation (5)—which suggests an economy that is out of equilibrium—can stem from a violation of one or more of the three conditions.

As emphasized by Jiang et al. (2020), Equation (5) is an *ex-ante* relationship that holds in both nominal and real terms. While this statement is strictly speaking true, it elides the important role of the price level in restoring the economy to equilibrium. As evidenced by Equation (1), inflation arises in this model whenever revenue from new debt issuances are insufficient to repay existing debt and fund any primary deficit at the originally expected lower price level. The impetus for this adjustment is a loss of faith by investors that debt can be rolled over, and in such a roll-over crisis, the currency-issuing sovereign can either explicitly default on its obligations or default via inflation. Thus, while the proximate cause of inflation is a difficulty rolling over debt, the ultimate cause is changing investor expectations about future surpluses.

Jiang et al. (2020) are skeptical that, in the case of the U.S. federal government, inflation can explain any discrepancy between the market value of outstanding debt and the present discounted value of current and future primary surpluses. As they point out, break-even inflation rates implied by bond markets suggest expectations of low inflation *ex ante*, and *ex post* inflation has limited potential to reduce debt burdens given the short duration (averaging about four years) of U.S. Treasury debt.

Two objections to Jiang et al. (2020)'s argument can be raised. First, as noted by Cochrane (2020), the likely result of a roll-over crisis will not only be inflation, but also "an unraveling of our payments, monetary, and financial institutions." In other words, inflation may coincide with a "peso event" of seismic proportions, with unknown effects on bond prices. To their credit, Jiang et al. (2020) calculate the probability of a peso event involving a permanent 8 percent reduction in the spending-GDP ratio, which would neutralize much of the observed discrepancy between the LHS and RHS of Equation (5). Using bond prices, the authors find an implied probability as large as 55 percent in 2018, which they find hard to countenance given no such event occurred in their 70-year sample. However, this is but one realization of a peso event, and it doesn't capture Cochrane's hypothesized combination of inflation and a sovereign debt crisis.

Second, the fact that U.S. Treasury debt has a short duration on average is exactly why inflation can occur according to the FTPL. Short-duration debt that is backed by an illiquid stream of cash flows like primary surpluses is particularly susceptible to roll-over crises, which require the sovereign to either default or induce inflation. As described by Cochrane

(2020), inflation in the FTPL has "the feel of a run," and can seemingly erupt out of nowhere, akin to "sunspots" in the classic Diamond-Dybvig (1983) model of bank runs.

Admittedly, roll-over crises and hyperinflations seem unlikely to plague the U.S. federal government, given the dollar's *de facto* status as the world's reserve currency and the widely-assumed safety of Treasury debt, which earns it a convenience yield. The convenience yield is actually an additional source of seigniorage revenue for the government, as the U.S. Treasury can sell bonds at higher prices (equivalently, lower yields) than their fundamental values. So, the same forces that shield Treasury debt from roll-over crises also push up the price of Treasury debt, further widening the divergence between the LHS and RHS of Equation (5). Using estimates of the convenience yield according to the methodology of Krishnamurthy and Vissing-Jorgensen (2012), Jiang et al. (2020) find that the seigniorage revenue generated is insufficient to explain the valuation puzzle. This is due to an offsetting discount-rate effect: a higher convenience yield raises the true riskfree rate given observed Treasury bond yields, lowering the present discounted value of future surpluses.

To summarize, Equation (5) may be violated empirically for any number of reasons: (i) *ex-post* inflation due to a roll-over crisis in short-maturity government debt; (ii) non-zero money demand by the representative consumer; (iii) a violation of the representative consumer's TVC; (iv) a convenience yield and accompanying seigniorage revenue for government debt; and (v) investor expectations of peso events that involve severe fiscal austerity.

As discussed in Section 2.1, in the context of state governments, Equation (5) is a *bona fide* budget constraint: state governments must run surpluses to repay their debts, or default. The price level in the United States does not adjust in response to an individual state government's debts. So, *ex-post* inflation has no role in explaining empirical violations of Equation (5) for state governments. Furthermore, since state governments do not issue their own currencies, or have any control over the amount of currency issued by the federal government, zero money demand by the representative consumer is not necessary to derive Equation (5). Finally, there is no evidence that individual state government debt earns a convenience yield that creates seigniorage revenue, although the tax deductibility of interest received on state bond holdings effectively functions as a fiscal transfer from the federal to state governments. Thus, an empirical test of Equation (5) along the lines of Jiang et al. (2020) for state governments would help elucidate which explanations of the valuation puzzle are structural and invariant to the context considered—like violations of the TVC—and which are artifacts of the federal context.

One additional consideration present in the state government context but not in the federal one is the possibility of a bailout or debt guarantee. The possibility of such a bailout—either explicit or implicit—will likely increase the market value of state government bonds beyond their fundamental values, causing the LHS of Equation (5) to exceed the RHS, *ceteris paribus*. Interestingly, bailouts and guarantees can be expected to increase the likelihood of *ex-post* inflation in the federal context, since their swift and expansive nature is unlikely to be met with offsetting higher federal taxation.

3 Empirical Strategy

Given the prediction of Equation (5) that the market value of outstanding government debt is equal to the present discounted value of current and future primary surpluses, a straightforward procedure for testing such a prediction is to model the surplus process for state governments, specify an asset pricing model to price claims to those surpluses, and compare the resulting values of the surplus claims to the market values of outstanding debt over time. While conceptually simple, the precise methodology and assumptions involved deserve further discussion.

3.1 Data Sources

Information on the prices and quantities of state-level debt issuances is obtained from the Municipal Securities Rulemaking Board (MSRB) and Bloomberg. The MSRB collects municipal bond trading data through its Electronic Municipal Market Access (EMMA) database. Since the MSRB is the primary regulator of the municipal market, the EMMA database contains the near-universe of transactions by investors and dealers in the over-the-counter market. The quantities of debt issued by state governments are obtained from Bloomberg: all matured or active general obligation (GO) bonds for which the state government is listed as the "ultimate borrower" are included. The market price of each GO bond is computed at a daily frequency as the par-value-weighted average of the transacted prices reported by the MSRB.

GO bonds are those issued by the state government that are backed by the full faith and credit of the state and/or the state's taxing power. The other main type of municipal debt—so-called "revenue bonds"—are those that repay creditors using income generated from specific funded projects (e.g., toll roads), and are typically collateralized. According to the most recent Moody's State Debt Medians Report, 40 states issue GO debt in some form, and GO debt constitutes more than half (51.2 percent) of all state net-tax supported debt.[2] For my analysis, I include any state for which GO debt constitutes more than half of outstanding net-tax supported debt in FY 2019; 26 states satisfied this criterion.

[2]The 2020 report is accessible via the State of Vermont Treasurer's website: https://www.vermonttreasurer.gov.

National statistics such as inflation and real GDP growth are obtained from the NIPA tables maintained by Bureau of Economic Analysis (BEA). One- and five-year constant-maturity Treasury yields are from FRED, and aggregate price-dividend ratio and dividend growth rates are collected from the Wharton Research Data Services' CRSP database.

Nominal state-level GDP estimates are obtained from the BEA; annual figures are available beginning in 1977. State-level fiscal variables are obtained from the Government Finance Database maintained by Hand, Pierson, and Thomspon; the database collects information reported by the U.S. Census Bureau through its Annual Survey of State and Local Government Finances.[3] Primary surpluses are calculated at an annual frequency by subtracting state-level expenditures (excluding interest payments on existing debt) from revenues. Two separate flavors of fiscal cash flows are reported by the Census Bureau; one using "total" figures, and another using "general" figures. According to the Census Bureau, general revenues include any taxes collected by the state, intergovernmental transfers, and other minor charges and miscellaneous items. Total revenues are defined as general revenues in addition to revenues from utilities, liquor stores, and social insurance trust systems. Similarly, total expenditures comprise general expenditures including expenditures for utilities, liquor stores, or social insurance trusts. Interest payments on outstanding debt have "total" and "general" flavors as well, where general debt excludes debt issued for utilities, premiums paid on debt retired, and federal interest payments on securities held by the state's insurance trust fund.

Table 1 reports summary statistics for the primary surplus-GDP ratios calculated using "total" variable flavors for each of the 26 states in the sample from 1977 to 2019. The primary surplus-GDP ratio for the federal government is listed at the bottom of the table. The final column (labeled "Corr") reports the correlations between the primary surplus-GDP ratios of the state and federal governments. In contrast to the federal government—which on average ran a negative primary surplus during the sample period—every state ran a positive primary surplus on average. This likely reflects the existence of balanced budget amendments (BBAs) and statutory debt limits at the state level that constrain the ability of state governments to run deficits.

To facilitate a closer comparison of trends in state-level and national-level primary surpluses, the primary surplus-GDP ratios for California and the United States are plotted in Figure 1. There is a strong, positive correlation between the two series ($\rho = 0.3721$), and, as expected, primary surpluses tend to fall in recessions and grow in expansions. The main difference between the two series is that, before the 2001 recession, California ran only positive primary surpluses, whereas the federal government ran negative surpluses

[3]The database, updated through FY 2018, can be accessed at the following link: https://willamette.edu/mba/research-impact/public-datasets/index.html.

TABLE 1: Primary surplus-GDP ratios by state, 1977-2019

	Surplus-GDP Ratio					
	Mean	Median	Std Dev	Min	Max	Corr
Arkansas	.0126869	.0153167	.0148745	-.0381104	.0375482	.2789
California	.0109534	.0149642	.0176337	-.0686375	.0368854	.3721
Connecticut	.0102626	.0104479	.0133238	-.027078	.0402018	.2167
Delaware	.018043	.0198578	.0157152	-.0251228	.0430425	.5432
Florida	.0106757	.0124989	.0124818	-.0384338	.0347496	.3047
Georgia	.0069527	.0088318	.0089577	-.0191421	.0188775	.3036
Hawaii	.016561	.0206687	.019797	-.0609837	.0480687	.3984
Illinois	.0076894	.0101274	.011101	-.0422838	.022101	.4762
Louisiana	.0082094	.0092619	.0136251	-.0410112	.0285075	.6442
Maryland	.0087373	.0124181	.0128492	-.0387927	.0314188	.5459
Minnesota	.0144892	.0180912	.016551	-.0505774	.0410445	.4705
Mississippi	.0123951	.0156399	.0167232	-.0504163	.0449483	.3341
Montana	.0207281	.0217586	.0169267	-.0376249	.0719189	.3342
Nevada	.0181254	.0188586	.0136756	-.0344029	.0441607	.2616
New Hampshire	.0113845	.0120793	.0080479	-.01787	.0240375	.5326
North Carolina	.011765	.0134941	.0127102	-.0448218	.0389336	.3991
Ohio	.0170239	.0249848	.0226393	-.0906797	.0460588	.4212
Oregon	.0235417	.0290947	.0278633	-.1015436	.0657797	.4756
Pennsylvania	.0076401	.0124746	.0169284	-.0672686	.0339803	.5939
South Carolina	.0068564	.0094234	.0151531	-.0572109	.0241659	.3651
Tennessee	.0060391	.0086055	.0091207	-.0330894	.0195752	.3880
Texas	.0096721	.0101121	.0089045	-.0153031	.0285978	.5959
Vermont	.0108816	.0127075	.0129472	-.0339483	.035601	.3859
Washington	.0113031	.0152906	.0164848	-.0510908	.0346414	.5096
West Virginia	.0146791	.014659	.0145116	-.0279341	.0512416	.1764
Wisconsin	.019646	.0262974	.0307743	-.1068344	.0592631	.4617
United States	-.0087899	-.0087117	.0241988	-.0716177	.0408689	1

throughout much of the 1980s. This finding is not unique to California, and further inspection of the data for each of the 26 states indicates that the vast majority of states never ran a primary deficit before 2001.[4]

[4]In fact, primary deficits were only present before 2001 for the following state-year pairs: Connecticut 1991, 1994; Louisiana 1983, 1984; New Hampshire 1977; Tennessee 1995; and Vermont 1982.

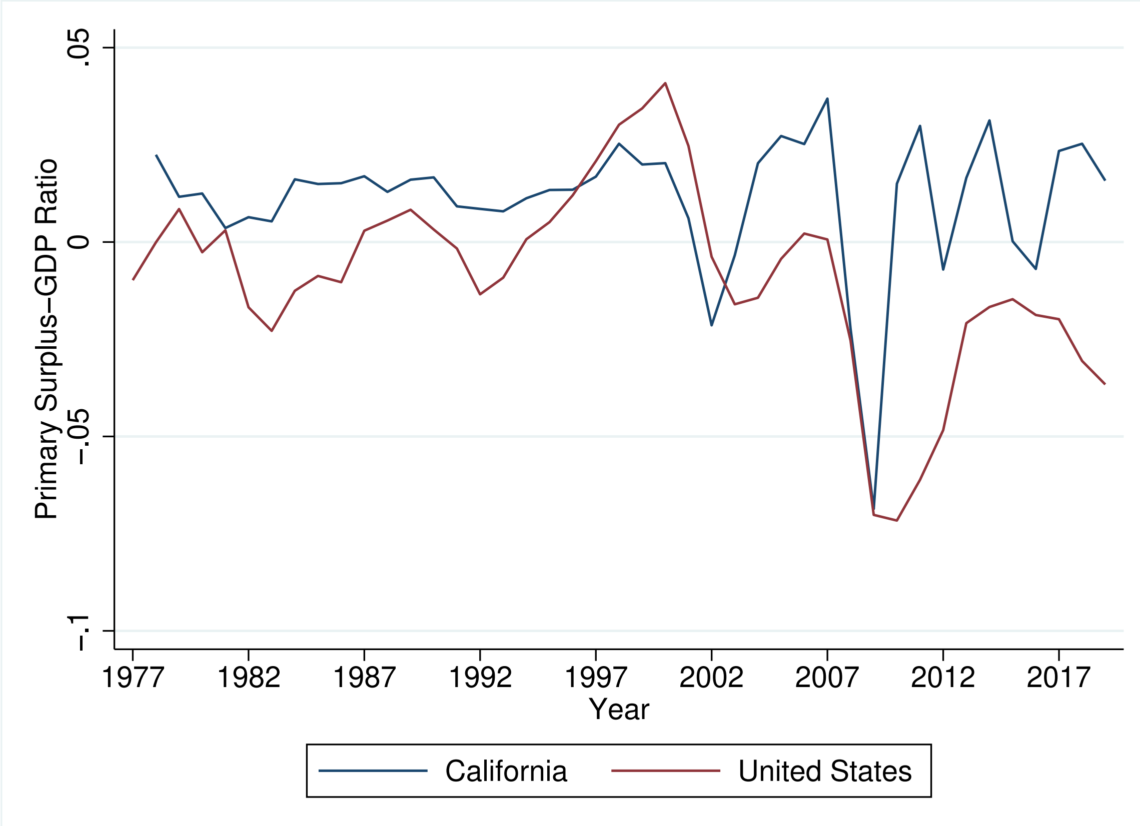

FIGURE 1: Primary Surplus-GDP Ratio, California vs. United States

3.2 Modeling Surplus Dynamics

Following early investigations of the time-series properties of the government's intertemporal budget constraint conducted by Hansen, Roberds, and Sargent (1991) and Bohn (1998), I specify a vector auto-regression (VAR) model to capture the dynamics of primary surpluses. Like Jiang et al. (2020), I divide the primary surplus into its revenue and spending components; specifically, Equation (5) becomes:

$$D_t = \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j} S_{t+j}\right] = \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}\left(T_{t+j} - G_{t+j}\right)\right] \equiv P_t^T - P_t^G \tag{6}$$

where P_t^T, P_t^G are the cum-dividend values of the revenue and spending claims, respectively:

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

Why deploy such a decomposition? To illustrate, note that Equation (6) can be rewritten as:

$$D_t = \sum_{j=0}^{\infty} P_t(j)\mathbb{E}_t\left[S_{t+j}\right] + \sum_{j=0}^{\infty} \text{Cov}_t\left(M_{t,t+j}, T_{t+j}\right) - \sum_{j=0}^{\infty} \text{Cov}_t\left(M_{t,t+j}, G_{t+j}\right). \tag{7}$$

The first term on the RHS of Equation (7) is the present discounted value of expected future surpluses using the term structure of riskfree bond prices. In other words, it's the present discounted value from the perspective of a risk-neutral investor. This is the only term present in the case of a constant SDF. As noted by Jiang et al. (2020), in this special case, the government's capacity to issue debt is constrained by its ability to generate current and future surpluses. The second and third terms are relevant in the case of time-varying discount rates. Government revenues are typically procyclical: they rise during economic expansions and fall during contractions. Thus, a claim to revenues is "risky" in an asset-pricing sense due to a positive covariance with the SDF, and the second term on the RHS of Equation (7) is negative. Government spending, on the other hand, is typically counter-cyclical due to the presence of automatic stabilizers such as unemployment insurance, so the spending claim is likely to have a negative covariance with the SDF, and the third term is positive. If both are true, then the difference between the two covariance terms is negative, and the government's debt capacity is lower than it would be in the case of a constant SDF.

Since there is ample evidence in the asset pricing literature that much of the variation in price-dividend ratios for stocks stems from variation in discount rates—see Cochrane (2011)—I choose to separately model the growth rates of revenue and spending in the VAR. I also include a variety of macro-financial indicators in the VAR to capture the cyclicality of revenues and spending. The inclusion of these variables is principally motivated by the assumption that the marginal investor for state-level debt considers these variables when forecasting future surpluses; in other words, they are likely to belong to the marginal investor's information set. A secondary motivation is that Jiang et al. (2020) included the same variables in their VAR at the federal level, so retaining these variables in the state-level VAR facilitates comparison between the two analyses.

Specifically, I assume that the $N \times 1$ vector of state variables z follows a Gaussian first-order VAR:

$$z_t = \Psi z_{t-1} + u_t = \Psi z_{t-1} + \Sigma^{\frac{1}{2}} \varepsilon_t \tag{8}$$

with $N \times N$ companion matrix Ψ and homoskedastic innovations $u_t \sim$ i.i.d. $\mathcal{N}(0, \Sigma)$. The Cholesky decomposition of the covariance matrix, $\Sigma = \Sigma^{\frac{1}{2}} \left(\Sigma^{\frac{1}{2}}\right)'$, has non-zero elements on and below the diagonal, implying that shocks to each state variable u_t are linear combinations of its own structural shock ε_t, and the structural shocks to the state variables that precede it in the VAR. Table 2 lists the variables included in the state vector, in order of appearance of the VAR. All state variables are demeaned by their time-series sample averages.

Fiscal cash-flow dynamics are captured in the VAR by $\Delta \log \tau_t$ and $\Delta \log g_t$, the log change in revenue-GDP and the log change in spending-GDP in the seventh and eight rows,

TABLE 2: List of 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-Dividend Ratio
6	Δd_t	μ_d	Log Stock Dividend Growth
7	$\Delta \log \tau_t$	μ_τ	Log Tax Revenue-GDP Growth
8	$\Delta \log g_t$	μ_g	Log Spending-GDP Growth
9	$\log \tau_t$	$\log \tau_0$	Log Tax Revenue-GDP Level
10	$\log g_t$	$\log g_0$	Log Spending-GDP Level

and τ_t and g_t, the log level of spending-GDP and the log level of revenue-GDP in the ninth and tenth rows. Spending and revenue growth are permitted to depend not only on their own lags, but also on lagged inflation, GDP growth, interest rates, the slope of the term structure, the price-dividend ratio of the aggregate stock market, and aggregate dividend growth. Innovations in these macro-financial variables are correlated with innovations in the cash flow variables.

Why include both growth rates and levels of revenue and spending in the VAR? As shown by Bohn (1998), government revenue and spending are typically co-integrated with GDP, so that revenue, spending, and GDP adjust when the revenue-GDP or spending-GDP ratios diverge from their long-run relationships. With cointegration, GDP innovations permanently alter all future surpluses: a recession not only raises current government spending and lowers current revenue as a fraction of GDP, it also lowers future spending and raises future revenue as a fraction of future GDP. By having spending-GDP growth $\Delta \log g_t$ (revenue-GDP $\Delta \log \tau_t$) depend on lagged spending g_t (lagged revenue-GDP τ_t) with a negative coefficient, the VAR captures this mean reversion. Mean reversion is amplified when $\Delta \log g_t$ ($\Delta \log \tau_t$) depends on lagged revenue-GDP τ_t (g_t) with a positive sign.

To provide statistical support for the contention of two cointegrating relationships, I conduct a Johansen cointegration test by estimating the vector error correction model (VECM):

$$\Delta w_t = A\left(B' w_{t-1} + c\right) + D \Delta w_{t-1} + \varepsilon_t, \qquad \text{where } w_t = \begin{pmatrix} \log T_t \\ \log G_t \\ \log GDP_t \end{pmatrix}.$$

For nearly every state in my sample, both the trace test and the max eigenvalue test fail to reject the null of cointegration rank 2, and reject the null of cointegration ranks 0 and 1. These findings support the existence of two cointegrating relationships, one between $\log T_t$ and $\log GDP_t$, and another between $\log G_t$ and $\log GDP_t$.

3.3 VAR Estimates

I estimate a first-order panel VAR using the methodology of Anderson and Hsiao (1982) by which state-specific fixed effects are removed using first differences. This methodology is suitable for my balanced panel setup with a lag order of unity. Since one would not expect the macro-financial variables contained in the vector z_t to be affected by the fiscal cash-flow dynamics of individual states, I zero out the elements in the upper-right rectangular block of Ψ. (However, lagged macro-financial variables are permitted to affect state-level fiscal variables.) The point estimates of Ψ are reported in Table 3.

TABLE 3: VAR Estimates Ψ

	π_{t-1}	x_{t-1}	$y^{\$}_{t-1}(1)$	$yspr^{\$}_{t-1}$	pd_{t-1}	Δd_{t-1}	$\Delta\log\tau_{t-1}$	$\Delta\log g_{t-1}$	$\log\tau_{t-1}$	$\log g_{t-1}$
π_t	0.615	-0.011	0.086	-0.330	0.001	0.028	0.000	0.000	0.000	0.000
x_t	-0.931	-0.100	0.589	0.796	0.008	0.062	0.000	0.000	0.000	0.000
$y^{\$}_t(1)$	-0.410	-0.310	1.079	0.120	0.002	0.081	0.000	0.000	0.000	0.000
$y_s pr^{\$}_t$	0.055	-0.137	-0.037	0.464	0.000	-0.023	0.000	0.000	0.000	0.000
pd_t	-2.839	1.593	0.278	-1.715	0.788	-0.295	0.000	0.000	0.000	0.000
Δd_t	0.518	0.882	-0.137	-0.056	0.004	0.310	0.000	0.000	0.000	0.000
$\Delta\log\tau_t$	-2.676	0.124	2.348	0.028	0.054	0.095	0.286	-0.456	-1.147	0.953
$\Delta\log g_t$	-0.386	-1.101	0.028	-0.127	0.021	-0.089	-0.005	0.028	0.004	-0.156
$\log\tau_t$	-2.676	0.124	2.348	0.028	0.054	0.095	0.286	-0.456	-0.147	0.953
$\log g_t$	-0.386	-1.101	0.028	-0.127	0.021	-0.089	-0.005	0.028	0.004	0.844

Consistent with the mean reversion in surplus dynamics imposed by cointegration, I find that $\Psi_{[7,9]} = -1.147 < 0$ and $\Psi_{[8,10]} = -0.156 < 0$. The cross-terms also have their expected signs ($\Psi_{[7,10]} = 0.953 > 0$ and $\Psi_{[8,9]} = 0.004 > 0$); however, the latter coefficient is barely distinguishable from zero.

3.4 Asset-Pricing Model

Following Jiang et al. (2020), I specify an exponentially affine SDF to price the risk in fiscal cash flows. This SDF requires only the assumption of no arbitrage, and it has been found to accurately price both the term structure of interest rates and the aggregate stock market. (See Ang and Piazzesi (2003).) The nominal SDF $M_{t+1} = \exp(m_{t+1})$ is conditionally lognormal:

$$m_{t+1} = -y_t(1) - \frac{1}{2}\Lambda_t'\Lambda_t - \Lambda_t'\varepsilon_{t+1}. \tag{9}$$

The priced sources of risk are the structural innovations in the state vector ε_{t+1} from the first-order VAR in Equation (8); these aggregate shocks are associated with a $N \times 1$ market price of risk vector Λ_t of the affine form:

$$\Lambda_t = \Lambda_0 + \Lambda_1 z_t, \tag{10}$$

where the $N \times 1$ vector Λ_0 collects the average prices of risk, while the $N \times N$ matrix Λ_1 captures time variation in risk premia. I choose to deploy a single SDF to price bonds of different states; this is akin to postulating the existence of a single representative investor for the entire United States, who prices Treasury bonds, the aggregate stock market, and state-level fiscal cash flows. In other words, while the vector of state variables z_t varies by state, the constant and time-varying risk prices Λ_0 and Λ_1 are identical across states.

For my analysis, I specify that shocks to state-level government revenue and spending growth are not priced by the representative investor; thus, the last four elements of Λ_0 and the last four rows of Λ_1 are populated with zeros. This decision is motivated by the fact that such a "national-level" representative investor who prices both Treasury bonds and the aggregate stock market is unlikely to price shocks to state-level fiscal cash flows given their relatively minor magnitude.

3.5 Surplus Pricing Equations

I now derive price-dividend ratios on the revenue and spending claims using the exponentially affine SDF in Equation (9). In essence, the price-dividend ratios are the sums of the price-dividend ratios of their respective strips, whose logs are affine in the state vector z_t:

$$\begin{aligned} PD_t^T &= \frac{P_t^T}{T_t} = \sum_{h=0}^{\infty} \exp\left(A_\tau(h) + B_\tau'(h) z_t\right) \\ PD_t^G &= \frac{P_t^G}{G_t} = \sum_{h=0}^{\infty} \exp\left(A_g(h) + B_g'(h) z_t\right). \end{aligned} \tag{11}$$

I will only present the derivation for the spending claim—the derivation for the revenue claim is similar. Note that nominal government spending growth can be written as

$$\Delta \log G_{t+1} = \Delta \log g_{t+1} + x_{t+1} + \pi_{t+1} = x_0 + \pi_0 + \mu_0^g + \left(e_{\Delta g} + e_x + e_\pi\right)' z_{t+1}.$$

We can conjecture that the log price-dividend ratios on the spending strips are affine in the state vector:

$$P_t^G(h) = \log\left(P_t^G(h)\right) = A^g(h) + B^{g\prime}(h) z_t.$$

Solve for the coefficients $A^g(h+1)$ and $B^g(h+1)$ and verify this conjecture using the Euler equation:

$$
\begin{aligned}
P_t^G(h+1) =& \mathbb{E}_t\left[M_{t+1}P_{t+1}^G(h)\frac{G_{t+1}}{G_t}\right] = \mathbb{E}_t\left[\exp\left\{m_{t+1} + \Delta \log g_{t+1} + x_{t+1} + \pi_{t+1} + P_{t+1}^G(h)\right\}\right] \\
=& \exp\left\{-y_0(1) - e_{yn}' z_t - \frac{1}{2}\Lambda_t'\Lambda_t + \mu^g + x_0 + \pi_0\right\} \\
& \times \exp\left\{\left(e_{\Delta g} + e_x + e_\pi + B^g(h)\right)' \Psi z_t + A^g(h)\right\} \\
& \times \mathbb{E}_t\left[\exp\left\{-\Lambda_t'\varepsilon_{t+1} + \left(e_{\Delta g} + e_x + e_\pi + B^g(h)\right)' \Sigma^{\frac{1}{2}}\varepsilon_{t+1}\right]
\end{aligned}
$$

Use the log-normality of ε_{t+1} and substitute in the affine expression for Λ_t from Equation (10) to get:

$$
\begin{aligned}
P_t^G(h+1) =& \exp\left\{-y_0(1) + \mu^g + x_0 + \pi_0 + \left(\left(e_{\Delta g} + e_x + e_\pi + B^g(h)\right)' \Psi - e_{yn}'\right) z_t + A^g(h)\right. \\
& + \frac{1}{2}\left(e_{\Delta g} + e_x + e_\pi + B^g(h)\right)' \Sigma \left(e_{\Delta g} + e_x + e_\pi + B^g(h)\right) \\
& \left. - \left(e_{\Delta g} + e_x + e_\pi + B^g(h)\right)' \Sigma^{\frac{1}{2}} \left(\Lambda_0 + \Lambda_1 z_t\right)\right\}.
\end{aligned}
$$

Taking logs and collecting terms, we obtain

$$
\begin{aligned}
A^g(h+1) =& -y_0(1) + \mu^g + x_0 + \pi_0 + A^g(h) \\
& + \frac{1}{2}\left(e_{\Delta g} + e_x + e_\pi + B^g(h)\right)' \Sigma \left(e_{\Delta g} + e_x + e_\pi + B^g(h)\right) \\
& - \left(e_{\Delta g} + e_x + e_\pi + B^g(h)\right)' \Sigma^{\frac{1}{2}}\Lambda_0 \\
B^g(h+1)' =& \left(e_{\Delta g} + e_x + e_\pi + B^g(h)\right)' \Psi - e_{yn}' - \left(e_{\Delta g} + e_x + e_\pi + B^g(h)\right)' \Sigma^{\frac{1}{2}}\Lambda_1
\end{aligned}
$$

and the price-dividend ratio of the cum-dividend spending claim is

$$
PD_t^G = \sum_{h=0}^{\infty} \exp\left(A^g(h+1) + B^g(h+1)' z_t\right).
$$

4 Results

After estimating the VAR coefficients and market prices of risk, I can calculate the expected present discounted value of primary surpluses for each of the 26 states in my sample according to the following formula:

$$
\mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}S_{t+j}\right] = \sum_{j=0}^{\infty}\mathbb{E}_t\left[M_{t,t+j}T_{t+j}\right] - \sum_{j=0}^{\infty}\mathbb{E}_t\left[M_{t,t+j}G_{t+j}\right] = P_t^T - P_t^G \tag{12}
$$

where P_t^T is the cum-dividend value of a claim to future nominal revenues and P_t^G is the cum-dividend value of a claim to future government spending from Equation (11). For expository purposes, I only graphically display the results for the state of California—similar

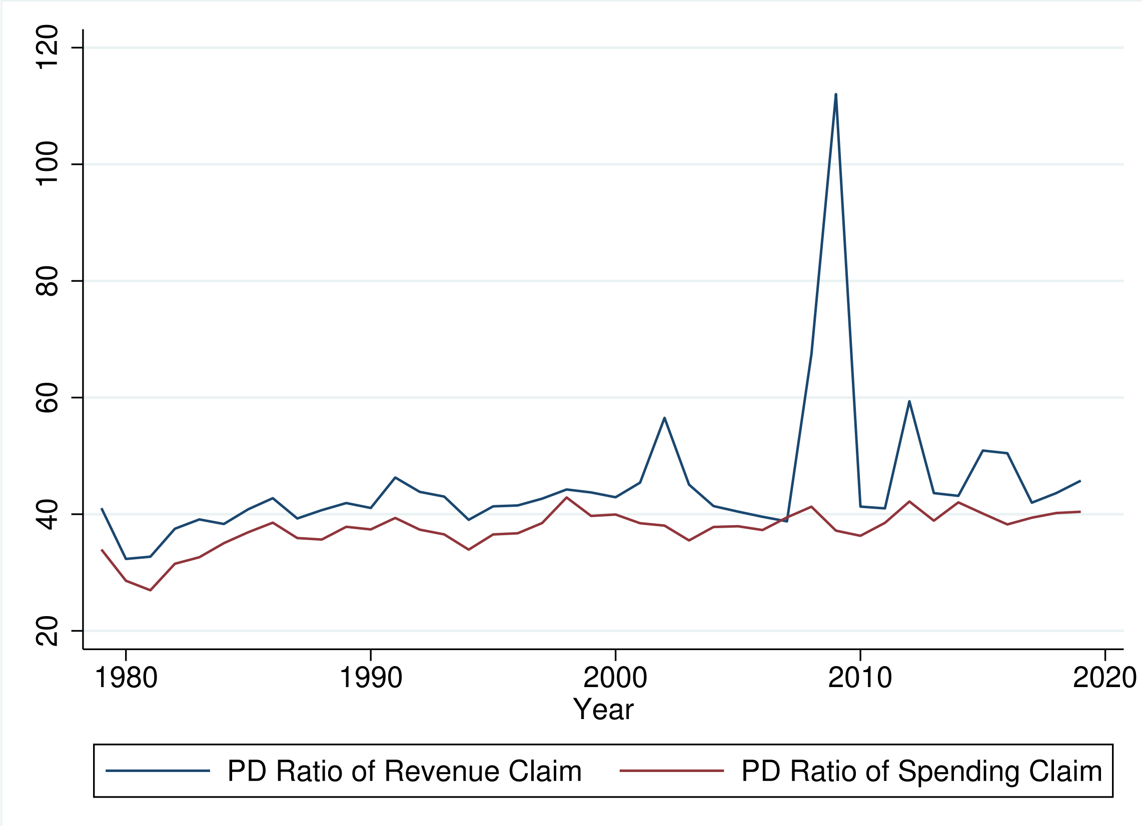

FIGURE 2: California Government Cash Flows and Prices

results are obtained for the other states in my sample.

Figure 2 plots the price-dividend ratios on claims to future revenues and expenditures for California. The time-series average of the price-dividend ratio on the revenue claim, $PD_t^T = P_t^T/T_t$, is 42.89. In other words, the representative agent would be willing to pay roughly 43 times a year's worth of revenues for the right to receive all current and future revenues. As expected, the price-dividend ratio of the revenue claim is highly procyclical, especially since 2000. The time-series average of the price-dividend ratio on a claim to future spending, $PD_t^G = P_t^G/G_t$, is 35.62. So, contrary to the federal context analyzed in Jiang et al. (2020)—where the average price-dividend ratios on the revenue and spending claims were 142.22 and 164.74, respectively—the spending claim for California is *less* valuable than the revenue claim. This state-federal discrepancy can be explained by a variety of factors, including balanced budget amendments that preclude countercyclical deficit spending and transfers from federal to state governments during recessionary periods.[5]

Figure 3 plots the present discounted value of primary surpluses for California along

[5]Although not included in my sample, the fiscal situation of many states during the COVID-19 recession suggests these factors are relevant: https://www.wsj.com/articles/the-state-covid-windfall-11608680178.

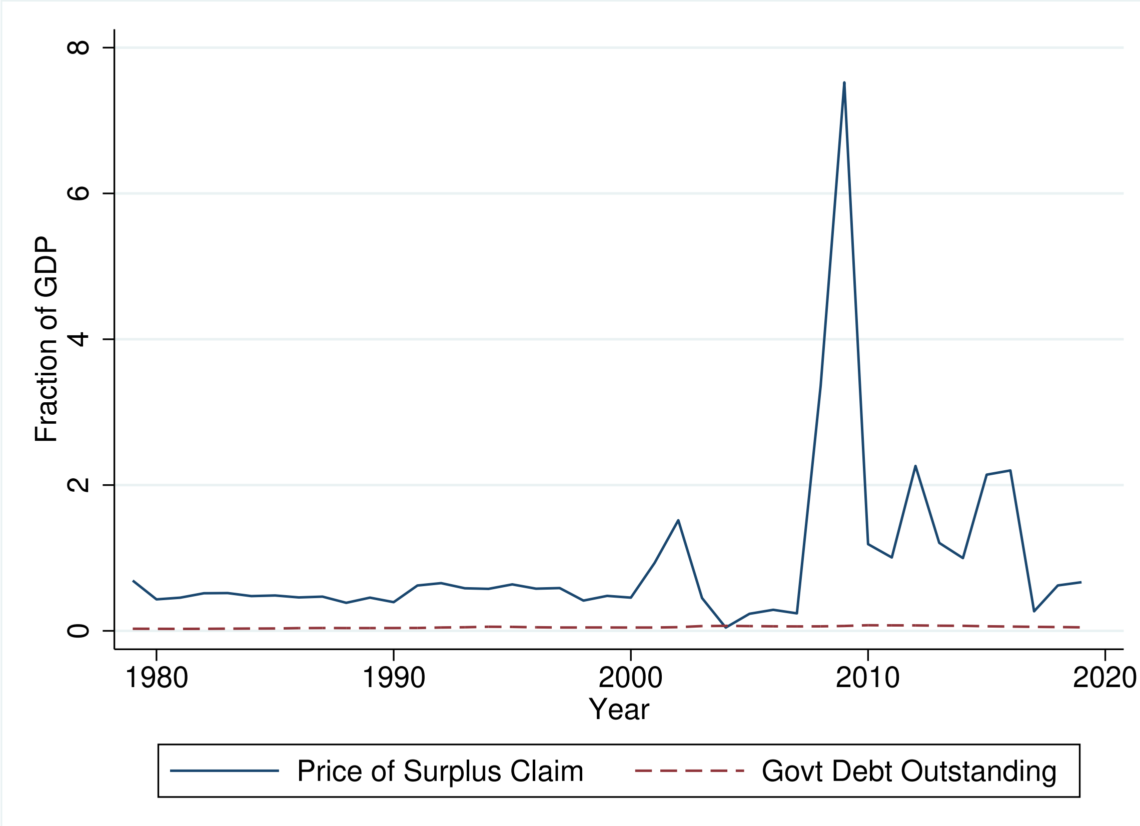

FIGURE 3: Present Value of Surpluses and Market Value of Government Debt for California

with the market value of outstanding debt over the same period. Both series are scaled by GDP for comparison. The difference between these two lines is what Jiang et al. (2020) refer to as the "government debt valuation puzzle." The average present discounted value of the surplus claim is 91.65 percent of GDP from 1979 to 2019, which is far greater than the average market value of outstanding government debt at 5.04 percent of GDP. The gap is 86.61 percent of GDP on average, and it is considerably larger in the post-2000 subsample.

In sum, at the state level, the valuation puzzle is the opposite of what has been documented at the federal level in Jiang et. al (2020): it appears that the market value of outstanding state debt is too small relative to that predicted by Equation (5) in Section 2. In the final section, I briefly discuss a few explanations for this finding before concluding.

5 Conclusion

The principal aim of this analysis was to determine whether a divergence between the market value of outstanding government debt and the present discounted value of current and future primary surpluses for the United States as presented in Jiang et al. (2020) is an artifact of the context considered. Based on the findings in Section 4, it appears that, if a valuation puzzle does exist at the state level, it is the reverse of what Jiang et al. (2020) find: the market value of outstanding debt is too low relative to that implied by the present discounted value of expected surpluses. Comparison between the two contexts was facilitated by the decision to use the same state variables, lag order structure, and SDF when computing the quantities and prices of risk in fiscal cash flows.

What potential factors can explain the divergence in findings across the two contexts? As alluded to in Section 2, the possibility of federal bailouts and transfers during recessionary periods likely raises the price of the revenue claim vis-à-vis the spending claim for state governments. Furthermore, the existence of statutory debt limits and BBAs forces state governments to drastically reduce expenditures during recessionary periods rather than engage in countercyclical stimulus spending like the federal government is wont to do. Finally, unfunded state-level pension liabilities and implicit guarantees of local government debt are not included in either the revenue or expenditure items tabulated by the Census Bureau in its Annual Survey of State and Local Government Finances. Thus, the primary surpluses of many state governments may be severely overestimated by excluding such state-contingent liabilities.[6] This final possibility is an intriguing avenue for further research, as it is an open question whether state pension funding shortfalls impact market participants' perceptions of the riskiness of fiscal surpluses.

[6]Unfunded pension liabilities for the State of California, for example, were approximately $250 billion in 2019: https://www.ppic.org/publication/public-pensions-in-california/.

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