How Ricardian Are We?[*]

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EARLY DRAFT

Abstract

Not very. To answer this question, we conjecture that households might be non-Ricardian because they do not have rational expectations over their future tax burden. Form this assumption, we derive a behavioral consumption function, where households act as if bonds are net wealth, and consume out of taxes and transfers. The coefficient on taxes is determined by the attenuation present in households' behavioral expectations. To estimate the coefficient, we derive a Bayesian limited information method that uses a large number of macroeconomic shocks form the literature as instrumental variables. We find that households internalize only 20% of their future taxes, implying a 33% marginal propensity to consume out of transfers. In a general equilibrium model, these values imply that public borrowing substantially crowds out private investment.

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1 Introduction

Neoclassical theory predicts that *ceteris paribus* private saving should increase one-for-one with government dissaving if we are *Ricardian* (Barro, 1974). But, how Ricardian are we? The answer is critical for the design of major macroeconomic policies – e.g. fiscal stimulus, public finance, and crisis response – and yet we have little idea what the number is.

We address this crucial question by bringing modern methods to bear on a classical problem: estimating the consumption function. A large literature in the 1980s investigated the Ricardian question by using aggregate time series regressions to estimate how taxes affect consumption on average.[1] However, the effect of taxes on consumption is unlikely to be identified in these regressions (Cebula et al., 1996; Cardia, 1997). This is because demand shocks (i.e. omitted variables in the consumption function) affect consumption directly, but can also affect taxes, income, and other determinants. Mainstream work with this strategy largely ceased, with the Ricardian question unanswered.

Time series evidence is necessary. After the aggregate consumption function approach was abandoned, microeconomic studies flourished.[2] Studies using interpersonal variation in taxes, transfers, and consumption are valuable for many reasons. But because of the *missing intercept problem*, they cannot (nor do they claim to) answer whether US households are Ricardian on average. To do so, macro evidence must be incorporated, either through full general equilibrium modeling (e.g. (Angeletos et al., 2024)) or some semi-structural approach (e.g. Wolf (2023)). We adopt a minimal structure by assuming a single structural equation: a behavioral consumption function.

Our strategy is to estimate the consumption function using a battery of macroeconomic shocks identified in the literature as instruments. A valid IV approach will resolve the endogeneity problems that prevented identification from traditional regressions using aggregate time series.[3] This approach is inspired by Barnichon and Mesters (2020), who suggest using exogenous shocks to estimate structural macroeconomic equations. The consumption function is a tempting application, and we build on their method in order to do so. Specifically, we develop a Bayesian limited information framework for using many external instruments to estimate macro models. This framework is a valuable enhancement for three reasons. First, we have designed it to accommodate a large number of instruments. This is impor-

[1] Well known examples include Barro and Feldstein (1978), Tanner (1979), Seater and Mariano (1985), and especially Kormendi (1983), which spawned a decade of comments and replies in the American Economic Review (Barth et al., 1986; Modigliani and Sterling, 1986; Kormendi and Meguire, 1986; Feldstein and Elmendorf, 1990; Modigliani and Sterling, 1990; Kormendi and Meguire, 1990; Graham, 1995; Kormendi and Meguire, 1995).

[2] A billion citations here.

[3] Early work recognized these problems and made some attempts to resolve them using lagged aggregate variables as IVs. See for example Hayashi (1982) or Feldstein (1982). Seater and Mariano (1985) argued that lagged aggregates are not valid IVs.

tant because, in contrast to the original Barnichon-Mesters application, the consumption function features many endogenous regressors.[4] Second, the set of well-identified potential instruments from the literature have a wide range of data coverages and frequencies. Our Bayesian method easily accommodates mixed frequencies and periods with missing data. Third, we can leverage all the usual strengths of Bayesian estimation, among which the most relevant is the use of informed priors. Macroeconomic shocks are notoriously weak instruments, so disciplining the parameter space with a Bayesian prior is valuable. For example, while there is uncertainty about size of the coefficient on taxes in the consumption function, many theories predict that the it should be bounded by zero and one.

We derive our structural consumption function in a general equilibrium model. Ricardian equivalence fails in this model because of a behavioral friction: agents do not forecast their future taxes with rational expectations. Instead, they discount future taxes with a behavioral factor, similar to a cognitive discounting bias (Gabaix, 2020). This behavioral approach is useful for letting the data identify the degree of Ricardianism without prejudice. Other mechanisms that break Ricardian equivalence – such as finite lifetimes (Blanchard, 1985) or liquidity constraints (Campbell and Mankiw, 1989) – imply strong predictions about the coefficient on taxes in the consumption function. Microeconomic evidence gives clear evidence about the strengths of these particular effects, but not about the bias due to non-rational expectations. However, we also show that models featuring an alternative mechanism for the Ricardian equivalence failure imply an isomorphic consumption function to ours. Thus we interpret our estimates as describing non-Ricardianism in general, independent of the fundamental cause.

[RESULTS PARAGRAPH HERE!] (I should relate to the eichenbaum survey results here instead of later, e.g. our esitmate of XX compares with survey evidence...)

[Point briefly to conclusions from the macro implications section]

Literature: The theory in this paper joins a revitalized literature studying the causes and consequences of non-Ricardian behavior. The most closely related studies are Gabaix (2020), Brzoza-Brzezina et al. (2024) and Eichenbaum et al. (2025), who study cognitive discounting and show that partial myopia amplifies the effects of fiscal policy. In particular, Eichenbaum et al implement a survey to measure how households' spending plans would be affected by hypothetical tax rebates. They find that households are far from Ricardian, and would consume roughly a third of the transfer. Other mechanisms used to study non-Ricardian behavior by relaxing full information rational expectations include finite planning horizons (Woodford, 2019; Lustenhouwer and Mavromatis, 2023) and adaptive learning (Evans et al., 2012; Eusepi and Preston, 2018; Branch and Gasteiger, 2023).

[4] *[mention how Lewis/Mertens offer a frequentist alterative]*

Woodford (2013) reviews older results along these lines. Other recent work has applied modern quantitative methods to tradition non-Ricardian mechanisms including finite lifetimes (Aguiar et al., 2023; Angeletos et al., 2024), constrained hand-to-mouth agents Galí et al. (2007); Nisticò (2016); Orchard et al. (2023), heterogeneous agents with borrowing constraints (Hagedorn et al., 2019; Auclert et al., 2024) and distortionary taxation Bianchi and Melosi (2022).

[METHODOLOGY LIT REVIEW PARAGRAPH HERE - Christian]

The remainder of the paper is organized as follows. Section 2 lays out the theoretical framework and derives the behavioral consumption function. Section 3 describes our Bayesian limited information estimator. Section 4 describes the data and estimation results. Section 5 explores the macroeocnomic implications of our findings. Finally, Section 6 concludes.

2 The Consumption Function

This section derives the consumption function from the relevant equilibrium conditions. This is useful to do before proceeding to the full model in Section 5, because it clarifies how general our result is.

In Section 2.1 we derive a generic consumption function that is determined by only two equations that are featured in many models: a household budget constraint and an Euler equation pricing non-contingent bonds.

Then in Section 2.2 we derive a specific *behavioral* form of the consumption function that we can plausibly estimate in the data. This form uses two additional ingredients: the government budget constraint and a behavioral relationship between agents' expectations and the rational expectation.

2.1 The Generic Consumption Function

Consider an economy which satisfies, among other things, the following two equilibrium conditions. First is the representative household's budget constraint:

$$B_{t-1} + R_t^K K_{t-1} + Y_t^N = C_t + T_t + Q_t B_t + K_t \tag{1}$$

where B_{t-1} is risk-free government debt acquired in the previous period, K_{t-1} is capital (and/or other financial assets) with net-of-depreciation return R_t^K, Y_t^N is non-financial income, C_t is consumption, T_t is taxes, and Q_t is the price of new government debt. The second equation is the household's Euler equation for pricing the debt:

$$Q_t = \beta \tilde{\mathbb{E}}_t \left[\frac{u'(C_{t+1})}{u'(C_t)} \right] + Z_t^d \tag{2}$$

where $\tilde{\mathbb{E}}_t [\cdot]$ is a (possibly non-rational) expectation operator, $u'(C_t)$ denotes a household's marginal utility of consumption, and Z_t^d is an exogenous intertemporal wedge.

The linearized forms (not *log*-linearized) of these two equations are

$$n_{t-1} + y_t = c_t + \tau_t + q_t \overline{B} + \beta n_t \tag{3}$$

$$q_t = \beta \tilde{\mathbb{E}}_t [\gamma \frac{1}{\overline{C}} (c_t - c_{t+1})] + z_t^d \tag{4}$$

where lower-case variables denote deviations from the steady state. $y_t = y_t^N + \overline{K} r_t^k$ represents *net* income, while financial wealth n_t is defined as

$$n_t \equiv b_t + \overline{R^k} k_t \tag{5}$$

with the assumption that $\overline{R^k} = 1/\beta$. Finally, $\gamma \equiv \frac{u''(\overline{C})\overline{C}}{u'(\overline{C})}$ denotes the steady state coefficient of relative risk aversion.

The consumption function is most concise with some recursive notation. The linearized tax present value equation is

$$\tilde{v}_t^\tau = \tau_t + \beta \tilde{\mathbb{E}}_t [\tilde{v}_{t+1}^\tau]$$

Similarly, define a present value equation for the remaining income component

$$\tilde{v}_t^y = y_t + \beta \tilde{\mathbb{E}}_t [\tilde{v}_{t+1}^y] \tag{6}$$

for government spending

$$\tilde{v}_t^g = g_t + \beta \tilde{\mathbb{E}}_t [\tilde{g}_{t+1}^y] \tag{7}$$

and the present value (or "console value") of future one-period bonds by

$$\tilde{v}_t^q = q_t + \beta \tilde{\mathbb{E}}_t [\tilde{v}_{t+1}^q] \tag{8}$$

We also use this approach to define an exogenous "demand" factor from the intertemporal wedges, which affects the consumption equation:

$$\zeta_t = -\frac{\overline{C}}{\gamma} z_t^d + \beta \tilde{\mathbb{E}}_t [\zeta_{t+1}] \tag{9}$$

The present value variables are written with tildes to denote that they depend on the behavioral expectation $\tilde{\mathbb{E}}$. If expectations are rational ($\mathbb{E}$) then we write them without the tilde, e.g. v_t^τ. As yet, we make no assumptions about the subjective expectations operator $\tilde{\mathbb{E}}_t$ other than linearity and that agents know current variables with certainty, e.g. $\tilde{\mathbb{E}}_t[n_t] = n_t$.

Proposition 1 *The linear consumption function is*

$$c_t = (1-\beta)\left(n_{t-1} + \tilde{v}_t^y - \tau_t - \beta\tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^\tau]\right) + \left(\frac{\overline{C}}{\gamma} - (1-\beta)\overline{B}\right)\tilde{v}_t^q + \zeta_t \tag{10}$$

Proof: Appendix A

Proposition 1 is derived only using the household budget constraint and Euler equation on risk-free bonds. It holds in the lion's share of representative agent models. The Euler equation is the only one that is directly affected by expectations; this is the channel through which distorted beliefs enter the consumption function.

However, the generic consumption function (10) is not well-suited to be estimated directly. $\tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^\tau]$ is not typically observed – if it was, we could directly estimate how $\tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^\tau]$ depends on the rational forecast without bothering with the consumption function at all. So instead, we need an additional model equation to transform the consumption function into a form that can plausibly be estimated in the data.

2.2 A Behavioral Consumption Function

We now introduce a third model equation, the budget constraint for a government that issues non-contingent debt:

$$B_{t-1} + G_t = T_t + Q_t B_t \tag{11}$$

where G_t is government expenditure. The linearized form is

$$b_{t-1} = \tau_t - g_t + \overline{B}q_t + \beta b_t \tag{12}$$

assuming that the steady state bond price is $\beta = \overline{Q}$.

We also now make an assumption about the relationship between the behavioral and rational expectation operators. Their forecasts for discounted future taxes is

$$\tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^\tau] = \theta\mathbb{E}[v_{t+1}^\tau] \tag{13}$$

for some scalar θ. Crucially, the θ parameter only disciplines the expectations of *taxes*. We are agnostic about the biases in expectations for all other variables.

Proposition 2 *If the government budget constraint is given by equation* (12) *and expectations satisfy equation* (13)*, then the consumption function can be expressed as*

$$c_t = (1-\beta)\left(n_{t-1} - \theta b_{t-1} + \tilde{v}^y_t - (1-\theta)\tau_t - \theta v^g_t + \theta \overline{B} v^q_t\right) + \left(\frac{\overline{C}}{\gamma} - (1-\beta)\overline{B}\right)\tilde{v}^q_t + \zeta_t \quad (14)$$

Proof. Iterate the government budget constraint (12) and take rational expectations:

$$\begin{aligned} b_{t-1} &= \tau_t - g_t + \overline{B}q_t + \mathbb{E}_t\left[\sum_{j=1}^{\infty}\beta^j(\tau_{t+j} - g_{t+j} + \overline{B}q_{t+j})\right] \\ &= \tau_t - g_t + \overline{B}q_t + \beta\mathbb{E}_t\left[v^\tau_{t+1} - v^g_{t+1} + \overline{B}v^q_{t+1}\right] \\ &= \tau_t + \beta\mathbb{E}_t\left[v^\tau_{t+1}\right] - v^g_t + \overline{B}v^q_t \end{aligned}$$

Combine with equation (13) to find

$$\beta\tilde{\mathbb{E}}_t[\tilde{v}^\tau_{t+1}] = \theta\left(b_{t-1} - \tau_t + v^g_t - \overline{B}v^q_t\right)$$

then use this result to replace $\beta\tilde{\mathbb{E}}_t[\tilde{v}^\tau_{t+1}]$ in the consumption function (10). ■

This form is useful for estimating Ricardianism, because the behavioral factor θ shows up directly in the coefficient on taxes τ_t. And it implies a straight-forward testable hypothesis: if agents are Ricardian, $\theta = 1$ so the coefficient on taxes is zero.

Moreover, the variables in the behavioral consumption function (14) can plausibly be observed. Consumption c_t, financial net worth n_{t-1}, government debt b_{t-1}, and taxes τ_t are all directly measured. $\tilde{v}^q_t$ is the market price of a console bond; it can be inferred with a model from the yield curve or simply approximated with long-term debt. v^q_t and v^g_t are rational expectations, which can be estimated. The most problematic variable is the household's expected discounted value of future net income $\tilde{v}^y_t$. One way to account for this variable is to include survey data on household income forecasts, although we will consider several alternative approaches.

2.3 Alternative Justifications for the Behavioral Consumption Function

In this section, we show that alternative mechanisms for non-Ricardianism lead to similar conclusions regarding the consumption function as in our behavioral approach. Instead of non-rational expectations, we examine cases where: (1) households have a different discount rate than the government, and (2) some households are hand-to-mouth.

2.3.1 A Discounting Wedge

This section considers the case where households discount the future with a different factor than the government does. This nests the intergenerational explanation for non-Ricardianism (Blanchard, 1985) whereby agents have some probability of death, after which they do not receive utility (or at least diminished utility from their dynasty). Alternatively, the wedge can capture occasionally binding liquidity constraints (Farhi and Werning, 2019). Angeletos et al. (2024) show that this mechanism leads to similar conclusions as in a full heterogeneous agents model.

With a discounting wedge ω, the assumptions for the generic consumption function in Proposition 1 still hold, albeit with discount factor $\beta\omega$. But we relax the assumption that the steady state bond price β is equal to the household's discount factor, so Proposition 2 no longer follows and rational expectations households may not be Ricardian.

And yet, Proposition 3 states that the resulting consumption function is *isomorphic* to the behavioral consumption function from Proposition 2, under the assumption that the present value of taxes follows an AR(1) process as in Eichenbaum et al. (2025). The usual Ricardian coefficient $1-\theta$ – which captures the deviation from rational expectations in the rest of the paper – now measures how far the discounting wedge ω is from one. That is to say: households and governments discounting at different rates is equivalent to households misextrapolating future tax liabilities.

Proposition 3 *If the government discounts by β and the household discounts by $\beta\omega$, the present value of taxes is AR(1) given by*

$$v_t^\tau = \rho v_{t-1}^\tau + \varepsilon_t^\tau \tag{15}$$

and households have rational expectations, then the consumption function can be expressed as

$$c_t = (1-\beta\omega)\left(n_{t-1} - \theta b_{t-1} + \tilde{v}_t^y - (1-\theta)\,\tau_t - \theta v_t^g + \theta \overline{B} v_t^q\right) + \left(\frac{\overline{C}}{\gamma} - (1-\beta\omega)\overline{B}\right)\tilde{v}_t^q \tag{16}$$

where

$$\theta = \omega\frac{1-\beta\rho}{1-\beta\omega\rho} \tag{17}$$

where for quantity x, v_t^x denotes the present value using the government's discount factor β, while $\tilde{v}_t^x$ denotes using the household's discount factor $\beta\omega$:

$$v_t^x = x_t + \beta\mathbb{E}_t[v_{t+1}^x] \qquad \tilde{v}_t^x = x_t + \beta\omega\mathbb{E}_t[\tilde{v}_{t+1}^x]$$

Proof: Appendix A

Given this equivalence, why do we bother with the behavioral expectations, when a household-government discounting wedge is already standard in our theories? Because a discounting wedge is too tightly disciplined by the microfoundations. For example, when the wedge is determined by the OLG structure so that ω represents the survival rate, ω is necessarily close to 1 so equation (17) implies that the tax coefficient θ cannot be much less than 1 either.[5] In contrast, we have very loose priors about θ as a cognitive discounting coefficient. Therefore, with behavioral expectations as the source of non-Canadianism, we are free to let the time series speak for themselves by choosing a relatively uninformed prior.

2.3.2 Liquidity Constraints

Liquidity constraints can also break Ricardian equivalence. This is because the consumption function (Proposition 1) is derived by iterating over future Euler equations, but when an agent is constrained, the Euler equation does not hold. A classic, tractable method of capturing this mechanism for non-Ricardianism is to introduce hand-to-mouth consumers (Campbell and Mankiw, 1989).[6] In this section, we describe a simple two-agent model, and show that the consumption function test of Ricardianism applies to this setting as well.

There is a measure λ of unconstrained consumers, and a measure $1-\lambda$ of constrained consumers. For simplicity, we assume government spending is constant with zero steady-state debt, both types of consumers receive the same tax and income processes, and have rational expectations.

The unconstrained households' income y_t^U and the constrained households' income y_t^C may follow different processes. They add up to aggregate income by

$$y_t = \lambda y_t^U + (1-\lambda) y_t^C \tag{18}$$

We write the present discounted values of these income streams as $v_t^{y,U}$ and $v_t^{y,C}$ respectively.

The unconstrained choose consumption c_t^U satisfying the Proposition 1 consumption function. The constrained consume

$$c_t^C = y_t^C - \tau_t \tag{19}$$

and aggregate consumption is given by

$$c_t = \lambda c_t^U + (1-\lambda) c_t^C \tag{20}$$

[5] Angeletos et al. (2023) choose a liberal calibration, setting the OLG survival rate at $\omega = 0.865$.

[6] This method is still used in modern two-agent New Keynesian (TANK) models (Galí et al., 2007), which approximate non-Ricardian behavior in richer heterogeneous agent models (Auclert et al., 2024).

Similarly, the unconstrained hold assets n_t^U while the constrained hold zero assets. Thus household-level assets are related to total assets by

$$n_t^U = \frac{n_t}{\lambda}$$

and similarly for bonds.

With this structure, Proposition 4 gives the aggregate consumption function when income is AR(1).

Proposition 4 *If households have rational expectations, then the aggregate consumption function in the two agent economy can be expressed as*

$$c_t = (1-\beta)\left(n_{t-1} - \lambda b_{t-1} + v_t^y - (1-\theta)\tau_t - \lambda v_t^g\right) + \lambda \frac{\overline{C}}{\gamma}\tilde{v}_t^q + \varsigma_t^C + \lambda\zeta_t \tag{21}$$

where the non-Ricardian parameter is now given by

$$\theta = 1 - \frac{1-\lambda}{1-\beta}$$

and $\varsigma_t^C \equiv (1-\lambda)\left(y_t^C - (1-\beta)v_t^{y,C}\right)$ *is a term that depends on the constrained income process.*

Proof: Appendix A

Unlike in the case of a discounting wedge, Proposition 4 shows that the consumption function in the two agent economy is similar but not quite equivalent to the behavioral consumption function from Proposition 2. Different restrictions relate the coefficients of the right-hand-side variables. And there is now a ζ_t^C term which depends on the income process of the constrained households. We can estimate including this term directly, but it may also be convenient to focus on one of several special cases where the ζ_t^C term is irrelevant (Corollary 1).

The crucial similarity is that taxes feature the usual Ricardian coefficient $1-\theta$. Except now, this coefficient captures the degree to which households are constrained, rather than the deviation from rational expectations. When there are no constrained households $\lambda = 1$ so $\theta = 1$, and households are Ricardian. This shows one reason why we focus on the impact of current taxes to measure Ricardianism. In the behavioral consumption function, θ also appeared as a coefficient on existing debt b_{t-1}. But debt has a different coefficient in the two agent economy; $\lambda \neq 1-\theta$, so if we want to be agnostic about the causes of non-Ricardianism, we cannot rely on restrictions to discipline the coefficients on taxes and debt.

Corollary 1 *If constrained households receive constant income* $y_t^C = \bar{y}^C$ *then the aggregate consumption function in the two agent economy reduces to*

$$c_t = (1-\beta)\left(n_{t-1} - \lambda b_{t-1} + v_t^y - (1-\theta)\tau_t - \lambda v_t^g\right) + \lambda \frac{\overline{C}}{\gamma} \tilde{v}_t^q + \lambda \zeta_t$$

Proof. When constrained income is constant, then its present discounted value is given by

$$v_t^{y,C} = \bar{y}^C + \beta \bar{y}^C + \beta^2 \bar{y}^C + ... = \frac{\bar{y}^C}{1-\beta}$$

thus ς_t^C is given by

$$\varsigma_t^C = (1-\lambda)\left(y_t^C - (1-\beta) v_t^{y,C}\right) = (1-\lambda)\left(\bar{y}^C - (1-\beta)\frac{\bar{y}^C}{1-\beta}\right) = 0$$

and the result follows from Proposition 4. ■

3 A Bayesian LIML Approach

Here Christian describes the Bayesian method

4 Application

4.1 Data

Estimating the behavioral consumption function (14) requires the following data:

- Time series for directly observed variables: n_t, b_t, c_t, τ_t
- Estimation of rational expectation variables: v_t^g, v_t^q
- Proxies for behavioral expectation variables: $\tilde{v}_t^y$, $\tilde{v}_t^q$
- Instruments (many!)

4.1.1 Directly Observed Variables

Christian describes macrodata refinement: detrending/transformation choices, etc.

Jonathan describes... GDP variables, why we use what we do, etc.

Name	Variable	Data Source	FRED code	Range
Household Net Worth	n_t	Fed Financial Accounts	TNWBSHNO	1945:Q4 -
Market Value of Federal Debt	b_t	Dallas Fed	MVMTD027MNFRBDAL	1942:M1 -
Consumption	c_t	NIPA	PCE	1947:Q1-
Personal Taxes	τ_t	NIPA	W055RC1Q027SBEA	1947:Q1 -
Government Expenditures	g_t	NIPA	see note	1947:Q1 -
Personal Income	y_t	NIPA	PINCOME	1947:Q1 -
Income Forecast	$\tilde{v}_t^y$	Michigan Survey of Consumers		1976:Q3-
		Survey of Professional Forecasters		1968:Q4-
		Livingston Survey		1946:S1-
3-Month T-Bill Yield	$r_t^{(1)}$	Fed Financial Accounts	TB3MS	1934:M1-
Consol Bond Value	$\tilde{v}_t^q$	Derived from yield curve (App. C)		

Table 1: Time Series Data (in progress)

Notes: Government Expenditures are net of government receipts not included in Personal Taxes. In terms of FRED codes, our expenditure measure is $GEXPND - (GRECPT - W055RC1Q027SBEA)$.

4.1.2 Rational Expectation Variables

The behavioral consumption function includes as arguments the rational expectation of the present discounted value of government spending v_t^g and future bond prices v_t^q. We can easily estimate these with a state space approach.

Consider a state vector X_t that includes current government spending g_t and one-period bond prices q_t. Suppose the state vector follows an AR(K) process:

$$X_t = \sum_{k=1}^{K} B_k X_{t-k} + \epsilon_t \tag{22}$$

where ϵ_t are i.i.d. unforecastable innovations. The h-period ahead rational expectation is given recursively by

$$\mathbb{E}_t[X_{t+h}] = \sum_{k=1}^{K} B_k \mathbb{E}_t[X_{t-k+h}]$$

The desired rational expectation variables are given by

$$v_t^g = \sum_{j=0}^{\infty} \beta^j e_g \mathbb{E}_t[X_{t+j}]$$

$$v_t^q = \sum_{j=0}^{\infty} \beta^j e_q \mathbb{E}_t[X_{t+j}]$$

where e_g and e_q denote the basis vector identifying the g_t and q_t entries of X_t.

4.1.3 Behavioral Expectation Variables

The behavioral consumption function also includes agents contemporary expectations of variables, which may not be rational and thus cannot be estimated ex post from realizations. To measure these variables – the *perceived* present discounted value of household income $\tilde{v}_t^y$ and future bond prices $\tilde{v}_t^q$ – we use data from surveys and asset markets.

We assume that agents form expectations per a state space model that is analogous to equation (22), but possibly incorrectly specified.

For household income, we assume that households are simplistic forecasters, modeling y_t as AR(1) in lags of y_t alone. The *perceived* law of motion is

$$y_{t+1} = \tilde{B}^y y_t + \tilde{\epsilon}_{t+1}^y + \tilde{\nu}_t^y \tag{23}$$

The perceived coefficient $\tilde{B}^y$ is not necessarily the true autocorrelation. We allow households to receive a perceived iid news shock $\tilde{\nu}_t^y$, while the residual $\tilde{\epsilon}_{t+1}^y$ of the perceived PLM is not forecasted. The one-period ahead subjective expectation is

$$\tilde{\mathbb{E}}_t[y_{t+1}] = \tilde{B}^y y_t + \tilde{\nu}_t^y$$

Accordingly, the implied perceived present value of future income $\tilde{v}_t^y = \sum_{j=0}^{\infty} \beta^j \tilde{\mathbb{E}}_t[y_{t+j}]$ is

$$\tilde{v}_t^y = y_t + \frac{\beta}{1 - \beta \tilde{B}^y} f_t^y \tag{24}$$

where $f_t^y = \tilde{\mathbb{E}}_t[y_{t+1}]$ is a measurement of households' one-period ahead income forecasts. Crucially, this structure implies that $\tilde{v}_t^y - y_t$ is linear in f_t^y. Thus, we do not need to know the PLM in order to account for household expectations; we only need to include the one-period ahead forecasts, which we take from the Michigan Survey of Consumers.[7] Unfortunately, the Michigan Survey only begins asking for income forecasts in 1976:Q3, and we would prefer to estimate the consumption function using the entire post-war sample. Therefore, we use GNP forecasts from the Survey of Professional Forecasters (SPF) and Livingston Survey as noisy proxy variables to estimate unobserved household forecasts before 1976:Q3.

For expectations of future one-period bond prices, we turn to time series from the term structure of interest rates. The expectation hypothesis implies that demeaned (i.e. removing

[7] The AR(1) structure is what allows the one-period-ahead forecast to be a sufficient statistic for the entire set of forecast horizons. We would prefer to assume a more flexible structure, but data availability prevents it. We would require data on household income forecasts over multiple horizons, which are not available in the Michigan Survey.

a constant risk premium) horizon-h nominal bond yields $i_t^{(h)}$ satisfy

$$i_t^{(h)} = \frac{1}{h}\sum_{j=0}^{h-1} \tilde{\mathbb{E}}_t\left[i_{t+j}^{(1)}\right]$$

and thus we can identify expected one-period yields from the term-structure by

$$\tilde{\mathbb{E}}_t\left[i_{t+h-1}^{(1)}\right] = h i_t^{(h)} - (h-1) i_t^{(h-1)}$$

A large literature tests these relationships under rational expectations, and find that they fail.[8] With our approach, we are implicitly taking the stance that such failures are due to expectations anomalies (Froot, 1989) or learning (Farmer et al., 2021), rather than time-varying risk premia (e.g. Wachter 2006).

Next, we can construct expectations for the real interest rate $r_{t+h}^{(1)}$ from the nominal interest rate $i_{t+h}^{(1)}$ and the one-period-ahead inflation rate π_{t+h+1}:

$$\tilde{\mathbb{E}}_t\left[r_{t+h}^{(1)}\right] = \tilde{\mathbb{E}}_t\left[i_{t+h}^{(1)}\right] - \tilde{\mathbb{E}}_t\left[\pi_{t+h+1}\right]$$

Aruoba term structure here or no? If so, I'll push this stuff to appendix

Finally, Appendix C implies that we can recover $\tilde{v}_t^q$ from expected yields by

$$\tilde{v}_t^q = -\overline{Q}^2\left(r_t^{(1)} + \sum_{j=1}^{\infty}\beta^j \tilde{\mathbb{E}}_t\left[r_{t+j}^{(1)}\right]\right) = -\overline{Q}^2\sum_{j=0}^{\infty}\beta^j\left(\tilde{\mathbb{E}}_t\left[i_{t+j}^{(1)}\right] - \tilde{\mathbb{E}}_t\left[\pi_{t+j+1}\right]\right)$$

$$\implies \tilde{v}_t^q = -\overline{Q}^2\left((1-\beta)\sum_{h=0}^{\infty}\beta^h(h+1)i_t^{(h+1)} - \sum_{h=0}^{\infty}\beta^h\pi_{t+1+h}\right) \tag{25}$$

Here we should discuss how to deal with... interpolation, extrapolation, missing variables etc. in the yield curve data. And detail when we use which data.

4.1.4 Instruments

To build our dataset of macro instruments, we collected a large variety of structural shocks identified by the literature.[9] Altogether, we use more than 30 shocks from 26 different

[8] Examples include Shiller (1979), Shiller et al. (1983), Fama (1984), Fama and Bliss (1987), and Campbell and Shiller (1991). However, even though yield curve-implied forecasts fail this test, that does not mean that they are necessarily bad forecasts. For example, these constructed forecasts have smaller forecast errors than those reported in the Survey of Professional Forecasters (Adams and Barrett, 2023).

[9] In related work, Adams and Barrett (2025) apply the monthly subset of these instruments, plus additional monetary shocks, to use an IV method to decompose how MPS depend on contemporaneous interest rate surprises versus news about future policy across many horizons.

sources covering the post-war period in the US (albeit unbalanced and with gaps). We organize them into six categories.

Modern estimates of monetary policy shocks (MPS) are the most cleanly identified structural shocks; their main drawback is that they tend to be weak instruments, explaining only a fraction of aggregate variation. Four sources identify their shocks form high-frequency data around monetary policy events: Miranda-Agrippino and Ricco (2021), Jarociński and Karadi (2020) who estimate both an interest rate shock and a Fed information shock, Bauer and Swanson (2023) who expand the set of Fed events used to estimate the shocks, and Swanson (2024) who decomposes the high-frequency asset price movements into a target rate shock, a forward guidance shock, a large-scale asset purchase shock. Two other sources use narrative methods: Aruoba and Drechsel (2024) build on ideas in Romer and Romer (2004), using natural language processing of internal documents to capture the Fed's information set. Drechsel (2024) uses data on Presidential interactions with Fed Chairs to estimate political pressure shocks in a narrative sign-restricted SVAR (Antolín-Díaz and Rubio-Ramírez, 2018).

For government spending, we began with several series previously collected and harmonized by Ramey (2016). These series use military events in some way as a source of exogenous variation: Fisher and Peters (2010) estimate shocks from excess returns for defense contractor stocks, Ramey (2011) uses narrative military shocks constructed from periodicals, and Ben Zeev and Pappa (2017) use a SVAR with medium-run restrictions to identify defense spending news shocks. To these, we add three sources of non-defense government spending shocks, all using narative methods. Romer and Romer (2016) identify transfer shocks from social security expanstions, Fieldhouse et al. (2018) use mortgage purchases from federal housing agencies, and Fieldhouse and Mertens (2023) use changes to federal R&D appropriations.

Two series of tax shocks are also sourced from the Ramey (2016) collection: Mertens and Ravn (2012) use records of the delay between passage and implementation of tax legislation to isolate anticipated vs. unanticipated tax changes; Leeper et al. (2012) estimate expected tax changes using spreads between federal and municipal bonds. In addition to these, we add the Lieb et al. (2024) tax shocks constructed from analysis of presidential speeches. We also include Federal borrowing shocks estimated by Phillot (2025) using high frequency data around news of treasury auction announcements.

To measure productivity shocks, we draw on the Barsky and Sims (2011) TFP news shocks estimed from an SVAR using medium-run restrictions, and the Ben Zeev and Khan (2015) investment-specific productivity shocks, which has both a news and surprise component. We also take innovations to the utilization-adjusted TFP series from Fernald (2014), which is regularly updated. Finally, we include the technology news shocks from

Miranda-Agrippino et al. (2019), which uses patent applications orthogonalized with respect to macroeconomic conditions as an instrument for future productivity.

Oil shocks come in three flavors. Kilian (2008) identifies oil supply shocks from conflicts in oil-producing countries. Baumeister and Hamilton (2019) use a Bayesian VAR incorporating prior information about elasticities to separately identify oil supply and demand shocks. Känzig (2021) uses high frequency asset price data around OPEC announcements to identify news shocks regarding future oil supply.

Finally, in order to cover as broad a set of macroeconomic forces as possible, we use several additional series that do not fit neatly into one of the above categories. Piffer and Podstawski (2018) estimate macroeconomic uncertainty shocks using high-frequency data on volatility in intraday gold prices around international financial and political events. Kim et al. (2022) estimate severe weather shocks that are relevant for the US macroeconomy. And Adams and Barrett (2024) identify shocks to inflation expectations using a SVAR with appropriate restrictions on the co-movement between forecasts and future inflation.

4.2 Results

We will describe the baseline estimation and a couple robustness checks. Then fill an appendix with many alternatives.

Some dimensions to consider for robustness checks:

- Alterative priors (e.g. tight vs loose prior on theta, beta)
- Alternative proxies for $\tilde{v}_t^y$, $\tilde{v}_t^q$, i.e. rational vs forecast-based
- Different sets of IVs (e.g. one where we exclude SVARs, one where we exclude narrative)
- Bayesian vs 2SLS
- Hand-to-mouth income inclusion
- Alternative detrending
- Extra variables in the regression (e.g. principle components) to try to capture the omitted variable

4.2.1 Consumption Function Estimates

results go here!

Reduced-form priors/posteriors (in particular the marginal propensity to consume out of taxes $(1-\beta)(1-\theta)$ and also the implied distributions of β and θ. Do we like means or medians for reporting point esitmates at the beginning?

Shock Source	Method	Notes	Range
Monetary Policy Shocks			
Jarociński and Karadi (2020)	HFI	2 shocks: pure monetary policy and Fed information	1990:M1-2016:M12
Miranda-Agrippino and Ricco (2021)	HFI	Surprises orthogonalized w.r.t. Greenbook forecasts	1991:M1-2009:M12
Bauer and Swanson (2023)	HFI	Uses Fed minutes and speeches	1988:M2-2023:M12
Swanson (2024)	HFI	3 types of MPS: FFR, forward guidance, & LSAP	1988:M2-2023:M12
Aruoba and Drechsel (2024)	Narrative	Natural language processing of Fed docs	1982:M10-2008:M10
Drechsel (2024)	SVAR	Political pressure on the Fed	1935:Q1-2016:Q4
Government Spending Shocks			
Fisher and Peters (2010)	External	Excess returns of defense contractors	1947:Q1-2008:Q4
Ramey (2016)	Narrative	Military news	1947:Q1-2013:Q12
Romer and Romer (2016)	Narrative	Social Security expansions	1951:M1-1991:M12
Fieldhouse et al. (2018)	Narrative	Government housing purchases	1952:M11-2014:M12
Fieldhouse and Mertens (2023)	Narrative	Government R&D expenditures	1947:Q1-2021:Q4
Ben Zeev and Pappa (2017)	SVAR	Defense spending news	1948:Q1-2007:Q4
Tax/Borrowing Shocks			
Leeper et al. (2012)	External	Fiscal news from bond markets, SPF	1947:Q1-2007:Q4
Phillot (2025)	HFI	Futures yields around Treasury announcements	1998:M10-2020:M01
Mertens and Ravn (2012)	Narrative	Anticipated and unanticipated	1947:Q1-2007:Q4
Lieb et al. (2024)	Narrative	News from Presidents' speeches	1951:Q4-2007:Q3
Technology Shocks			
Fernald (2014)	External	Utilization-adjusted TFP	1947:Q2-2024:Q4
Miranda-Agrippino et al. (2019)	External	Patent filing news	1982:M10-2014:M12
Barsky and Sims (2011)	SVAR	TFP news	1961:Q1-2007:Q4
Ben Zeev and Khan (2015)	SVAR	IST news, IST surprise, TFP	1952:Q1-2012:Q1
Oil Shocks			
Kilian (2008)	External	OPEC conflict events	1971:Q1-2004:Q3
Baumeister and Hamilton (2019)	SVAR	Oil supply, consumption/inventory demand	1975:M2-2024:M3
Känzig (2021)	HFI	Oil supply news	1975:M1-2023:M6
Other Shocks			
Piffer and Podstawski (2018)	HFI	Uncertainty shocks from intraday gold prices	1979:M1-2025:M4
Kim et al. (2022)	External	ACI severe weather shocks	1964:M4-2019:M5
Adams and Barrett (2024)	SVAR	Shocks to inflation expectations	1979:M1-2024:M5

Table 2: Structural Shock Instruments

4.2.2 Dynamic Effects of Structural Shocks

We can show some IRFs here (which ones are most interesting? tax shocks, right?)

5 Macroeconomic Implications

Large changes TBD in this section

In this section, we explore the macroeocnomic implications of our results in a general equilibrium economy. Because tax cuts increase consumption by non-Ricardian households, they also reduce savings. Thus, government borrowing crowds out private capital.

here quantify the effects!

We also use the model to illustrate the econometric challenges in a Monte Carlo simulation. When the consumption function features demand shocks, OLS is biased, but structural shocks can be used as instruments to consistently estimate the consumption function.

5.1 Model Assumptions

We study a standard real business cycle model modified with behavioral expectations. Government finances exogenous spending with taxes and risk-free debt. Taxation follows a fiscal rule subject to exogenous shocks. We include a variety of additional shocks in order to challenge our simulated estimated, include TFP, IST, government spending, risk, and demand shocks.

5.1.1 Households

The representative household's preferences over current and future consumption are represented by

$$\tilde{\mathbb{E}}_t \left[\sum_{s=0}^{\infty} \beta^s u(C_{t+s}) \right] \tag{26}$$

where C_t is the household's consumption in period t, β is its discount factor, $u(\cdot)$ is a strictly concave utility function, and $\tilde{\mathbb{E}}_t$ is the household's subjective expectation.

The household earns two kinds of income. It inelastically works L_t units of time, for which it is paid real wage W_t. And it rents capital K_{t-1} at rental rate R_t. The household can save by purchasing risk-free bonds B_t, which pay one unit of the numeraire and cost Q_t. It can buy and sell capital K_t at stochastic cost Z_t^k, and capital depreciates at rate δ. The household spends its remaining income on consumption C_t and taxes T_t. The household's budget constraint is

$$W_t L_t + R_t K_{t-1} + Z_t^k (1-\delta) K_{t-1} + B_{t-1} = C_t + T_t + Q_t B_t + Z_t^k K_t \tag{27}$$

The household's savings decisions are characterized by two Euler equations. The Euler equation for bonds is:

$$Q_t = \beta \tilde{\mathbb{E}}_t \left[\frac{u'(C_{t+1})}{u'(C_t)} \right] + Z_t^d \tag{28}$$

while the Euler equation for capital is

$$1 = \beta \tilde{\mathbb{E}}_t \left[\frac{u'(C_{t+1})}{u'(C_t)} R_{t+1}^K \right] + Z_t^d + Z_t^r \tag{29}$$

where

$$R^K_{t+1} \equiv \frac{R_{t+1} + Z^k_{t+1}(1-\delta)}{Z^k_t}$$

denotes the return on capital. We introduce two ad hoc exogenous wedges to the Euler equations. The stochastic Z^d_t is an intertemporal wedge that affects both; the stochastic Z^r_t is a risk wedge the affects only capital demand.

5.1.2 Future Taxes

We write the perceived present value of current and future taxes as

$$\tilde{V}^T_t = \tilde{\mathbb{E}}_t \left[\sum_{s=0}^{\infty} P_{t,t+s} T_{t+s} \right] \tag{30}$$

where $P_{t,t+s} \equiv \prod_{r=0}^{s-1} Q_{t+r}$ denotes the relative price between consumption in different periods, with $P_{t,t} \equiv 1$. The perceived tax burden $\tilde{V}^T_t$ follows a recursive law of motion:

$$\tilde{V}^T_t = T_t + Q_t \tilde{\mathbb{E}}_t[\tilde{V}^T_{t+1}] \tag{31}$$

5.1.3 Production

Competitive firms rent capital and labor from the household. They produce generic output using a constant returns to scale production function. For the representative firm, output is given by

$$Y_t = A_t F(K_{t-1}, L_t) \tag{32}$$

where A_t is total factor productivity. The firm's factor demand functions are

$$A_t F_K(K_{t-1}, L_t) = R_t \tag{33}$$

$$A_t F_L(K_{t-1}, L_t) = W_t \tag{34}$$

Output is used for consumption, government spending, and investment. The economy-wide resource constraint is:

$$Y_t = C_t + G_t + Z^K_t(K_t - (1-\delta)K_{t-1}) \tag{35}$$

5.1.4 Government

The government must finance exogenous government expenditures G_t, and does so by taxing and issuing risk-free bonds B_t at price Q_t. The government's budget constraint is

$$G_t = T_t + Q_t B_t - B_{t-1} \tag{36}$$

and define deficits D_t by

$$D_t \equiv G_t - T_t$$

which implies that the government's lifetime budget constraint can be written

$$B_{t-1} = -\sum_{s=0}^{\infty} P_{t,t+s} D_{t+s}$$

or

$$B_{t-1} = \sum_{s=0}^{\infty} P_{t,t+s} T_{t+s} - \sum_{s=0}^{\infty} P_{t,t+s} G_{t+s}$$

Taxes T_t and government spending G_t are both exogenous.

5.1.5 Equilibrium Definition

A *behavioral expectations equilibrium* is a stationary series of 3 prices (Q_t, W_t, R_t), 5 quantities $(Y_t, K_t, B_t, C_t, T_t)$ and exogenous time series $(A_t, L_t, G_t, Z_t^u, Z_t^k)$, satisfying 8 equations:

1. Households maximize expected utility: their Euler equations (28) and (29) hold.
2. Firms produce by (32) and satisfy factor demands (33) and (34)
3. Fiscal variables follow the government budget constraint (36)
4. The resource constraint (35) is satisfied

5.1.6 Linearized Equilibrium Conditions

We linearize the model around the deterministic steady state. In the linear equations, lowercase letters denote deviations (except for taxes, whose deviation is denoted by τ_t) from the steady state, while uppercase with bars denote steady state values.

The budget constraint becomes clarify to get in original form with n, and appropriately net out investment

$$w_t \overline{L} + r_t \overline{K} + \overline{R}^k k_{t-1} + b_{t-1} = c_t + \tau_t + q_t \overline{B} + \beta b_t + k_t$$

which uses $\overline{R^k} = \overline{R} + 1 - \delta$.

The Euler equations (28) and (29) become

$$q_t = \beta\tilde{\mathbb{E}}_t[\gamma\frac{1}{\bar{C}}(c_t - c_{t+1})] + z_t^d \tag{37}$$

$$0 = \beta\tilde{\mathbb{E}}_t[\gamma\frac{1}{\bar{C}}(c_t - c_{t+1}) + r_{t+1} + (1-\delta)z_{t+1}^k] - z_t^k + z_t^d + z_t^r \tag{38}$$

where $\gamma = \frac{u''(\overline{C})\overline{C}}{u'(\overline{C})}$ is the steady state coefficient of relative risk aversion. The second equation uses that $r_t^k = r_t + (1-\delta)z_t - \overline{R}^k z_{t-1}$, as well as $\overline{Z}^k = 1$ and $\overline{R}^k = 1/\beta$.

With inelastic labor supply, output (equation (32)) is given by

$$y_t = \overline{Y}a_t + \bar{R}k_{t-1} \tag{39}$$

with steady state productivity normalized to $\overline{A} = 1$. Similarly, the capital demand (33) is linearized as

$$r_t = \overline{R}a_t + \bar{F}_{KK}k_{t-1} \tag{40}$$

and the labor demand (34) is linearized as

$$w_t = \overline{W}a_t + \bar{F}_{LK}k_{t-1} \tag{41}$$

The government budget constraint (36) is where is q? I don't need to assume 0 ss debt

$$b_{t-1} = \tau_t - g_t + \beta b_t \tag{42}$$

The resource constraint (35) is

$$y_t = c_t + g_t + k_t - (1-\delta)k_{t-1} + \delta\overline{K}z_t^k \tag{43}$$

with the normalization $\overline{Z}^k = 1$.

The consumption function in this model follows the general behavioral consumption function in Proposition 2.

We assume that the exogenous terms follow AR(1) processes. The linearized stochastic wedges are given by

$$\text{Demand} \qquad \zeta_t = \rho_\zeta \zeta_{t-1} + \epsilon_t^\zeta \tag{44}$$

$$\text{TFP} \qquad a_t = \rho_a a_{t-1} + \epsilon_t^a \tag{45}$$

$$\text{IST} \qquad z_t^k = \rho_k z_{t-1}^k + \epsilon_t^k \tag{46}$$

$$\text{Risk} \qquad z_t^r = \rho_r z_{t-1}^r + \epsilon_t^r \tag{47}$$

$$\text{Gov. Spending} \qquad g_t = \rho_g g_{t-1} + \epsilon_t^g \tag{48}$$

where $(\epsilon_t^\zeta, \epsilon_t^a, \epsilon_t^k, \epsilon_t^r)$ are independent Gaussian shocks. GOV SPENMDING?¿? The present value of taxes v_t^τ is also AR(1):

$$\text{Taxes ALM} \qquad v_t^\tau = \rho_\tau v_{t-1}^\tau + \epsilon_{t-1}^\tau \tag{49}$$

which depends on the *lagged* tax shock ϵ_{t-1}^τ, because with our simplifying assumptions, the government budget constraint implies $b_{t-1} = v_t^\tau$, so v_t^τ must be known at time $t-1$. Lastly, $v_t^\tau = \tau_t + \beta \mathbb{E}[v_{t+1}^\tau]$ implies that the the exogenous tax process τ_t satisfies

$$\tau_t = \rho_\tau \tau_{t-1} - \beta \epsilon_t^\tau + \epsilon_{t-1}^\tau$$

5.1.7 Expectations

To be internally consistent, we represent the behavioral expectations with a *perceived law of motion* (PLM). We assume that households have rational expectations about most exogenous processes, i.e. recognizing that they follow equations (44) - (48). However, instead of the actual law of motion (49), households act as if the present value of taxes follow

$$\text{Taxes PLM} \qquad v_t^\tau = \theta \rho_\tau v_{t-1}^\tau + \epsilon_{t-1}^\tau \tag{50}$$

with $\theta \in [0, 1]$. This structure recovers the relationship assumed in Section 2 (equation (13)).

5.2 The Effects of Tax Shocks

this section not updated yet, hopefully to be mostly replaced with CIR analysis

To understand how Ricardianism is affected by a consumer's behavioral expectations, consider an unexpected change in the exogenous tax component h_t that does not affect government spending.

5.2.1 Immediate Effects

First, the government budget constraint disciplines how future taxes can respond to the shock. This is because government debt must equal the present value of future surpluses. Recurring the linearized government budget constraint gives:

$$b_{t-1} = \sum_{j=0}^{\infty} \beta^j (\tau_{t+j} - g_{t+j})$$

and taking rational expectations implies

$$b_{t-1} = v_t^\tau - v_t^g \tag{51}$$

where v_t^τ and v_t^g are the rational present values satisfying

$$v_t^\tau = \tau_t + \beta \mathbb{E}_t[v_{t+1}^\tau] \tag{52}$$

$$v_t^g = g_t + \beta \mathbb{E}_t[v_{t+1}^g] \tag{53}$$

Second, differentiate the government's budget constraint:

$$\frac{db_{t-1}}{dh_t} = \frac{dv_t^\tau}{dh_t} - \frac{dv_t^g}{dh_t}$$

b_{t-1} is predetermined, and the hypothetical tax shock does not affect government spending, so $\frac{db_{t-1}}{dh_t} = \frac{dv_t^g}{dh_t} = \frac{dv_t^\tau}{dh_t} = 0$ From the recursive present value equation, this implies

$$0 = \frac{d\tau_t}{dh_t} + \beta \frac{d\mathbb{E}_t[v_{t+1}^\tau]}{dh_t}$$

$$\implies -\frac{1}{\beta} = \frac{d\mathbb{E}_t[v_{t+1}^\tau]}{dh_t}$$

Next, differentiate the household's consumption function 10:

$$\frac{d}{dh_t} c_t = (1-\beta)\left(\frac{d}{dh_t} n_{t-1} + \frac{d}{dh_t}\tilde{v}_t^y - \frac{d}{dh_t}\tau_t - \frac{d}{dh_t}\beta\tilde{\mathbb{E}}_t[v_{t+1}^\tau]\right) + \left(\frac{\overline{C}}{\gamma} - (1-\beta)\overline{B}\right)\frac{d}{dh_t}\tilde{v}_t^q$$

n_{t-1} is predetermined, while expectations of future taxes and current taxes are constrained. Let the parameter θ denote the attenuation to expectations of future taxes:

$$\theta \equiv \frac{d\tilde{\mathbb{E}}_t[v_{t+1}^\tau]}{d\mathbb{E}_t[v_{t+1}^\tau]}$$

Thus the consumption response is given by

$$\frac{d}{dh_t}c_t = (1-\beta)\left(\frac{d}{dh_t}\tilde{v}_t^y\right) + \left(\frac{\overline{C}}{\gamma} - (1-\beta)\overline{B}\right)\frac{d}{dh_t}\tilde{v}_t^q - (1-\beta)(1-\theta)$$

What determines the consumption response? How their perceived income component present value $\tilde{v}_t^y$ moves, how their perceived console value $\tilde{v}_t^q$ moves, and the degree to which the behavioral parameter θ differs from one.

As an example, suppose households are myopic, so that $\tilde{\mathbb{E}}_t[\tilde{v}_t^y] = 0$. Then, $\tilde{v}_t^y$ is predetermined. Also, suppose that steady state debt (which is not otherwise pinned down) satisfies $\frac{\overline{C}}{\gamma} = (1-\beta)\overline{B}$. In this case, the effect on consumption is clear:

$$[\frac{\overline{C}}{\gamma} = (1-\beta)\overline{B},\ \frac{d}{dh_t}\tilde{v}_t^y = 0]: \qquad \frac{d}{dh_t}c_t = -(1-\beta)(1-\theta)$$

consumption has zero response, i.e. households are Ricardian, *only if households have rational expectations*. If their expectations of future taxes are attenuated at all ($\theta < 1$), then *consumption falls when taxes rise*.

We will see that this result holds more generally.

5.2.2 Dynamic Effects

Now consider the dynamic effects of a shock to taxes.

Parameter	Symbol	Value
Discount factor	β	0.99
Capital share	α	0.4
Depreciation rate	δ	0.02
Steady state risk aversion	γ	1
Steady state debt	$\bar{B}$	0
Shock autocorrelation	$\rho_\zeta, \rho_a, \rho_k, \rho_r, \rho_\tau$	0.5
Std. dev. of shocks	$\sigma_\zeta, \sigma_a, \sigma_k, \sigma_r, \sigma_\tau$	1
Std. dev. of IV errors	$\sigma_{\xi,1}, \sigma_{\xi,2}$	0.1, 0.2

Table 3: Parameter Values for the Quarterly Business Cycle Model

The model is intended to be illustrative, so we choose a generic quarterly parameterization (Table 3), but do not attempt to estimate or discipline the time series properties of the exogenous wedges. When conducting the Monte Carlo study, we will vary the shock variances

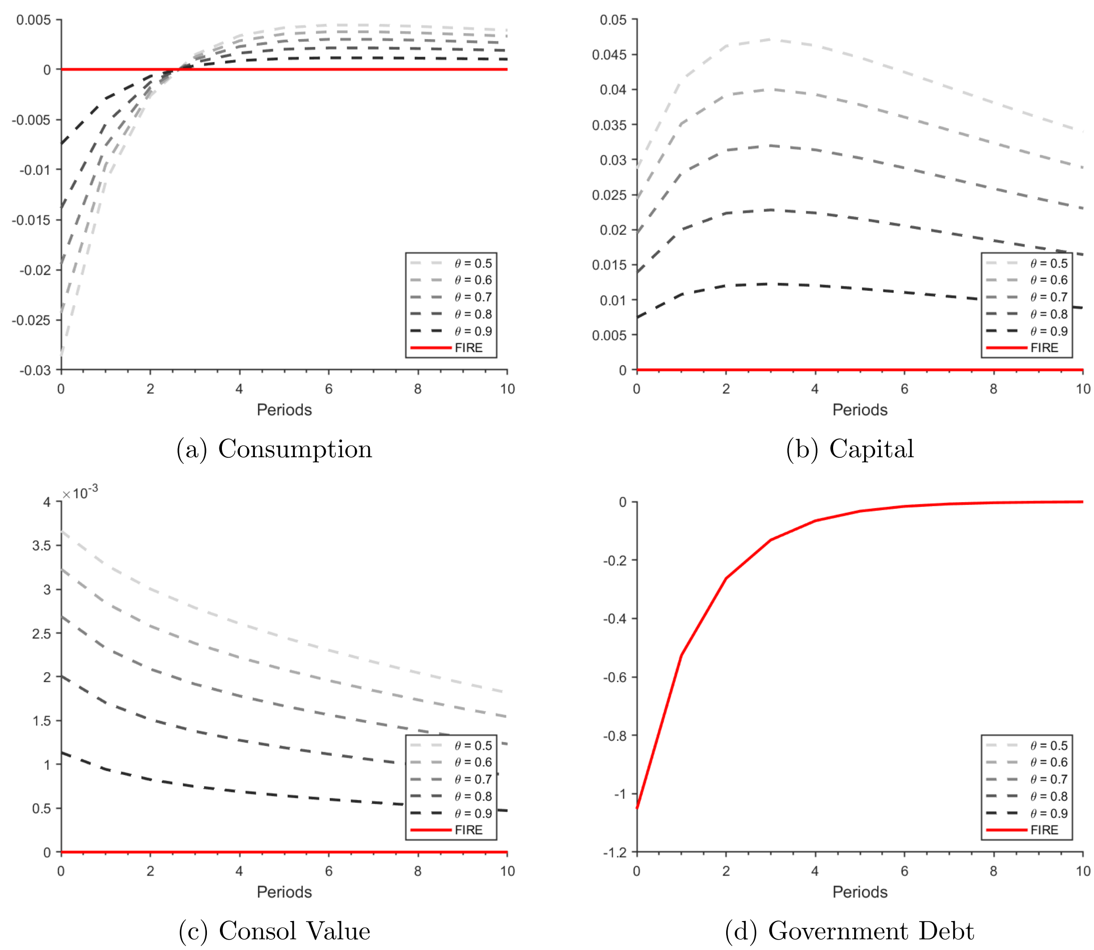
DESCRIBE CALIBRATION, EXPECTATIONS HERE.

We need to choose a fiscal rule that satisfies the government budget constraint. In this section, we let $g_t = 0$ and $\bar{B} = 0$ so that the government budget constraint simplifies to:

$$b_{t-1} = \tau_t + \beta b_t$$

and we let $f_0 = 0$ and $f_1 = 0$ so that taxes are entirely exogenous.

Changes to taxes can affect consumption because households can substitute from consumption to savings. Market clearing implies that any decline in consumption is offset by an investment increase. Under Ricardian equivalence, tax shocks have no effect on consumption, because agents know that current tax changes will be paid by (or pay for) future tax changes. However, when households are not Ricardian, then tax changes distort the consumption/savings decision.



(a) Consumption

(b) Capital

(c) Consol Value

(d) Government Debt

Figure 1: Non-Ricardian Responses to Tax Shocks

Figure 1 plots the impulse responses to a tax shock u_t for a variety of θ values. When $\theta < 1$, agents expect that future taxes will be higher than the rational expectation, and so would like to decrease consumption (Panel 1a). The unconsumed GDP is instead used for investment, so the capital stock accumulates (Panel 1b). Because there is savings vehicle, consol values (Panel 1c) do not need to rise nearly as much as in the capital-less mode. As θ shrinks, households are less Ricardian, and want to decrease consumption by even more. This leads to greater capital accumulation. In all these cases, the tax increase reduces government debt (Panel 1d). Thus, when $\theta < 1$, *government debt crowds out capital.*

5.2.3 Cumulative Impulse Responses

THIS SECTION IN PROGRESS!

Discounted cumulative impulse responses (DCIR) are a convenient way to analyze dynamic effects. We use bold variables to denote the discounted sum of future responses, conditional on a unit tax shock at time $t = 0$, e.g. for some variable x_t:

$$\mathbf{x} = \sum_{h=0}^{\infty} \beta^h \mathbb{E}[x_{t+h} | \epsilon_t^\tau = 1]$$

Similarly, the we use tildes to denote the discounted sum *perceived* by households with behavioral expectations:

$$\tilde{\mathbf{x}} = \sum_{h=0}^{\infty} \beta^h \tilde{\mathbf{E}}_{t,t+h-1}[x_{t+h} | \epsilon_t^\tau = 1]$$

where $\tilde{\mathbf{E}}_{t,t+j}[x_{t+j+1}]$ denotes the iterated expectation

$$\tilde{\mathbf{E}}_{t,t+j}[x_{t+j+1}] = \tilde{\mathbb{E}}_t \tilde{\mathbb{E}}_{t+1} \tilde{\mathbb{E}}_{t+2} ... \tilde{\mathbb{E}}_{t+j} \left[x_{t+j+1}\right]$$

A bold variable written with a zero subscript denotes the impact effect, i.e.

$$\mathbf{x}_0 = \frac{dx_t}{d\epsilon_t^\tau}$$

Our linear model admits a state space representation, whereby time t choice variables are linear in the endogenous states (k_{t-1}, n_{t-1}) and exogenous states $(\zeta_t, a_t, z_t^k, z_t^r, g_t, v_t^\tau)$.

Following the assumptions refer back to state-space calibration/explanation behavioral expectations of tax effects are related to rational expectations by

$$\tilde{\mathbb{E}}[x_{t+h} | \epsilon_t^\tau = 1] = \theta \mathbb{E}[x_{t+h} | \epsilon_t^\tau = 1]$$

DCIRs are convenient from dynamic equations – we call this *DCIR algebra.* Discounted recursive equations relate DCIRs to impact effects, e.g.

$$x_t = z_t + \beta\tilde{\mathbb{E}}_t[x_{t+1}] \implies \mathbf{x}_0 = \mathbf{z}$$

and backwards-looking equations are even simpler, e.g.

$$x_t = z_t + \alpha x_{t-1} \implies \mathbf{x} = \mathbf{z} + \alpha\beta\theta\mathbf{x}$$

With these tools, we can easily derive the DCIR summarizing the effects of tax shocks on output and consumption:

Proposition 5 *If households have rational expectations about income and interest rates, then the discounted cumulative impulse response (DCIR) of a unit tax shock on output is*

$$\mathbf{y} = \frac{(1-\theta)}{1 + (1-\theta)\overline{B}\bar{F}_{KK}/\bar{R}}$$

and the immediate effect on consumption is

$$\mathbf{c}_0 = \frac{\bar{C}}{\gamma}\frac{(-\bar{F}_{KK})}{\bar{R}}\mathbf{y}$$

I've got the sign wrong here

Proof: Appendix A

Proposition 5 shows that the degree of non-Ricardianism θ amplifies the effects of taxes on real activity. When agents are Ricardian, $\theta = 1$ so taxes have no effect on output or consumption. As θ shrinks and households fail to internalize their future taxes, the DCIR $\mathbf{y}$ increases. This is because consumption falls on impact AHHHHH REVISIT THIS

Corollary 2 *If steady-state debt is $\bar{B} = 0$, then θ is a sufficient statistic for the output DCIR:*

$$[\bar{B} = 0] \qquad \implies \qquad \mathbf{y} = 1 - \theta$$

5.3 Monte Carlo Simulation

In this section we simulate the model in order to demonstrate the challenges involved in estimating Ricardianism.

We maintain the specialized assumptions from Section 5.2.2: government spending is fixed ($g_t = 0$), steady state debt is $\bar{B} = 0$, and taxes $\tau_t = h_t$ are entirely exogenous. I had to drop that assumption right?

this is confusing. which epsilon is the tax shock?? oh they both are, notation is confiusing

With these assumptions, the behavioral consumption function is even simpler than in Proposition 2.

update to include shock and Bbar in the proof

Corollary 3 *If government spending is constant ($g_t = 0$), and perceived future taxes are proportional to the rational expectation by $\tilde{\mathbb{E}}_t[v^\tau_{t+1}] = \theta \mathbb{E}_t[v^\tau_{t+1}]$, then the consumption function can be written in terms of financial assets n_{t-1}, government debt b_{t-1}, taxes τ_t, console values $\tilde{v}^q_t$, and perceived non-financial wealth $\tilde{v}^y_t$ as:*

$$c_t = (1-\beta)\left(n_{t-1} - \theta b_{t-1} + \tilde{v}^y_t - (1-\theta)\tau_t\right) + \left(\frac{\overline{C}}{\gamma} - (1-\beta)\overline{B}\right)\tilde{v}^q_t + \zeta_t \tag{54}$$

Proof. With constant government spending, the government budget constraint (51) implies

$$\beta b_t = \beta \mathbb{E}_t[v^\tau_{t+1}]$$

Plugging into equation (10):

$$c_t = (1-\beta)\left(n_{t-1} + \tilde{v}^y_t - \tau_t - \theta\beta b_t\right) + \left(\frac{\overline{C}}{\gamma} - (1-\beta)\overline{B}\right)\tilde{v}^q_t$$

and the constraint $b_{t-1} = \tau_t + \beta b_t$ implies

$$c_t = (1-\beta)\left(n_{t-1} - \theta b_{t-1} + \tilde{v}^y_t - (1-\theta)\tau_t\right) + \left(\frac{\overline{C}}{\gamma} - (1-\beta)\overline{B}\right)\tilde{v}^q_t$$

■

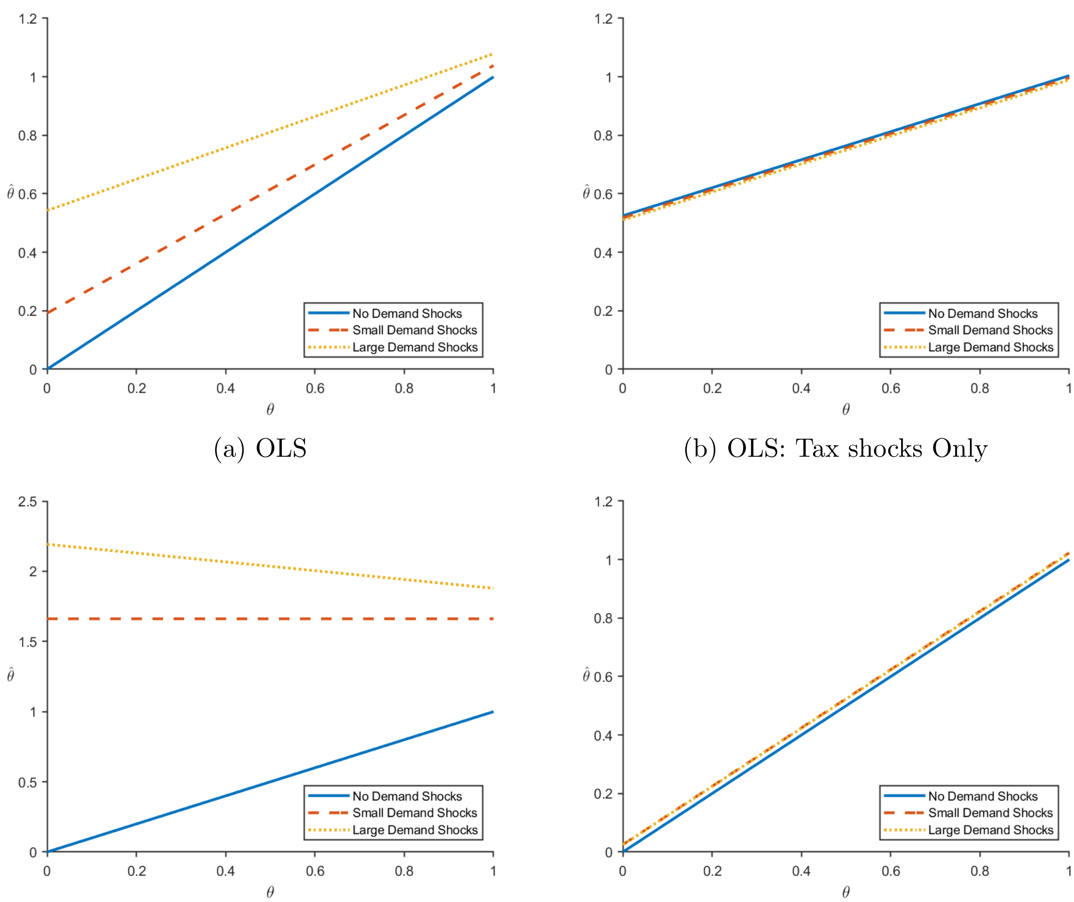
5.3.1 Estimation by OLS and IV

In this section we simulate a large sample from the model in order to demonstrate how OLS estimation of the consumption function goes wrong, and how IV can resolve the problem.

The residual ζ_t in the consumption function (54) introduces an omitted variable problem. Even if the econometrician observes n_{t-1}, b_{t-1}, v^y_t, τ_t, and v^q_t, the demand shock ζ_t will affect both consumption and time t endogenous variables, so OLS estimates will be biased. In this example, taxes τ_t are entirely exogenous. But omitted variable bias still affects the coefficient on τ_t because we are estimating the effect of variation in τ_t orthogonal to the other regressors.

Thus, classic OLS estimates of the consumption function can go wrong. Figure 2a demonstrates how, by plotting the estimated coefficient on τ_t from a regression of c_t on n_{t-1},

b_{t-1}, v_T^y, τ_t, and v_t^q. The solid blue line shows how the estimated coefficient varies with the behavioral factor θ when there are no demand shocks. When households are Ricardian ($\theta = 1$), taxes have no effect on consumption. As households become less Ricardian, taxes have larger effects on consumption; when households are myopic ($\theta = 0$), taxes reduce consumption by the entire MPC $1 - \beta$. Coefficients on the blue line identify the Ricardian factor, because there is no unobserved demand shock. But the dashed red line and dotted yellow lines plot regression coefficients when ζ_t has a small and large variance, respectively. These lines diverge from the blue line: the estimates are biased. The higher the variance of the unobserved shock, the worse the omitted variable bias.



(a) OLS

(b) OLS: Tax shocks Only

(c) IV (Lagged Variables)

(d) IV (TFP, IST, and Risk Shocks)

Figure 2: Monte Carlo Estimates of the Consumption Effects of Tax Shocks

Each panel plots the result of a different estimation method for the consumption function in the general equilibrium model. The x-axis corresponds to the true θ value, which varies across Monte Carlo simulations. The solid blue lines ("No Demand Shocks") set $\sigma_\zeta = 0$, the dashed red lines ("Small Demand Shocks") set $\sigma_\zeta = 1$, and the dotted yellow lines ("Large Demand Shocks") set $\sigma_\zeta = 2$. Each method estimates $-(1-\beta)(1-\theta)$, so each estimate is transformed into an implied estimate $\hat{\theta}$, plotted on the y-axis.

Applied macroeconomists have identified plausibly exogenous tax shocks with a number of methods (e.g. Mertens and Ravn, 2012 and Leeper et al., 2012). These shocks should be orthogonal to the demand shocks that create the omitted variable bias documented in Figure 2a. Can the behavioral factor θ be identified by simply regressing consumption on exogenous tax shocks? No. Tax shocks are orthogonal to demand shocks, but also affect consumption through other channels (e.g. interest rates). And with this approach, those other channels become omitted variables. Accordingly, the OLS regression of consumption on tax shocks is biased, except in the case of exact Ricardianism ($\theta = 1$). Figure 2b demonstrates: the estimated coefficients are not affected by the presence of demand shocks, but the OLS estimates are attenuated towards Ricardianism compared to the true value $\beta(1-\theta)$ (the blue line from Figure 2a).

Using lagged macroeconomic variables as instruments does not work either. Early in the Ricardian equivalence literature it was clear that OLS might be biased; Hayashi (1982) proposed estimation by IV with lagged variables. This solution is valid if demand shocks are uncorrelated. But in the Monte Carlo model, demand shocks are autocorrelated. Figure 2c plots the estimated WHAT IS IT using lagged consumption, capital, and console values to instrument for the endogenous regressors. The method is consistent when there are no demand shocks (blue line), but when the demand shock variance increases, the method's bias does as well.

Macro shocks as instrumental variables can resolve the problem. The Monte Carlo model's consumption function (54) has three endogenous variables (n_{t-1}, $\tilde{v}_t^y$, and $\tilde{v}_t^q$) and two exogenous variables (b_{t-1} and τ_t) so three non-collinear exogenous instruments are needed. We use productivity a_t, the capital cost (IST) z_t^k, and the risk premium z_t^r as IVs. These IVs affect the endogenous variables, but not taxes τ_t, debt b_{t-1}, nor demand shocks ζ_t. Then the consumption function is estimated by two stage least squares. Figure 2d reports the estimated coefficients on τ_t from this exercise. Regardless of the presence of demand shocks, the IV estimation recovers the correct effect of a tax change.

6 Conclusion

TBD

References

Adams, Jonathan J. and Philip Barrett, "Identifying News Shocks from Forecasts," *IMF Working Papers*, September 2023, *2023* (208), 1–78.

_ **and** _ , "Shocks to Inflation Expectations," *Review of Economic Dynamics*, October 2024, *54*, 101234.

_ **and** _ , "What Are Empirical Monetary Policy Shocks? Estimating the Term Structure of Policy News," *IMF Working Papers*, June 2025, *2025* (128), 1. Publisher: International Monetary Fund (IMF).

Aguiar, Mark A., Manuel Amador, and Cristina Arellano, "Pareto Improving Fiscal and Monetary Policies: Samuelson in the New Keynesian Model," June 2023.

Angeletos, George-Marios, Chen Lian, and Christian K. Wolf, "Can Deficits Finance Themselves?," April 2023.

_ **,** _ **, and** _ , "Can Deficits Finance Themselves?," *Econometrica*, 2024, *92* (5), 1351–1390. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.3982/ECTA21791.

Antolín-Díaz, Juan and Juan F. Rubio-Ramírez, "Narrative Sign Restrictions for SVARs," *American Economic Review*, October 2018, *108* (10), 2802–2829.

Aruoba, S. Borağan and Thomas Drechsel, "Identifying Monetary Policy Shocks: A Natural Language Approach," May 2024.

Auclert, Adrien, Matthew Rognlie, and Ludwig Straub, "The Intertemporal Keynesian Cross," *Journal of Political Economy*, December 2024, *132* (12), 4068–4121. Publisher: The University of Chicago Press.

Barnichon, Regis and Geert Mesters, "Identifying Modern Macro Equations with Old Shocks*," *The Quarterly Journal of Economics*, November 2020, *135* (4), 2255–2298.

Barro, Robert J., "Are Government Bonds Net Wealth?," *Journal of Political Economy*, November 1974, *82* (6), 1095–1117. Publisher: The University of Chicago Press.

Barro, Robert J and Martin Feldstein, "The impact of social security on private saving: Evidence from the US time series," 1978. Publisher: AEI: American Enterprise Institute for Public Policy Research.

Barsky, Robert B. and Eric R. Sims, "News shocks and business cycles," *Journal of Monetary Economics*, April 2011, *58* (3), 273–289.

Barth, James R., George Iden, and Frank S. Russek, "Government Debt, Government Spending, and Private Sector Behavior: Comment," *The American Economic Review*, 1986, *76* (5), 1158–1167. Publisher: American Economic Association.

Bauer, Michael D. and Eric T. Swanson, "A Reassessment of Monetary Policy Surprises and High-Frequency Identification," *NBER Macroeconomics Annual*, May 2023, *37*, 87–155. Publisher: The University of Chicago Press.

Baumeister, Christiane and James D. Hamilton, “Structural Interpretation of Vector Autoregressions with Incomplete Identification: Revisiting the Role of Oil Supply and Demand Shocks,” *American Economic Review*, May 2019, *109* (5), 1873–1910.

Bianchi, Francesco and Leonardo Melosi, “Inflation as a fiscal limit,” 2022. Publisher: FRB of Chicago Working Paper.

Blanchard, Olivier J., “Debt, Deficits, and Finite Horizons,” *Journal of Political Economy*, April 1985, *93* (2), 223–247. Publisher: The University of Chicago Press.

Branch, William A and Emanuel Gasteiger, “Endogenously (non-) Ricardian beliefs,” Technical Report, ECON WPS 2023.

Brzoza-Brzezina, Michal, Paweł Remigiusz Galiński, and Krzysztof Makarski, “Monetary and Fiscal Policy in a Two-Country Model with Behavioral Expectations,” *Available at SSRN 4911442*, 2024.

Campbell, John Y. and N. Gregory Mankiw, “Consumption, Income, and Interest Rates: Reinterpreting the Time Series Evidence,” *NBER Macroeconomics Annual*, January 1989, *4*, 185–216. Publisher: The University of Chicago Press.

_ **and Robert J. Shiller**, “Yield Spreads and Interest Rate Movements: A Bird’s Eye View,” *The Review of Economic Studies*, May 1991, *58* (3), 495–514.

Cardia, Emanuela, “Replicating Ricardian Equivalence Tests with Simulated Series,” *The American Economic Review*, 1997, *87* (1), 65–79. Publisher: American Economic Association.

Cebula, Richard J., Chao-Shun Hung, and Neela D. Manage, “Ricardian equivalence, budget deficits, and saving in the United States, 1955:1-1991:4,” *Applied Economics Letters*, August 1996, *3* (8), 525–528. Publisher: Routledge _eprint: https://doi.org/10.1080/135048596356168.

Drechsel, Thomas, “Estimating the Effects of Political Pressure on the Fed: A Narrative Approach with New Data,” May 2024.

Eichenbaum, Martin, Joao Guerreiro, and Jana Obradovic, “Ricardian Non-Equivalence,” *mimeo*, 2025.

Eusepi, Stefano and Bruce Preston, “Fiscal Foundations of Inflation: Imperfect Knowledge,” *American Economic Review*, September 2018, *108* (9), 2551–2589.

Evans, George W., Seppo Honkapohja, and Kaushik Mitra, “Does Ricardian Equivalence Hold When Expectations Are Not Rational?,” *Journal of Money, Credit and Banking*, 2012, *44* (7), 1259–1283. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1538-4616.2012.00531.x.

Fama, Eugene F., “The information in the term structure,” *Journal of Financial Economics*, December 1984, *13* (4), 509–528.

— **and Robert R. Bliss**, "The Information in Long-Maturity Forward Rates," *The American Economic Review*, 1987, *77* (4), 680–692. Publisher: American Economic Association.

Farhi, Emmanuel and Iván Werning, "Monetary Policy, Bounded Rationality, and Incomplete Markets," *American Economic Review*, November 2019, *109* (11), 3887–3928.

Farmer, Leland, Emi Nakamura, and Jón Steinsson, "Learning About the Long Run," Working Paper 29495, National Bureau of Economic Research November 2021.

Feldstein, Martin, "Government deficits and aggregate demand," *Journal of Monetary Economics*, January 1982, *9* (1), 1–20.

— **and Douglas W. Elmendorf**, "Government Debt, Government Spending, and Private Sector Behavior Revisited: Comment," *The American Economic Review*, 1990, *80* (3), 589–599. Publisher: American Economic Association.

Fernald, John, "A quarterly, utilization-adjusted series on total factor productivity," in "in" Federal Reserve Bank of San Francisco 2014.

Fieldhouse, Andrew J and Karel Mertens, *The Returns to Government R&D: Evidence from US Appropriations Shocks*, Federal Reserve Bank of Dallas, Research Department, 2023.

— , — , **and Morten O Ravn**, "The Macroeconomic Effects of Government Asset Purchases: Evidence from Postwar U.S. Housing Credit Policy*," *The Quarterly Journal of Economics*, August 2018, *133* (3), 1503–1560.

Fisher, Jonas D.M. and Ryan Peters, "Using Stock Returns to Identify Government Spending Shocks," *The Economic Journal*, May 2010, *120* (544), 414–436.

Froot, Kenneth A., "New Hope for the Expectations Hypothesis of the Term Structure of Interest Rates," *The Journal of Finance*, 1989, *44* (2), 283–305. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1540-6261.1989.tb05058.x.

Gabaix, Xavier, "A Behavioral New Keynesian Model," *American Economic Review*, August 2020, *110* (8), 2271–2327.

Galí, Jordi, J. David López-Salido, and Javier Vallés, "Understanding the Effects of Government Spending on Consumption," *Journal of the European Economic Association*, March 2007, *5* (1), 227–270.

Graham, Fred C., "Government Debt, Government Spending, and Private-Sector Behavior: Comment," *The American Economic Review*, 1995, *85* (5), 1348–1356. Publisher: American Economic Association.

Hagedorn, Marcus, Iourii Manovskii, and Kurt Mitman, "The Fiscal Multiplier," February 2019.

Hayashi, Fumio, "The Permanent Income Hypothesis: Estimation and Testing by Instrumental Variables," *Journal of Political Economy*, October 1982, *90* (5), 895–916. Publisher: The University of Chicago Press.

Jarociński, Marek and Peter Karadi, "Deconstructing Monetary Policy Surprises—The Role of Information Shocks," *American Economic Journal: Macroeconomics*, April 2020, *12* (2), 1–43.

Kilian, Lutz, "Exogenous Oil Supply Shocks: How Big Are They and How Much Do They Matter for the U.S. Economy?," *The Review of Economics and Statistics*, May 2008, *90* (2), 216–240.

Kim, Hee Soo, Christian Matthes, and Toan Phan, "Severe weather and the macroeconomy," *Federal Reserve Bank of Richmond Working Papers, 21-14R*, 2022.

Kormendi, Roger C., "Government Debt, Government Spending, and Private Sector Behavior," *The American Economic Review*, 1983, *73* (5), 994–1010. Publisher: American Economic Association.

_ and Philip G. Meguire, "Government Debt, Government Spending, and Private-Sector Behavior: Reply," *The American Economic Review*, 1995, *85* (5), 1357–1361. Publisher: American Economic Association.

_ and Philip Meguire, "Government Debt, Government Spending, and Private Sector Behavior: Reply," *The American Economic Review*, 1986, *76* (5), 1180–1187. Publisher: American Economic Association.

_ and _ , "Government Debt, Government Spending, and Private Sector Behavior: Reply and Update," *The American Economic Review*, 1990, *80* (3), 604–617. Publisher: American Economic Association.

Känzig, Diego R., "The Macroeconomic Effects of Oil Supply News: Evidence from OPEC Announcements," *American Economic Review*, April 2021, *111* (4), 1092–1125.

Leeper, Eric M., Alexander W. Richter, and Todd B. Walker, "Quantitative Effects of Fiscal Foresight," *American Economic Journal: Economic Policy*, May 2012, *4* (2), 115–144.

Lieb, Lenard, Adam Jassem, Rui Jorge Almeida, Nalan Baştürk, and Stephan Smeekes, "Min(d)ing the President: A Text Analytic Approach to Measuring Tax News," *American Economic Journal: Macroeconomics*, 2024.

Lustenhouwer, Joep and Kostas Mavromatis, "The Effects of Fiscal Policy When Planning Horizons are Finite," *Journal of Money, Credit and Banking*, 2023, *n/a* (n/a). _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/jmcb.13100.

Mertens, Karel and Morten O. Ravn, "Empirical Evidence on the Aggregate Effects of Anticipated and Unanticipated US Tax Policy Shocks," *American Economic Journal: Economic Policy*, May 2012, *4* (2), 145–181.

Miranda-Agrippino, Silvia and Giovanni Ricco, "The Transmission of Monetary Policy Shocks," *American Economic Journal: Macroeconomics*, July 2021, *13* (3), 74–107.

— , **Sinem Hacioglu Hoke, and Kristina Bluwstein**, "When Creativity Strikes: News Shocks and Business Cycle Fluctuations," SSRN Scholarly Paper ID 3371021, Social Science Research Network, Rochester, NY April 2019.

Modigliani, Franco and Arlie G. Sterling, "Government Debt, Government Spending, and Private Sector Behavior: A Further Comment," *The American Economic Review*, 1990, *80* (3), 600–603. Publisher: American Economic Association.

— **and Arlie Sterling**, "Government Debt, Government Spending and Private Sector Behavior: Comment," *The American Economic Review*, 1986, *76* (5), 1168–1179. Publisher: American Economic Association.

Nisticò, Salvatore, "Optimal Monetary Policy and Financial Stability in a Non-Ricardian Economy," *Journal of the European Economic Association*, October 2016, *14* (5), 1225–1252.

Orchard, Jacob, Valerie A. Ramey, and Johannes F. Wieland, "Micro MPCs and Macro Counterfactuals: The Case of the 2008 Rebates," August 2023.

Phillot, Maxime, "US Treasury Auctions: A High-Frequency Identification of Supply Shocks," *American Economic Journal: Macroeconomics*, January 2025, *17* (1), 245–273.

Piffer, Michele and Maximilian Podstawski, "Identifying Uncertainty Shocks Using the Price of Gold," *The Economic Journal*, 2018, *128* (616), 3266–3284. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/ecoj.12545.

Ramey, V. A., "Chapter 2 - Macroeconomic Shocks and Their Propagation," in John B. Taylor and Harald Uhlig, eds., *Handbook of Macroeconomics*, Vol. 2, Elsevier, January 2016, pp. 71–162.

Ramey, Valerie A., "Identifying Government Spending Shocks: It's all in the Timing*," *The Quarterly Journal of Economics*, February 2011, *126* (1), 1–50.

Romer, Christina D. and David H. Romer, "A New Measure of Monetary Shocks: Derivation and Implications," *American Economic Review*, September 2004, *94* (4), 1055–1084.

— **and** — , "Transfer Payments and the Macroeconomy: The Effects of Social Security Benefit Increases, 1952-1991," *American Economic Journal: Macroeconomics*, October 2016, *8* (4), 1–42.

Seater, John J. and Roberto S. Mariano, "New tests of the life cycle and tax discounting hypotheses," *Journal of Monetary Economics*, March 1985, *15* (2), 195–215.

Shiller, Robert J., "The Volatility of Long-Term Interest Rates and Expectations Models of the Term Structure," *Journal of Political Economy*, December 1979, *87* (6), 1190–1219. Publisher: The University of Chicago Press.

— **, John Y. Campbell, Kermit L. Schoenholtz, and Laurence Weiss**, "Forward Rates and Future Policy: Interpreting the Term Structure of Interest Rates," *Brookings Papers on Economic Activity*, 1983, *1983* (1), 173–223. Publisher: Brookings Institution Press.

Swanson, Eric T., "The Macroeconomic Effects of the Federal Reserve's Conventional and Unconventional Monetary Policies," *IMF Economic Review*, September 2024, *72* (3), 1152–1184.

Tanner, J. Ernest, "An Empirical Investigation of Tax Discounting: Comment," *Journal of Money, Credit and Banking*, 1979, *11* (2), 214–218. Publisher: [Wiley, Ohio State University Press].

Wachter, Jessica A., "A consumption-based model of the term structure of interest rates," *Journal of Financial Economics*, February 2006, *79* (2), 365–399.

Wolf, Christian K., "The Missing Intercept: A Demand Equivalence Approach," *American Economic Review*, August 2023, *113* (8), 2232–2269.

Woodford, Michael, "Macroeconomic Analysis Without the Rational Expectations Hypothesis," *Annual Review of Economics*, 2013, *5* (1), 303–346. _eprint: https://doi.org/10.1146/annurev-economics-080511-110857.

— , "Monetary Policy Analysis When Planning Horizons Are Finite," *NBER Macroeconomics Annual*, January 2019, *33*, 1–50. Publisher: The University of Chicago Press.

Zeev, Nadav Ben and Evi Pappa, "Chronicle of A War Foretold: The Macroeconomic Effects of Anticipated Defence Spending Shocks," *The Economic Journal*, August 2017, *127* (603), 1568–1597.

— **and Hashmat Khan**, "Investment-Specific News Shocks and U.S. Business Cycles," *Journal of Money, Credit and Banking*, 2015, *47* (7), 1443–1464.

A Proofs

Proof of Proposition 1. Shift the budget constraint (3) forward one period and take expectations:

$$n_t + \tilde{\mathbb{E}}_t[y_{t+1}] = \tilde{\mathbb{E}}_t[c_{t+1} + \tau_{t+1} + \overline{B}q_{t+1} + \beta n_{t+1}]$$

Let $\tilde{\mathbf{E}}_{t,t+j}[x_{t+j+1}]$ denote the iterated expectation

$$\tilde{\mathbf{E}}_{t,t+j}[x_{t+j+1}] = \tilde{\mathbb{E}}_t\tilde{\mathbb{E}}_{t+1}\tilde{\mathbb{E}}_{t+2}...\tilde{\mathbb{E}}_{t+j}\left[x_{t+j+1}\right]$$

iterate this equation forward and multiply by β:

$$\beta n_t + \sum_{j=1}^{\infty}\beta^j\tilde{\mathbf{E}}_{t,t+j-1}[y_{t+j}] = \sum_{j=1}^{\infty}\beta^j\tilde{\mathbf{E}}_{t,t+j-1}\left[c_{t+j} + \tau_{t+j} + \overline{B}q_{t+j}\right]$$

then replace βn_t in the time-t constraint (3) to get:

$$n_{t-1} + y_t + \sum_{j=1}^{\infty}\beta^j\tilde{\mathbf{E}}_{t,t+j-1}[y_{t+j}] = c_t + \tau_t + \overline{B}q_t + \sum_{j=1}^{\infty}\beta^j\tilde{\mathbf{E}}_{t,t+j-1}\left[c_{t+j} + \tau_{t+j} + \overline{B}q_{t+j}\right]$$

Substituting with $\tilde{v}_t^y$ and $\tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^\tau]$ simplifies the budget constraint to

$$n_{t-1} + \tilde{v}_t^y = c_t + \tau_t + \beta\tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^\tau] + \overline{B}q_t + \sum_{j=1}^{\infty}\beta^j\tilde{\mathbf{E}}_{t,t+j-1}\left[c_{t+j} + \overline{B}q_{t+j}\right]$$

Then, use the Euler equation (4) to write expectations of future consumption in terms of current consumption and bond prices:

$$\tilde{\mathbb{E}}_t[c_{t+1}] = c_t - \frac{\overline{C}}{\beta\gamma}q_t + \frac{\overline{C}}{\beta\gamma}z_t^d$$

$$\implies [j > 1]: \qquad \tilde{\mathbf{E}}_{t,t+j-1}\left[c_{t+j}\right] = c_t + \frac{\overline{C}}{\beta\gamma}(z_t^d - q_t) + \frac{\overline{C}}{\beta\gamma}\sum_{i=1}^{j-1}\tilde{\mathbf{E}}_{t,t+i-1}(z_{t+i}^d - q_{t+i})$$

thus the discounted sum of future consumption can be written as

$$\sum_{j=1}^{\infty}\beta^j\tilde{\mathbf{E}}_{t,t+j-1}\left[c_{t+j}\right] = \frac{\beta}{1-\beta}c_t + \frac{\overline{C}}{\gamma}\frac{1}{1-\beta}(z_t^d - q_t) + \frac{\overline{C}}{\gamma}\frac{1}{1-\beta}\sum_{j=1}^{\infty}\beta^j\tilde{\mathbf{E}}_{t,t+j-1}\left[(z_{t+j}^d - q_{t+j})\right]$$

so the budget constraint becomes

$$
\begin{aligned}
n_{t-1} + \tilde{v}_t^y = \frac{1}{1-\beta} c_t + \tau_t + \beta \tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^\tau] \\
+ \left(\overline{B} - \frac{\overline{C}}{\gamma} \frac{1}{1-\beta} \right) q_t + \sum_{j=1}^{\infty} \beta^j \tilde{\mathbf{E}}_{t,t+j-1} \left[\left(\overline{B} - \frac{\overline{C}}{\gamma} \frac{1}{1-\beta} \right) q_{t+j} \right] \\
+ \frac{\overline{C}}{\gamma} \frac{1}{1-\beta} z_t^d + \sum_{j=1}^{\infty} \beta^j \tilde{\mathbf{E}}_{t,t+j-1} \left[\frac{\overline{C}}{\gamma} \frac{1}{1-\beta} z_{t+j}^d \right]
\end{aligned}
$$

and substitute in with $\tilde{v}_t^q$ and ζ_t :

$$
n_{t-1} + \tilde{v}_t^y = \frac{1}{1-\beta} c_t + \tau_t + \beta \tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^\tau] + \left(\overline{B} - \frac{\overline{C}}{\gamma} \frac{1}{1-\beta} \right) \tilde{v}_t^q - \frac{1}{1-\beta} \zeta_t
$$

Rearrange to isolate consumption:

$$
c_t = (1-\beta) \left(n_{t-1} + \tilde{v}_t^y - \tau_t - \beta \tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^\tau] \right) + \left(\frac{\overline{C}}{\gamma} - (1-\beta) \overline{B} \right) \tilde{v}_t^q + \zeta_t
$$

■

Proof of Proposition 3. Proposition 1 implies that with rational expectations and discount factor $\beta\omega$, the consumption function is

$$
c_t = (1-\beta\omega) \left(n_{t-1} + \tilde{v}_t^y - \tau_t - \beta\omega \mathbb{E}_t[\tilde{v}_{t+1}^\tau] \right) + \left(\frac{\overline{C}}{\gamma} - (1-\beta\omega) \overline{B} \right) \tilde{v}_t^q + \zeta_t
$$

The government budget constraint implies

$$
\begin{aligned}
b_{t-1} &= \tau_t - g_t + \overline{B} q_t + \sum_{j=1}^{\infty} \beta^j \mathbb{E}_t[\tau_{t+j} - g_{t+j}] \\
&= \tau_t - g_t + \overline{B} q_t + \beta \mathbb{E}_t \left[v_{t+1}^\tau - v_{t+1}^g + \overline{B} v_{t+1}^q \right] \\
&= \tau_t + \beta \mathbb{E}_t \left[v_{t+1}^\tau \right] - v_t^g + \overline{B} v_t^q
\end{aligned}
$$

Rearrange to write neatly as

$$
\beta \mathbb{E}_t[v_{t+1}^\tau] = b_{t-1} - \tau_t + v_t^g - \overline{B} v_t^q \tag{55}
$$

By definition $\tau_t = v_t^\tau - \beta \mathbb{E}_t[v_{t+1}] = \tilde{v}_t^\tau - \beta\omega \mathbb{E}_t[\tilde{v}_{t+1}^\tau]$. This implies that v_t^τ and $\tilde{v}_t^\tau$ are related by

$$
\tilde{v}_t^\tau = \sum_{j=0}^{\infty} (\beta\omega)^j \mathbb{E}_t \left[v_{t+j}^\tau - \beta v_{t+1+j}^\tau \right]
$$

which, per equation (15), simplifies to

$$= \frac{1-\beta\rho}{1-\beta\omega\rho} v_t^\tau$$

Combined with equation (55), this implies that $\beta\omega\mathbb{E}_t[\tilde{v}_{t+1}^\tau]$ can be written

$$\beta\omega\mathbb{E}_t[\tilde{v}_{t+1}^\tau] = \omega\frac{1-\beta\rho}{1-\beta\omega\rho}\left(b_{t-1} - \tau_t + v_t^g - \overline{B}v_t^q\right)$$

then use this result to replace $\beta\omega\mathbb{E}_t[\tilde{v}_{t+1}^\tau]$ in the consumption function. ■

Proof of Proposition 4. Proposition 1 implies that with rational expectations, the unconstrained agents' consumption function is

$$c_t^U = (1-\beta)\left(n_{t-1}^U + v_t^{y,U} - v_t^\tau\right) + \left(\frac{\overline{C}}{\gamma} - (1-\beta)\overline{B}\right)v_t^q + \zeta_t$$

Iterating the government budget constraint $b_{t-1} = \tau_t - g_t + \overline{B}q_t + \beta b_t$ implies

$$b_{t-1} = v_t^\tau - v_t^g + \overline{B}v_t^q$$

Substituting for taxes in the consumption function gives

$$c_t^U = (1-\beta)\left(n_{t-1}^U - b_{t-1} + v_t^{y,U} - v_t^g\right) + \frac{\overline{C}}{\gamma}v_t^q + \zeta_t$$

Taxes do not appear; the unconstrained households are Ricardian because they have rational expectations and the same discount rate as the government.

Combining this result with the constrained consumption function given by equation (19), the aggregation equation (20) implies aggregate consumption is given by

$$c_t = \lambda\left((1-\beta)\left(n_{t-1}^U - b_{t-1} + v_t^{y,U} - v_t^g\right) + \frac{\overline{C}}{\gamma}v_t^q + \zeta_t\right) + (1-\lambda)\left(y_t^C - \tau_t\right)$$

Use $n_{t-1} = \lambda n_{t-1}^U$ and $v_t^y = \lambda v_t^{y,U} + (1-\lambda)v_t^{y,C}$ and rearrange

$$= (1-\beta)\left(n_{t-1} - \lambda b_{t-1} + v_t^y - \lambda v_t^g\right) - (1-\lambda)\tau_t + \lambda\frac{\overline{C}}{\gamma}v_t^q - (1-\lambda)(1-\beta)v_t^{y,C} + (1-\lambda)y_t^C + \lambda\zeta_t$$

which gives the appropriate result for $\theta = 1 - \frac{1-\lambda}{1-\beta}$, and $\varsigma_t^U = (1-\lambda)y_t^C - (1-\lambda)(1-\beta)v_t^{y,C}$.
■

Proof of Proposition 5. The linearized production function (39) implies

$$\mathbf{y} = \bar{R}\beta\theta\mathbf{k} \tag{56}$$

while the linearized resource constraint (43) implies

$$\mathbf{y} = \mathbf{c} + (1-(1-\delta)\beta\theta)\mathbf{k}$$

Capital demand (40) and supply (38) combine to give

$$0 = q_t + \beta\tilde{\mathbb{E}}_t[\bar{R}a_{t+1} + \bar{F}_{KK}k_t + (1-\delta)z^k_{t+1}] - z^k_t + z^r_t$$

which yields

$$0 = \mathbf{q} + \bar{F}_{KK}\beta\theta\mathbf{k} \tag{57}$$

Welllllll so long as backwards equations only use beta, we get rbar beta k = y, and c = 0 *man this method is awesome... if it were a ratex model hahaha! hard to handle otherwise* actually, even when i work through ratex case with demand shocks, i still get confusing answers... theres a mistake somewhere

Equation (6) implies that the CIR for the present value of income is

$$\mathbf{v}^y_0 = \mathbf{y}$$

and similarly equation (8) implies

$$\mathbf{v}^q_0 = \mathbf{q}$$

however Euler equation (37) implies

$$\mathbf{q} = \frac{\gamma}{\bar{C}}\left((\beta-1)\mathbf{c} + \mathbf{c}_0\right) \tag{58}$$

The immediate impact on the behavioral consumption function (2) is

$$\mathbf{c}_0 = (1-\beta)\left(\mathbf{v}^y_0 - (1-\theta)\boldsymbol{\tau}_0\right) + \frac{\overline{C}}{\gamma}\mathbf{v}^q_0$$

$$= (1-\beta)\left(\mathbf{y} - (1-\theta)\boldsymbol{\tau}_0\right) + \frac{\overline{C}}{\gamma}\mathbf{q}$$

Plugging this into the bond Euler equation gives

$$\frac{\bar{C}}{\gamma}\mathbf{q} = (\beta-1)\mathbf{c} + (1-\beta)\left(\mathbf{y} - (1-\theta)\boldsymbol{\tau}_0\right) + \frac{\overline{C}}{\gamma}\mathbf{q}$$

Rearrange:

$$\mathbf{c} = \mathbf{y} - (1-\theta)\boldsymbol{\tau}_0 \tag{59}$$

The production function and resource constraint combine to give

$$\mathbf{y} = \mathbf{c} + \frac{(1-(1-\delta)\beta\theta)}{\bar{R}\beta\theta}\mathbf{y}$$

however $\bar{R} = \beta^{-1} - 1 + \delta$ per equation (29), so $\frac{1-(1-\delta)\beta\theta}{\bar{R}\beta\theta} = \frac{1-\theta}{\bar{R}\beta\theta} + 1$, thus

$$0 = \mathbf{c} + \frac{1-\theta}{\bar{R}\beta\theta}\mathbf{y}$$

Combine with equation (59):

$$-\frac{1-\theta}{\bar{R}\beta\theta}\mathbf{y} = \mathbf{y} - (1-\theta)\boldsymbol{\tau}_0$$

$$\implies \mathbf{y} = \frac{1-\theta}{1-\frac{1-\theta}{\bar{R}\beta\theta}}\boldsymbol{\tau}_0$$

which proves the output DCIR result for $\boldsymbol{\tau}_0 = 1$.

■

B Model Extensions

TBD

B.1 Non-Contingent Debt

B.2 Long-Term Debt

B.3 Discounting Wedges with Higher-Order Tax Processes

B.4 Non-Constant Constrained Income

C Consol Values and Yields

The market value of a consol bond (one period before any coupon payment) is given by equation (8). The analogous rational value of a consol bond is thus

$$v_t^q = q_t + \beta\mathbb{E}_t[v_{t+1}^q]$$

Why does this describe the value of a consol bond? A consol bond pays a constant coupon in perpetuity. Equivalently, the consol pays a one-period bond every period in advance of the associated coupon payment.

We can also relate the value of the consol to the yields at different horizons. The price Q_t of a one-period bond is related to its yield $R_t^{(1)}$ by

$$Q_t = \frac{1}{1+R_t^{(1)}}$$

which is linearized as

$$q_t = -\overline{Q}^2 r_t^{(1)}$$

Thus the consol value maps to yields by:

$$v_t^q = -\overline{Q}^2 r_t^{(1)} + \beta\mathbb{E}_t[v_{t+1}^q]$$

$$\propto \sum_{h=0}^{\infty} \beta^h r_{t+h}^{(1)}$$