The Municipal Government Channel of Monetary Policy

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Abstract

Interest rate policy in the U.S. affects the borrowing costs of state and local governments, incentivizing municipal borrowing and spending during monetary expansions. Municipal yields increase by 22bp after a 100bp positive monetary shock, though the effect varies across states. Illiquidity dampens monetary passthrough to munis, while default risk amplifies it. To study the effects of these borrowing cost elasticities on local fiscal policy, I model U.S. localities as small open economies in a monetary union. Here, local governments conduct fiscal policy in response to borrowing costs and economic conditions. In a model calibrated to the U.S., median passthrough of monetary policy shocks to municipal borrowing costs implies a dampening of transmission to output of over half relative to a model which ignores the muni market. Realistic cross-sectional differences in borrowing cost responses result in up to a 50% difference in monetary transmission across localities, and account for 10-20% of observed monetary transmission differences in U.S. data.

Keywords: monetary policy, state and local governments, municipal bonds, small open economies, fiscal policy.

JEL codes: E52, E62, E63, F41, F45, G12, H72, H74

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1 Introduction

State and local government debt is a significant sector in the U.S. economy, with important implications for monetary policy. In 2019, the market for state and local government (municipal) bonds was valued at \$3.9 trillion, over 1/3 the size of the corporate bond market and greater than 3% of the valuation of the global bond market. Additionally, while most state and local governments in the U.S. have measures in place to prevent an excessive use of debt financing for expenditures, debt financing is nevertheless a key component of municipal public finance. State and local government debt outstanding is about 100% of state and local government total expenditures, and interest payments on municipal debt take up around 5% of annual general fund expenditures. Furthermore, rather than "leaning against" monetary expansions, state and local government spending tends to expand when interest rates fall[1], suggesting the presence of a municipal public finance channel of monetary policy transmission, by which national *monetary* policy affects local *fiscal* policy.

This paper seeks to be the first to describe and illuminate this "Municipal Government Channel" of monetary policy. To do this, I first outline a framework for modeling U.S. localities as small open New Keynesian economies in a monetary union, each with a representative household and fiscal authority. These local fiscal authorities choose debt and public goods spending on locally-produced goods, subject to borrowing costs which are *imperfectly* and *heterogeneously* linked to the risk-free interest rate. The elasticities of these borrowing costs to changes in the risk-fee rate determine the effect of monetary policy on the local government's budget; the more the government's budget relaxes after a monetary expansion, the more it can engage in stimulative spending. In the empirical section of the paper, I use time series and panel data to study the size and source of the response of municipal borrowing costs to monetary shocks, finding that municipal yields decrease (increase) by 22bp in response to a 100bp decrease (increase) in treasury yields, though there is sizeable heterogeneity across U.S. states, driven in part by liquidity and default risk factors. Finally, I calibrate the baseline model to reflect U.S. localities, showing that realistic municipal bor-

[1] Appendix C.1 present some time series evidence of the responses of some public finance variables to monetary shocks. A 1 s.d. expansionary monetary shock increases municipal government spending in the medium term by up to 0.25%, after an initial decrease which is possibly due to decreases in automatic stabilizers.

rowing cost elasticities result in a significant departure from a "risk-free rate" assumption, imply monetary transmission heterogeneity of up to 50% across states, and can account for 10-20% of transmission heterogeneity in the data.

The paper begins by outlining a model of state and local governments as small open economies in a monetary union, with local governments facing potentially heterogeneous borrowing costs. Each locality is populated by two types of agents, intertemporal and hand-to-mouth, which work and consume to optimize the representative household's utility. Consumption is comprised of tradable and non-tradable goods; the non-tradable goods are produced locally by a New Keynesian production market, with Calvo-style price setting. The locality's representative government receives a stream of tax revenue, and chooses debt issuance and public goods spending to maximize household utility, which also depends on public goods consumption on non-tradable goods. The municipal government does not borrow at the risk-free rate set by the monetary authority; rather, its idiosyncratic borrowing cost is determined on an external financial market, and is imperfectly linked to the risk-free rate.

When the national monetary authority lowers the risk-free rate, borrowing costs for the local fiscal authority decrease, relaxing the government's budget constraint and incentivizing public spending. Because public spending occurs with non-tradable goods produced by a New Keynesian market, public spending is stimulative for both output and employment, amplifying the existing expansionary effects of a drop in interest rates. Consequently, the extent to which monetary policy passes through to municipal borrowing costs is of crucial importance for determining the size of this channel. Heterogeneity in municipal debt pricing could result in significant monetary transmission differences; it is to the empirical evidence on the response of municipal bonds to monetary shocks the paper turns next.

To explore the effects of monetary shocks on municipal bond yields, I first use time series evidence from the yields on a series of SP municipal bond indices. Yields on indices of all general obligation bonds in the United States increase 22bp in response to a 100bp monetary shock, with no difference between state bonds or local bonds. This response represents a far lower elasticity than we see with corporate bonds. Additionally, I find evidence of significant heterogeneity across states, which exhibit coefficients implying responses of 17bp to 40bp.

While default risk does explain responses of municipal bonds to monetary shocks, as high risk indices respond more strongly, persistently low responses across the board imply a role for illiquidity in determining these responses.

To investigate the role of illiquidity in municipal bond responses to monetary shocks, I use transaction-level MSRB data of municipal bonds. An exercise as in Gilchrist, Yue, and Zakrajšek (2019), who are concerned with soveriegn bonds, suggest liquidity factors play a role in determining municipal yield responses. This is consistent with literature documenting search frictions, bargaining power, and transaction costs in the municipal bond market. Decomposing average spreads into liquidity and risk components also indicates that movements in spreads after a monetary shock tend to occur in the liquidity component. Finally, I connect the bond microdata for a subset of the sample with annual government finance data, yielding consistent, but not significant, evidence that smaller governments' borrowing costs respond more strongly to monetary shocks; this could be due to risk or liquidity factors.

Armed with empirical estimates of the average and range of municipal yield responses to monetary shocks, I calibrate the small open economy to respresent average U.S. localities, and study the magnitude of the municipal government channel of monetary policy. Using the main response coefficient from the empirical section, I show that including the average passthrough of monetary shocks to municipal yields in the model dampens monetary transmission by over half, relative to a case in which one assumes the local fiscal authority has access to borrowing at the risk-free interest rate. One immediate conclusion, then is that the exact nature of municipal financial markets are crucial in any model of state and local governments over the business cycle.

Additionally, realistic heterogeneity over municipal debt pricing results in meaningful differences in monetary transmission. Increasing a locality's borrowing cost responses from the low end of empirical estimates to the high end of estimates results in up to a 50% increase in monetary transmission to output and employment. Furthermore, the dispersion of peak monetary transmission implied by the state-level empirical estimates can account for 10-20% of observed dispersion of monetary transmission across U.S. localities, based on my own estimates and estimates from the literature. While localities in the U.S. differ on a multitude of dimensions affecting monetary transmission, the ability of monetary policy to influence their borrowing costs is a factor policymakers should pay attention to.

Given that I have constructed a model of state and local governments that links financial markets and business cycles, it is natural to use the model to lend insight into other macroeconomic questions besides monetary transmission. I use the model to provide an explanation for why state and local government spending decreased in the wake of the 2008 recession, the first time it has ever done so. In my model, a real recession induces fiscal stimulus, but the same recession combined with a lockup of financial markets sees a fiscal contraction; this result suggests the financial nature of the 2008 recession placed heavy constraints on the ability of municipal governments to respond. I also consider a shock to the model representing the early days of the COVID-19 pandemic; in the model, quick actions by the Fed to shore up municipal debt markets prevent a prolonged dampening of government spending.

Related Literature. This paper provides meaningful contributions to a number of important strands of economic literature. The baseline model is, in most ways, a canonical open economy New Keynesian model. In this vein, it adds to papers such as Galí and Monacelli (2008), Beetsma and Jensen (2005), Farhi and Werning (2017a), Farhi and Werning (2017b), Nakamura and Steinsson (2014), and Chodorow-Reich (2019), which study monetary and fiscal policy in monetary unions, by highlighting that interest rates for the member governments of a monetary union may differ substantially in response to the same monetary policies. Similarly, in showing how monetary policy works *through* municipal fiscal policy, this paper merges the monetary union literature with the literature on monetary policy passthrough, exemplified by Bernanke, Gertler, and Gilchrist (1999), McKay, Nakamura, and Steinsson (2016), and Kaplan, Moll, and Violante (2018). More specifically, although focused on local governments, this paper contributes to a literature on international monetary transmission to small open economies, as in Auer et al. (2019) and Cesa-Bianchi, Thwaites, and Vicondoa (2016). In contrast to papers which study optimal fiscal policy for a member of a monetary union, I study the government as an agent in the model, whose behavior in response to monetary policy is taken as part of the passthrough effect.

By analyzing a model of a locality in the U.S., this paper enters in to the discussion on regional effects of monetary policy, and macroeconomic models with regions in general, as in Beraja et al. (2019) and Beraja, Hurst, and Ospina (2019). Other papers, such as Seegert (2015), Cashin et al. (2018), and Fisher and Wassmer (2014), examine the responses of state and local governments to significant macro events; I use the model in this paper as a playground to study the behavior of state and local governments in the aftermath of the financial crisis. Finally, the over-the-counter markets version of the model in Section 2.8 builds on the work of Duffie, Garleanu, and Pedersen (2005), who model OTC markets for financial assets, and Bethune, Sultanum, and Trachter, 2019, who model the issuance side of OTC markets. I show in the paper how such a model can be connected to a DSGE macro model as a microfounded explanation for why borrowing costs may differ from the risk-free rate for local governments.

The results from the empirical section of this paper contribute to a number of strands of literature. First, and most obviously, this paper adds to recent work on the effect of U.S. monetary policy on various asset prices. Rosa (2014) does this for municipal bonds; I expand on his work by including a host of indices and exploiting a trade-level panel dataset to investigate potential determinants of muni responses to monetary shocks. Gilchrist, Yue, and Zakrajšek (2019) studies the response of international sovereign yields to U.S. monetary shocks; I perform similar exercises to their paper, but in the U.S. municipal bond market. Anderson and Cesa-Bianchi, 2020 study how firm leverage affects corporate bond responses to monetary shocks.

By shedding light on the relationship between municipal bond yields and U.S. monetary policy, I also add to a robust literature on municipal bond pricing, especially as it relates to risk and liquidity; mine is the first paper to explore explicitly the roles of these channels in determining monetary policy responses. Two important papers, Schwert (2017) and Ang, Bhansali, and Xing (2014), debate the relative importance of risk and liquidity in municipal bond spreads, with the former emphasizing risk and the latter liquidity. Another strand of papers (Harris and Piwowar, 2006; Green, Hollifield, and Schürhoff, 2007b; Green, Hollifield, and Schürhoff, 2007a; Brancaccio, Li, and Schúrhoff, 2020; Garrett et al., 2018; Moldogaziev, 2018) highlights explicit frictions in the secondary market for municipal bonds, such as information asymmetries and market power, that result in price dispersion over given bonds. A number of other papers explore determinants of municipal bond prices, from state laws on bankruptcy (Yang, 2019) to climate change (Painter, 2020). Other relevant municipal bond pricing papers include Gao, Lee, and Murphy (2019), Grigoris (2019), Adelino, Cunha, and Ferreira (2017), and a host of others.

2 A model of a municipal government

In order to examine the effects of the financial market for municipal bonds on municipal behavior and household welfare, I propose a quantitative heterogeneous agents DSGE model of municipalities in a monetary union, with municipal government debt sold on outside markets, with financial frictions. The economies in question are small open economies,[2] reflecting the tens of thousands of distinct municipal governments in the United States. In this model, households choose labor and purchases of local municipal bonds, financial markets buy and sell bonds, local governments choose spending debt issuance, and the central government chooses the risk-free interest rate. Local output is produced by monopolistically competitive firms using labor from households, resulting in standard New Keynesian features for prices.

This model is able to quantify the effects of financial frictions, which appear here as a wedge between the risk-free rate and municipal borrowing costs, and may potentially arise from an OTC framework, on local fiscal policy in response to macroeconomic shocks. As such, it serves as a contribution to the macro literature on passthrough of shocks, the fiscal policy literature, monetary unions models, models of the regional effects of macroeconomic shocks, and possibly models on OTC asset pricing. Note that, in this section, as well as in the main quantitative results, I focus on the problem of a single locality for simplicity.

2.1 Environment

The locality is modelled as a small open economy with a representative household and representative government, each of which maximizes the utility of the representative consumer. The household is made up of $1-\kappa$ traditional consumers and κ "hand to mouth," or HTM,

[2] The model builds on the canonical Calvo model found in Schmitt-Grohe and Uribe (2016), adding the municipal government sector and hand-to-mouth consumers.

consumers. The traditional, or "Ricardian," optimizers in the household choose a consumption bundle comprised of two types of final goods, tradable (c^T) and non-tradable (c^N), as well as labor supply h and debt d^H. The government chooses government purchases of non-tradable goods g and municipal debt d^G, given a tax rate τ^G on the exogenous stream of tradable goods for the economy, y^T. HTM consumers simply choose labor h^H, and consume exactly their labor income in every period.

Tradable goods and bonds of both agents are traded with the rest of the world, where the locality is endowed with an exogenous income of the tradable good in every period. Non-tradable goods are produced using domestically supplied labor by monopolistically competitive firms within the region to satisfy demand for non-tradable consumption and government purchases of public goods. Inflation is induced by Calvo-style price setting on the part of these monopolistic competitors, who maximize expected future profits subject to household and government demand, as well as the expected constraints on price changes.

The aggregate risk-free interest rate in the economy is determined by a central authority, and is exogenous with respect to local variables. Additionally, both the household and the government are subject to their own "proprietary" interest rates, r^H and r^G, which depend on the aggregate rate, deviation of debt from steady state, and parameters determining the relationship between monetary shocks and the actual interest rate paid by either the household or the government. Of particular interest in this project is the response of the *government's* borrowing costs to monetary shocks. The strength of this response will affect passthrough of interest rate shocks to households, and presents a potential source of heterogeneity of monetary passthrough in the U.S. economy.

2.2 Household

2.2.1 Basic problem

The household in the small economy is made up of $1-\kappa$ "Ricardian" agents and κ "hand-to-mouth" agents. The representative Ricardian optimizer solves

$$\max_{\{c_t^T, c_t^N, h_t, d_{t+1}\}} E_0 \beta^t \big[U(c_t) - V(h_t) + W(g_t)\big], \tag{1}$$

where

$$c_t = A(c_t^T, c_t^N) \tag{2}$$

$$c_t^T + p_t c_t^N + d_t = y_t^T(1-\tau^G) + w_t h_t + \frac{d_{t+1}}{1+r_t^H} + T_t. \tag{3}$$

Here, tradable consumption and debt are denominated in terms of the "national" price, which is normalized to unity. Prices p_t and w_t are prices–of non-tradables and labor, respectively–relative to the price of the tradable good. τ^G is the tax on exogenous tradable good allocation, and T_t is the lump-sum transfers to households from firm profits. Quantities are in per-person terms, such that total labor supply from optimizers is given by $(1-\kappa)h_t$.

2.2.2 Optimality conditions

Accordingly, the household's first order conditions are given as follows:

$$\lambda_t = U'(c_t)A_1(c_t^T, c_t^N) \tag{4}$$

$$\frac{A_2(c_t^T, c_t^N)}{A_1(c_t^T, c_t^N)} = p_t \tag{5}$$

$$\frac{\lambda_t}{1+r_t^H} = \beta E_t \lambda_{t+1} \tag{6}$$

$$V'(h_t) = \lambda_t w_t. \tag{7}$$

Equation 4 is the first order condition for tradable goods consumption, defining the shadow value of income denominated in the tradable goods price. The condition for non-tradable consumption, when plugged into Equation 4, yields 5, which allocates consumption according to the relative price of the two goods. Equation 6 trades off the benefits of borrowing today with the costs of paying it back tomorrow, and Equation 7 equates marginal costs and benefits of labor supply.

2.2.3 Hand-to-mouth agents

The remaining κ agents in the economy behave in a hand-to-mouth manner. These agents supply per-capita labor h_t^H, and use labor income to consume tradable and non-tradable goods:

$$c_t^{T,H} + p_t * c_t^{N,H} = w_t * h_t^H. \tag{8}$$

Here, as above, consumption is aggregated according to $c_t^H = A(c_t^{T,H}, c_t^{N,H})$.

The first order conditions for these consumers mirror those of the traditional agents, without the intertemporal condition:

$$\lambda_t^H = U'(c_t^H) A_1(c_t^{T,H}, c_t^{N,H}) \tag{9}$$

$$\frac{A_2(c_t^{T,H}, c_t^{N,H})}{A_1(c_t^{T,H}, c_t^{N,H})} = p_t \tag{10}$$

$$V'(h_t^H) = \lambda_t^H w_t. \tag{11}$$

The total amount of non-tradable consumption in the economy, then, is the sum $(1-\kappa)c_t^N + \kappa c_t^{N,H}$, and likewise with tradable consumption $(1-\kappa)c_t^T + \kappa c_t^{T,H}$ and total labor $(1-\kappa)h_t + \kappa h_t^H$. This departure from Ricardian equivalence in the model allows a realistic local government spending multiplier to be calculated.

2.3 Local government

The representative local government uses local fiscal policy to solve the problem 1[3] by choosing a borrowing level d_{t+1}^G subject to

$$g_t = \tau^G y_t^T + \frac{d_{t+1}^G}{1 + r_t^G} - d_t, \tag{12}$$

[3]Note that fiscal policy in this model is "passive" in the sense that policymakers are concerned primarily with the efficient provision of public goods. The local policymaker does not factor explicitly its stimulative effects on the economy. Beetsma and Jensen (2005) shows that such passive policies in a two-economy fiscal union result in welfare loss relative to centralized optimization or fiscal policy rules. However, it is reasonable to think of small local economies in the U.S. as being more concerned with public goods provision than stabilization at the level of a fiscal union. In a case in which the local government was optimizing according to a fiscal rule, or if fiscal policy was coordinated at the union level, its borrowing costs would not matter for fiscal adjustments. Additionally, these adjustments would "lean against" monetary policy, which is contrary to the data on local government responses.

Other than its choice variables, another key difference emerges for the local government: it exerts full market power over its debt. In other words, while the representative household is a price taker with respect to the interest rate, the local government can only be thought of as a singular agent and the only issuer of its asset. The government, therefore, must take into account the effect of its debt issuances on its borrowing costs, both in the current period and in the future. The first order condition with respect to debt purchases, then, is given by

$$W'(g_t)\frac{1+r_t^G - d_{t+1}^G \frac{\partial r_t^G}{\partial d_{t+1}^G}}{(1+r_t^G)^2} = \beta E W'(g_{t+1})\Big(-1+\frac{-d_{t+2}^G \frac{\partial r_{t+1}^G}{\partial d_{t+1}^G}}{(1+r_{t+1}^G)^2}\Big). \tag{13}$$

In an analog to the household's debt decision, the government uses debt issues to balance government increased spending now with decreased spending from debt obligations later. When the yields on municipal bonds move strongly with interest rate shocks, these fiscal policy responses will tend to be greater, while the opposite is true when responses of yields to monetary shocks are weak.

The condition that the government take into account its effect on interest rates is not an innocent one. It affects the response of debt to transitory shocks, but it also has an effect on the steady state of the model. Figure 1 presents this as an illustrative example using the functional forms and calibration from the quantitative section of the paper. Failing to account for the effects of debt on borrowing costs would result in massive increases in government debt, under the same parameterization.

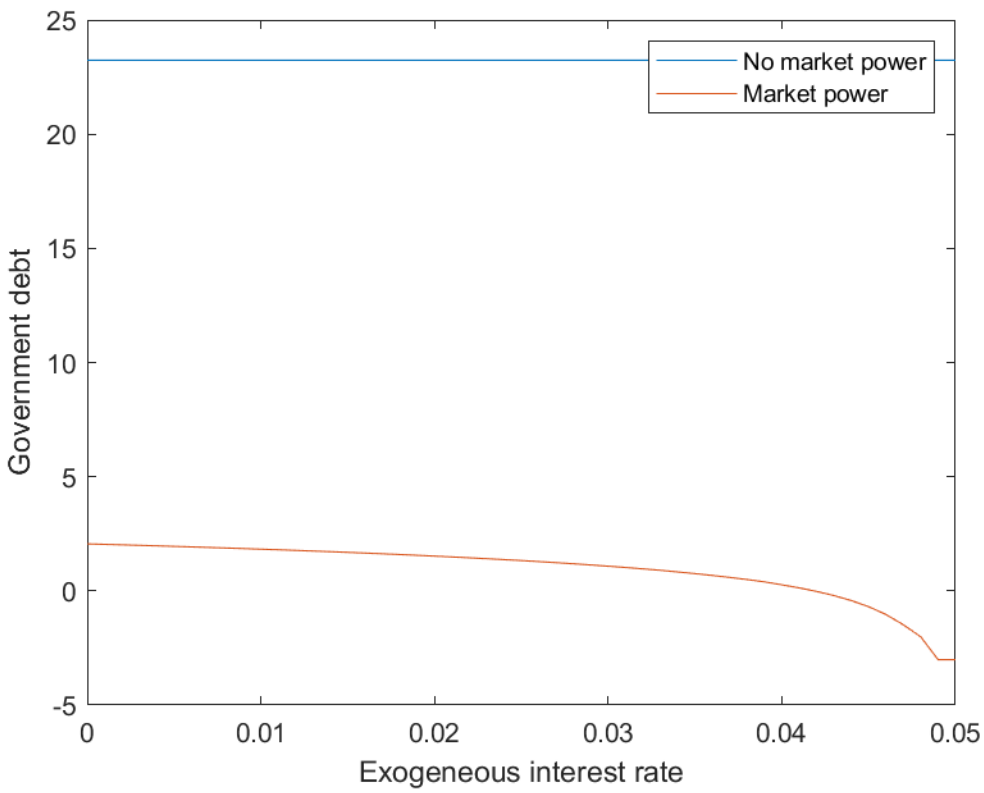
2.4 New Keynesian Production

2.4.1 Final goods production

The non-tradable good y_t^N is produced by a final goods producer which buys intermediate goods y_{it}^N from a continuum of intermediate goods producers in the local economy. Production of the final good from intermediates is determined by the aggregating equation

$$y_t^N = \Big(\int_0^1 (y_{it}^N)^{1-\frac{1}{\mu}} di\Big)^{\frac{1}{1-\frac{1}{\mu}}}, \tag{14}$$

Figure 1: Steady State Comparison, Local Government Debt



and final goods firm profits are given by

$$P_t^N y_t^N - \int_0^1 P_{it}^N y_{it}^N di.$$

Profit maximization on the part of the final goods producer implies the demand equations for the monopolistically competitive intermediate goods producers

$$y_{it}^N = y_t^N \left(\frac{P_{it}^N}{P_t^N} \right)^{-\mu}.$$

Here, the domestically produced good is used both for consumption–by both types of agents– and government spending,

$$y_t^N = (1-\kappa)c_t^N + \kappa c_t^{N,H} + g_t, \tag{15}$$

so the relevant demand equations become

$$y_{it}^N = ((1-\kappa)c_t^N + \kappa c_t^{N,H} + g_t) \left(\frac{P_{it}^N}{P_t^N} \right)^{-\mu}. \tag{16}$$

P_t^N here is the price of final non-tradable goods, which is given by the aggregator $P_t^N = \left(\int_0^1 (P_{it}^N)^{1-\mu} di \right)^{\frac{1}{1-\mu}}$.

2.4.2 Intermediate Goods Producers

Intermediate goods firms exist on the continuum $[0,1]$, and produce differentiate inputs to the final non-tradable good using household labor:

$$y_{it}^N = h_{it}^{\alpha}, \quad \alpha \in (0,1]. \tag{17}$$

The choice variable for these firms is the price for good i, P_{it}^N, which determines demand for the intermediate good as in Equation 16. Profit for an individual intermediate goods firm is given by $P_{it}^N y_{it}^N - (1-\frac{1}{\mu})W_t h_{it}$, where W_t is the raw wage and $(1-\frac{1}{\mu})$ is a labor subsidy meant to offset the distortions from monopolistic competition.

Plugging in the demand equations and production functions, period t profits for the intermediate goods firm are given as a function of the chosen price P_{it}^N:

$$P_{it}^N((1-\kappa)c_t^N + \kappa c_t^{N,H} + g_t)\left(\frac{P_{it}^N}{P_t^N}\right)^{-\mu} - (1-\frac{1}{\mu})W_t((1-\kappa)c_t^N + \kappa c_t^{N,H} + g_t)^{\frac{1}{\alpha}}\left(\frac{P_{it}^N}{P_t^N}\right)^{-\frac{\mu}{\alpha}}.$$

Prices are sticky according to a Calvo mechanism, i.e., intermediate goods firms may only change prices in each period with probability $(1-\theta)$. In Appendix A, I show that maximization of expected profits on the part of intermediate goods firms, since all price-adjusting firms choose the same price, result in choosing the flexible relative price $\tilde{p_t}^N$ to equate present value marginal costs and marginal revenues, $mr = mc$, where

$$mr_t = \frac{\mu-1}{\mu} y_t^N p_t(\tilde{p_t}^N)^{1-\mu} + \beta\theta E_t \frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\tilde{p_t}^N}{\tilde{p_{t+1}}^N}\frac{1}{\pi_{t+1}^N}\right)^{1-\mu} mr_{t+1} \tag{18}$$

and

$$mc_t = \frac{1-\frac{1}{\mu}}{\alpha}(y_t^N)^{\frac{1}{\alpha}} w_t(\tilde{p_t}^N)^{-\frac{\mu}{\alpha}} + \beta\theta E_t \frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\tilde{p_t}^N}{\tilde{p_{t+1}}^N}\frac{1}{\pi_{t+1}^N}\right)^{-\frac{\mu}{\alpha}} mc_{t+1}. \tag{19}$$

I also show in Appendix A that inflation dynamics are given by

$$1 = \theta(\pi_t^N)^{\mu-1} + (1-\theta)(\tilde{p_t}^N)^{1-\mu}, \tag{20}$$

where $\pi_t^N = \frac{P_t^N}{P_{t-1}^N}$, and aggregate production is given by $y_t^N = s_t^{-\alpha} h_t^{\alpha}$, where $s_t = \int_0^1 \left(\frac{P_{it}^N}{P_t^N}\right)^{-\frac{\mu}{\alpha}}$ represents the amount of price dispersion in the intermediate goods sector that has a dampening effect on aggregate output. Price dispersion evolves according to

$$1 = \theta s_{t-1}(\pi_t^N)^{\mu/\alpha} + (1-\theta)(\tilde{p_t}^N)^{-\mu/\alpha}, \tag{21}$$

2.5 Financial Sector

As mentioned before, household and government debt are traded on an external financial market, resulting in two interest rates r_t^H and r_t^G. These interest rates reflect the aggregate interest rate r_t^*, debt stock/purchases d_t, d_{t+1}, d_t^G, and d_{t+1}^G, and monetary shocks. The interest rates can be thought of as being determined by the functions

$$r_t^H = f^H(d_t, d_{t+1}, r_t^*, m_t) \tag{22}$$

and

$$r_t^G = f^G(d_t^G, d_{t+1}^G, r_t^*, m_t). \tag{23}$$

The function $f^G(m_t)$ is of particular interest in this paper, as it will be a key determinant of the passthrough of monetary policy to local governments. The response of municipal government borrowing costs could vary based on a multitude of factors, including trading costs and illiquidity in the muni market, as I will show in the empirical section.

These pricing functions could arise from a number of financial market specifications. For example, a common formulation in the international literature is the debt-elastic interest rates of Schmitt-Grohe and Uribe (2003). Below, I will show another alternative to this formulation, which incorporates a standard over-the-counter asset market model into the model; such a feature serves as a microfoundation for the functions $f^H(m_t)$ and $f^G(m_t)$ and provides intuition into the mechanism working behind the empirical investigations.

2.6 Aggregation

Thus far I have focused on the problem of a single locality. In a full version of the model, there are a large number of localities subscripted by $s \in \{1, ..., S\}$. These economies exchange tradable goods and debt with each other, as well as with the rest of the world.[4] The nationwide interest rate r_t^* is set by the economy's monetary authority in response to aggregate output and inflation, which are made up of of local values:

$$r_t^* = R(\{y_{st}^T\}_s, \{y_{st}^T\}_s, \{\pi_{st}\}_s). \tag{24}$$

[4]The relaxation of market clearing at the union-wide level is essentially a preservation of the assumption of an external financial market with which households and governments trade. This allows the monetary authority to easily set r_t^*. Such an approach is consistent with the regional model found in Beraja et al. (2019).

2.7 Equilibrium

A competitive equilibrium is a set of quantities y_t^N,c_t^T, c_t^N, h_t, g_t, d_t, d_t^G, λ_T, π_t^N, s_t, mr_t, mc_t and prices p_t, w_t, $\tilde{p}_t{}^N$, r_t^H, and r_t^G for each locality s satisfying:

(i) The optimizing household problem is solved by Equations (4), (5), (7), and (6)

(ii) Hand-to-mouth quantities satisfy Equations (11), (9), and (10)

(iii) The government's problem is solved by Equation (13)

(iv) Marginal revenue and marginal cost are given by Equations (18) and (19), where $mr = mc$

(v) Aggregate production satisfies $y_t^N = s_t^{-\alpha}((1-\kappa)h_t + \kappa h_t^H)^\alpha$

(vi) Inflation and price dispersion evolve according to Equations (20) and (21)

(vii) Inflation is defined by $\pi_t^N = \frac{p_t}{p_{t-1}}$

(viii) Market clearing in tradable goods implies $(1-\kappa)c_t^T + \kappa c_t^{T,H} + d_t = y_t^T + \frac{d_{t+1}}{1+r_t^H}$

(ix) Interest rates satisfy Equations (22) and (23)

(x) The risk free rate is set by the monetary authority according to Equation 24

given the exogenous processes $y_t^T$and initial conditions s_{-1}, d_0, and d_0^G.

2.8 An Over-the-Counter Markets Model for Debt Pricing

While the borrowing cost functions in the model above are presented in a reduced form way, the finance literature provides a path to a microfounded relationship between monetary shocks and municipal yields. Specifically, I consider the class of models for which Duffie, Garleanu, and Pedersen (2005) was the seminal work, in which the trading of assets on secondary OTC markets is modeled carefully. In summary, municipal bonds are bought and sold to risk-neutral financial firms on primary markets, then sold on secondary markets to buyers who value the bonds highly but are subject to trading costs or incomplete market power. This friction in the secondary market dampens the response of the present value of the asset for financial firms to changes in the aggregate interest rate, thereby muting the primary market price response to monetary policy.

Every period, the municipal government makes debt issues x_t. Municipal bonds pay coupon rate c and mature with probability ν. Governments buy and sell from risk-neutral financial firms at competitive prices. A mass α of municipal buyers purchase bonds from financial firms; these buyers value the asset above its present value, at value v^H. This high valuation can be thought of as reflecting the tax advantage in municipals or warm-glow utility from supporting projects in one's community.[5]

The value of the bond for the financial firm, v^F, then, is the present value of the bond at time t, discounted by the expected path of aggregate interest rates r_t:

$$v_t^F = E_t \sum_s^{\infty} \left[c(1-\nu)(1-p_{t+s}^{sell}) + (1-\nu)P_{t+s}p_{t+s}^{sell} + \nu \right] \prod_{k=1}^{s} \frac{1}{1+r_k}(1-p_{t+k})(1-\nu)). \quad (25)$$

The price P_t is the price of the bond on the secondary market, which is determined by Nash bargaining, as in the OTC literature:

$$P_t = \theta v_t^F + (1-\theta)v^H. \quad (26)$$

θ is a key parameter in the OTC model: it captures the financial frictions in the market resulting from trading costs or asymmetric information, which can broadly be described as contributing to illiquidity in munis. Additionally, p_t is the probability that a given muni held by the financial firm–that does not mature–is sold in period t, which is given by the system

$$p_t^{sell} = \max\left\{ \frac{\alpha - (1-\nu)B_t^H}{(1-\nu)B_t^F}, 1 \right\}$$

$$B_{t+1}^F = (1-p_t^{sell})(1-\nu)B_t^F + x_t$$

$$B_{t+1}^H = (1-\nu)B_t^H + p_t^{sell}(1-\nu)B_t^F,$$

[5] In support of both of these motivations, Pirinsky and Wang (2011) shows a great deal of market segmentation in the muni market, wherein household buyers tend to buy munis primarily from their own geographic areas.

where B_t^F and B_t^H are the bond holdings of financial firms and buyers, respectively. At any time t, we have $D_t = B_t^F + B_t^H$.

For simplicity, assume municipal governments face the competitive price–the financial firm's valuation of the bonds–for their issuances and purchases of municipal bonds, v^F. We can now transform this model into the structure of the full model, where $r_t^G = f^H(d_t, d_{t+1}, r_t^*, m_t)$. In the model, the government's net income from debt purchases is given by $y_t^G = \frac{d_{t+1}^G}{1+r_t^G} - d_t^G$. In the context of an OTC model, this income is given by $y_t^G = v_t^F x_t - (\nu + (1-\nu)c)d_t^G$. By setting these terms equal to each other, we get that the *effective* interest rate at time t for the municipal government is given by

$$r_t^G = \frac{d_{t+1}^G}{v_t^F d_{t+1}^G + (1-\nu)(1-c-v_t^F)d_t^G} - 1, \tag{27}$$

where v_t^F is defined as above. Here, monetary shocks work through the term v_t^F, as they affect the future path of aggregate interest rates r_t.

For this formulation of debt pricing to make sense, we need both that $\frac{\partial r_t^G}{\partial d_{t+1}^G} > 0$ and $\frac{\partial r_t^G}{\partial r_t^*} > 0$.

2.9 Elasticities of interest

A few key elasticities are important for understanding the passthrough of monetary policy through municipal public finance and its potential heterogeneity using this model. First, we need to know the effect of borrowing costs on government spending. Results in Table 2 suggest these effects could be quite sizeable, though these results are merely suggestive and not the main focus of the paper. Additionally, it is important to know the local government spending multiplier: a helpful review in Chodorow-Reich (2019) suggests a point estimate of 1.8, suggesting a meaningful role of fiscal policy at the local level.

Of course, knowing the effects of an aggregate interest rate shock on the borrowing costs of municipal governments is a crucial piece of studying the potential size of this channel. Furthermore, any heterogeneity in these yield elasticities will result in differential fiscal policy responses across municipalities, and therefore different passthroughs in different localities. In the following empirical section, I investigate in depth the effect of monetary shocks on municipal bond yields, identifying significant heterogeneity in responses across government and highlighting a few possible sources.

3 The effect of US monetary shocks on municipal bonds

The key elasticity in the model outlined above is the effect of interest rate shocks on the borrowing costs of state and local governments in the U.S. The extent to which these borrowing costs respond to monetary shocks will determine the strength of the municipal public finance channel of monetary policy; my baseline estimate of the response coefficient is 0.22. Additionally, heterogeneity across municipalities in the responses of their borrowing costs to monetary shocks will imply heterogeneity in the transmission of monetary policy to households, as shocks will induce dispersion of borrowing costs. This section documents the average effects of monetary shocks on municipal borrowing costs, as well as the variance of such effects across state and local governments. I also investigate whether we can identify root causes of response heterogeneity, such as liquidity or risk in the muni market. I find evidence for both possibilities; a transaction-level dataset suggests illiquidity as a key factor, while high-yield (lower rated) indices respond twice as strongly to monetary shocks than the most highly rated indices.

I begin the section with a brief description of the municipal bond market, explaining the similarities and differences between munis and treasuries. Next I present summary statistics from the muni market, highlight its behavior during the financial crisis, and discuss the monetary shock identification strategy. I also provide some brief evidence that municipal bond yields on the secondary market are valid representations of municipal borrowing costs; in short, secondary market yields both reflect primary market prices and have a statistically significant effect on municipal government behavior. After this, I move on to the main empirical exercises.

The first set of exercises investigate the time series evidence on the effect of monetary shocks on a set of muni indices; this section is in the spirit of Rosa (2014), who looks at munis, and Gilchrist, Yue, and Zakrajšek (2019), who study foreign bond responses to U.S. interest rate shocks. I find that an index of General Obligation (GO) municipal bonds responds to a 100bp monetary shock by an average of 22bp; furthermore, I find evidence of substantial heterogeneity by state, as responses vary from 17bp to 40bp across space, despite little difference between state and local bonds. High-risk indices respond more strongly to monetary shocks, as one might expect, but the coefficients remain persistently low, suggesting a role for illiquidity in dampening these coefficients.[6]

The second set of exercises exploits a trade-level dataset of the municipal bond market, in which liquidity and risk can be explored further as possible drivers of monetary transmission (or lack thereof). First, I perform an exercise from Gilchrist, Yue, and Zakrajšek (2019), finding joint significance for some possible indicators of illiquidity, but not risk. Second, I replicate the main strategy of Schwert (2017), who decomposes the (tax-adjusted) municipal spread into liquidity and risk components, and compute the response of each of these spread components to monetary shocks, finding that the liquidity component of spreads may exhibit a transitory response to monetary shocks. Finally, I take a sample of munis from the largest state and local governments, for which I can match annual finance data from the Census of Governments, finding that correlates of government size tend to lower the response coefficient, though without much statistical significance. In any case, my overall results suggest dampened (relative to, say, corporate bonds) but heterogeneous responses of municipal borrowing costs to U.S. interest rate shocks, with which I can use the municipal open economy model to evaluate the characteristics of monetary passthrough via state and local governments.

3.1 The municipal bond market

State and local governments in the U.S. rely heavily on debt markets to finance a wide range of activities, from covering budget shortfalls to infrastructure investment. When a government decides to raise funds through a debt issue, it issues municipal bonds through a financial broker, one of a number of bidders for the rights to issue the bonds. At the time of issue, the broker sells the bonds on a "primary market" investors and other broker-dealers.

[6] The tax-free nature of municipal bonds, in the absence of risk or illiquidity, would imply coefficients of $1 - \tau$, where τ is the relevant tax rate. Coefficients lower than this, as I find here, suggest the presence of illiquidity.

After the primary market sale, municipal bonds are traded in Over-the-Counter (OTC) markets, rather than on a central exchange. The OTC nature of the municipal secondary market requires a specific buyer-seller match for a sale to take place. Harris and Piwowar (2006) and Green, Hollifield, and Schürhoff (2007b) show that buyer characteristics, namely size, influence prices on the secondary market, such that there is price dispersion even on the same day for a given bond; some investors may have better information and market power than others. Municipal bonds are not like treasuries in that they are tax-free and not entirely risk-free; additionally, the OTC market induces and amount of transaction costs into this market. The average municipal bond is traded every 10 days, suggesting that price adjustment may be slower in this market than in other markets.

There is a wide dispersion on the yields of municipal bonds in the MSRB data discussed below, reflecting a high degree of heterogeneity in municipal borrowing costs. Table 1 presents basic summary statistics on these yields, and Figures 2 and 3 shows the dispersion of yields conditional on time to maturity for the years just before and during the financial crisis. As mentioned in the introduction, there are three main avenues by which yields on municipal bonds might differ from yields on U.S. treasuries of similar maturities, as well as yields of other municipal bonds: taxes, risk, and liquidity. There are some differences in marginal tax rates across locations in the U.S., which may be driving a small portion of these differences, but as Figure 4 shows, the variance of muni spreads varies at a higher frequency than changes in tax rates. Most importantly, all three of these figures suggest a massive change in yield dispersion in the wake of the recent financial crisis[7].

Returning to Figure 4, note the systematic difference in spread behavior in the aftermath of the financial crisis. In addition to the increase in the variance of spreads, note that spreads move from negative to positive on average. Despite the tax advantage of municipals, yields were higher during and after the crisis than comparable treasuries; in other words, yields on municipals did not decrease as rapidly as yields on treasuries during a time of unprecedented monetary expansion. For further motivation of the importance of market inefficiencies in the behavior of muni yields, Figure 5 shows average daily yields for the same

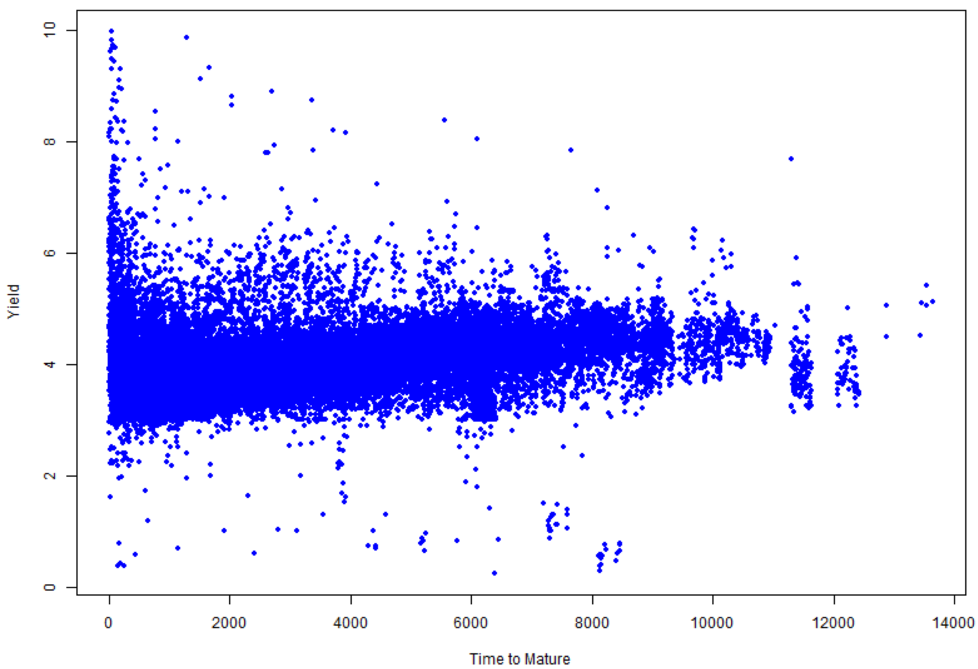
[7]The yields plotted here are simply the raw trade-level yields in the MSRB data, described in Appendix B.1.

Table 1: Summary Statistics, Daily Municipal Bond Yields

	Mean	Variance	25th	50th	75th
Yield, 2005-2019	2.760	2.077	1.630	2.743	3.758
Yield, 2008-2014	2.712	2.494	1.452	2.600	3.754
Spread, 2005-2019	0.4216	1.856	-0.535	0.155	1.147
Spread, 2008-2014	0.9137	2.171	-0.076	0.767	1.774

Note: Each variable is the median of daily trades for each municipal bonds. The sample does not include a bond on days in which it is not traded. Spreads are calculated as the difference between a bond's yield and an interpolated hypothetical U.S. treasury bond of the same length to maturity in days.

Figure 2: Muni Yields on FOMC Dates, 2006



time period, broken out by the IRC illiquidity measure used in Schwert (2017) and described in Appendix B.3. The bonds recorded as "illiquid" on this measure, i.e., those with high average imputed trading costs, saw a bigger increase in spreads during the crisis, despite similar behavior beforehand. This movement is suggestive that macroeconomic shocks may have heterogeneous effects on municipal borrowing costs; I return to an experiment with a financial crisis later in the paper.

Heterogeneity in yields will be important for the upcoming framework, as I will show that there is also a heterogeneity over the degree to which muni prices respond to monetary shocks. This heterogeneity in response implies that different types of governments not only

Figure 3: Muni Yields on FOMC Dates, 2008

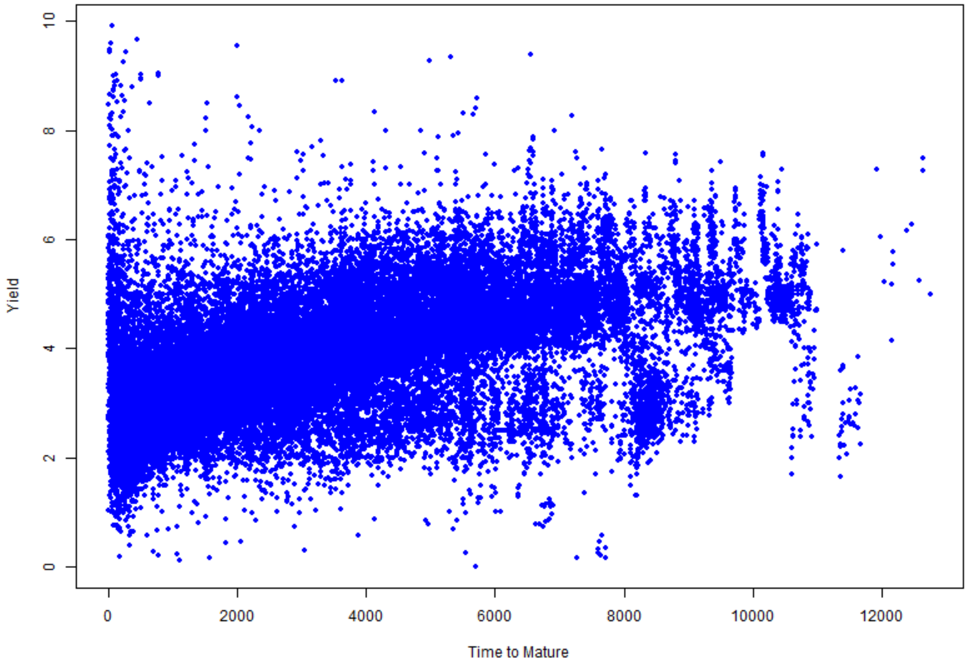


Figure 4: Muni Spreads over Time

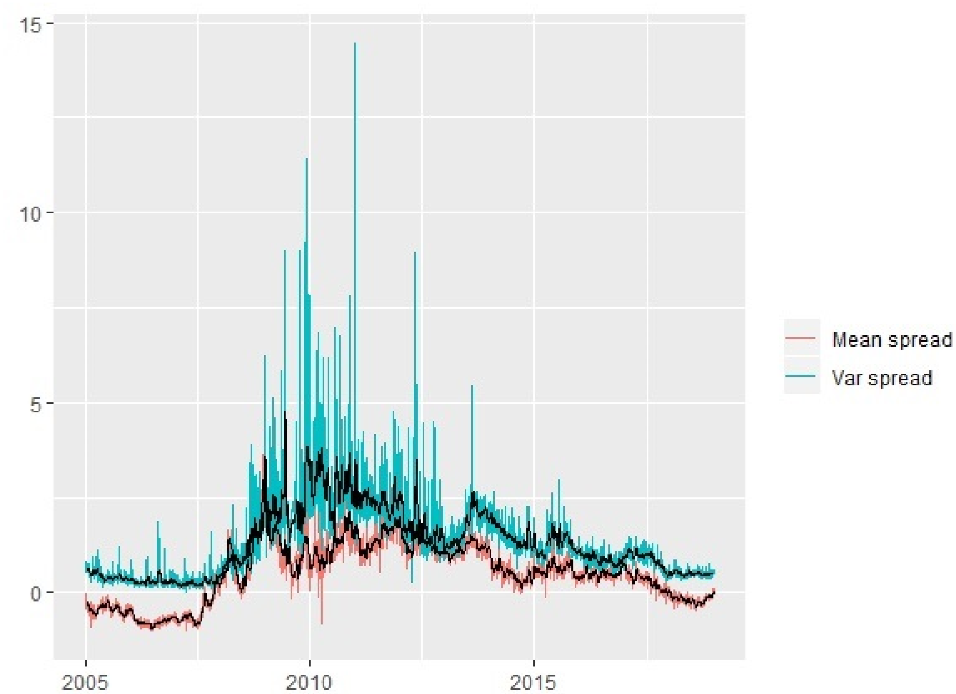
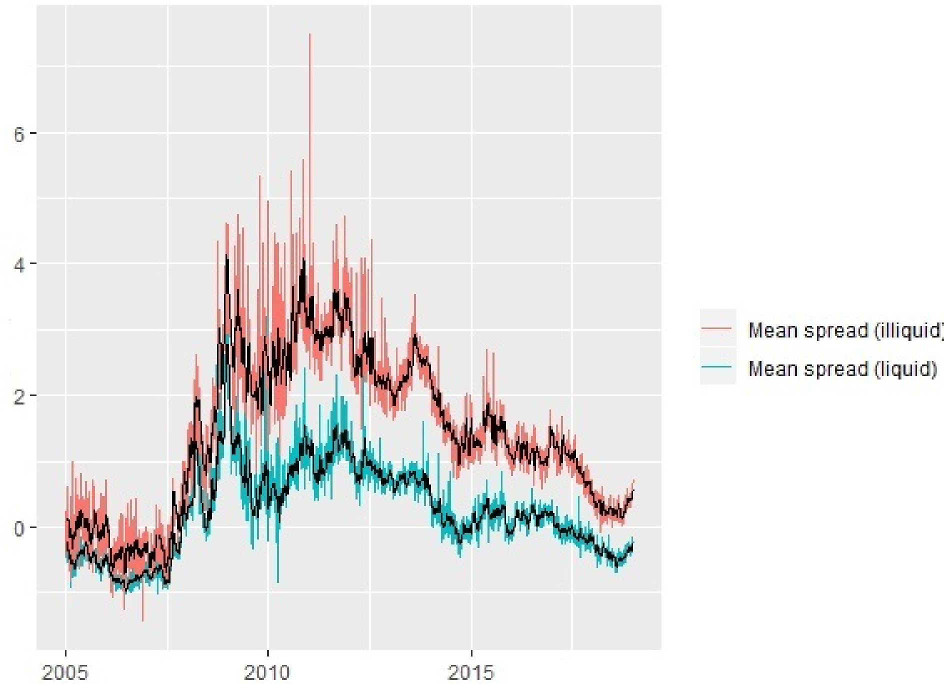


Figure 5: Muni Spreads, by Illiquidity



have varying borrowing costs over the long run, but will also encounter differing changes in borrowing costs after short-run shocks. As a result, the transmission of shocks through municipal borrowing costs should be expected to have both level and distributional effects, as governments are affected differentially by shocks, depending on factors such as trading costs and liquidity.

3.2 The importance of the secondary market for municipal finance

So far I have described the secondary market for state and local government debt, i.e., the market in which the yields on bonds which have already been issued are determined. Of course, the going yield on bond A does not affect the payments of its issuer, which simply continues to make the predetermined coupon payments to whomever is in possession of bond A at the time. In order to argue that yields affect borrowing costs, one must know that the yield of bond A has an effect on the cost of issuing bond B in the future. In this section I argue that secondary market yields not only affect borrowing costs, but the real behavior of state and local governments.

Table 2: Government responses to secondary market muni yields (IV)

	log(Debt Issues)	log(Current Exp)	log(Capital Exp)
Yield ($100bp = 1$)	-5.814	1.122	-0.6605
	(2.476)	(0.4715)	(0.4342)

Note: An observation is a municipality-year pair. The sample includes all municipalities in the Census Bureau's Annual Survey of State and Local Government Finances for which average revenues are greater than $500,000 and bonds could be found on the Bloomberg database from 2005 to 2012. Control variables include GDP, municipal revenues, and treasury rates. The explanatory variable is instrumented using summed monetary shocks as described below.

First, consider the association between the secondary market and the "primary" market for municipal bonds. I define a bond's "unexplained yield" as the residual ξ_{it} on the regression

$$R_{it} = 1 + \beta_1 T_{it} + \beta_2 i_{it} + \xi_{it}, \tag{28}$$

where R_{it} is the yield on muni i on day t, T_{it} is its time to maturity, and i_{it} is a benchmark treasury rate. This simple distinction yields a high correlation between an issuer's (defined as a 6-digit CUSIP code) unexplained yields on the debt issued before day t and debt issued on date t: 0.68. This is a strong correlation, suggesting a strong relationship between the primary and secondary markets.

Secondary markets may be strongly related to primary markets and borrowing costs, but do they actually *affect* state and local government behavior? To explore this question, I connect governments with revenues more than $50 million from the Census Bureau's annual survey of state and local governments with CUSIP-6 issuer codes in the MSRB data. I use this dataset to estimate the regression equation

$$\log G_{it} = 1 + \beta R_{it} + \Gamma X_{it} + \varepsilon_{it}, \tag{29}$$

where G_{it} represents a few categories of government spending in a year, while R_{it} is the average yield of that government's debt on the secondary market and X_{it} is a vector of controls, including the average treasury yield. These yields are instrumented with an annualized version of the monetary shocks used later in the paper. Results are summarized in Table 2.

A couple of key suggestive results emerge from this exercise. The first, and most striking, is the apparent massive effect of secondary yields on new debt issues. An decrease of average annual yields on a government's debt of 100 basis points results in a *sixfold* increase in its new debt issues. Municipalities seem to respond in powerful ways to borrowing costs. Additionally, note that higher borrowing costs seem to shift the *composition* of municipal spending away from debt-financed capital projects to current expenditures. The secondary market for municipal debt clearly influences states and localities, both in terms of debt issuance and spending composition.[8]

3.2.1 Monetary shocks

For the monetary shocks used in the exercise of this section, I use the strategy of Bu, Rogers, and Wu (2019) to identify monetary shocks on FOMC announcement dates. I give a brief overview of the identification strategy here, with a full presentation in Appendix B.2. The BRW method uses the movements of prices of zero-coupon U.S. Treasury bonds with maturities $i \in \{1, 2, ..., 30\}$ on FOMC announcement dates to back out the implied monetary shocks on each date. This is accomplished in a Fama-Macbeth-style (Fama and MacBeth, 1973) procedure, which starts by making a standardizing assumption that defines the monetary shock as having a one-to-one effect on the five-year Treasury yield:

$$\Delta R_t^5 = \alpha + m_t + \eta_t. \tag{30}$$

Here ΔR_t^5 is the one-day movement in the five-year treasury yield, α is a constant, $_t$ is the monetary shock at date t, and η_t catches all other factors affecting the yield. Armed with this equation, we can use the change in the five-year Treasury yield on FOMC dates as a proxy to back out the monetary shocks m_t.

First, we need to estimate the sequence of 30 time series equations

$$\Delta R_{it} = \alpha_i + \beta_i \Delta R_t^5 + \varepsilon_{it} \tag{31}$$

for each zero-coupon bond $i \in \{1, 2, ..., 30\}$.[9] Armed with estimates $\hat{\beta}_1, \hat{\beta}_2, ..., \hat{\beta_{30}}$, shocks can

[8] For aggregate time series evidence, see Appendix C.1.

[9] In practice, these are estimated with a heteroskedasticity-based IV approach a la Rigobon and Sack (2004). Details are found in Appendix B.2.

be backed out by regressing the daily yield changes on the set of estimated $\hat{\beta}_i$ on each FOMC announcement date. This requires estimating the following equation for each $t \in \{1, 2, ..., T\}$:

$$\Delta R_{it} = \alpha_t + \hat{m}_t \hat{\beta}_i + \varepsilon_{it}. \tag{32}$$

The set of estimated $\hat{m}_t$ from each of these estimations is taken to be the monetary shock series.

The Bu, Rogers, and Wu (2019) monetary shock series has a number of desirable characteristics. First, it relies completely on publicly available data; the treasury yield is taken from the Federal Reserve website, and the estimated zero-coupon yields as estimated by Gürkaynak, Sack, and Wright (2006) are found at https://www.federalreserve.gov/pubs/feds/2006/200628/200628abs.html. The publicly available nature of the data allows the shocks to be constructed at no cost, and the series is quite easy to update through the current date. Furthermore, the authors argue in the paper that this series is robust to the information critique of Nakamura and Steinsson (2018), but is nevertheless highly correlated with existing estimates of monetary policy shocks. Finally, these shocks are able to incorporate well the unconventional nature of monetary policy in the aftermath of the financial crisis; this is an especially important feature for this paper, as my sample only begins in 2005.

3.3 Time series evidence

The main set of results I use for the calibration of the model are time series estimates of the response of municipal yields to monetary shocks based on the yields of muni indices constructed by SP.[10] The exercise is in the spirit of Rosa (2014), who studies the effect of monetary shocks on indices of AAA and AA bonds exclusively. I expand on Rosa's work by considering indices representing a broader set of munis, as well as specific geographic and sectoral indices, reminiscent of Gilchrist, Yue, and Zakrajšek (2019), who study the effects of U.S. interest rate shocks on the sovereign bond yields of several small open economies. While

[10] All of these indices are available for download at https://www.spglobal.com/spdji/en/index-family/fixed-income/

my results for highly rated bonds are similar to what Rosa finds, my other results provide a fuller picture of the effect of monetary shocks on the municipal bond market, especially with regard to potential heterogeneity.

SP constructs these indices using a broad selection of bonds issued by state, local, and regional government entities in the U.S., which are not subject to income taxes. The bonds must have been issued in 2010 or later, and must have a minimum of 2 million U.S. dollars par value on the market. The indices are constructed as value weighted averages of the constituent bonds.[11]

For each of the indices in question, I am interested in estimating the equation

$$\Delta y_t = \beta_0 + \beta_1 m_t + \varepsilon_t, \tag{33}$$

where m_t is the Bu, Rogers, and Wu (2019) monetary shock series and $\Delta y_t = y_{t+1} - y_{t-1}$ is the two-day change in the yield to maturity of the asset around the FOMC meeting date.[12] The coefficient $\hat{\beta}_1$ reflects the number of basis points the muni index yield should increase for every 1bp monetary shock, and is estimated with heteroskedasticity-robust standard errors.

3.3.1 Baseline results

This section summarizes the average response of municipal bond yields to monetary shocks. Table 3 gives the estimated coefficients of monetary shocks on yields for three indices of general obligation municipal bonds. These indices group all municipals, state governments, and local governments, respectively, with an index for bonds from SP 500 firms for comparison[13]. I choose to focus on general obligation bonds, which are backed by the full taxing power of the issuer rather than a specific revenue source, in order to more closely match the budget situation of the government in the model. These bonds can be reasonably thought

[11]More information is available at https://www.spglobal.com/spdji/en/indices/fixed-income/sp-municipal-bond-index/#overview.

[12]I follow GYZ in choosing a 2 day window; their alternative window of 6 days produces similar results.

[13]Suppose that the tax free nature of municipals were the only difference between munis and corporate bonds. In this case, the yield on municipal bonds y^m would simply be the after-tax return of corporate bonds, $(1-\tau)y^c$. The link between munis and treasuries, then, would be the coefficient on corporates discounted by the tax rate, $\frac{\partial y^m}{\partial r} = (1-\tau)\frac{\partial y^c}{\partial r}$. To the extent the coefficient on munis is lower than this, I say that the response of munis is *dampened* relative to corporates, for reasons other than their tax-free nature.

Table 3: Baseline Time Series Results

	All GO	State GO	Local GO	SP 500	All GO	State GO	Local GO	SP 500
Monetary shock	0.22	0.24	0.22	0.50	0.23	0.23	0.28	0.65
	(0.08)	(0.08)	(0.08)	(0.14)	(0.14)	(0.16)	(0.13)	(0.21)
Horizon	2 days	2 days	2 days	2 days	6 days	6 days	6 days	6 days
N	2147	2147	2147	2147	2139	2139	2139	2139

Note: An observation corresponds to one day, around which a window is constructed from the previous day's price and the price at a given horizon. Each column refers to a separate time series regression of an index on monetary shocks. Heteroskedasticity-robust standard errors are reported in parentheses.

of as representing the borrowing cost situations of their local governments.

This exercise closely mirrors that of Rosa (2014), though my results exhibit slightly higher responses to monetary shocks than his; the reasons for this will be explained in part when I break these bonds out by rating. Nevertheless, the coefficients are quite dampened relative to models in which governments can borrow at the risk-free rate: municipal bond yields only increase (decrease) by 22 basis points in response to a 100 point change in the risk free rate, which is less than half of the response of corporate bonds, and far less than treasuries. This dampened response cannot be fully explained by the tax-free nature of municipals, and must be composed of illiquidity and/or risk effects. Models that do not take this dampened response into account will tend to overestimate the effects of monetary policy on local fiscal policy.

Interestingly, there does not seem to be much difference, on average, between the responses of state bonds and local bonds to monetary shocks. This result is somewhat surprising, given the quite different tax and spending obligations between these two types of governments. Instead, it seems heterogeneity shows up in other ways, which I show in the next sections.

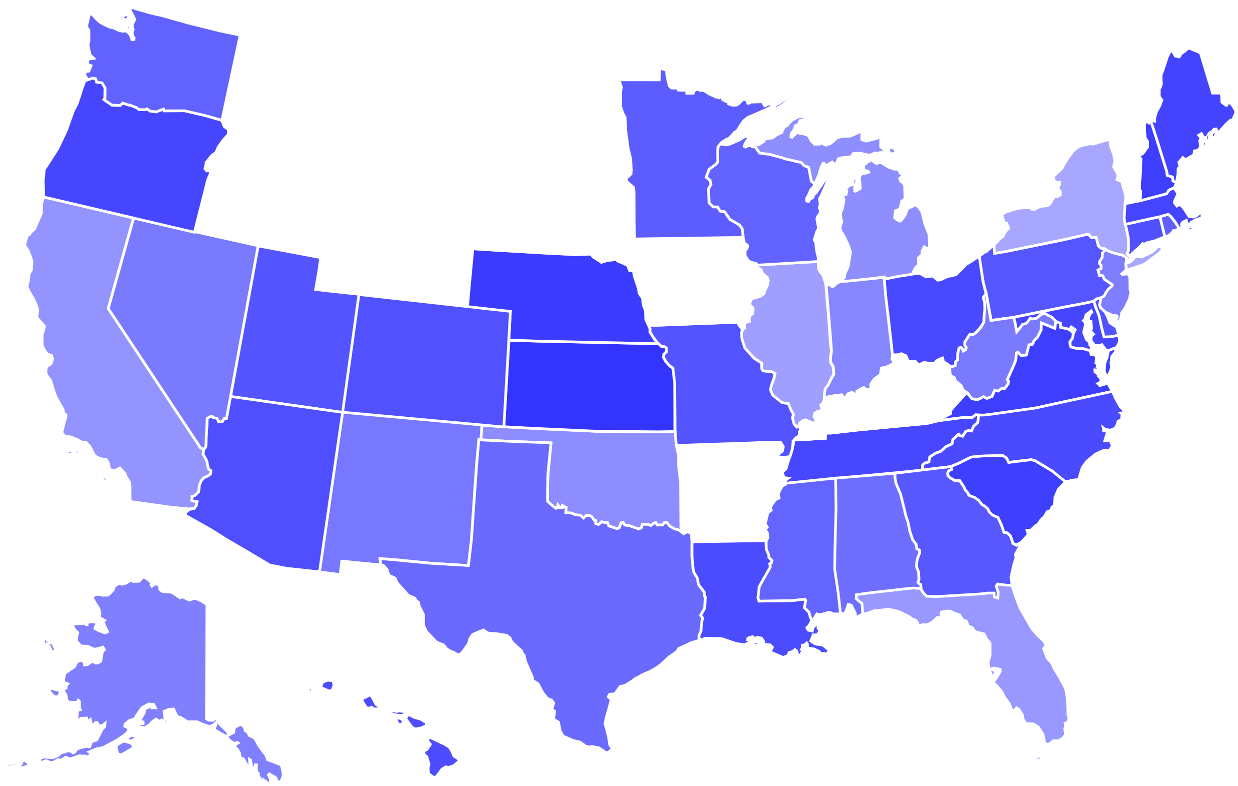
3.3.2 Heterogeneity by state

A natural place to look for heterogeneity across localities is in the presence of *geographic* variation. For this section, I estimate Equation 33 separately for indices of GO bonds originating in U.S. states, for which these indices exist.[14] Figure 6 summarizes the estimates, highlighting visually the heterogeneity of responses across the U.S.

A few notes on these results are worth highlighting. First, the range of coefficients runs

[14] A number of states prohibit or limit the use of GO bonds.

Figure 6: Responses of Muni Yields to Monetary Shocks



Note: Darker color indicates a stronger response of municipal yields issued in the state to monetary shocks. Missing states are those for which an index of GO bonds is not available. Maximum value: 39.81 (KS); minimum value: 17.32 (NY).

Table 4: Time Series Results by SP Rating

	AAA	AA	A	BBB Band	BB Band	NR
Monetary shock	0.087	0.062	0.021	0.194	0.218	0.372
	(0.078)	(0.077)	(0.090)	(0.099)	(0.674)	(0.170)

Note: An observation corresponds to one day, around which a window is constructed from the previous day's price and the price at a given horizon. Each column refers to a separate time series regression of an index on monetary shocks. Heteroskedasticity-robust standard errors are reported in parentheses.

from 17.32 for New York to 39.81 for Kansas.[15] Second, no immediately obvious patterns emerge, save the apparent tendency for high-population areas to have muni bonds which response *more weakly* to monetary shocks; this tendency is suggested, though not proven by any means, later in Section 3.4.4. In any case, the results suggest that heterogeneity exists across space in the U.S. in the response of municipal bond yields to monetary shocks, and monetary policy may affect different areas of the U.S. differently.

3.3.3 Heterogeneity by risk and sector

In this section, I investigate heterogeneity in yield responses for muni indices broken out by rating and sector. Lower rated and unrated bonds seem to respond more strongly to monetary shocks than highly rated bonds, providing an explanation for why the magnitudes in this paper might differ somewhat from Rosa (2014). There does not seem to be much explanatory power in examining differences in municipal bonds broken out by sector.

Table 4 shows the coefficient estimates of Equation 33 run separately for indices of bonds in various SP rating categories, at the 2-day horizon. Although some of the coefficient estimates are not statistically significant, there is a clear upward trajectory, i.e., the coefficients on riskier bonds are higher. This is consistent with a world in which expansionary monetary policy–for example–lowers default risk for risky bonds.[16] Furthermore, the coefficients on AAA and AA bonds are consistent with the findings of Rosa (2014), who only looks at low-risk indices. My baseline estimates, therefore, are higher than his in part because the GO index is not made up entirely of AAA and AA bonds.

[15] We can reject that New York's response is 39.81 or higher, though the standard error bands for the two estimates do overlap. Even though sample size reduces power in this exercise, I interpret these results as evidence of heterogeneity across location given the remarkable consistency of coefficients for most of the sector-level indices and for state vs. local bonds.

[16] It is worth noting that the majority of munis fall in the investment-grade category.

Another way in which municipal bonds may differ from each other is the sector for which the bond was issued, especially for revenue bonds. Many local government entities may issue debt: schools, utility authorities, etc. While not directly entering a local government's general fund, these bonds do contribute to the overall burden of debt for local governments in a given places. Perhaps surprisingly, there is not much evidence of heterogeneity in the responses of these indices by sector, whose results can be found in Appendix C.2. Most of the coefficients, with a small number of exceptions, are close to and slightly lower than the baseline estimate of around 0.22.

Ultimately, this section has documented the presence of heterogeneity in municipal bond responses to monetary shocks, which are dampened on average relative to U.S. treasuries and corporate bonds. The type of government does not seem to make much difference, though it is possible that smaller and riskier governments have greater responses to monetary shocks. In the next section, I move from time series to panel data in order to obtain more evidence on the potential sources of this heterogeneity, including illiquidity, which is suggested by the consistently low values of these coefficients.

3.4 Panel evidence: MSRB data

Clearly, monetary shocks have a dampened effect on municipal bonds, with a fair amount of heterogeneity across different types of bonds. There is some evidence that risk may be driving some of this, but time series evidence cannot say whether liquidity and transaction costs may also be a contributing factor. Additionally, there may be information about specific local governments that influence the responses of munis to monetary shocks. Knowing that there is heterogeneity in these responses is important for the quantitative exercise below, but knowing the *reasons* for this heterogeneity may be necessary to begin drawing out policy implications from the model.

To investigate more fully the sources of heterogeneity in monetary passthrough, I use a transaction-level dataset of municipal bond trades from the Municipal Securities Rulemaking Board, hereafter MSRB. These data are available through Wharton Research Data Services, and are available from 2005 onward. I end the sample on December 31, 2019 to avoid entanglements with the tumultuous nature of the muni market in early 2020. I restrict

Table 5: Baseline Panel Estimates

	Yield	Yield	Spread	Spread
Monetary shock	0.44	0.63	-0.01	0.16
	(0.27)	(0.28)	(0.17)	(0.24)
N	22758	22758	22699	22699
Time to Maturity Controls?	N	Y	N	Y

Note: An observation corresponds to an FOMC date-bond pair. Each column refers to a separate regression. Standard errors are reported in parentheses, and are clustered at the date level.

the sample to general obligation (GO) bonds issued by general governments (as defined by Bloomberg). Appendix B.1 provides more details on the dataset construction.

In this section–with the exception of the Schwert procedure–I estimate the equation

$$\Delta y_{it} = \beta_0 + \beta_1 m_t + \Gamma_0 X_{it} + \Gamma_1 X_{it} m_t + \varepsilon_{it}, \tag{34}$$

where m_t is the same monetary shock as before and X_{it} reflect bond-specific characteristics that might influence a bond's response to monetary shocks. Here, I allow a longer adjustment period for yields (and spreads) y_{it}, owing to the sparse nature of municipal bond trades. My baseline time period of adjustment is two weeks; furthermore, I assign a bond's yield as its most recent daily yield, provided the trade happened within the last week. Standard errors are clustered at the time level, owing to the grouped nature of the shock m_t.

3.4.1 Average results

Before moving on to other dimensions of heterogeneity, it may be helpful to benchmark baseline estimates in the panel data. In Table 5, I present coefficient estimates of β_1 from Equation 34. These estimates represent four regressions of monetary shocks on muni yields and spreads, and varying the inclusion of controls for time to maturity.

Of particular note here is the coefficients on the response of muni yields to monetary shocks. Why are these estimates higher than the baseline estimate in the time series section? The main reason is the selection inherent in this exercise: in order to properly impute a price to bonds in this data, I only assign prices for trades within the last week. Trading rates of municipal bonds are quite low, so *conditional on trade*, we should expect individual-level responses to be higher. If we include those bonds which trade before the shock but not after, coding them as $\Delta y_{it} = 0$, the estimates (on yields) are quite close to the baseline 0.22 from the time series section. In any case, these estimates, should be kept in mind as a baseline as we move through the rest of the section.

3.4.2 GYZ Method

In addition to time series evidence on the effect of monetary policy on sovereign bond yields, Gilchrist, Yue, and Zakrajšek (2019) also perform an experiment to evaluate the effects of risk and liquidity on these responses. Specifically, in the context of Equation 34, X_{it} includes an indicator for whether a bond is investment grade or not (SP rating BBB- or above), as well as a series of basic characteristics that the authors argue may *influence* liquidity: par value $\log PAR_i$, age $\log(1 + AGE_{it})$, time to maturity $\log T2M_{it}$, and coupon $\log(1 + COUP_{it})$. Furthermore, the response variable is the change in the muni spread rather than the yield.

Table 6 reports results from this estimation exercise, along with a joint test for the significance of the liquidity variables together. While none of the individual interactions are significant, the interactions of the four liquidity variables are significant for determining yields, suggesting a role for bond characteristics in the responses of borrowing costs. Finally, while the coefficient on risk is noisy–in contrast to the GYZ results for sovereign bonds–the sign is consistent with theory and time series evidence, in which less risky bonds exhibit lower responses to monetary shocks.

3.4.3 Schwert spread components

While GYK deals with sovereign bonds, Schwert (2017) is a paper at the frontier of the municipal bond pricing literature. The main exercise in the paper exploits the microstructure of the MSRB data to examine the portions of tax adjusted muni spreads that are accounted for by risk and illiquidity concerns. The basic procedure assumes that yields on municipal bond trades are determined according to

$$y_{it} = (1 - \tau)(r_t + \gamma_{it} + \psi_{it}),$$

Table 6: Heterogeneous Responses: GYZ Method

	Yield	Spread
Monetary Shock	1.48	1.11
	(1.01)	(1.06)
Investment Grade = 1	0.01	0.01
	(0.02)	(0.02)
$\log PAR_i$	0.03	0.03
	(0.00)	(0.00)
$\log(1 + AGE_{it})$	-0.00	0.00
	(0.00)	(0.00)
$\log T2M_{it}$	-0.00	-0.02
	(0.01)	(0.01)
$\log(1 + COUP_{it})$	-0.00	0.00
	(0.03)	(0.03)
Monetary Shock * Investment Grade = 1	-0.14	-0.16
	(0.21)	(0.15)
Monetary Shock * $\log PAR_i$	-0.02	-0.02
	(0.04)	(0.04)
Monetary Shock * $\log(1 + AGE_{it})$	-0.01	-0.01
	(0.03)	(0.02)
Monetary Shock * $\log T2M_{it}$	-0.14	-0.11
	(0.11)	(0.12)
Monetary Shock * $\log(1 + COUP_{it})$	0.21	0.05
	(0.31)	(0.29)
P-value, liquidity interactions	0.051	0.228
N	22758	22699

Note: An observation corresponds to an FOMC date-bond pair. Each column refers to a separate regression. Standard errors are reported in parentheses, and are clustered at the date level.

where τ is the marginal tax rate, r_t is the risk-free rate, γ_{it} is the risk premium, and ψ_{it} reflects illiquidity, perhaps in the form of trading costs or asymmetric information.

To estimate the liquidity component ψ_{it}, the method first constructs λ_{it}, an average of several (standardized) illiquidity measurements from the literature. I describe these illiquidity measures in more detail in Appendix B.3; I follow Schwert closely, dropping a measure that requires more observations in order to extend to a larger sample of municipal bonds from smaller governments. The following equation for (tax-adjusted) spreads is then estimated at each time t:

$$\frac{y_{it}}{1-\tau_{it}} - r_t = \beta_0 + \beta_t \lambda_{it} + \beta_t^R Rating_{it} + \varepsilon_{it}. \tag{35}$$

Here, y_{it} is the daily yield of a bond, τ_{it} is an imputed tax rate,[17] r_t is the zero coupon U.S. treasury rate of similar maturity, and $Rating_{it}$ is a factor variables describing the SP bond rating, if one exists. Armed with a series of betas on each day, the series of liquidity spread components is computed according to

$$\psi_{it} = \beta_t(\lambda_{it} - \lambda_{1t}), \tag{36}$$

where λ_{1t} is the first percentile of the liquidity measure. The risk component, γ_{it}, is simply computed as the portion of the tax-adjusted spread unexplained by the liquidity component.

Because the individual measures of these components are noisy, Schwert aggregates them into time series variables, using the four-month rolling average of daily cross-sectional mean spread components. This results in the time series γ_t and ψ_t, which are plotted in Figure 7. Note that my estimates of the relative magnitudes of these components differ substantially from Schwert's, which put the majority of the weight on risk; this is because I am using a more extensive sample of municipal bonds, whereas he uses only the largest state and local governments. This suggests a difference in spread makeup between smaller and larger state governments, and merits investigation in future research.

I estimate the effects of monetary shocks on these series, as in the time series results above, and present results in Table 7. Not much of significance stands out here, although there is

[17] In my estimation, this is the same for all bonds, since I want to use this procedure on the full range of the data and cannot match all bonds to a geographic area.

Figure 7: Muni Spread Components

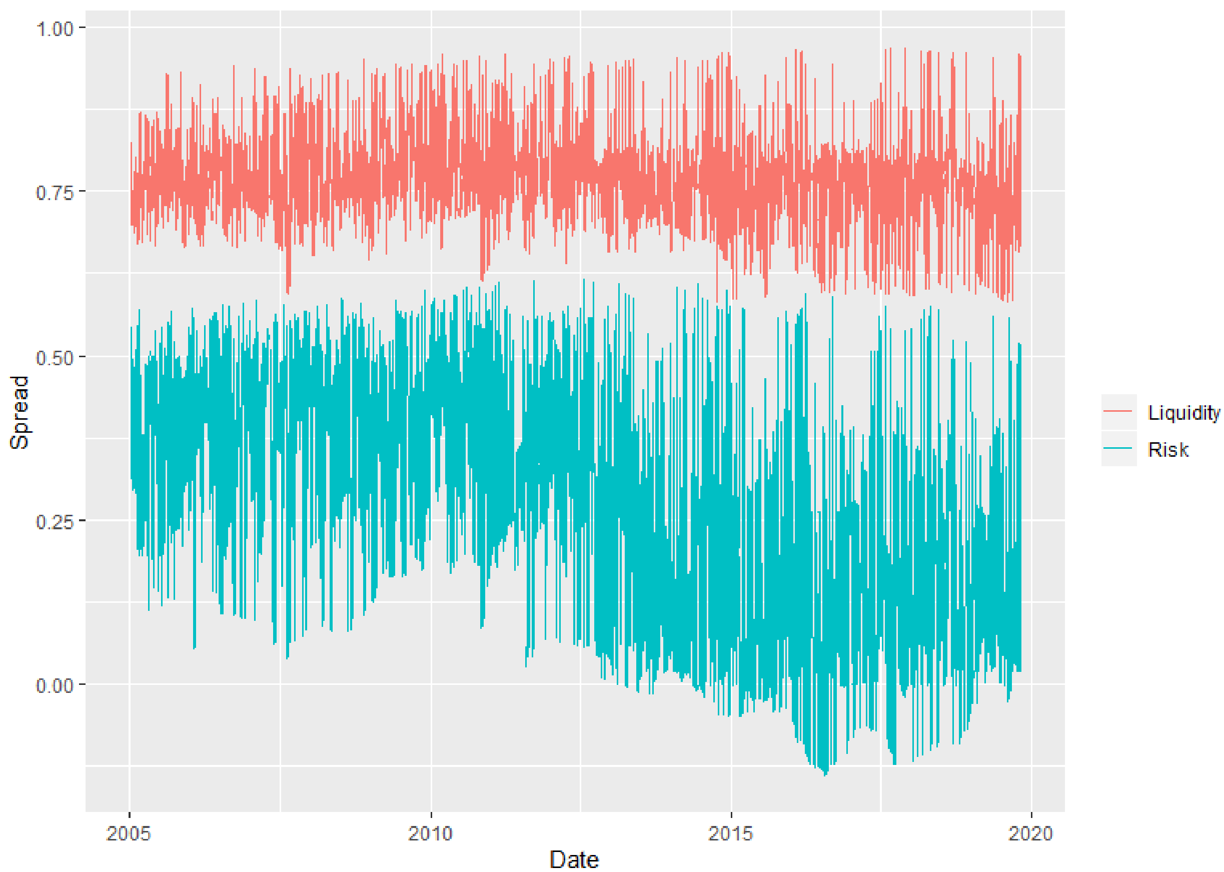


Table 7: Effect of Monetary Shocks on Spread Components

	Default spread	Default spread	Liquidity spread	Liquidity spread
Monetary shock	-0.11	-0.10	0.10	0.02
	(0.27)	(0.17)	(0.05)	(0.08)
N	2952	2944	3360	3352
Horizon	2 days	6 days	2 days	6 days

Note: An observation corresponds to one day. Each column refers to a separate regression. Heteroskedasticity-robust standard errors are reported in parentheses.

some weak evidence of a transitory effect of monetary shocks on the liquidity component of spreads. Overall, it does not seem, to the extent monetary policy affects borrowing costs in a heterogeneous way, that the effect is working through altering the components of risk and liquidity on spreads.

3.4.4 Government finances data

The last margin of heterogeneity I investigate involves a series of finance variables for municipalities. To obtain these data, I use the Census/Survey of Governments data from the U.S. Census. This survey obtains hundreds of balance sheet variables for state and local governments in the U.S., taking a representative sample annually and a full population sample every five years. Following Schwert (2017), I select the local governments in the U.S. with annual revenues of over $50 million. I then obtain the 6-digit CUSIP codes for these government issuers from the Bloomberg Terminal, and connect them to my panel dataset.

I estimate a series of regressions using these financial variables, and results are given in Tables 11, 12, and 13 in Appendix C.3. None of the coefficients are precisely estimated. However, a clear pattern emerges: larger values seem to depress the response of bond yields to monetary policy. While not a smoking gun, this pattern is consistent with the state-level index coefficients on monetary shocks, which seem to imply that bonds from more populous states respond less to monetary shocks. This is a conjecture, however, and requires a more powerful identification strategy. Unfortunately, these finance statistics only vary at the annual level, and such data is not universally available for all muni issuers in all periods.

3.5 Empirical takeaways

This empirical section has studied, from a number of angles, the effect of monetary shocks on municipal bond markets. On average, the yields on an index of general obligation municipal bonds respond by 22 basis points to a 100 basis point shock to the risk-free rate. Furthermore, while the "level" of the issuer does not seem to matter, the location of the issuer does. In other words, I document heterogeneity across the U.S. in the response of municipal yields to monetary shocks. This heterogeneity maps to the model from Section 2.

I then investigate potential sources of this heterogeneity. There is some limited evidence that the heterogeneity may arise from differences in bond ratings or liquidity considerations, which map to a model of over-the-counter debt pricing. There may be an association as well between the size of a locality and its borrowing costs' response to monetary shocks, but the data on government finances is limited, especially for smaller governments. In the main quantitative results below, I do not take a stance on the source of heterogeneous responses, but the various options may carry different policy implications.

4 Quantitative Results

This section shows quantitatively the importance of the municipal public finance channel of monetary transmission; significantly, the estimated heterogeneity in muni yield responses to monetary shocks implies heterogeneous effects of monetary policy on localities, depending on local financial frictions. Increasing the response of local government borrowing costs from the lowest state-level estimates to the highest implies an increase of up to a half percent of household utility for an expansionary shock of 25bp. Furthermore, the nature of municipal bonds and frictions in muni markets significantly dampen this channel: allowing a municipal government to borrow at the aggregate risk-free rate more than triples the output response to a monetary shock. Finally, although expansionary monetary policy is stimulative in early periods, the increase in municipal debt finance becomes a drag on local economies far into the future.

In this section, I focus on the response of single small open economies, abstracting from a full model of the U.S. I take this approach for ease of exposition. In Appendix D.1, I show that the results on heterogeneity of borrowing costs indeed carry over to a model in which there are multiple localities at one time. The only difference from the perspective of the locality is the process of the risk-free rate; when I consider the "partial equilibrium" with only one locality, I take the vector $[y_t^T r_t^*]$ as an exogeneous process, as is common in the international literature. I specify its process below.

4.1 Calibration and solution

Before moving on to the quantitative results, it is necessary to discuss specifics on the calibration of the model for proper interpretation, which in this case is a U.S. municipality as a small open economy. I first discuss functional form choices, then parameters which are taken from the literature or estimated. I also calibrate a set of parameters to match some average statistics on state and local spending, revenues, consumption, and debt, followed by an investigation into the effects of local openness on the local fiscal multiplier. Finally, I briefly discuss the solution method.

4.1.1 Functional forms

In the body of the paper, I use the model outlined above, opting for an *ad hoc* version of financial markets, in the vein of models with external debt elastic interest rates in the open economy literature. I use a simpler formulation for simplicity and ease of mapping the empirical response coefficients. Furthermore, while the sources of heterogeneity in borrowing costs have been investigated in multiple ways, this formulation allows an abstraction from taking a stand on their relative magnitudes for the time being. To begin, assume the exogenous tradable endowment y^T reflects shocks in the aggregate economy. Then let the aggregate risk-free r_t^* be determined by the system

$$z_t = Bz_{t-1} + \varepsilon_t^z, \tag{37}$$

where $z_t = \left[\log \frac{y_t^T}{y^{T*}} \log \frac{1+r_t^*}{1+r^*}\right]'$, and y^{T*}, r^* are parameters reflecting steady state values. $\varepsilon_t^z = [\varepsilon_t^y m_t]'$ reflect the exogenous shocks, with m_t being our shock of interest. Household interest rates are given by a standard debt-elastic interest rate formulation,

$$r_t^H = r_t^* + \phi^H(\exp(d_t^H - \bar{d^H}) - 1). \tag{38}$$

The benefit of this formulation is the ability to set any arbitrary steady state debt level; in the baseline calibration, I make the representative local household a *saver*, i.e., $\bar{d^H} < 0$.[18] I set

[18]This imposition captures two features of the real world. First, it is more reasonable to assume that a household saves at the risk-free rate than that it borrows at this rate, and I wish to abstract from the market

the government's borrowing costs in a similar fashion, but with a friction on the adjustment to the treasury rate:

$$r_t^G = r^* + \theta^G(r_t^* - r^*) + \phi^G(\exp(d_t^G - \bar{d^G}) - 1). \tag{39}$$

First, note the imperfect response of actual borrowing costs to the risk-free rate, governed by θ^G, which will be the key parameter of interest capturing the response of muni yields to aggregate interest rate shocks. These pricing functions will be used in the main results of this paper, and similar results for the OTC model can be found in Appendix D.2.

Utility over consumption in this model is CRRA, with log utility over leisure and public goods consumption:

$$U(c) = \frac{c^{1-\sigma} - 1}{1 - \sigma} \tag{40}$$

$$V(h) = \Phi \log(\bar{h} - h) \tag{41}$$

$$W(g) = \gamma \log(g). \tag{42}$$

Furthermore, the consumption aggregator is CES:

$$A(c^T, c^N) = \left(Ac^{T1-\frac{1}{\xi}} + (1-A)c^{N1-\frac{1}{\xi}}\right)^{\frac{1}{1-\frac{1}{\xi}}}, \tag{43}$$

where ξ determines the substitution elasticity across tradable and non-tradable consumption, and A represents the "openness" of the economy, which will be a key factor in the size of the local fiscal multiplier–more on this below.

4.1.2 Parameters

The parameters in the model are set using a combination of data and literature. Table 8 gives the basic parameters from the model which are standard in the literature. Nothing of extreme note is here, other than to note the decreasing returns to scale in intermediate production, which are consistent with the labor share of production in the U.S.

for household debt in this project. Second, it provides a "demand side" for the external financial market; while not strictly necessary here, it may be helpful for the reader to be able to think of having borrowers and savers in the model.

Table 8: Fixed parameters

Parameter	Description	Strategy	Value
σ	CRRA utility parameter	Literature	2
α	Labor share of production	Data/Literature	0.6
μ	Elasticity of substitution in production	Literature (Gali and Monacelli, markup target 20 percent)	6
β	Discount rate	Literature, imply s.s. interest rate of 0.03	0.9694
θ	Calvo parameter	Data/Literature (target average 10 mos between price changes)	0.7
$\bar{h}$, h	Labor endowment and steady state	Literature, labor supply = 1/3	3, 1
Φ	Leisure utility	Set to solve $mr = mc$ in steady state	
γ	Government utility	Normalize to log utility	1
ξ	Elasticity of substitution	Literature, set to $1/\sigma$	1/2

The exogeneous process for y_t^T and r_t^* is defined by the coefficient matrix B, which amounts to a VAR process with a lag of one period. For the baseline results, I simply estimate the matrix B as a bivariate VAR on the series $[log(Y_t)\ log(r_t)]'$, where Y_t is real GDP and r_t is a treasury rate, in this case, the U.S. 10-year. This estimation results in the (quarterly) coefficient matrix

$$\hat{B} = \begin{bmatrix} 0.985 & -0.0004 \\ 0.012 & 0.96 \end{bmatrix}.$$

The baseline elasticity of municipal borrowing costs to the exogenous component of the aggregate interest rate is taken directly from the main time series result for all general obligation bonds in the empirical section, $\theta^G = 0.22$. In the section studying the effects of heterogeneity in this elasticity, I use the distribution of the state-level estimates as plausible *lower bounds* on the heterogeneity, since they themselves represent averages to some extent. The low and high end of these estimates are used to define “low” and “high” elasticities, respectively.

The remaining six parameters,[19] y^{T*}, A, τ^G, $\bar{d^H}$, $\bar{d^G}$, ϕ^G and κ are calibrated to a set of moments that represent averages for state and local governments in the U.S. economy, in addition to a selected point estimate from the literature on local spending multipliers. These targets and their values–approximated for simplicity–are given in Table 9. At this point, a discussion is necessary on the exact interpretation of this small open economy.

[19] I also set $\phi^H = 1$. This matches fairly well the persistence of the household debt response to a monetary shock in the Christiano, Eichenbaum, and Evans (1996) style procedure mentioned previously, as well as the magnitude of the economy's output response.

Table 9: Calibration targets

Target	Value
State and local government consumption and investment / GDP	0.11
State and local government own revenues / GDP	0.09
State and local government debt / GDP	0.15
Household savings / GDP	0.05
Imports / total shipments, from CFS (> 50 miles)	0.66
Municipal bond yield	2.75
Local government spending multiplier (Chodorow-Reich)	1.8

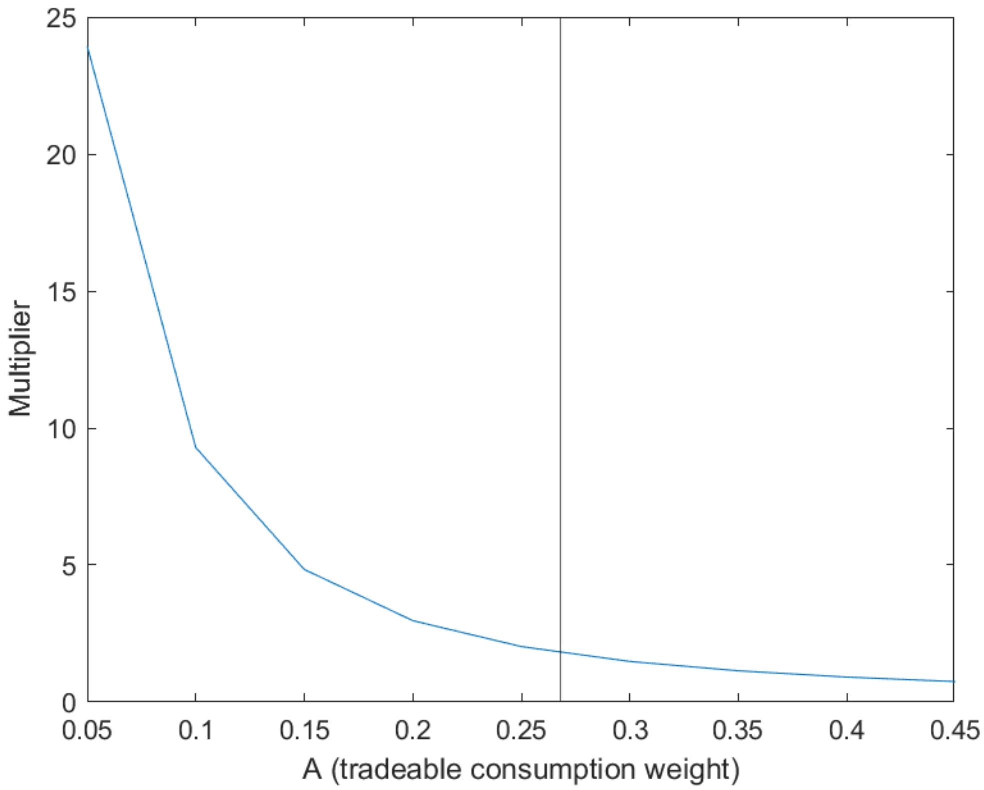
Is it a state government or a local government, or something else? The issue, of course, is that households in the U.S. are under the jurisdiction of multiple tiers of governments, each of which exerts its own sphere of responsibility. Why are state *and* local expenditures being used for calibration? A robust literature exists describing the determination of public policy in federalist systems, but it is not the goal of this paper to enter in to that exciting discussion. Suffice it to say, for now, that the "government" imagined in this model is some sufficiently small combination of government roles that can be thought to be representative of its constituents' value functions. In the baseline calibration, I set a tradable consumption to total consumption ratio of 0.66, matching the proportion of shipments in the Commodity Flow Survey that travel further than 50 miles. This yields a value for A of 0.2683.

The degree of openness, given in this paper by the parameter A, can also be thought of as defining the "size" of the locality in question. As the locality's area increases, a higher proportion of household consumption is produced within the locality; for example, a good produced in San Francisco but consumed in Oakland is considered an import if the locality is defined by the Oakland city limits, but as a domestic good if we define the locality as the state of California or the more nebulous "Bay Area." To see how the choice of openness affects the multiplier, Figure 8 plots the on-impact government multiplier as a function of A, holding the rest of the calibration constant.[20]

In this figure, the vertical line represents the baseline calibration, which is chosen to match the preferred local government spending multiplier from the literature survey in Chodorow-

[20] ϕ is dependent on the choice of A, for market clearing.

Figure 8: Local Government Multiplier and Openness



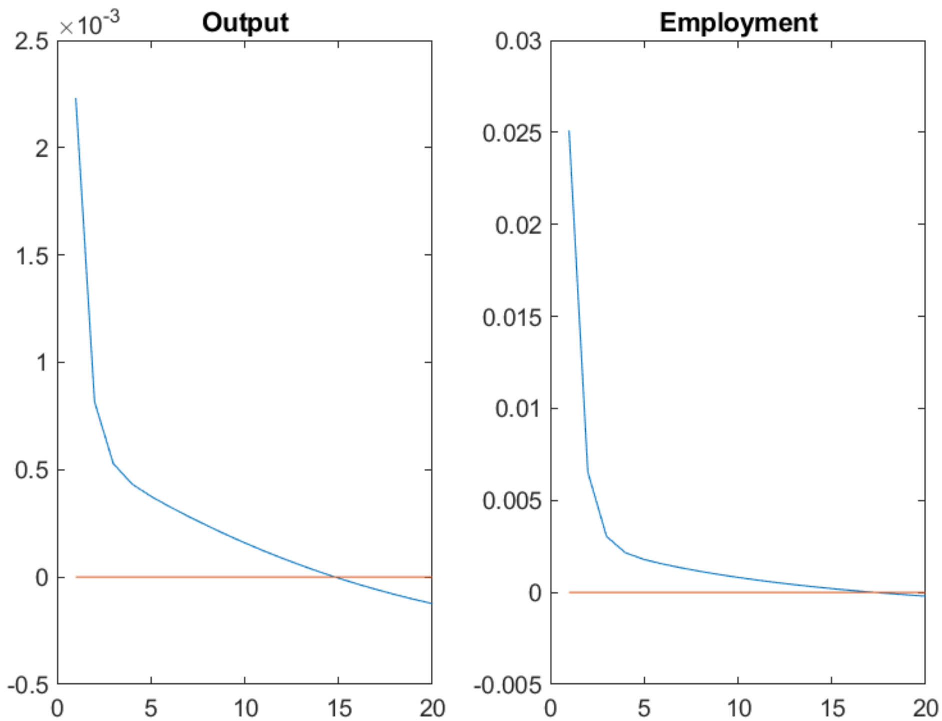
Reich (2019), which puts forward 1.8 as a good value. Clearly, the impact multiplier depends crucially on the definition of a locality, or its openness. Alternative definitions of a locality, such as a state, in which tradable consumption is less important, will result in larger multipliers. As the economy becomes increasingly closed, the multiplier increases, as we approach the closed economy case. The multiplier,in addition to openness, also depends crucially on the proportion of non-Ricardian agents in the household, κ; these two determinants stand in agreement with the papers of Chodorow-Reich (2019) and Farhi and Werning (2017a), which analyze fiscal multipliers in monetary unions. A resulting implication is that if openness A decreases, fewer non-Ricardian agents will be required to match the preferred multiplier. Finally, this impact multiplier does not take into account the dynamic effects of local fiscal policy; the next section presents these effects in fuller detail.

4.1.3 Solution method

For the results in this paper, I solve for the impulse response functions of the model by simulating the model's response to a one-time, unexpected shock to the exogenous portion of the interest rate. I assume that the economy is in steady state before the shock, and returns to steady state after 300 periods. While more computationally intensive than a perturbation strategy, this method allows me to later extend the model by including explicit constraints on debt issuance by the local government.

For the calibration of the hand-to-mouth share κ to match the local government spending multiplier of 1.8, I iterate over solutions of a stripped-down version of the model with exogenous government spending. Because this calibration procedure requires potentially many evaluations of the response of the economy to an exogenous government spending shock, I compute these responses with a second-order perturbation in the `Dynare` package for `Matlab`. The quantitative responses from perturbation methods are quantitatively similar to those obtained from the more computationally intensive "MIT shock" method.

Figure 9: IRFs, 25bp Expansionary Shock

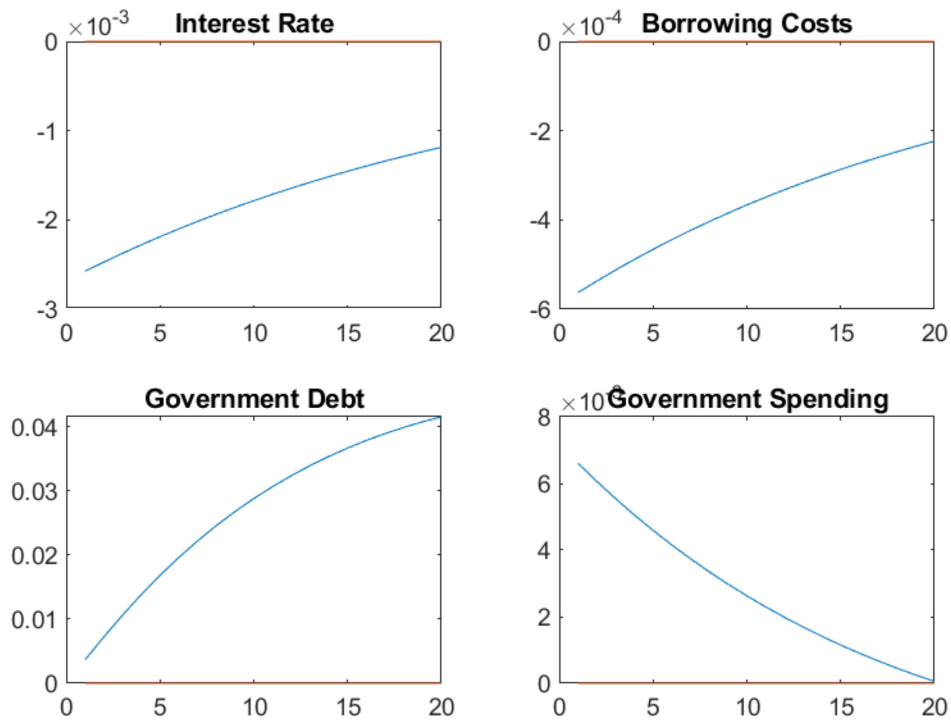


4.2 Results of an interest rate shock

The response of this calibrated economy to a 25bp expansionary monetary shock is shown in Figures 9 and 10. The figure shows the percent deviations from the steady state in response to the monetary shock. Notice the logic of the channel shwon in the second figure: borrowing costs decrease, increasing government debt and spending, resulting in output stimulus. In the baseline calibration, a 25bp decrease in the risk-free rate results in over a 3 tenths percent increase in output on impact.

Note, however, there is a long-run effects of the government debt buildup. Because the only margins of fiscal adjustment for the government are debt and spending–revenues are exogeneous–the government will have to reverse its debt accumulation through costly decreases in government spending later on. One immediate consequence of this result is the importance of thinking about the long-term consequences of stimulating debt-financed spending. Expansionary monetary policy allows local governments to shift spending from

Figure 10: IRFs, 25bp Expansionary Shock

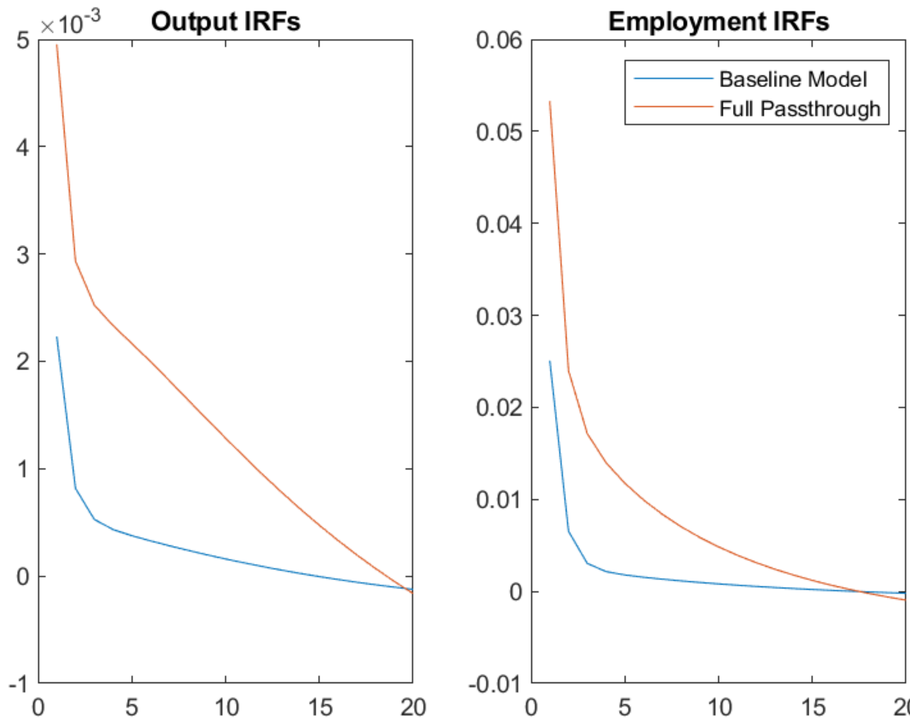


far in the future to the present, stimulating output in the short run but depressing it in the long run, even after interest rates have returned to steady state.

In the empirical section, I noted that the responses of municipal yields to monetary shocks were muted relative to what one might expect. As a result, the stimulative or depressive effects of monetary policy through local public finance are lower in a model which takes these features of muni markets into account, relative to a model which assumes local governments can borrow at the risk-free rate. To see the magnitude of the difference between the calibrated model and a model with borrowing costs at the risk-free rate, see Figure 11.

In the model that does not take the muted response of local borrowing costs to monetary shocks into account, the stimulative effects of monetary policy are more than double the model with realistic borrowing costs. When local government borrowing costs are tied more closely to the risk-free rate, local government debt increases by almost five percent relative to the steady state, and the reaction of spending, output, and labor are much higher than before. This stark difference suggests that models which assume municipal governments have access to borrowing at the aggregate risk-free rate will significantly overstate the stimulative

Figure 11: IRFs Compared to Standard Case



effects of monetary policy on local economies; such models will also *understate* the possibility for heterogeneity of stimulus across localities.[21] I take up the extent of the heterogeneity in the next section.

In Figure 20, I plot an estimated response of output to a monetary shock according to the Christiano, Eichenbaum, and Evans (1996) methodology mentioned earlier. The peak response of output to a one standard deviation monetary shock matches very well the magnitude of the peak response in the calibrated model, suggesting that the magnitudes of response in this model are reflective of the real world. Across the board, this type of "canonical" open economy DSGE model fails to generate the hump-shaped responses of economic variables to monetary shocks observed in VARs. One could imagine a number of features to supplement the model which might better match these hump shapes, but these features are not the focus of this paper.

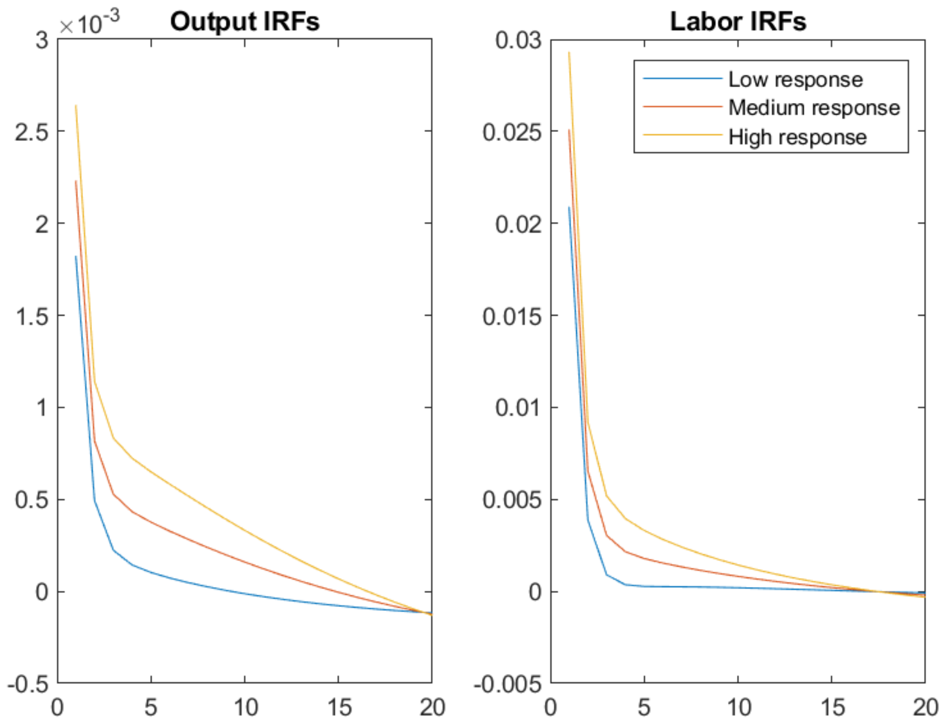
4.3 Heterogeneity over monetary responses

A model that assumes a one-for-one relationship between municipal borrowing costs and national interest rates eliminates the possibility that borrowing costs might respond differently to monetary shocks in different localities. As a result, such a model will eliminate an important source of heterogeneity in the passthrough of monetary shocks across regions and localities in the U.S. In Figure 12, I plot the same impulse response functions as in the previous section for the baseline economy $\theta^G = 0.22$, and two additional economies: $\theta^G = 0.1$ and $\theta^G = 0.34$. These two additional economies are symmetric deviations from the baseline estimate of muni yield responses to monetary shocks, roughly corresponding to the low-end and and high-end of the state-level responses described in Section 3.3.2.

Realistic differences in the response of local government borrowing costs to monetary shocks have quantitatively important implications for heterogeneity in monetary transmission. For example, Francis, Owyang, and Sekhposyan (2012) estimate the responses of several U.S. cities to monetary shocks, grouping them according to region, and finding that the dif-

[21] In Appendix D.3, I show that the inclusion of an explicit limit on debt issuances dampens the effect even further, resulting in anther potential source of heterogeneity, depending on the distribution of such limits in practice.

Figure 12: IRFs by Response Elasticity



ference between the smallest regional peak employment response and the smallest is about tenfold. In the model here, the difference is just under twofold. Furthermore, the dispersion of peak employment responses to monetary shocks in the full model of Appendix D.1 is about 9% of estimated dispersion in the responses obtained from a series of simple VARs[22]. These two comparisons combined suggest that differences in borrowing cost responses to monetary shocks account for 10-20% of the variation in monetary transmission across U.S. states.

The municipal bond market is the only difference[23] between the economies in Figure 12, yet monetary transmission is markedly different between the economies. A government whose borrowing costs fall more after an expansionary shock borrows more, spends more, and sees greater output and labor increases on impact; the impact effects on output and labor are almost 50 percent greater in the high-response economy than the low-response economy. In the long run, of course, these effects will be flipped: the high-response governments have more debt to pay down, and thus a bigger future recession. The magnitude of response of municipal bond prices to monetary shocks is a key parameter, then, in determining both the *size* and *path* of local economic outcomes.

Why is this effect important? First, such differences in passthrough may affect the desirability of a given central bank policy in a monetary union. The results here suggest that, for example, the Federal Reserve should take into account heterogeneous effects on municipal governments across the U.S. when it is considering a given policy. Additionally, to the extent that a given policy can strengthen the relationship between treasuries and munis, that policy can increase the short-term output effects of monetary policy on the economy as a whole. Finally, since we have a calibrated model of a local government in a monetary union, in which the muni market plays an important role, we can examine the implications of this model for the two most recent U.S. crises, providing insights into local government behavior during each of them. It is to these crises that the next section now turns.

[22]The experiment here is the following. For each U.S. state, I estimate a VAR of state employment, national GDP, and the federal funds rate with a lag of four quarters, calculating the peak employment response to a one standard deviation shock to the federal funds rate for each state. I define dispersion of the responses as the standard deviation of percent deviations from the mean peak response. Dispersion in the model is 0.0746, versus 0.8421 in the data

[23]Appendix D.4 gives one example of another difference between localities which might affect transmission: the steady state level of government spending. Unsurprisingly, the municipal spending channel of monetary policy is stronger when steady state government spending is higher.

5 Application: two crises

In the previous sections, I have specified and calibrated an open-economy model of a local government. The open-economy model highlights the key role of financial markets in municipal government decisions over the business cycle. Such a model, then, is a good candidate for studying the effects of some recent economic crises on state and local governments.[24] First, I use the model to show that the effect of a recession combined with a financial crisis, as in 2008, dampens the ability of local governments to respond; this corresponds with the true observed behavior of state and local spending following the Great Recession. Finally, I am able to generate some predictions going forward from the current COVID-19 crisis.

5.1 State and local government spending during the financial crisis

The Great Recession and its subsequent recovery were unique in myriad ways, and the behavior of state and local governments is no exception. For the three recessions leading up to 2008, state and local government expenditures increased during the immediate recovery. In 2009, however, state and local governments *decreased* their spending, representing a break from previous recoveries. Figure 13 shows these recoveries.

One key difference in 2008, aside from the severity of the recession, was the associated crisis in financial markets. The model outlined in this paper allows us to examine the interaction between financial markets and state and local fiscal policy during recessions. Table 1 shows that, while U.S. treasury yields decreased quite dramatically during 2008-2014, municipal bond yields did not move much at all, especially at the high end of yields. This suggests either a decrease in liquidity in muni markets, or an increased perception of risk due to financial conditions.

[24]It should be noted that the results in this section are meant to be more illustrative that quantitative. The model of the paper is built for more conventional study of monetary policy transmission. Specifically, abstracting from the default decision in the model is generally acceptable for steady state, given the extremely low rates of municipal default. Crises of unprecedented size, as these are, might render this abstraction unrealistic. Nevertheless, the experiments here help to illustrate some of the issues at hand; it may be helpful to think of the government as a state government, since these governments in general do not default on their debt.

Figure 13: State and Local Government Spending After Recessions

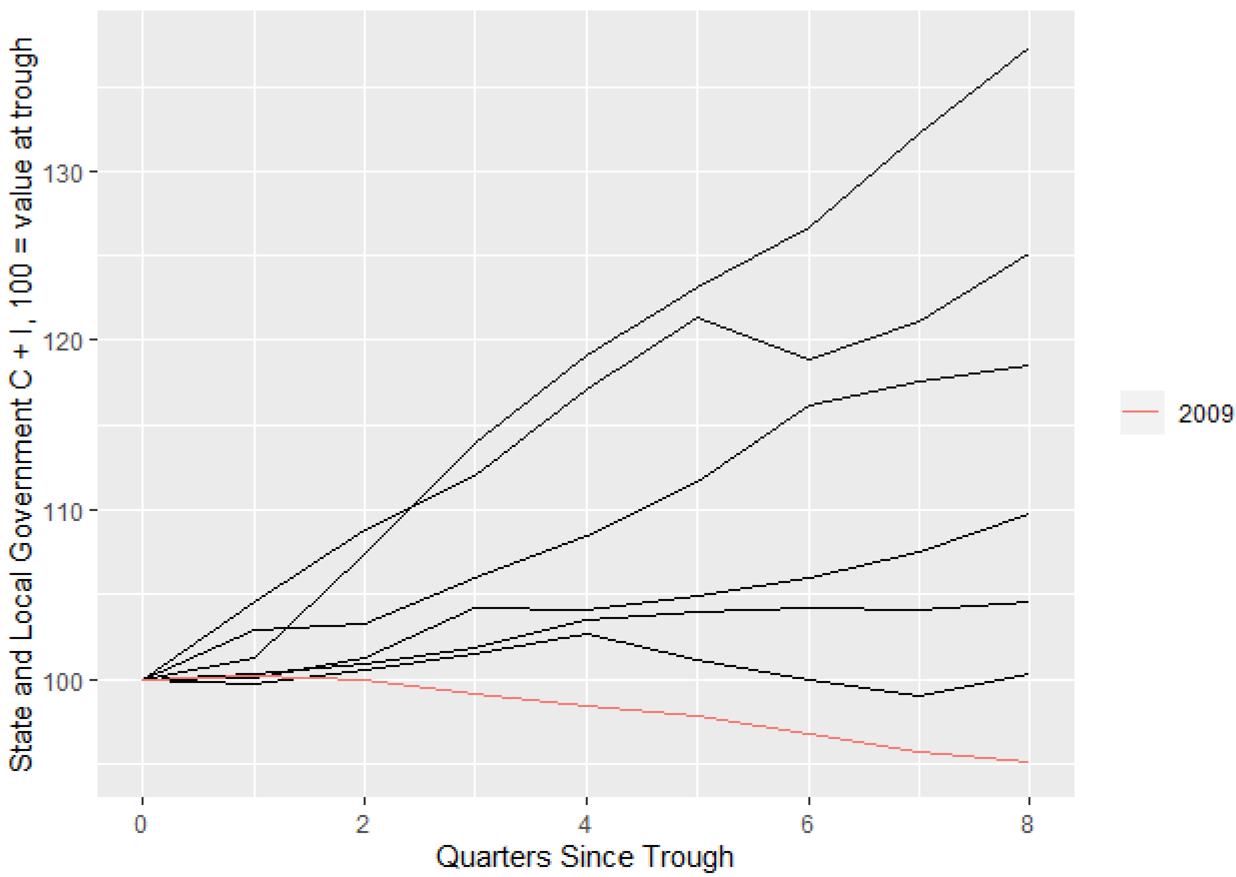


Figure 14: Government Spending After Two Recessions

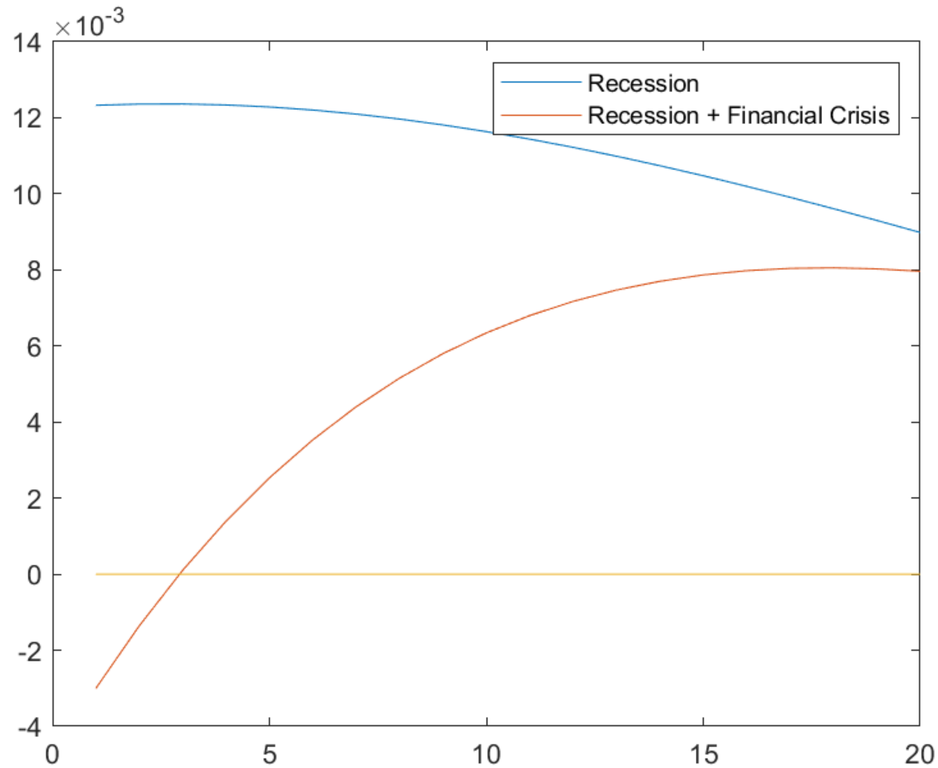
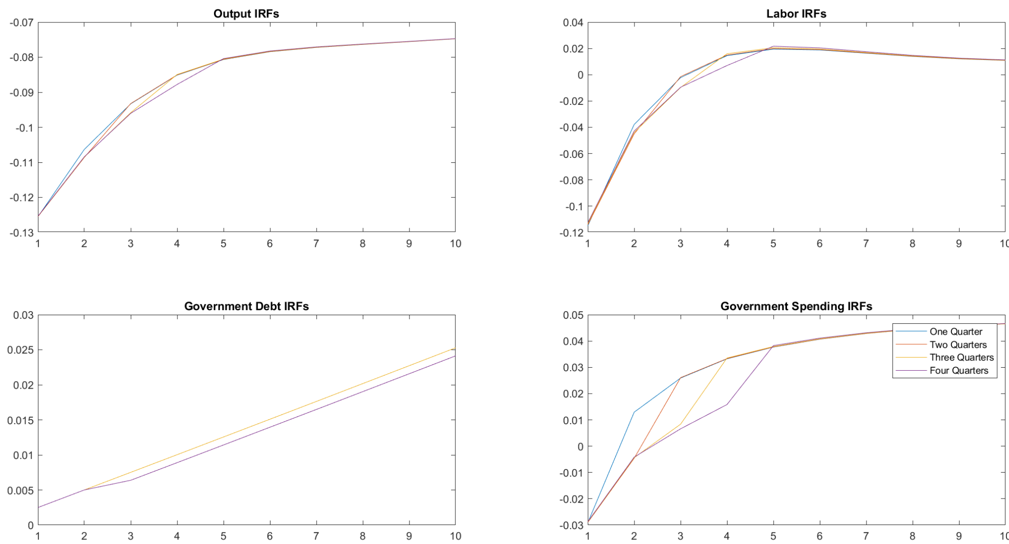


Figure 14 plots the response of government spending in the open-economy model to two types of models. The first is a simple decrease in the tradable endowment y^T; in other words, an external crisis. The second combines an external crisis with a *financial* crisis; following the muni market during and after the Great Recession, I define this as a negative shock to θ^G, i.e., a dampening of the ability of municipal bond yields to decrease during the recession, and an increase in ϕ^G, meaning that inceasing debt becomes costlier.

Clearly, the financial crisis dampens the fiscal response of state and local governments to an external crisis. While a *decrease* is not induced for long, the financial crisis does cut out much of the government's fiscal response. A number of factors go in to the fiscal decisions of these governments in response to crises, including political considerations and budget rules, the non-response of borrowing costs during the Great Recession is likely an important factor in the lack of fiscal response by state and local governments.

Figure 15: IRFs to a Pandemic Shock by Fed Response Time



5.2 Municipal budgets and COVID-19

In March 2020, the COVID-19 pandemic caused widespread economic shutdowns in the U.S. Additionally, municipal bond markets went haywire, precipitating unprecedented action by the Federal Reserve to stabilize prices, including a mechanism by which the Fed would purchase munis, in addition to other assets. Despite the stabilization, it is widely thought that state and local governments will now be faced with many quarters of low revenues and difficult fiscal pressure. How does this crisis show up in the context of the model of this paper, and what might it tell us about the future path of state and local government spending?

While this model can't replicate everything about the current pandemic crisis, I interpret the events thus far in three ways. First, as an external crisis like in Section 5.1, with a decrease in yT, reflecting the contraction in the entire U.S. Second, I shock $\bar{h}$, which in this model reflects an exogenous shock to unemployment, corresponding to the pandemic-induced lockdowns. I include a limit on debt increases to 2.5%, refelcting real debt issuance constraints faced by governments in times of crisis. Finally, I insert a transitory positive shock to borrowing costs, reflecting the chaos in the muni market which resulted in yields increasing by over 100bp at one point, relative to the baseline levels to which the Fed helped return them.

Figure 15 shows four hypothetical pandemic crises, each imposing a different persistence of the shock to borrowing costs for the local government. These can be thought of as hypothetical scenarios reflecting the speed of response by the Fed; in other words, what might have happened had the Fed delayed in its response to shore up liquidity in the municipal bond markets. In each case, the temporary financial market shock dampens government spending to a significant degree. Clearly, time of response has a moderate effect on the response of state and local governments, preventing governments from spending as much as they'd like to support households. These effects are transitory, however, as government spending and output quickly catch up to their preferred levels when interest rates return to "normal" levels. This simple experiment supports the rationale for the Fed's quick actions to prop up state and local government debt and spending in the early phases of the crisis.

6 Conclusion

This paper has provided a framework for understanding the passthrough of monetary policy to localities in the U.S. through state and local government spending. In an open economy model of a small U.S. region, the financial market underlying municipal borrowing costs affect the local government's ability to borrow and spend on fiscal policy in response to a change in the national risk-free rate. Municipal bond yields in the data exhibit dampened but heterogeneous responses to monetary shocks. These responses may be affected by liquidity in the over-the-counter municipal market, default risk perceptions, or some combination of the two.

Realistic heterogeneity in the response of municipal borrowing costs to monetary shocks implies differences of over 20 percent in output and employment responses to monetary shocks in the calibrated small open economy model. The financial market is important: failing to take into account the dampened response of municipal yields to monetary shocks would overstate the local stimulative effects of monetary policy by more than double. The importance of borrowing costs in determining local fiscal policy provides a playground which may give some insight into local fiscal policies in response to recent economic crises.

References

Adelino, Manuel, Igor Cunha, and Miguel A. Ferreira. “The Economic Effects of Public Financing: Evidence from Municipal Bond Ratings Recalibration”. In: *The Review of Financial Studies* (2017).

Amihud, Yakov. “Illiquidity and stock returns: Cross-section and time series effects”. In: *Journal of Financial Markets* (2002).

Anderson, Gareth and Ambrogio Cesa-Bianchi. “Corssing the Credit Channel: Credit Spreads and Firm Heterogeneity”. In: *Bank of England Working Paper* (2020).

Ang, Andrew, Vineer Bhansali, and Yuhang Xing. “The Muni Bond Spread: Credit, Liquidity, and Tax”. In: *Columbia Business School Research Paper* (2014).

Auer, Simone et al. “International monetary policy transmission through banks in small open economies”. In: *Journal of International Money and Finance* (2019).

Beetsma, Roel M.W.J. and Henrik Jensen. “Monetary and fiscal policy interactions in a micro-founded model of a monetary union”. In: *Journal of International Economics* (2005).

Beraja, Martin, Erik Hurst, and Juan Ospina. “The Aggregate Implications of Regional Business Cycles”. In: *Econometrica* (2019).

Beraja, Martin et al. “Regional Heterogeneity and the Refinancing Channel of Monetary Policy”. In: *The Quarterly Journal of Economics* (2019).

Bernanke, Ben S., Mark Gertler, and Simon Gilchrist. “The Financial Accelerator in a Quantitative Business Cycle Framework”. In: *Handbook of Macroeconomics* (1999).

Bethune, Zachary, Bruno Sultanum, and Nicholas Trachter. “Asset issuance in over-the-counter markets”. In: *Review of Economic Dynamics* (2019).

Brancaccio, Giulia, Dan Li, and Norman Schúrhoff. “Learning by Trading: The Case of the US Market for Municipal Bonds”. In: *Working paper* (2020).

Bu, Chunya, John H. Rogers, and Wenbin Wu. “A Unified Measure of Fed Monetary Policy Shocks”. In: *FEDS Working Paper* (2019).

Cashin, David et al. “Fiscal policy and aggregate demand in the USA before, during, and following the Great Recession”. In: *International Tax and Public Finance* (2018).

Cesa-Bianchi, Ambrogio, Gregory Thwaites, and Alejandro Vicondoa. “Monetary policy transmission in an open economy: new data and evidence from the United Kingdom”. In: *Bank of England Working Paper* (2016).

Chodorow-Reich, Gabriel. “Geographic Cross-Sectional Fiscal Spending Multipliers: What Have We Learned?” In: *American Economic Journal: Economic Policy* (2019).

Christiano, Lawrence J., Martin Eichenbaum, and Charles Evans. “The Effects of Monetary Policy Shocks: Evidence from the Flow of Funds”. In: *The Review of Economics and Statistics* (1996).

Duffie, Darrell, Icolae Garleanu, and Lasse Heje Pedersen. “Over-the-counter markets”. In: *Econometrica* (2005).

Fama, Eugene F. and James D. MacBeth. “Risk, Return, and Equilibrium: Empirical Tests”. In: *Journal of Political Economy* (1973).

Farhi, Emmanuel and Iván Werning. “Fiscal Multipliers: Liquidity Traps and Currency Unions”. In: *Handbook of Macroeconomics* (2017).

— “Fiscal Unions”. In: *American Economic Review* (2017).

Feldhutter, Peter. “The same bond at different prices: Identifying search frictions and selling pressures”. In: *Review of Financial Studies* (2012).

Fisher, Ronald C. and Robert W. Wassmer. “The Issuance of State and Local Debt During the United States Great Recession”. In: *National Tax Journal* (2014).

Francis, Neville, Michael T. Owyang, and Tatevik Sekhposyan. “The Local Effects of Monetary Policy”. In: *The B.E. Journal of Macroecnomics* (2012).

Galí, Jordi and Tommaso Monacelli. “Optimal monetary and fiscal policy in a currency union”. In: *Journal of International Economics* (2008).

Gao, Pengjie, Chang Lee, and Dermot Murphy. “Municipal borrowing costs and state policies for distressed municipalities”. In: *Journal of Financial Economics* (2019).

Garrett, Daniel et al. “Tax Advantages and Imperfect Competition in Auctions for Municipal Bonds”. In: *NBER Working Paper* (2018).

Gilchrist, Simon, Vivian Yue, and Egon Zakrajšek. “U.S. Monetary Policy and International Bond Markets”. In: *Journal of Money, Credit, and Banking* (2019).

Green, Richard C., Burton Hollifield, and Norman Schürhoff. “Dealer intermediation and price behavior in the aftermarket for new bond issues”. In: *Journal of Financial Economics* (2007).

— “Financial Intermediation and the Costs of Trading in an Opaque Market”. In: *The Review of Financial Studies* (2007).

Grigoris, Fotis. “The term structure of municipal bond yields, local economic conditions, and local stock returns”. In: *Working paper* (2019).

Gürkaynak, Refet S., Brian Sack, and Jonathan H. Wright. “The U.S. Treasury Yield Curve: 1961 to the Present”. In: *FEDS Working Paper* (2006).

Harris, Lawrence E. and Michael S. Piwowar. “Secondary Trading Costs in the Municipal Bond Market”. In: *The Journal of Finance* (2006).

Jankowitsch, Rainer, Amrut Nashikkar, and Marti G. Subrahmanyam. “Price dispersion in OTC markets: A new measure of liquidity”. In: *Journal of Banking and Finance* (2011).

Kaplan, Greg, Benjamin Moll, and Giovanni L. Violante. “Monetary Policy According to HANK”. In: *American Economic Review* (2018).

McKay, Alisdair, Emi Nakamura, and Jón Steinsson. “The Power of Forward Guidance Revisited”. In: *American Economic Review* (2016).

Moldogaziev, Tima T. “The Market(s) Left Behind: Price Formation in Municipal secondary Trades”. In: *Working paper* (2018).

Nakamura, Emi and Jón Steinsson. “Fiscal Stimulus in a Monetary Union: Evidence from US Regions”. In: *American Economic Review* (2014).

— “High-Frequency Identification of Monetary Non-Neutrality: The Information Effect”. In: *The Quarterly Journal of Economics* (2018).

Painter, Marcus. “An inconvenient cost: The effects of climate change on municipal bonds”. In: *Journal of Financial Economics* (2020).

Pirinsky, Christo A. and Qinghai Wang. “Market Segmentation and the Cost of Capital in a Domestic Market: Evidence from Municipal Bonds”. In: *Financial Management* (2011).

Rigobon, Roberto and Brian Sack. “The impact o fmonetary policy on asset prices”. In: *Journal of Monetary Economics* (2004).

Rosa, Carlo. "Municipal Bonds and Monetary Policy: Evidence from the Fed Funds Futures Market". In: *The Journal of Futures Markets* (2014).

Schmitt-Grohe, Stephanie and Martin Uribe. "Closing small open economy models". In: *Journal of International Economics* (2003).

— "Nominal Rigidity, Exchange Rates, and Unemployment". In: *Open Economy Macroeconomics* (2016).

Schwert, Michael. "Municipal Bond Liquidity and Default Risk". In: *The Journal of Finance* (2017).

Seegert, Nathan. "The Performance of State Tax Portfolios During and After the Great Recession". In: *National Tax Journal* (2015).

Yang, Lang. "Not All State Authorizations for Municipal Bankruptcy Are Equal: Impact on State Borrowing Costs". In: *National Tax Journal* (2019).

Appendices

A New Keynesian Model Details

This appendix section provides further details on some of the equations in the New Keynesian portion of the model. First, consider again the period t profits of an intermediate goods producer,

$$P_{it}^N(c_t^N+g_t)\left(\frac{P_{it}^N}{P_t^N}\right)^{-\mu}-(1-\frac{1}{\mu})W_t(c_t^N+g_t)^{\frac{1}{\alpha}}\left(\frac{P_{it}^N}{P_t^N}\right)^{-\frac{\mu}{\alpha}},$$

where P_{it}^N is the firm's price. When a firm is given the opportunity to set its price, it maximizes the present value of these per-period profits, taking into account the probability θ that its chosen price will continue on to the next period:

$$E_t\sum_{s=0}^{\infty}Q_{t,t+s}\theta^s\left[\tilde{P}_{it}^N y_{t+s}^N\left(\frac{\tilde{P}_{it}^N}{P_{t+s}^N}\right)^{-\mu}-(1-\frac{1}{\mu})W_{t+s}(y_{t+s}^N)^{\frac{1}{\alpha}}\left(\frac{\tilde{P}_{it}^N}{P_{t+s}^N}\right)^{-\frac{\mu}{\alpha}}\right].$$

Here $\tilde{P}_{it}^N$ is the chosen price of the firm, W_t is the raw wage in time t, and $Q_{t,t+s}$ is the nominal discount factor that converts income in $t+s$ to payments t; this discount factor is based on β and λ_t. The first order condition associated with this problem is given by

$$E_t\sum_{s=0}^{\infty}Q_{t,t+s}\theta^s\left(\frac{\tilde{P}_{it}^N}{P_{t+s}^N}\right)^{-\mu}\left\{\frac{\mu-1}{\mu}\tilde{P}_{it}^N-\frac{1}{\alpha}(1-\frac{1}{\mu})W_{t+s}\left[y_{t+s}^N\left(\frac{\tilde{P}_{it}^N}{P_{t+s}^N}\right)^{-\mu}\right]^{\frac{1-\alpha}{\alpha}}\right\}=0.$$

The first term of the bracketed piece is the marginal revenue in each period, while the second term is the marginal cost. Separating the two terms results in a present value marginal revenue and a present value marginal cost, and recognizing that all adjusting firms will choose the same price $\tilde{P}_t^N$, marginal costs and revenues can be written recursively as

$$mr_t=\frac{\mu-1}{\mu}y_t^N\tilde{P}_t^N\left(\frac{\tilde{P}_t^N}{P_t^N}\right)^{-\mu}+\theta E_tQ_{t,t+1}mr_{t+1}$$

and

$$mc_t=-\frac{1}{\mu}(1-\frac{1}{\mu})(y_t^N)^{\frac{1}{\mu}}W_t\left(\frac{\tilde{P}_t^N}{P_t^N}\right)^{-\frac{\mu}{\alpha}}+\theta E_tQ_{t,t+1}mc_{t+1}.$$

Converting to relative variables $w_t = \frac{W_t}{P_t^N}$, $\tilde{p}_t^N = \frac{\tilde{P}_t^N}{P_t^N}$, and using $\pi_t^N = \frac{P_t^N}{P_{t-1}^N}$ and $Q_{t,t+1} = \beta\frac{\lambda_{t+1}}{\lambda_t}$ results in Equations 18 and 19 from the text.

The nontradable price index is defined by

$$P_t^N = \int_0^1 (P_{it}^N)^{1-\mu} di^{\frac{1}{1-\mu}}.$$

Again using the fact that all prices set in period t will be the same, we see that

$$(P_t^N)^{1-\mu} = \theta(P_{t-1}^N)^{1-\mu} + (1-\theta)(\tilde{P}_t^N)^{1-\mu}.$$

Dividing both sides by $(P_t^N)^{1-\mu}$ gives rise to Equation 20 in the text.

Similarly, to obtain Equation 21, consider the aggregation of total hours worked, along with the definition of production and demand equations:

$$h_t = \int_0^1 h_{it} di = \int_0^1 (y_{it}^N)^{\frac{1}{\alpha}} di = \int_0^1 \left(y_t^N \left(\frac{P_{it}^N}{P_t^N} \right)^{-\mu} \right)^{\frac{1}{\alpha}} di = y_t^{N\frac{1}{\alpha}} \int_0^1 \left(\frac{P_{it}^N}{P_t^N} \right)^{-\frac{\mu}{\alpha}} di.$$

Define price dispersion

$$s_t = \int_0^1 \left(\frac{P_{it}^N}{P_t^N} \right)^{-\frac{\mu}{\alpha}} di,$$

such that now $y_t^N = s_t^{-\alpha} h_t^\alpha$. Again making use of the symmetry of price decisions, we get

$$s_t = \theta \left(\frac{P_{t-1}^N}{P_t^N} \right)^{-\frac{\mu}{\alpha}} + (1-\theta) \left(\frac{\tilde{P}_t^N}{P_t^N} \right)^{-\frac{\mu}{\alpha}},$$

which simplifying gives Equation 21.

B Empirical methodology appendix

B.1 sample selection and data cleaning

This appendix describes the process for selecting and cleaning the trade-level municipal bond data for use in the paper. First, I use the Bloomberg terminal to obtain CUSIP codes for all General Obligation (GO) bonds issued by general governments at any time up to present day. Depending on download limits, it may be necessary to break up the downloads into blocks of 5000 bonds or fewer.

Bloomberg provides CUSIP codes for each bond at the 8-digit level, consisting of a 6-digit issuer code followed by a 2-digit issue-specific code. MSRB, however, reports CUSIPs at the 9-digit level. The 9th digit in any CUSIP code is an automatically generated character according to the following algorithm:

1. Assign each character of the 8-digit code a numeric value x_i, with numeric characters being assigned their own value $0-9$, and alphabetic characters assigned numeric values beginning with 10: $A = 10$, $B = 11$, ... $Z = 35$

2. Construct a sum $S = \sum_{i=1}^{8}(1 + I(i))x_i$, where $I(i) = 1$ if i is even, and $I(i) = 0$ if i is odd. In short, every other x_i is multiplied by 2.

3. Let s be the last (ones) digit of the sum S

4. Assign the 9th digit of the CUSIP code to be the *complement* of s, i.e., $10 - s$, or simply s if $s = 0$.

With the full 9-digit CUSIP codes in hand, I then request the full trade-level MSRB dataset from WRDS, which includes info on every brokered trade of a muni bond included in the list of CUSIPs I provide. This data begins in 2005, when brokers in the municipal bond market were required to provide real-time transaction information to the MSRB, and continues to the present day. The MSRB data includes bond characteristics such as coupon, dated date, and maturity date, and trade characteristics like par value, price, yield, time and date, and whether the trade was a purchase from or sale to a customer or if it was an inter-dealer trade.

I broadly follow Schwert's conditions for cleaning this trade-level dataset to remove potential errors in the data. This includes all bonds with coupons greater than 20% and times to maturity over 100 years in the future. It also drops individual trades with a yield to maturity of 0, a price outside the range $[50, 150]$, or a recorded trade date after the maturity date. This results in a dataset of XX trades from 2005 to 2019.

The dataset used in the main estimation procedure takes the monetary shocks series described below and merges with a dataset of daily yields and spreads. Daily yields and spreads are assumed to be the median value for a bond-day pair. An observation in the resulting data is an FOMC decision day-muni bond pair, with two sets of yields and spreads. The first is the most recent daily price as of the FOMC day, and the second is the most recent daily price as of the day two weeks after the FOMC day; for a bond that has not been traded in two weeks, these two values may be the same.[25]

B.2 Identification of monetary shocks

As mentioned in the body of the paper, I employ the method of Bu, Rogers, and Wu, 2019 to identify monetary shocks at the FOMC date frequency. The BRW method uses a Fama-MacBeth two-step procedure to extract monetary shocks from a series of U.S. treasury yields. The procedure normalizes monetary shocks m_t such that they enter one-to-one into daily changes in the 5-year treasury yield[26]:

$$\Delta R_t^5 = \alpha + m_t + \eta_t.$$

The method then takes the zero-coupon treasury series, representing years to maturity i from $i = 1$ to $i = 30$. Each of these yields are assumed to respond to monetary shocks on FOMC dates according to

$$\Delta R_t^5 = \tilde{\alpha}_i + \beta_i m_t + \eta_{it}.$$

The first step of the procedure seeks to estimate the series of 30 parameters β_i. Since m_t is unobserved, the method uses the normalization to R_t^5, allowing us to instead plug in and

[25] Though as I note in the body of the paper, such observations are ultimately dropped

[26] The choice of maturity is not crucial to the procedure, a 1- or 2- year bond would work, as well.

estimate the equation

$$\Delta R_{it} = \alpha_i + \beta_i \Delta R_t^5 + \varepsilon_{it},$$

where $\alpha_i = \tilde{\alpha}_i + \beta_i \alpha$ and $\varepsilon_{it} = \eta_{it} + \beta_i \eta_t$.

An immediate problem arises in this estimation: ε_{it} is correlated with R_t^5 through η_t, resulting in a biased OLS estimate. To deal with this issue, the BRW method estimates each β_i using a Rigobon and Sack (2004) instrumental variables method. In short, an estimate for β_i can be obtained from the equation

$$[\Delta R_{it}] = \alpha_i + \beta_i [\Delta R_t^5] + \mu_{it},$$

where $[\Delta R_t^5] = (\Delta R_t^5, \Delta R_t^{5*})'$ and $[\Delta R_{it}] = (\Delta R_{it}, \Delta R_{it}^*)'$. Variables with a * represent a one-day movement in the corresponding rate one week before the FOMC date. The instrumental variable for this estimation is $[\Delta R_t^{IV}] = (\Delta R_t^5, -\Delta R_t^{5*})'$. The procedure relies on the assumption that the variance of *non-monetary* news does not change from week to week.

The second step, armed with the IV estimates $\hat{\beta}_i$, then estimates the equation

$$\Delta R_{it} = \alpha_t + \hat{m}_t \hat{\beta}_i + \varepsilon_{it}$$

on each day t, recovering the estimated monetary shocks m_t as the resulting coefficients.

B.3 Schwert Illiquidity Measures

In Section 3.4.3 I describe the method for decomposing municipal spreads into risk and illiquidity components, as in Schwert (2017). To construct the illiquidity measure ψ_{it}, I standardize three measures of illiquidity used by Schwert, and construct ψ_{it} as the monthly average of these three measures. The monthly average is used due to the paucity of munis with multiple trades on a given day, which is required for the daily measures.

The first measure originated in Feldhutter (2012), and is intended to explicitly capture the transaction costs introduced by the over-the-counter nature of bond markets, in which bonds might trade at multiple prices at the same time. This is the "Imputed Round-Trip

Cost" measure of illiquidity, and is measured as follows:

$$IRC_{its} = \frac{P_{its}^{max} - P_{its}^{min}}{P_{its}^{min}}, \tag{44}$$

where P is the price, i is a CUSIP code, t is a given day, and s is a trade size. The idea of this measure is to capture the common occurence in which a dealer matches a buyer with a seller, with the difference in the prices representing the costs of finding and making the transaction. In the data, trades of the same bond on the same day of the same size are coded as round-trip trades, and the daily illiquidity measure is the average of round-trip trades on that day.

Another measure of the transaction costs element of liquidity is the "Price Dispersion" measure from Jankowitsch, Nashikkar, and Subrahmanyam (2011). This measure is similar to the first measure, but uses all prices on a given day. This measure of illiquidity represents the average dispersion around the "market consensus" price, or the average price on a given day:

$$DISP_{it} = \sqrt{\frac{1}{\sum_j Q_j} \sum_j (P_{ij} - M_{it})^2 Q_j}, \tag{45}$$

where j represents a trade of bond i on day t, P_{ij} is the price of trade j, Q_j is the par value of the trade, and $M_{it} = \frac{\sum_j P_{ij} Q_j}{\sum_j Q_j}$. If a bond's prices are highly dispersed on a given day, it could reflect high transaction costs or inventory risks for dealers, among other sources of illiquidity in bond markets.

The third measure, from Amihud (2002), is meant to capture the price impact of trades for a municipal bond. This is related to the market depth component of liquidity, i.e., the ability of a bond to sustain large trades without large movements in price. If, on a day for which there are multiple price changes for a muni, the average price change relative to trade size is large, then trades are having an impact on prices, and market depth is low. The Amihud (2002) measure, then, is given by

$$DEPTH_{it} = \frac{1}{N_{it}} \sum_{j=2}^{N_{it}} \frac{\left| \frac{P_{ij} - P_{i,j-1}}{P_{i,j-1}} \right|}{Q_j}, \tag{46}$$

where notation is the same as above, and N_{it} is the number of trades of bond i on day t. Note that this measure begins with the second trade on a given day, since intraday price changes are the object of interest here.

C Additional empirical results

C.1 VAR evidence of government behavior

This section provides aggregate time series evidence on the repsonse of state and local government fiscal policy to monetary shocks. I follow closely the strategy of Christiano, Eichenbaum, and Evans (1996), by estimating the VAR equation

$$Y_t = A + B_1 Y_{t-1} + ... + B_4 Y_{t-4} + \varepsilon_t, \tag{47}$$

where t corresponds to one quarter. The vector Y includes variables in the following order:

$$Y = [\log GDP \ \ \log C \ \ \log P \ \ \log I \ \ \log X \ \ \log WL \ \ R \ \ \log \Pi \ \ \Delta M],$$

where GDP is GDP, C is Personal Consumption Expenditures, P is the GDP deflator, I is private investment, WL is earnings, R is the federal funds rate, Π is profits, and ΔM is the change in M2 from the previous period. t represents a quarter in the U.S.; for monthly variables I use the first month of the quarter.

X here is the response variable of interest, corresponding to state and local government total debt, consumption expenditures, investment, or consumption + investment. The expenditures are reported at the quarterly level as a part of NIPA. Debt is included in the Federal Reserve's flow of funds data; due to a definitional change in 2004, I adjust pre-2004 values to match the post-2004 series, imputing the 2004Q1 growth rate to 2003Q4. Figures 16, 17, 18, and 19 here show the effect of an expansionary shock to the federal funds rate on the variables of interest. Furthermore, Figure 20 gives the estimated response of output in the VAR with debt.

While there is an initial decrease in expenditures in the short run, due to conventional leaning-against-the-wind factors, expenditures do seem to rise in the medium run. This increase corresponds with the peak of the debt buildup response. As such, it is consistent with the borrowing costs channel put forward in this paper.

Figure 16: CEE Impulse Response to Fed Funds Shock

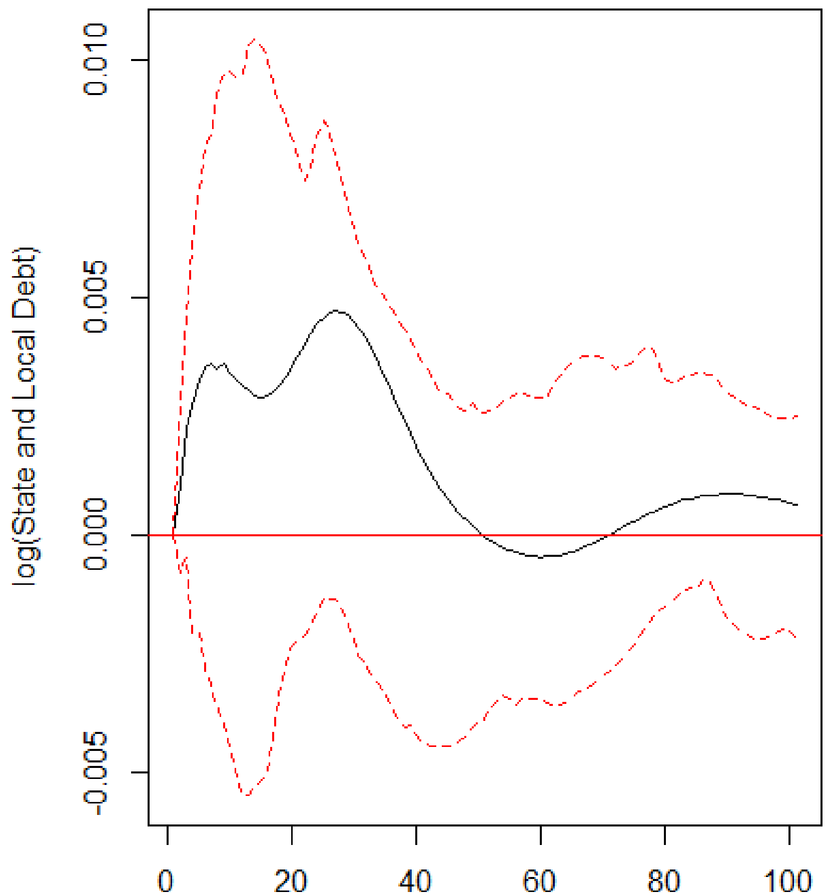


Figure 17: CEE Impulse Response to Fed Funds Shock

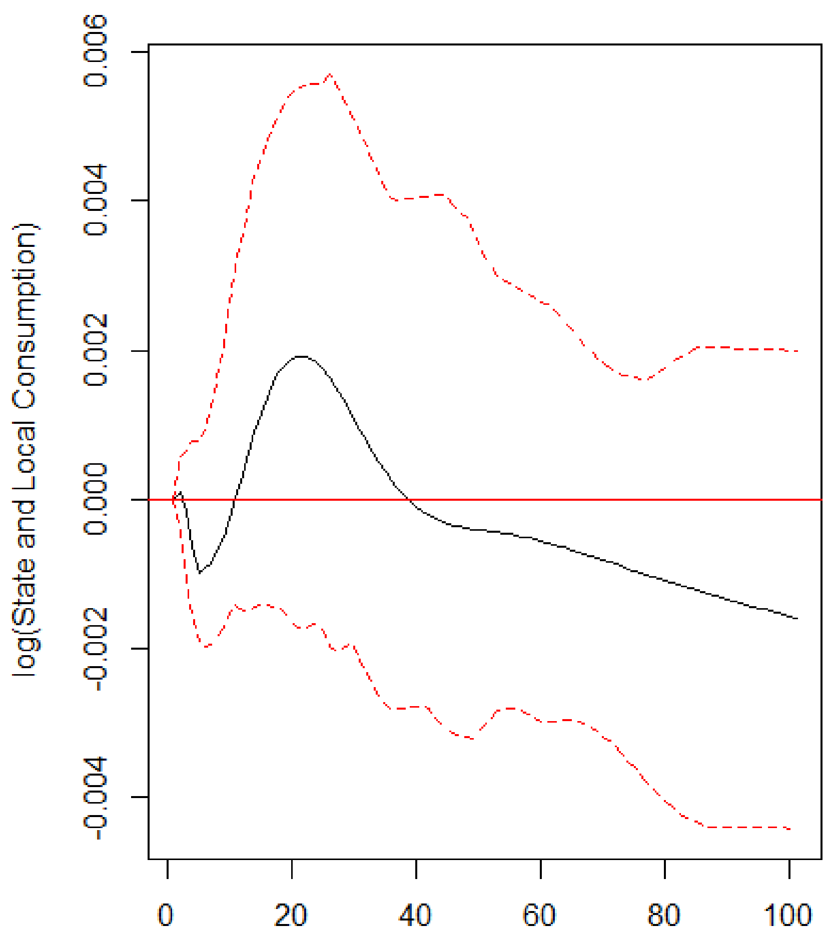


Figure 18: CEE Impulse Response to Fed Funds Shock

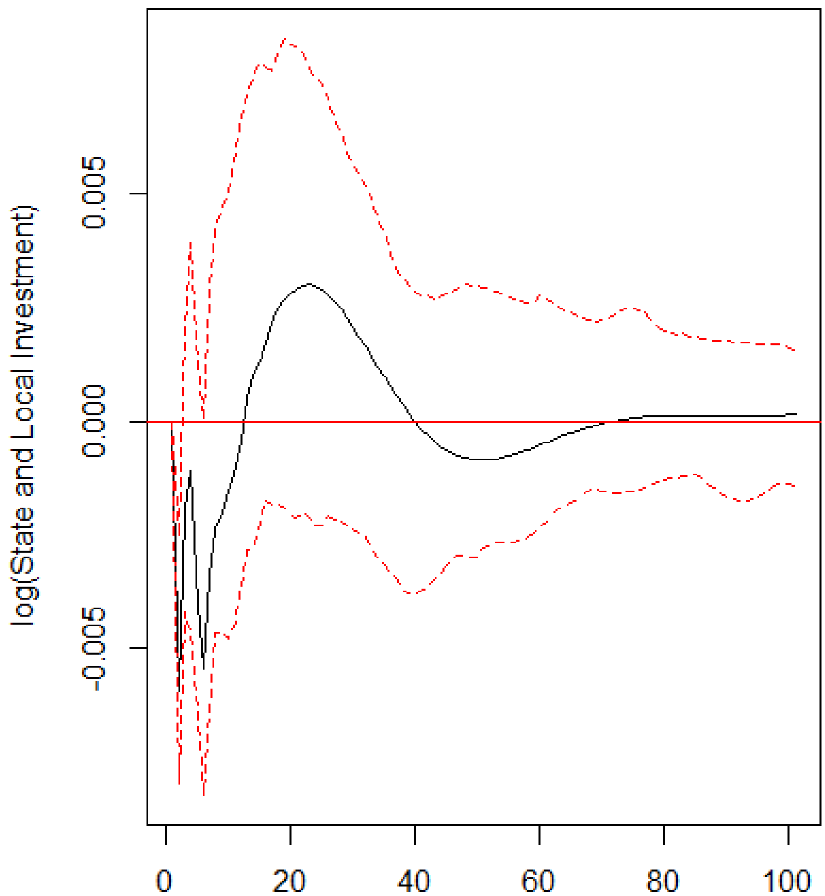
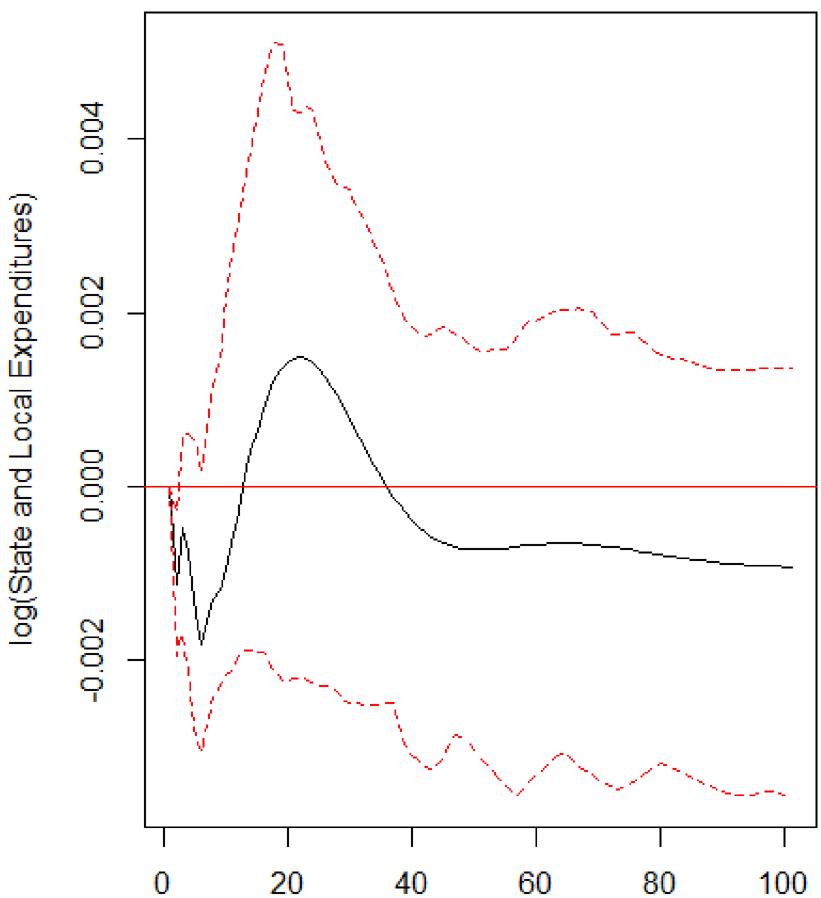


Figure 19: CEE Impulse Response to Fed Funds Shock



C.2 Sector-level time series

In Table 10, I summarize estimates of Equation 33, computed separately for sector-level indices.

C.3 Government Finance Variables

In Tables 11, 12, and 13, I summarize estimates of Equation 34, computed separately for a number of government finance statistics. The coefficient estimates in these tables represent the interaction between the variable and the monetary shock, in separately estimated regressions. The tables correspond to revenues, expenditures, and other categories, respectively.

C.4 Government type

In addition to the heterogeneity in the body of the paper, and in order to provide a more comprehensive view of heterogeneity in municipal bond spreads, I investigate the response of muni yields and spreads to monetary shocks on two important dimensions. The first is government type. Insofar as bonds issued by state governments are different in terms of liquidity (or risk) than their city and county counterparts, these bonds might respond differently to monetary shocks. In particular, if these bonds are on average more liquid than bonds of smaller governments, we might expect their yields to respond more strongly to monetary shocks. One piece of suggestive evidence in this direction is the fact that state governments are disproportionately represented in the sample of bonds which actually record a trade in the window following a monetary shock.

To identify what type of government issued a particular bond, I first retrieve the bond issuer names from the Bloomberg Terminal. I then keep those issuers which include the words "state" or "commonwealth," and label these the "big" government issuers.[27] The estimate of interest, then, is the differential magnitude of response to monetary shocks for these "big" governments *vis-à-vis* other types of governments. Table 14 repeats the estimation of Equation 34, reporting the interaction between the estimated shock and government type.

[27] I can also break out the smaller governments by the words "city," "county," "town," "village," etc., but the most important distinction seems to be the fifty states versus all other governments. Surely there is heterogeneity within cities and towns; this is a potential direction for future research.

Table 10: Sector-level Time Series Estimates

Sector	Coefficient (s.e.)
Airport	0.175
	(0.078)
Education	0.205
	(0.083)
Health Care	0.170
	(0.075)
Higher Education	0.195
	(0.083)
Infrastructure	0.206
	(0.116)
Land Backed	1.291
	(0.684)
Lifecare	0.160
	(0.071)
Multifamily	0.150
	(0.078)
Nursing	0.569
	(0.169)
Port	0.178
	(0.079)
Public Power	0.210
	(0.291)
Single Family	0.090
	(0.058)
Student Loan	0.205
	(0.086)
Tobacco	0.230
	(0.145)
Toll Road	0.194
	(0.085)
Transportation	0.197
	(0.084)
Utility	0.197
	(0.122)
Water and Sewer	0.191
	(0.080)

Note: An observation corresponds to one day, around which a window is constructed from the previous day's price and the price at a given horizon. Each column refers to a separate time series regression of an index on monetary shocks. Heteroskedasticity-robust standard errors are reported in parentheses.

Table 11: Panel Estimates: Interactions with Public Finance Revenue Variables

Interaction Variable (log)	Interaction Coefficient (s.e.)
Total	-0.204
	(0.138)
General	-0.199
	(0.136)
Total Tax	-0.190
	(0.127)
Property Tax	-0.031
	(0.017)
Sales Tax	-0.094
	(0.052)
Income Tax	-0.064
	(0.045)
Intergovernmental	-0.192
	(0.128)
Miscellaneous	-0.180
	(0.133)
Interest	-0.150
	(0.122)
Utilities	-0.074
	(0.057)

Note: An observation corresponds to an FOMC date-muni bond pair. Each *row* corresponds to a regression with the specified variable interacted with monetary shocks, as in Equation 34. The reported coefficient is the coefficient on the interaction term. Standard errors are reported in parentheses, and are clustered at the date level. $N = 12100$ for all regressions.

Table 12: Panel Estimates: Interactions with Public Finance Expenditure Variables

Interaction Variable (log)	Interaction Coefficient (s.e.)
Total	-0.198
	(0.135)
Current	-0.192
	(0.138)
Capital	-0.192
	(0.138)
Construction	-0.175
	(0.114)
Interest	-0.187
	(0.127)
Benefits	-0.097
	(0.062)
Wage	-0.199
	(0.138)
General	-0.196
	(0.134)
Education	-0.085
	(0.056)
Health	-0.104
	(0.068)
Highway	-0.156
	(0.102)
Housing	-0.122
	(0.096)
Public Welfare	-0.088
	(0.062)
Utility	-0.095
	(0.076)
Retirement	-0.095
	(0.063)

Note: An observation corresponds to an FOMC date-muni bond pair. Each *row* corresponds to a regression with the specified variable interacted with monetary shocks, as in Equation 34. The reported coefficient is the coefficient on the interaction term. Standard errors are reported in parentheses, and are clustered at the date level. $N = 12100$ for all regressions.

Figure 20: CEE Impulse Response to Fed Funds Shock

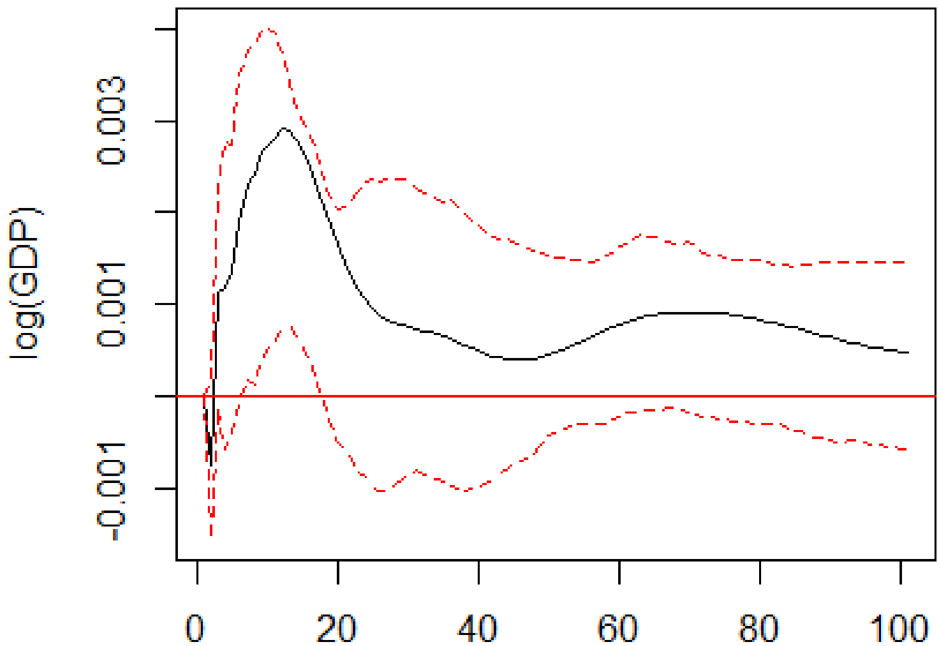


Table 13: Panel Estimates: Interactions with Other Public Finance Variables

Interaction Variable (log)	Interaction Coefficient (s.e.)
Population	-0.236
	(0.148)
Total Long Term Debt	-0.173
	(0.119)
Total LTD Issued	-0.173
	(0.119)
Total Cash and Securities	-0.169
	(0.117)
Total Cash and Securities (non-insurance)	-0.194
	(0.136)

Note: An observation corresponds to an FOMC date-muni bond pair. Each *row* corresponds to a regression with the specified variable interacted with monetary shocks, as in Equation 34. The reported coefficient is the coefficient on the interaction term. Standard errors are reported in parentheses, and are clustered at the date level. $N = 12100$ for all regressions.

Table 14: 2-week response of muni yields to monetary shocks, by issuer type

	d yield	d yield ($\neq 0$)	d spread	d spread ($\neq 0$)
Big government	0.01***	0.06***	0.01**	0.05***
	(0.00)	(0.01)	(0.00)	(0.01)
Monetary shock	0.24***	0.66***	0.05	0.10
	(0.06)	(0.15)	(0.07)	(0.16)
Monetary shock * Big government	-0.02	-0.21*	-0.13*	-0.22**
	(0.09)	(0.13)	(0.07)	(0.11)
N	74338	36747	74286	36685

Note: An observation corresponds to an FOMC date-bond pair. Each column refers to a separate regression. Standard errors are reported in parentheses, and are clustered at the date level.

The results lend some further insight into the pattern observed earlier, in which the average response of muni yields to monetary shocks is made up of some bonds that adjust and some that do not. Interestingly, while there does not seem to be any differential response *on average* between bonds from big governments and smaller governments, there is a difference conditional on adjustment. Among the bonds which adjust price in response to a monetary shock, the bonds for state governments adjust 45 basis points in accordance with a 100 bp shock, whereas all other bonds adjust 66 basis points on average. Of course, the bonds for these bigger governments are a larger proportion of the "responding" sample than the full sample; in other words, their yields are more likely to respond to a monetary shock than those of smaller governments. Because these bonds trade at a higher frequency, their price adjustments in response to a given shock, conditional on adjustment, are smaller than those bonds which trade at a lower frequency. The pattern for spreads exhibits a similar pattern, in which the coefficient on the interaction term is more negative and more precisely estimated in the reduced sample; the average response remains zero, as before.

The second additional margin of heterogeneity involves an attempt at a comprehensive measure of unexplained spreads, which is made up of liquidity, risk, and tax components. I residualize the implied spread on every transaction in the original data by regressing out time to maturity and fixed effects at the month level. For each bond, I take the average of its residualized (actual minus predicted) spread to compute a time-invariant measure of unexplained spreads for each muni. If average residuals are above zero, I code the bond as "high spread;" similarly, I code as "low spread" those bonds for which average residuals are below zero. Of course these unexplained spreads include liquidity, risk, and tax components, but

Table 15: 2-week response of muni yields to monetary shocks, by high/low spreads

	d yield	d yield ($\neq 0$)	d spread	d spread ($\neq 0$)
Low spread	0.02***	0.05***	0.02***	0.05***
	(0.00)	(0.01)	(0.00)	(0.01)
Monetary shock	0.22***	0.56***	-0.00	-0.02
	(0.09)	(0.21)	(0.08)	(0.18)
Monetary shock * Low spread	0.03	0.05	0.03	0.06
	(0.06)	(0.12)	(0.06)	(0.12)
N	74143	36651	74080	36596

Note: An observation corresponds to an FOMC date-bond pair. Each column refers to a separate regression. Standard errors are reported in parentheses, and are clustered at the date level.

they represent a simple and intuitive margin of heterogeneity that does not require dropping observations yet carries some important information about the desirability of certain types of bonds.

Table 15 presents the results of analogous regressions, in which the more liquid (and less risky) bonds are expected to be in the "low unexplained spread" category. The "average unexplained spreads" dimension of heterogeneity seems not to have much of an effect on the response of muni yields to monetary shocks, in either the conditional or unconditional specifications. Note that these measures are time invariant and the bond level; while a time-varying measure of excess spread would be helpful, many of these bonds simply aren't traded at a high enough frequency to obtain a meaningful measure.

While the average spread differential doesn't reveal a systematic response in the same way that government type does, it may be the case that a differential response is revealed *within* certain types of governments. To finish the investigation into heterogeneity of responses, I include both the government issuer's type and unexplained spreads in the regression specifications. Results are given in Table 16.

As before, state governments respond less strongly to monetary shocks, especially conditional on adjustment, and low unexplained spreads have zero effect on the response of yields to a monetary shock. Note, however, the triple-difference coefficient in these specifications. Big governments with low excess spreads do not exhibit a lower response to monetary shocks, even conditional on adjustment; this coefficient almost completely negates the negative coefficient on being a state government. In these specifications, the bonds which exhibit a lower response to monetary shocks are only those which are issued by state governments with high

Table 16: 2-week response of muni yields to monetary shocks, by issuer type and high/low spreads

	d yield	d yield ($\neq 0$)	d spread	d spread ($\neq 0$)
Big Government	0.01	0.06***	0.01	0.06***
	(0.01)	(0.01)	(0.01)	(0.01)
Low spread	0.02***	0.05***	0.02***	0.05***
	(0.00)	(0.01)	(0.00)	(0.01)
Monetary shock	0.28***	0.76***	0.08	0.17
	(0.08)	(0.20)	(0.08)	(0.18)
Monetary shock * Big government	-0.21	-0.55**	-0.29**	-0.50***
	(0.14)	(0.23)	(0.12)	(0.20)
Monetary shock * Low spread	-0.06	-0.15	-0.04	-0.10
	(0.06)	(0.14)	(0.07)	(0.16)
Big government * Low spread	0.01	-0.01	0.01	-0.01
	(0.01)	(0.01)	(0.01)	(0.01)
Monetary shock * Big government * Low spread	0.29**	0.51**	0.24*	0.41*
	(0.13)	(0.22)	(0.12)	(0.22)
N	74338	36743	74264	36681

Note: An observation corresponds to an FOMC date-bond pair. Each column refers to a separate regression. Standard errors are reported in parentheses, and are clustered at the date level.

excess spreads.

The results of this section, to the extent they say anything systematic about heterogeneity in the response of municipal bond yields to monetary shocks, may be summarized as follows. Bonds issued from state governments ("big" governments) are traded more often, and therefore are more likely to experience a price change as a result of a monetary shock. Unsurprisingly, the magnitude of their responses are smaller on average. This lower response is mainly driven by state bonds with high excess spreads, reflecting higher illiquidity or potentially higher risk premia than other bonds from similar issuers.

D Additional Quantitative Results

D.1 Full model results

In the body of the paper, I show the effects of changing the coefficient θ^G on the monetary transmission to each locality. I focused on one locality at a time for ease of exposition. Here, I consider the full model with a large number of localities, and confirm that monetary shocks transmit in a heterogeneous manner when localities' financial markets differ.

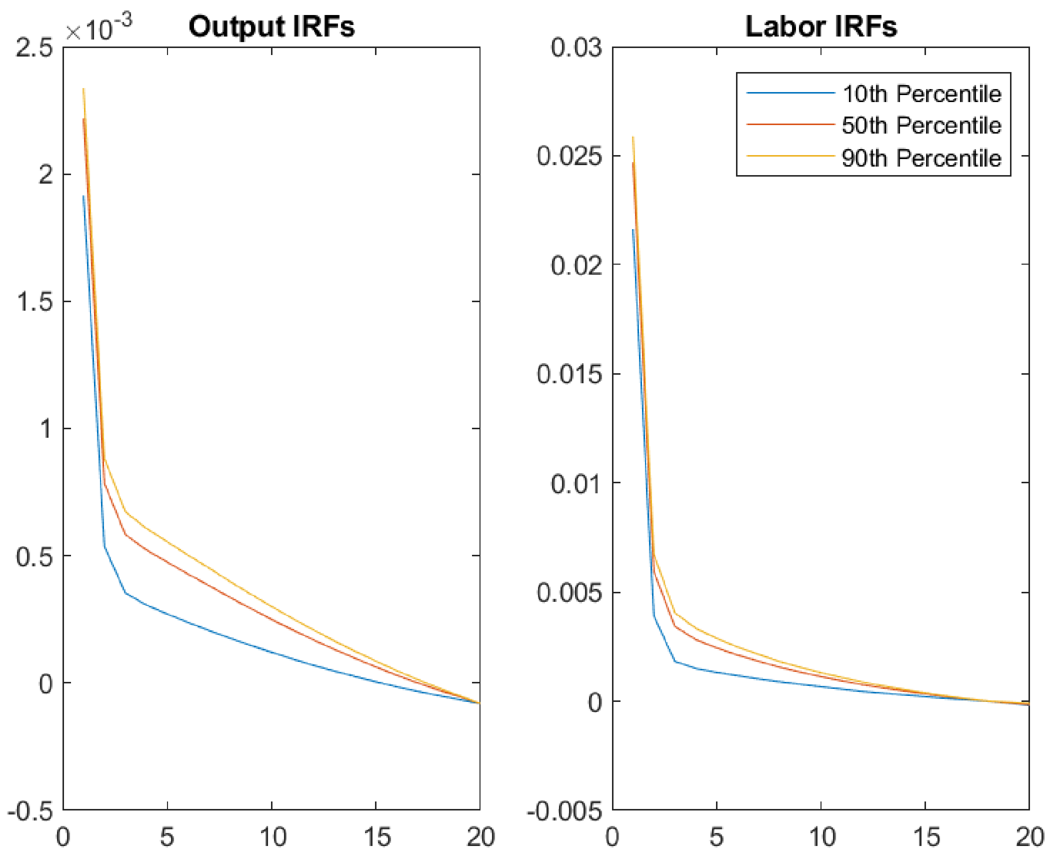
In the data, I identified the municipal yield responses to monetary shocks of 41 U.S. states. In this specification, then, I set $S = 41$, and assign each state a θ^G corresponding to one of the empirical estimates, while all other parameters remain the same. Aggregate output is defined as total output, and aggregate inflation as average inflation of non-tradables across localities. The risk-free rate is set according to a Taylor rule which mimics the interest rate process in the body of the paper, replacing y^T with total output and adding in a response of inflation, where the risk-free rate responds to a basis point of lagged inflation with a 1.5 basis point rate increase.

Figure 21 shows the responses of percentiles of the full economy to a 25bp shock to the risk-free rate set in the Taylor Rule. Consistent with the results in the paper, realistic heterogeneity in monetary passthrough to munis results in significant transmission to U.S. localities. Here, also, we see that the difference between the 10th percentile and the median is much greater than that between the 90th and median. This is reflective of the asymmetry of the distribution of coefficient estimates in the data.

D.2 OTC model results

Here, I present some brief results from the OTC version of the model described in Section 2.8 of the main paper. Calibration moves forward similarly as in the baseline model, with a few additions. First, for simplicity I assume that financial firms are immediately able to sell bonds on the secondary market, i.e., $p^{sell} = 1$. A fuller examination of heterogeneity in muni pricing would require a more specific specification of the thickness of this secondary market, but in this section I will show simply the basic results. I calibrate v^H and ν to match the

Figure 21: IRFs Under Muni Heterogeneity



steady state d^G and r^G from the baseline model, and set $\theta = 0.5$ for simplicity.[28]

This model behaves similarly to the baseline model in terms of the directions of the IRFs. Note, however, in this special case of the model, the response of government debt and spending is much lower than the baseline model. The reason for this is the costs involved in issuing debt: the explicit inclusion of coupon payments and debt retirements puts upward pressure on their borrowing costs. As a result, $\frac{\partial r^G}{\partial d^G}$ is quite large, dampening significantly the responses to monetary shocks. In the baseline model, this translates to a larger value for ϕ^G.

D.3 Explicit Debt Constraints

This paper examines in detail the effect of municipal bond markets' response to monetary shocks on the size and potential heterogeneity in monetary policy transmission. Another fiscal dimension on which state and local governments differ is the stringency of balanced-budget rules, which vary across governments. Most governments have some sort of balanced budget requirement on the books; the rules surrounding these requirements likely result in an effective *politically imposed* on the amount of debt a government can issue.

Figures 24 and 25 show how the results in the paper are affected by an additional constraint on debt issued by a local government: $d^G_{it} \leq 1.025 d^G_{i,t-1}$. First, note that the debt constraint dampens the transmission of monetary policy, even relative to the already-dampened baseline case, on the order of about 10 percent in the baseline case. This dampening seems to be stronger for the economies with more responsive debt prices (Figure 25), making the medium- and high- response economies almost equal. Just as the response of borrowing costs to monetary shocks affects monetary transmission through local fiscal policy, so too will the debt issuance constraints placed on these localities through various budgeting laws.

D.4 Steady State Government Debt

Figure 26 shows the positive relationship between steady state local government debt and the transmission of monetary policy in the baseline calibrated model. Here I recalibrate the

[28]Monetary responses do vary with θ, but without variation in α cannot match the observed heterogeneity in the data.

Figure 22: IRFs, 25bp Expansionary Shock

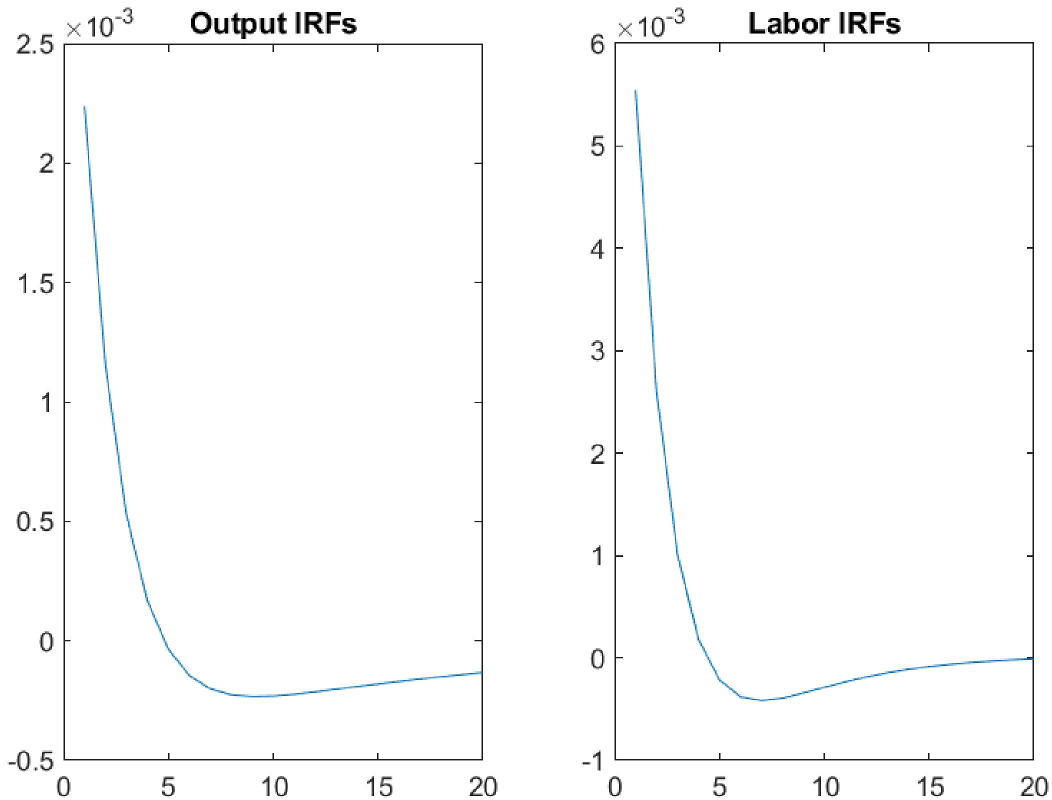


Figure 23: IRFs, 25bp Expansionary Shock

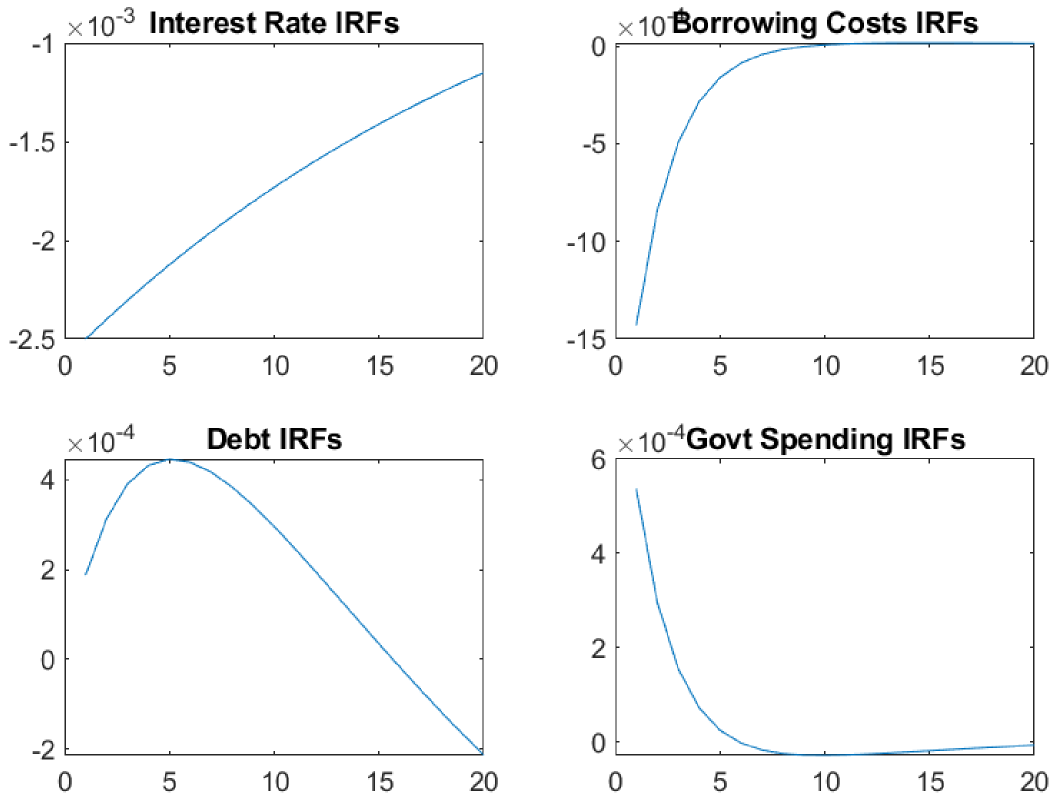


Figure 24: The Effect of Debt Constraints

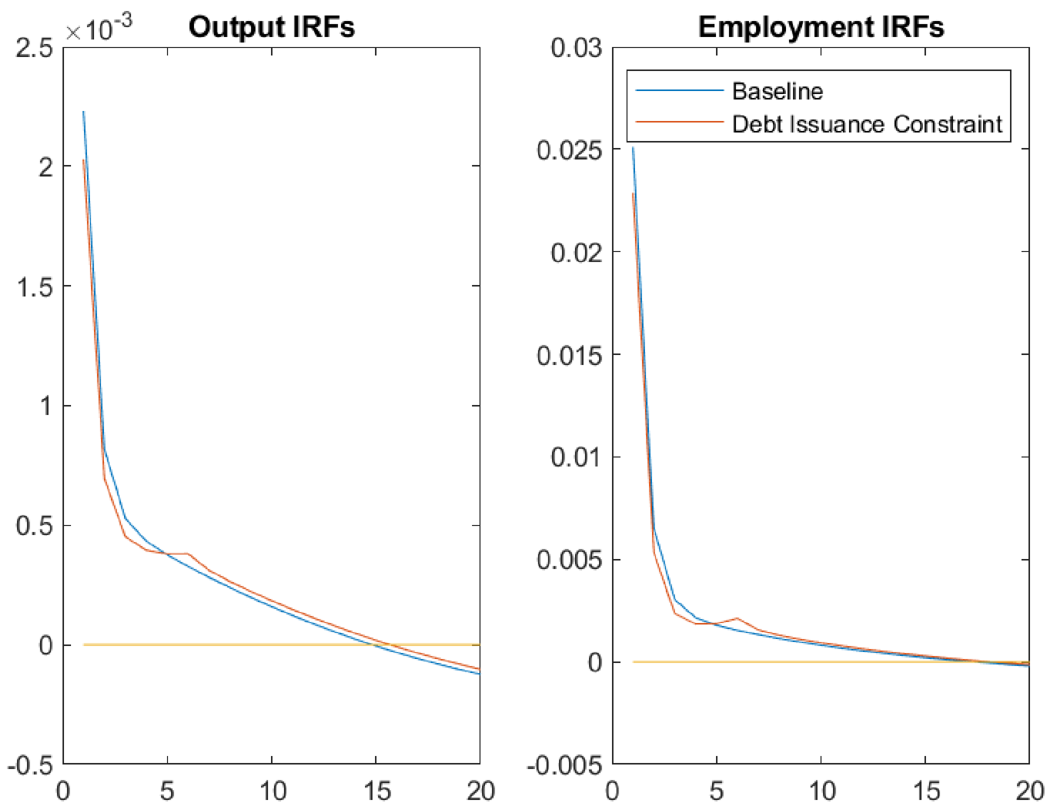


Figure 25: IRFs by Response Elasticity, Debt Issue Constrained

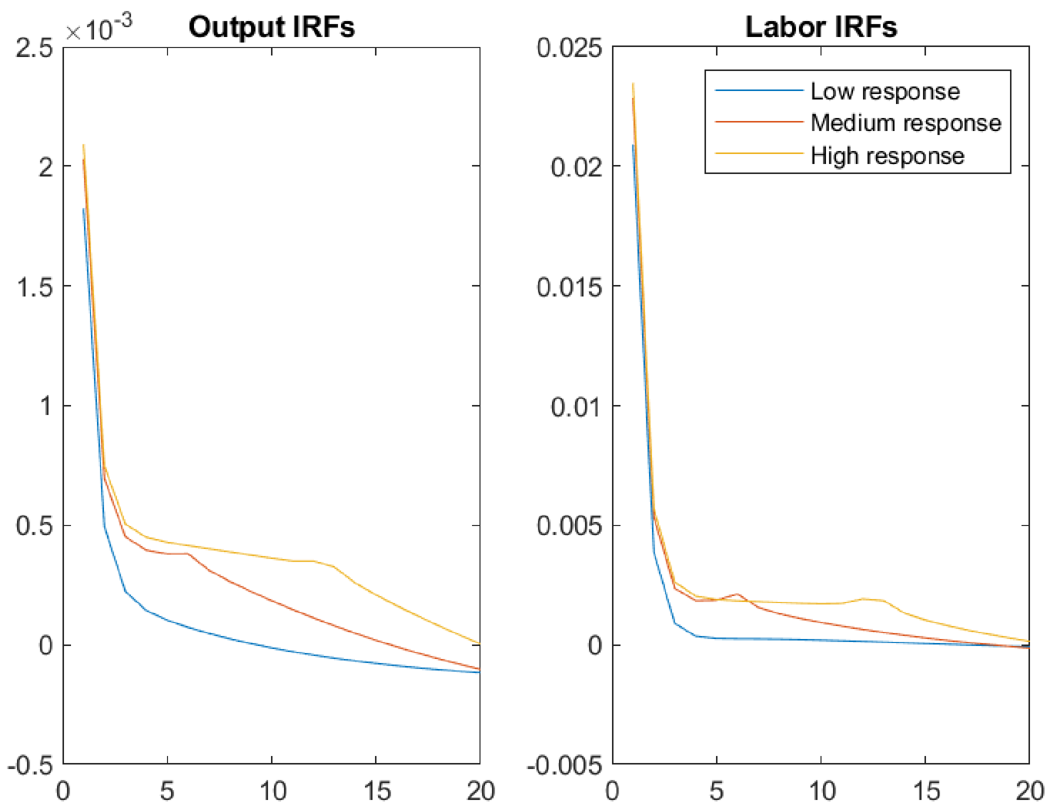
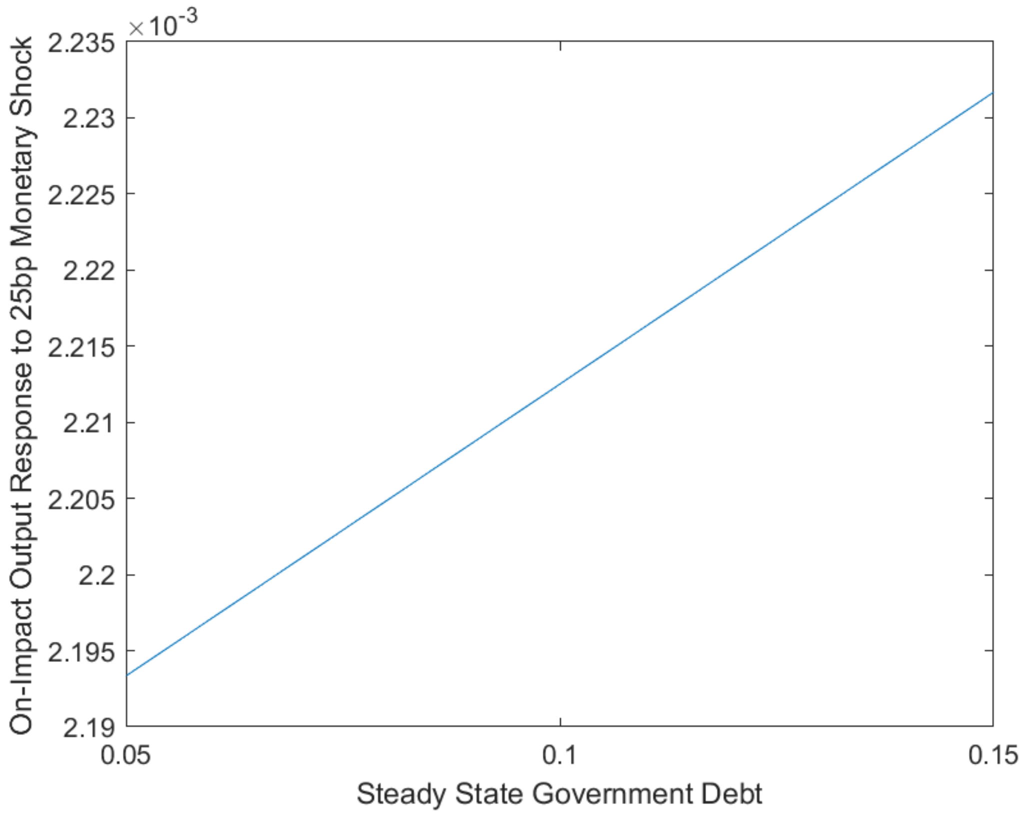


Figure 26: Monetary Transmission and Government Debt



parameters of the model in the same way as the body of the paper for a number of values for steady state local government debt as a fraction of output, from 0.05 to 0.15. I record the on-impact transmission of monetary policy for each of these economies in the figure.

Clearly, there is a positive correlation between the steady state level of government debt and monetary transmission. The same percentage increase in government spending will be more stimulative for a government which spends more in steady state. The steady state level of government spending is one of many possible dimensions on which these governments may differ, and which may contribute to the transmission of monetary policy.