A macroeconomic consideration of the factors affecting changes in US bond yields and the extent to which the average value of daily traded collateral in the repurchasing market is attributable.

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Abstract

This paper seeks to examine the existence of a causal macroeconomic relationship between changes in the volume of collateral traded in the US repurchasing market and bond yield fluctuations. The study considers US treasury securities only as means of collateral and assesses monthly data from July 2008 to July 2023. It is hypothesised an increase in the volume of collateral traded will have a negative effect on bond yields. Given the lack of comparable literature in this research area, the paper begins by assuming that there is no significant relationship. However, through a series of statistical testing and econometric analysis, evidence to reject this null hypothesis is established. A lagged OLS was employed as the final model to best explain the relationship. Other independent variables were used as controls. These were GDP growth, LCR dummy, repo rate, real interest rate, inflation expectation and market CMDI, each will be discussed in turn. Numerous regressors underwent transformations as to not violate OLS assumptions. The main result of this study showed, of the variables considered, changes in the volume of collateral traded had the largest impact on bond yield variation at the 10% significance level. Calculations explain this relationship is highly elastic at -3.673% demonstrating that changes in collateral volumes have a greater than proportionate effect on the change of bond yields. The results illustrate the importance of a holistic understanding of the key drivers of the bond market and how these factors can be manipulated for use in repurchasing agreements for monetary policy purposes. The specific selection of regressors has not previously been studied, indicating these results add notable evidence to existing literature. A broader understanding into the role of bonds in the US repurchasing market and what drives their yield may encourage the need to research the benefits of implementing a daily trading limit to allow for more consistent returns. Additionally, it underscores importance of separating commercial and investment banks when investing public money.

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1. Introduction

1.1 Context

The repurchasing (repo) market is a ready-made collaterol market allowing institutions with excess securities to borrow cheaply and those with excess capital to lend in a risk-free market whilst returning a profit. In the US, an average of $2-4 trillion collateralised short-term loans are traded daily (Cheng and Wessel 2020) where traditionally, government bonds are used as collaterol. The 'contractual arrangement' between parties, involves one selling securities to another with the commitment to later buy them back at a specified higher price. The Federal Reserve participates in these transactions to conduct monetary policy by either injecting into, or draining reserves from, the financial system. Most government repo transactions involve a third party known as a clearing house who are used as an intermediary to facilitate the exchange and ensure opportunities for arbitrage are not exploited.

This investigation seeks to understand whether the monetary value of traded collateral influences the yields the collateralised bonds accrue when they mature, or whether more researched macroeconomic indicators are the driving forces for these fluctuations. These include, but are not limited to, inflation, the repo rate, and the debt-to-GDP ratio.

In 2023, between July and September, the Fed printed $1 trillion with the primary aim to allow for greater engagement in the repo market (Travis Brohawk 2023). More frequently, the US government requires capital for public investment and the repo market allows for quick sourcing of cash with much lower repayment rates than that offered by alternative lenders.

The government is authorised to create bonds which they may sell to the Fed who act as a lender by printing capital to purchase a bond. This happens under the assumption that at the agreed time, the government will engage in the reverse repo and buy back the bond. Until then, the internal economy is temporarily indebted to itself, increasing the debt-to-GDP ratio. This prompts the Fed to enact monetary policy to increase inflation and erode the real value of the debt. If, at the agreed date, the government cannot afford to repurchase the bond, they create another to sell to the Fed to obtain capital to repurchase the first. This creates a continuous cycle of bond creation from the government and quantitative easing by the Fed. This drastically reduces consumer confidence in the Fed's economic stability and government's ability to repay loans, meaning other lenders- predominantly the BRICs who short bonds- instead choose not to engage with the market, resulting in a declining demand to purchase US debt.

The hegemony of the US dollar is also declining due to the creation of trade agreements which are no longer dependent upon the existence of the dollar. A prime example of this is the abandonment of the petrodollar following the Russia-Ukraine War where multiple nations are now using gold to trade oil supplies (Shah 2024).

If this continues, and the hold of dollar reserves is no longer paramount to foreign trade, there is no requirement for external investment in US debt and the purchase of bonds. This has created a scenario reminiscent of a 'banana republic' in the US where the government is having to purchase its own debt due to overreliance on trading the dollar as a commodity. This further decreases demand since it implies to investors the government is unable to repay its debt. The Fed therefore increases interest rates to manage inflation and ultimately raise the yield on bonds.

This is an example of how demand for bonds and the resultant volume of their trading has an indirect effect on their yield. This paper seeks to explore whether this is the primary driver or whether other factors play a larger role in these fluctuations.

It will consider monthly data in the US over 181 periods from 2008-2023. The regular data collection means large spikes and drops in the aforementioned indicators will not be omitted during econometric testing. The US is an appropriate international member to test the hypothesis given its hegemon status and ability to influence global affairs. The study focuses on market functioning post the 2008 financial crisis, so the breakdown of variable relationships is not a confounding factor during analysis.

1.2 Rationale

Since bond yields reflect the cost of borrowing and investor sentiment, the bond market provides governments key insights into market confidence and economic stability. A lower yield implies borrowing is cheaper and there is subsequently a reduction of interest on public debt. The Fed monitors and evaluates the durability of a market's operations so they can implement effective monetary policies and alter economic conditions accordingly. For investors, a stable bond yield indicates fiscal health, meaning their demand increases. Consequently, there is a rise in the volume of market transactions.

The Glass Steagall act was imposed in 1933 and instigated the separation of commercial and investment banks to protect public savings from being liable or lost in the event of widespread financial distress. It was revoked under Clinton in 1999, initiating unmonitored commercial bank engagement in investment banking activities, enabling them to invest public deposits for private gain (Crawford 2011). Many of these investments start with a repo transaction to obtain capital for further expenditure. This paper seeks to demonstrate how government policy and party decisions have widespread impacts across the economy and cannot be contained solely to the problem area. The Glass Steagall act is one of many where its reinstatement may have the power to prevent future economic crises.

This draws out the profound role the repo market plays in the economy and the way in which its mechanics have the potential to affect public spending and finances. Understanding the driving forces of bond yields is therefore crucial to protect the taxpayer from the possibility of bailing out banks following poor investment choices- as was observed in 2008. The financial crash evidenced the detriments of privatising profits and subsiding losses, and the dangers imposed from the moral hazards of an integrated banking system.

Lastly, given the stated importance of bond yield stability for economic health, a potential implication arising from this analysis is the introduction of an upper limit on daily trading volumes for repo transactions. This would prevent drastic spikes and falls in bond demand due to changes in the repo rate and better guarantee a level of consistency and predictability. The relationship between demand and price would remain unchanged, however the existence of a ceiling means the circularity of the system would become self-regulating. This would also make it impossible for multiple banks to be highly vulnerable simultaneously.

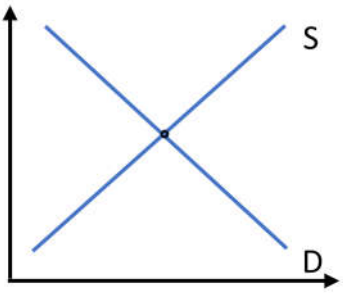
2. Literature review

2.1 Economic theory

The repurchasing market is a complex and miscellaneous system with both public and private stakeholders globally involved in any given transaction. Blackrock (2023) describes these affairs as a contractual arrangement between two entities.

The distinction between the price and yield of bonds is a fundamental one. The price of a bond represents its market value which is determined by the mechanics of supply and demand (figure 1) whereas the yield is the annual return on investment (a percentage of its price) and reflects generated income. The yield is a fixed rate set at the time of bond creation whereas the price can fluctuate- the two have an inverse relationship where a higher bond price results in a lower yield. JP Morgan (2016) explained bonds pay a fixed interest rate that becomes more attractive if interest rates fall, driving up demand and the price of the bond. This is also in line with research done by Ayu and Widayat (2019) when they state interest rates have a positive relationship with bond yields.

Figure 1



As noted, the repo market is used as a tool to conduct monetary policy and manipulate the flow of capital. By borrowing securities and selling them short, there is a reduced risk of market squeezes (ICMA group 2019) which happens when the supply of a particular security is cornered and there is a temporary imbalance of supply and demand. The system also helps address market failures like information asymmetry by providing a transparent and collateralised platform for short-term borrowing where the use of securities prevents counterparty risk.

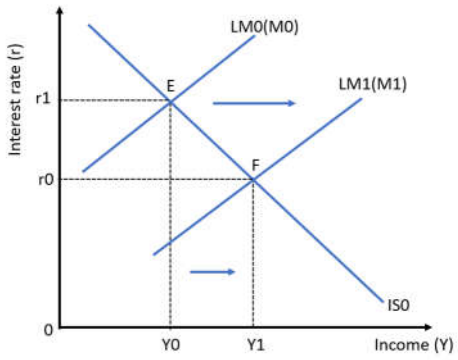
Despite the government benefits of engaging in these open market operations, the repo market is also one of the largest facilitators of arbitrage (Stebunovs 2011). This is particularly true in Japan (CGFS 2017) where large asset purchasing programmes offer arbitrage opportunities between central bank counterparties. This occurs when price differentials between securities and cash are exploited. Traders can borrow low risk securities and simultaneously short them at a higher price to create a profit- taking advantage of temporary imbalances between the two markets. The Federal Reserve Bank of Chicago (2020) explored this issue by illustrating how the Fed fund rate might be adjusted to influence the availability and cost of money meaning customer expectations about the yield accrued on a rolling bond no longer remain true, therefore preventing prices from balancing out profit opportunities as they would in a well-functioning capital market.

The viability of collateral relies on its perceived value and potential for forfeit in the event of default. When there is insufficient liquidity, lenders may encounter difficulties in selling the bond to acquire their owed capital. In September 2019, the repo rate spiked to highs of 10% causing many financial institutions to refuse to lend due to risk concerns and the implied shortage of market liquidity (Cheng and Wessel 2020). These spikes unsettle policymakers due to the prospective spillover effects to the Fed fund rate, compromising interest rate control and monetary policy implementation (Ennis and Huther 2021). If the repo rate rises and banks begin to compete to borrow reserves from each other, there is an increase in

demand, putting upward pressure on the Fed fund rate meaning investors require a higher return, and bond yields increase relative to their price. Given the Fed's capacity for large-scale transactions, heightened government borrowing fosters greater demand for funds, making it vulnerable to crowding out where they begin competing for cash with the institutions they regulate as well as other market participants (Bao and Pan 2013). Subsequently, market engagement and efficiency are impeded, with consequential effects on interest rates.

The Fed's conduct of these open market operation can be illustrated by the IS-LM curve (figure 2) which describes the interaction between economic goods and loanable market funds. In this context, the purchasing of bonds by the Fed reduces the sum of bonds accessible in the market, thereby increasing their price and lowering their yield (r1-r0) (Dornbusch, Fischer & Startz 2014). The shift in investment preferences away from bonds and towards capital is facilitated by lowered interest rates, resulting in an equilibrium move from E to F. The lower yield causes investment spending to increase from Y0-Y1, contingent upon the sensitivity of money demand to interest rates (Dornbusch et al, 2014). This process demonstrates the transmission mechanism that explains how government actions can impact aggregate demand for a good (Meyer 2020). The equilibrium move means individuals and firms are holding more cash than is optimal, known as portfolio disequilibrium, subsequently altering asset prices, yield and, by extension, causes a shift in aggregate demand and total output in the economy (Dornbusch et al 2014). Here, the IS-LM curve illustrates how government action can have large impacts on bond yields and the repo market.

Figure 2



Macroeconomic theories are studied by investors to analyse the accuracy of bond yield predictions. One of these theories is the efficient market hypothesis (random walks) theory which suggests consistently outperforming the market is difficult, as new information is quickly priced in, making it nearly impossible for investors to predict future returns or capitalise on profit opportunities. Applied to the repo market, the theory suggests prices accurately reflect information, theoretically limiting opportunities for arbitrage. However, the structure of the repo market still allows for arbitrage under certain conditions, particularly in times of liquidity stress. (Degutis & Novickytė 2014). Clarke et al (2001) explored the trade-off between accurate prediction techniques and their cost in terms of research and business and found returning a profit is almost unachievable without choosing higher-risk assets to add to a profile (Gabriela 2015).

Brookings (2022) describe how the repo rate and the Fed fund rate tend to move in tandem over time. This means dramatic changes in the interest rate can have mirrored impacts in the repo market, on borrowing costs and returns on collateral. The Fisher equation (equation 1) depicts the relationship between nominal interest rates, real interest rates and inflation expectations. This is relevant because if players expect increased inflation levels, lenders

demand higher interest rates to compensate the anticipated loss of purchasing power, resultantly increasing bond yields (Meyer 2020). Philips (2006) refined this equation to what is expressed in equation 2 where the interest rate is indexed by the time of the bond to maturity (m) and uses m-period to offset the effects of inflation expectations as discussed. This addition has been used in various studies and contributed to the conclusion that markets are more likely to misprice bonds when inflation is hard to predict and volatile (Balfoussia and Wickens 2005)- again highlighting the influence inflation has on the attractiveness and subsequent yield of bonds.

$(1+i)=(1+r)(1+\pi)$……..……Equation 1

$i_t^m = r_t^{e,m} + \prod_t^{e.m}$……..……..…..Equation 2

2.2 Discussion of existing literature

Meyer (2020) investigated the relationship between government bond yields and a range of additional economic parameters and determined the relationship between bond yields and interest rates is positive. Therefore, a lower repo rate will cause a relative decline in bond yields. Mega and Widayat (2019) also found from all their tested variables, interest rates had the largest effect on bond yields and that low interest rates are associated with high bond prices.

Social considerations are also valuable to examine, particularly government stability and public confidence. Research conducted in Africa (Presbitero, Ghura, Adedeji and Njie, 2016) found high levels of GDP per capita and low public debt levels are conducive to a healthily functioning repo market. The study also highlighted the importance of a stable government for efficient issuances of sovereign bonds. Moreover, Meyer (2020) determined rising government debt because of weak fiscal positions had a positive relationship with bond yields due to rising risk levels.

The literature agrees higher levels of inflation are often paired with higher bond yields and lower prices. Tarditi (1996) identified a positive relationship between the two, while Kumar and Baldacci (2010) observed bond yields rise under increasing inflation expectations and higher fiscal deficits. This finding draws out the relationship between inflation and inflation expectations. Rickards (2022) investigated this association and discovered, owing to consumer behaviour, increasing levels of inflation become a self-fulfilling prophecy. When demand for a good exceeds the supply chain's ability for production, there is an excess demand, causing individuals to exhibit hoarding behaviour as they fear essential goods will be unavailable or too expensive for purchase- this was demonstrated with paper goods in the 2020 pandemic. As consumers increase their purchases of a specific good, by the law of supply and demand, its price rises accordingly. Conversely, during deflationary periods, buyers observe declining prices and delay investment as they anticipate additional price drops- exemplifying further deflationary conditions. This behaviour contradicts the typical forces of supply and demand and demonstrates a phenomenon known as the liquidity trap.

The effects of liquidity on bond yields have been researched extensively and Favero (2007) found no economically important effect of liquidity variables on bond returns. They also considered liquidity to only be valued when investors find no other attractive alternative investment opportunities (no substitute goods). The demand for liquidity primarily responds to the magnitude of transaction costs and changes in investment opportunities. This explores

how the repo rate affects the demand for bonds indirectly through liquidity, as high transaction costs discourage trading and hinder the smooth functioning of the market. The Federal Reserve Board (2011) describe the liquidity effect as a result of a reduction in the real interest rate. Its scale can be determined by the slope of the demand curve for reserve balances which depends negatively on the interest rate. This was supported by Fuhrer in 2017 who found distinctive intraday patterns in repo market liquidity and that it is negatively impacted by stress in the global financial system, such as high levels of debt, whereby increased interest rates are used as a mitigation strategy. This is in line with studies considering government stability as discussed.

Fink (2003) investigated an alternative relationship by looking at the impact of bond yields on GDP growth using a standard OLS regression. The study concluded more than 30% of the variation seen in economic growth in the US is attributable to the analysis of yield curves. In such examinations, it is difficult to determine a causal relationship however, documentation of a correlation is suitable evidence to justify the inclusion of GDP growth in the econometric analysis. Consequently, we would expect to see as growth increases, bond yields mirror this since there is a growing demand for capital.

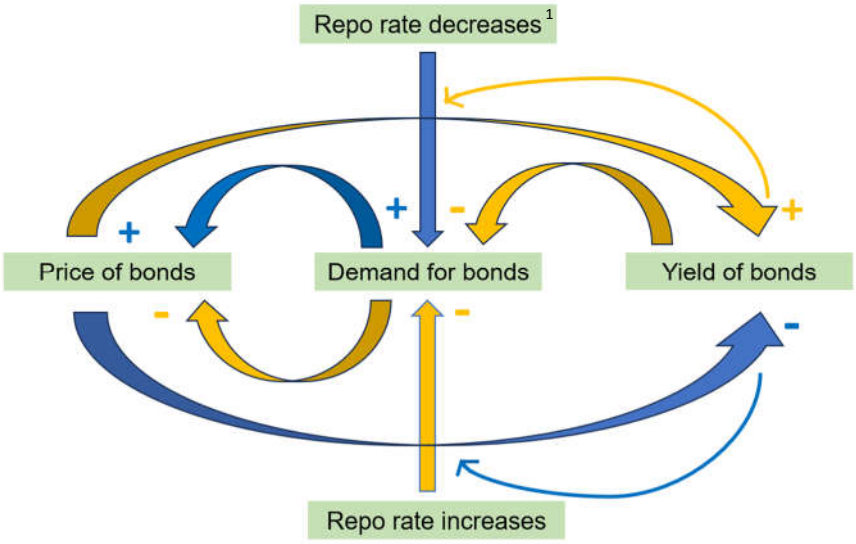
In a paper titled Global Waves of debt, the World Bank (2020) labelled debt to be one of the main sources of risk to global financial stability and economic growth. In the US, the debt-to-GDP ratio at the time of writing sits at around 123% and is perpetually increasing. Reinhart and Rogoff (2010) conducted extensive research into the existence of a threshold for debt levels that were still conducive with a growing economy and subsequent strong economic performance. From their research, it is generally considered that when external debt exceeds 60% of GDP, annual growth rates decline by 2%. When this reaches 90%, growth rates are cut in half. The research prompts further inquiry into the sustainability of current debt levels in the US. When debt is high, the price of bonds are forced down since there are concerns about default risks, meaning investors demand higher yields.

2.3 Methodology and hypothesis

Many papers aiming to establish a causal relationship among macroeconomic indicators derive conclusions based on ordinary least squares analysis. The method allows for hypothesis testing and determination of the significance of coefficients. It also helps to isolate potential confounding variables in the model. This was the case for Chowdhury (2013) who explained how OLS minimises the sum of residual squares.

This paper seeks to build on existing literature investigating the driving forces of changes in US government bond yields. The hypothesis relies on the assumption that the relationship between supply and demand is inverse as is demonstrated in figure 1. If this holds true, when the repo rate falls, the demand for bonds increases since they become attractive collateral for inexpensive borrowing. This results in more repo transactions taking place and more collateral being traded. Subsequently, due to both the law of supply and demand, and investors seeking a better return, the price rises and yield declines resultantly. This relationship can be demonstrated by a causal loop diagram as seen below.

Figure 3



The analysis of empirical studies provides a synopsis into the existing literature exploring the potential macroeconomic drivers of bond yields. Recurring variables in the papers are inflation, interest rates, debt levels and liquidity however the volume of traded collateral in monetary terms has to date not been explored. Currently, research relies heavily on the assumption that players in a repo transaction are rational consumers and act accordingly to the law of supply and demand. Branches of behavioural economics consider how the average consumer may lack smoothing preferences or be solely motivated by utility but is instead driven by other innate human tendencies such as greed, judgement, and fear. This paper seeks to investigate whether such behaviours are observable in the repo market, demonstrating how human purchasing patterns may drive the emergence of economic dynamics that influence bond yields and, in turn, reinforce these behaviours. Alternatively, the discussed literature may already possess full capability for explaining yield fluctuations which will also be considered in turn.

3. Data and variables

The data used in this analysis draws on various sources, namely the Federal Reserve Economic Database (FRED), to offer a holistic response to the question at hand. The time series data consists of 181 monthly observations from July 2008 to July 2023 examining various macroeconomic indicators in the US. This time frame was considered to ensure reasonable consideration of major economic events such as the 2008 recession and the COVID19 pandemic. It was necessary to use frequent data to account for the extreme volatility observed in the bond market. Monitoring of the repo market and data collection of daily trading volumes only began in 2008 following the fallout of the global financial crisis meaning the choice of sample time frame was limited. Table 1 offers an overview of all variables.

Table 1: All variables considered in the analysis.

[1] The repo rate is the interest rate at which central banks lend money to commercial banks and investors.

Variable	Source	Description
Change in bond yield[2]	FRED	The yield on US Treasury Securities with a constant 1-month maturity, quoted on an investment basis.
Change in value of collateral traded[3]	New York Fed	The value of collateral traded daily on the first of every month of the tri-party repo market. This is the market value of the collateral including the accrued interest.
GDP growth rate	Y charts	The growth rate of real GDP.
Inflation	Investing markets	Consumer price index- the change in the price of goods and services contained in a basket of consumer items.
1-year Inflation expectation[4]	FRED	The expected rate of CPI inflation in 12 months' time.
Debt-to-GDP-ratio	Calculated with FRED data	The ratio between a country's government debt and its GDP- used to indicate the ability for a country to repay debt.
Repo rate	FRED	Fed fund rate used as a proxy- the interest rate that depository institutions lend reserve balances to each other in overnight agreements.
Market CMDI	Federal Reserve Bank of New York	Corporate bond market distress index. Considers multiple indicators including primary and secondary market pricing, liquidity, and relative pricing between traded and non-traded bonds.
Asset liquidity	FRED	($millions), liquidity refers to the ease securities can be readily converted into cash without having subsequent impacts on their market price.
Real interest rate	FRED	The nominal interest rate adjusted for inflation, representing the purchasing power of capital.
Recession dummy	Calculated with Y charts data	Defined by two consecutive quarters of declining GDP.

[2] The growth rate of bond yields has been calculated for use in the regression rather than the raw data to ensure uniformity in data comparisons. It means all variables used in the final model are represented as a percentage. Additionally, since the aim is to determine causality, using the growth rates of the dependent and primary explanatory variable will help to enhance the robustness of the results by focusing on relative changes rather than absolute levels.

[3] The growth rate has been used for this variable due to the scale of the figures in the raw data. Large numbers can lead to multicollinearity and overfitting which provides unreliable coefficients. It also makes graphical illustrations of various plotted datasets easier to interpret.

[4] Endogeneity is a common issue in time series data. Forecasting future values creates a version of a lagged variable (independent exogenous variable) and can be useful to act as a predictor in analysis. This helps to mitigate the effect of endogeneity since values are not influenced by the current errors in the model.

LCR dummy	BIS	Bank policy to maintain a minimum liquidity coverage ratio based on their holdings of high-quality liquid assets (HQLA).

Table 2: Summary statistics of key variables.

Variable	Mean	Maximum	Minimum	Median	Standard deviation
Change in bond yield	-44%	100%	-4600%	0%	351%
Change in collateral value	0%	13%	-8%	1%	3%

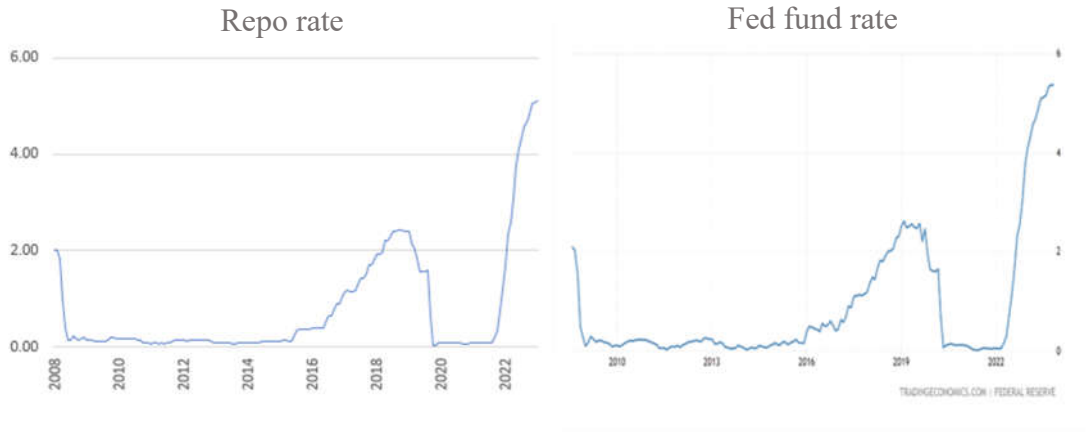
The dependent variable in this analysis is the change in bond yields. Models will assess the impact of various explanatory variables on the yields to determine the main driver for the observed changes through a series of statistical regressions. The change in collateral value is the primary independent variable chiefly attributable to its ability to represent demand and the hypothesised importance this has in driving market changes. It should be noted increases in the volume of collateral assumes a higher number of transactions rather than larger transactions in monetary terms- the same is true for a decrease.

An initial assessment of correlation between the two variables produced a value of 0.657 which is considered a moderately positive relationship. However, correlation cannot indicate causation, demonstrating the need for the inclusion of control variables for robust econometric testing.

There are various other macroeconomic indicators which, to a degree, drive bond yields that have been extensively covered in the discussed academic literature. For validity and robustness reasons, these have been included as control variables in the analysis- initially to determine their significance and then the degree to which they account for the observed changes in yield. Additionally, this will reduce omitted variable bias and assist in establishing a comprehensive conclusion. The analysis considers repeatedly occurring variables in the literature, namely interest rates, inflation, and the debt-to-GDP ratio, in addition to GDP growth, asset liquidity, bond distress index, the repo rate, a recession dummy and an LCR policy dummy.

The Fed Fund rate has been used as a proxy for the repo rate as the two generally move in tandem (Brookings 2022) as seen in figure 4. The similarity between the two measures makes the Fed fund rate an appropriate substitute since raw repo rate data is costly to obtain.

Figure 4



4. Methodology

To determine if there is a statistically significant causal relationship between collateral value and bond yields, econometric analysis has been carried out with data in monthly intervals over 15 years from July 2008 to July 2023.

The specified model is a lagged ordinary least squares model that employs first differences and lags for certain variables, alongside robust standard errors and the transformation into squared form for rigorous analysis. The primary reason for this model selection was its ability to capture temporal dependencies in both the dependent and independent variables. The model also offers ease of adaptability meaning issues of seasonality and non-linear relationships (as assumed with the debt-to-GDP ratio by Reinhart and Rogoff) can be captured and addressed. The model was established through a series of statistical tests assessing the robustness and appropriability of the data.

As is important for time series data, firstly, all variables were tested for stationarity and the presence of a unit root using the Augmented-Dickey Fuller (ADF) test. The null hypothesis is that a unit root is present, and the data is non-stationary, the opposite is true for the alternative hypothesis. The status of the variables is determined by the given P-value where a numeric <0.05 indicates the null hypothesis can be rejected and there is no unit root in the data. This is a crucial first step since non-stationary data can lead to a spurious regression. To offset the effects of any non-stationary variables, first differences were taken and tested again using the ADF test, the results of which can be seen below in table 3.

Table 3: Results of test for stationarity.

Variable	**Pass(I(0))/Fail(I(1))**	
	Before first differencing	*After first differencing*
Change in bond yield	I(0)[5]	NA
Change in value of collateral	I(0)	NA
GDP growth rate	I(0)	NA
Inflation	I(0)	NA

[5] I(0) indicates the variable is integrated order of 0 meaning the data is stationary

Inflation expectation	I(1)[6]	I(0)
Debt-to-GDP ratio	I(1)	I(0)
Repo rate	I(1)	I(0)
Market CMDI	I(1)	I(0)
Asset liquidity	I(1)	I(0)
Real interest rate	I(1)	I(0)
Recession Dummy	NA	NA
LCR dummy	NA	NA

After running the pre-requisite tests on the data, an initial OLS model was run to determine the explanatory power of the primary independent regressor alone on changes in bond yields. The R^2 for this test is 0.037 indicating very weak predictive capability. For further insight into this relationship, all other independent variables were added as a robustness test which returned an R^2 value of 0.18. Those variables that were not significant in this model were removed.

At this stage, a time dummy was added to capture any underlying patterns or systematic trends in the data occurring over time. Time variables also help to capture seasonality or cyclical fluctuations that may not have been addressed through differencing.

The model was then tested for autocorrelation using the Durbin-Watson test where a P-value of >0.05 indicates there is no autocorrelation. The P-values for this model showed positive autocorrelation was present. This violates the OLS assumption that all independent variables are uncorrelated with the error term. To control for this, lags were added to the variables to mitigate the influence of past values on future ones.

The Bayesian Information Criterion (BIC) was used to establish the minimum number of lags required for each variable; the results can be seen in table 4. BIC was preferred for this determination since it penalises mode complexity more heavily than AIC and carries a larger penalty for additional parameters- this means it is a better criterion to find the simplest model. The highest lag order is 4 meaning some variable behaviour is influenced by up to 4 months prior. This indicates there are potentially some quadrimestre trends in the data, the effects of which will be removed by including the lags in the regression as they adequately capture any underlying patterns. Once included, the LM test was used to retest for the presence of autocorrelation which returned a value >0.05 meaning the issue was resolved.

Table 4: Results for minimum number of lags.

Variable	**BIC minimum lags**
Change in bond yield	0
LCR dummy	NA
Collateral value change	4
GDP growth rate	0
Market CMDI	0
d_Repo rate	2
d_Real interest rate	4
d_Inflation expectation	1

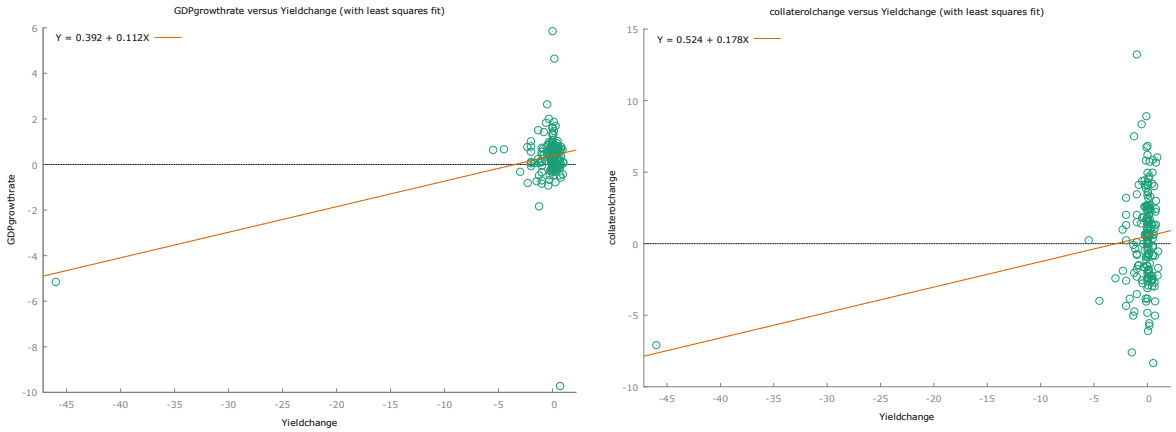
[6] I(1) indicates the variable is integrated order of 1 meaning there is a unit root and the variable is non-stationary

For this investigation, it was not appropriate to include lags of the dependent variable since it could introduce endogeneity and compromise the primary goal of establishing causality. Additionally, stationarity was already established in the dependent variable meaning the past values do not exhibit systematic patterns over time and there are minimal temporal differences in the data.

Once lagged, the relevant variables were checked for collinearity using the variance inflation factor (VIF). Collinearity is frequently problematic for time series data due to the existence of seasonality and time trends. A VIF value >10 indicates there is collinearity in the regression, all variables had results <10 demonstrating this was not an issue.

The change in collateral underwent transformation to its squared value as well as the GDP growth rate, following the guidance of Ockey (2011), to improve predictive accuracy and identify potential quadratic effects and interactions that may not be captured alone in the linear terms. The BDS non-linearity test was carried out on both variables and concluded there was no significant non-linearity in the data. Therefore, their linear terms were excluded in the model to avoid multicollinearity as the squared terms were sufficient to capture any non-linear relationships between the dependent and independent variables. The graphs below illustrate a scatter plot for each of the squared variables in their linear form plotted against the dependent variable.

Figure 5



The GDP growth rate variable was squared as to align with the literature where, using this technique, Ockey (2011) found benefits of equal variance in the error terms, improving the model fit and R^2. Selectivity in squaring variables was crucial as to not overfit the model. It is possible some squared variables could be highly correlated with other linear terms in the model (e.g. inflation and inflation expectations). Additionally, adding squared terms has the potential to give rise to multicollinearity which was not initially an issue. This method was more appropriate than logging the data since numerous variables in the model were growth rates of highly volatile indicators meaning there were negative values. Since these cannot be logged, multiple data points would have been omitted, reducing the robustness and reliability of any conclusions drawn from the data. Finally, Occam's razor suggests simpler models should be preferred when not at the detriment of model performance.

As to not violate the OLS assumption which states errors are normally distributed, the variables of interest were tested for normality using the Doornik-Hansen test as well as interpretation from histograms. Normality means the distribution is symmetric around the mean and the distribution of the mean, median and mode is equal at the centre of the

distribution. Normal distributions are characterised by a bell shape meaning the variance is constant. All variables of interest were normally distributed.

Another OLS assumption is that the variance terms of errors should be consistent for all observation. This assumption is violated in the presence of heteroskedasticity, which can be tested using the Breusch-Pagan test. A p-value less than 0.05 indicates heteroskedasticity exists. The test returned a value of 0.799 indicating the assumption is not infringed. Despite this, there is still merit in adding HAC robust standard errors to ensure statistical integrity and model ability to provide reliable estimates of uncertainty that may otherwise be compromised by previous autocorrelation.

5. Model specification

As explained, the final model aims to produce a holistic and reliable explanation for the reasons for movements in US bond yields. Table 5 illustrates the results of the model best fulfilling this objective.

Table 5: Final model specification results.

Specification:

$$\Delta TreasuryBondYield = \beta_0 + \beta_1((\Delta CollaterolChange_{t-4})^2) + \beta_2({GDPgrowth_t}^2) + \beta_3 LCRdummy_t + \beta_4 \Delta RepoRate_{t-2} + \beta_5 \Delta RealInterestRate_{t-4} + \beta_6 \Delta InflationExpectation_{t-1} + \beta_7 \Delta MarketCMDI_t + t + \epsilon t$$

Dependent variable: Change in bond yields

Variable	Coefficient	Standard error	t-ratio	p-value	Significance
Constant	-0.841	0.310	-2.710	0.007	***
Sq_CollateralChange~_4	0.150	0.090	1.672	0.096	*
Sq_GDPGrowthRate	-0.104	0.048	-2.152	0.033	**
LCRDummy	0.567	0.258	2.195	0.030	**
d_RepoRate~_2	-1.105	1.481	-0.756	0.457	
d_RealInterestRate~_4	-1.849	1.028	-1.798	0.074	*
d_InflationExpectation~_1	0.350	0.439	0.797	0.427	
d_MarketCMDI	-32.559	19.815	-1.643	0.102	
TimeVariable	0.008	0.007	1.122	0.264	

*** Indicates significance at the 1% level, ** indicates significance at the 5% level and * indicates significance at the 10% level.

S.E of regression	2.912
R-squared	0.357
Adjusted R-squared	0.331

To be able to interpret the coefficients correctly, it is important to highlight the dependent variable is linear and the independent variables are a mix of linear and quadratic representations. To calculate the magnitude of impact of the independent variables, the formula $\beta_1(X_t/Y_t)$ was employed. This calculation allows the coefficients to be read as elasticities to determine a proportionate effect on the dependent variable. The results are given as a percentage change of bond yield change following a 1% increase in any given variable, shown in table 6.

Table 6: calculated elasticities

Variable	Elasticity (effect of 1% change in X as a % change on Y)
Change in collateral volume	-3.673
GDP growth rate	0.347
Repo rate	0.044
Real interest rate	-0.001
Inflation expectation	0.002
Market CMDI	-0.141

6. Empirical analysis

6.1 Discussion

When interpreting the calculated elasticates under the assumption of ceteris paribus, it is vital to isolate the effects of each explanatory variable on the dependent variable to establish causality. To hold the other variables constant, numerous control factors were included in the regression to ease the interpretability of the results and identify the primary drivers of changes in bond yields.

The elasticities in table 6 demonstrate the monthly change in collateral traded has a statistically significant negative effect on the change in bond yields at the 10% significance level, representing a 10% probability of incorrectly rejecting the null hypothesis. Table 6 shows, for the selected sample of treasury bond yields in the US over the 15-year sample, a 1% increase in the growth rate of collateral traded will have more than a -3% impact on the growth rate of bond yields. This means for the average yield change of approximately -43%, a 1% change of the independent variable raises this to -47%.

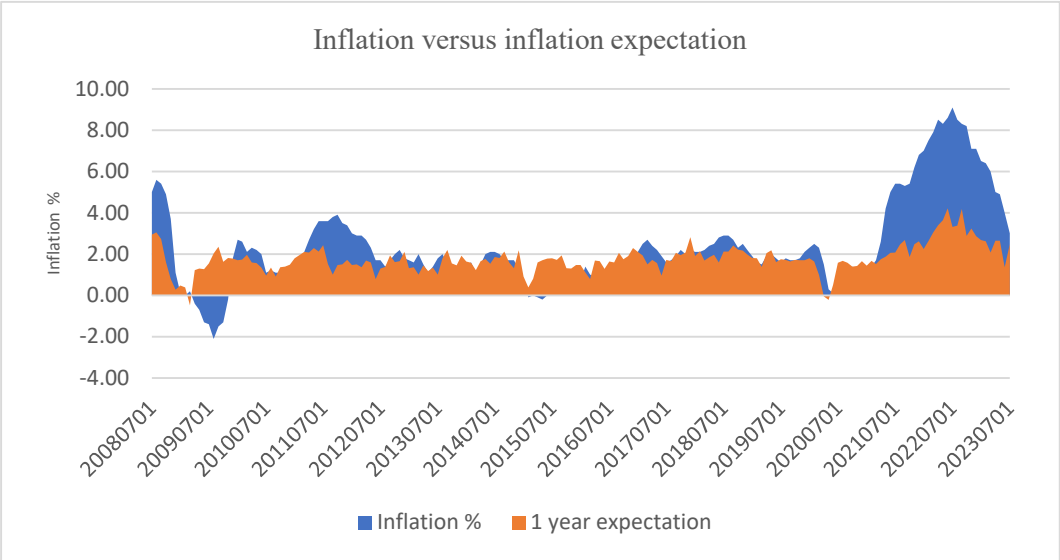
This result has the potential to offer significant contributions to existing academia. As discussed in the literature review, to date, explanatory factors considered to drive bond yields were constrained to historically researched macroeconomic indicators such as interest rates and inflation. The finding that collateral value has a statistically significant relationship with bond yields proves the previous neglect of the dynamics of supply and demand provides a less than whole insight into those drivers. The relatively high calculated elasticity also implies the change in bond yields is more than proportionately affected by the change in the volume of collateral traded. This is in line with the theory outlined in the causal loop diagram in figure 3 demonstrating that, as the collateral traded increases, yields decrease.

The result on row 5 indicates a slight inverse relationship between bond yields and interest rates. This contrasts the findings of Meyer (2020) who concluded there is a positive relationship between the two factors, similarly to the work of Mega and Widayat (2019), where interest rate had the largest effect on bond yields. Despite the difference in results, the elasticity is only fractionally negative, indicating the relationship is very inelastic and insensitive to change. This discrepancy may partly be explained by the lags added to the variable. Lags can cause multicollinearity and impact the transmission mechanism between the two variables blurring any causal distinction- this limits the capacity to account for variation.

Tarditti (1996) found a positive relationship between inflation rates and bond yields. Since inflation erodes the purchasing power of fixed interest payments on bonds, investors demand a higher yield to compensate the loss in real returns. Kumar and Baldacci (2010) found inflation expectations are a cause for increasing bond yields. This is supported by the findings

in table 5 showing there is a positive relationship between the two variables, although this is not statistically significant. Figure 6 displays the relationship between real inflation rates and inflation expectations, the two have a high correlation of 0.701 where inflation expectation is lagged by one period. The graph supports Rickards (2022) in that inflation levels are a somewhat 'self-fulfilling prophecy' and that consumer expectations about inflation cause a change in consumption behaviour and therefore the real rate of inflation in the following periods.

Figure 6

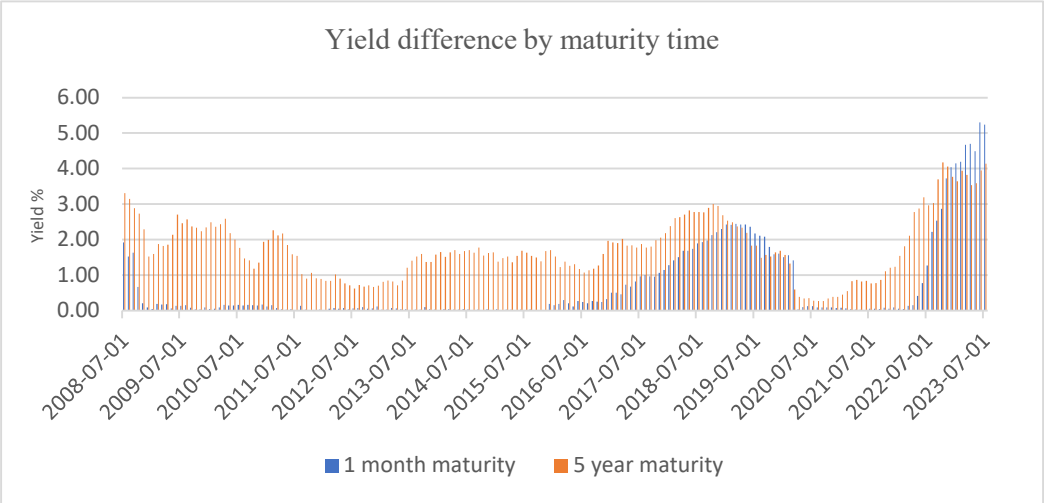


The inflation expectation elasticity for the assessed time series is also minimal meaning bond yields are generally unresponsive to changes in inflation expectations for the sample examined.

Brookings (2020) explain the changes made by the Basel Committee on banking supervision requiring banks to hold a minimum liquidity ratio based on the amount of high-quality liquid assets (HQLA) on their balance sheet. The regulatory expectation was that bank liquidity holdings would be sufficient to last 30 days of stress. In this change, government bonds were considered HQLA. This transition was accounted for in the regression and represented as the LCR dummy which was statistically significant at the 5% significance level. Ott (2020) found this change in policy obligation increased the demand for bonds. It suggests a step change in the demand for government bonds following the policy introduction in January 2015. The causal loop diagram in figure 3 shows an increased demand will decrease the yield of the bonds. Although the analysis does not include raw demand figures, the notable implied demand surge, evidenced by the LCR significance, suggests it is a strong driver for bond yields.

Figure 3 also explains how we would expect an increase in the repo rate to lead to an immediate decrease of bond yields. However, the elasticity calculated for the effect of the repo rate on bond yields demonstrates the opposite. One reason for this could be because the maturity of the bonds used in the dataset is one month. Generally, the longer the time to maturity, the higher the yield, accounting for the associated risk. Figure 7 helps visualise this comparison.

Figure 7



	Average
1-month maturity	0.71
5-year maturity	1.77

Although various market factors influence bond yields across different maturities, longer-term bonds typically offer higher returns. Considering 1-month as a significant amount of time for markets to adjust to changes in the repo rate, it is logical to assume the results in table 5 depict a long-term result of the change in the repo rate- illustrated by the second half (yellow arrows) of figure 3. The graph in figure 7 also evidences how yields increase during uncertainty (financial crisis, COVID19, rising inflation). This is because risk in the very short-term is considered higher than in the long-term, so customers demand a higher yield to accommodate this. This phenomenon creates a negative yield curve and can indicate declining interest rates prior to a recession (Rickards 2024).

The value of including GDP growth squared was highlighted by Barrow and Sala-i-Martin (1992) when explaining long-term economic growth rates. The variable is significant at 5% and, of the regressors included, is one of the primary drivers for changes in bond yields with an elasticity of 0.347%. This demonstrates a 1% increase in the squared growth rate of GDP will have approximately a 0.35% impact on the change in bond yields. This occurs because GDP reflects a countries economic health meaning high growth leads to higher inflation expectations and a subsequent sudden spike in demand for capital.

Variables not carried forward into the final model or those that display no significance were market CMDI, asset liquidity, debt-to-GDP ratio, and the recession dummy. It is important to note these factors are still required to understand the complexities, implications, and shortcomings of yield movements in the repo market, however, analysis of the magnitude of their effect is not within the scope of this study. It can also be difficult to acquire wholly reliable data for some of the variables such as liquidity since the market can be victim to facilitation of price discovery, allowing institutions to take advantage of arbitrage opportunities as discussed. This demonstrates issues of incomplete and imperfect information potentially producing misleading results.

7. Conclusion

7.1 Summary of main results

This paper uses econometric techniques in an OLS regression to assess the macroeconomic drivers of bond yields in the US. It aims to demonstrate the importance of considering the volume of collateral traded- which is indicative of demand. The evidence rejects the null hypothesis that collateral traded has no statistically significant relationship with bond yields- considered at monthly intervals in the US between 2008 and 2023. Using collateral volumes as a primary regressor has not yet been explored in the published literature. This paper successfully demonstrates the importance of its inclusion within assessments of the bond and repo markets.

The repo market facilitates short term overnight loans amongst both public and private investors and lenders. Understanding the economic mechanisms driving the observed yield accrued on the collateral used in these loans is crucial to allow for efficient trading practices and by extension, government investment into public services. Smooth running of the repo market is therefore reflective of Treasury decisions and a healthy liquidity ratio. Having a firm grasp of the conditions leading to economic contractions allows for effective mitigation of these scenarios through strategised monetary policy techniques.

The elasticity of -3.673% for changes in collateral volumes indicates bond yields are highly sensitive to those observed changes in collaterol. This evidence adds to the robustness and completeness of existing literature.

Despite the volume of collateral traded having the most dramatic impact on bond yields in terms of responsiveness, it is not the only regressor to have a statistically significant relationship. The results show GDP growth, and the real interest rate have a minimal yet significant inelastic impact on the US yields. Other significant variables can also be described as drivers of bond yields although their impact is largely inelastic as can be seen in table 6. The significance observed in other variables is broadly consistent with existing literature.

7.2 Policy implications

This paper recommends for the existence of an upper limit imposed on the total value of daily transactions in the repo market to curb the frequently large fluctuations observed in the yield data. Creating this stability means the yield on bonds is more consistent, subsequently preventing the oscillating bull and bear markets. The sustained bond yield will deter panic purchasing and manipulation of markets to obtain a favorable rate, further lessening the risk of arbitrage opportunities arising and the presence of moral hazards leading to market failures (BIS 2017).

Additionally, the Glass Steagall act proves more relevant today than ever where outside private demand for government bonds effectively corners policymakers into exercising options that prevent increasing levels of debt to ensure market attractiveness and favorable borrowing conditions. From this, it is reasonable to infer that government involvement in the repo market may indicate that the best interests of the public are not always central to the implementation of fiscal and monetary policy.

7.3 Recommendations for future research

Given both more resources and time, greater reliability of this research could be achieved with a larger sample size to conduct econometric testing. This should be both a longer time frame and the consideration of other countries, specifically those who have experienced

recent major economic downturns since this would better account for the impact of recession. Extending the time series may allow for greater consideration of the COVID-19 pandemic. To examine this, a dummy variable may be included to determine the magnitude of its impact.

It may also be beneficial to consider a wider range of bond types including corporate bonds and convertible bonds to understand more comprehensively the role of the private bond market and how public involvement in private markets may disrupt their efficient running. This should also involve an assessment of how the results differ for a range of time to bond maturities- specifically how the effects of the key identified drivers may change in the long and short run.

To pursue this, an in depth understanding of the TIC (Treasury International Capital) report is required to offer insight into private and foreign investors perceived safety and liquidity of bonds. This helps gauge international confidence in US debt to inform economic policy decisions and monitor global capital flows to assess market dynamics.

Lastly, analysis on the siloed relationship between certain explanatory variables, like the highly correlated inflation and inflation expectations, should be investigated for the existence of a causal relationship. This approach helps to address potential collinearity that cannot be identified through statistical testing.

It should be noted that failure to address the identified shortcomings in this report may mean the results suffer from omitted variable bias and lack of accuracy however, recognised issues have been thoroughly caveated throughout the paper.

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