MGT 6769 Fixed Income Securities
Term Project Report

SUBMITTED BY GROUP B

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Analysis of Common Shocks in Stocks and Bonds

1 Introduction

We start this exploration journey with the motivation to find the macroeconomic indicators or variables that drive the stock and bond market returns in tandem, and also have an economically justifiable intuition behind it. In other words, our aim is to find the mutual shocks driving the stock market and Bond yield returns. Although there are asset pricing models which can demonstrate a tight link between the variation in stocks and bonds, this kind of link is difficult to prove empirically. Also, good drivers of stock returns have poor results trying to gauge bond returns.

The crux of this paper [1] is the idea to decompose the variation in the US stock market and the Treasury yield curve into orthogonal shocks which have an intuitive economic interpretation. They isolate growth news, monetary news, and two distinct shocks generating time-varying risk premiums as common drivers of stocks and yields, recognizing that stocks and yields are differentially exposed to those shocks. Our aim is to model and explain the movement, or more importantly the comovement of these stocks and bond returns as a function of these 4 orthogonal shocks.

1.1 Related literature

Our project idea is taken from Anna Cieslak and Hao Pang (2019) [1]. They have based and referred to a series of research work in this domain that builds up to this idea of decomposing and figuring out shocks that can drive stock and bond returns.

Baele et al. (2010) [2] show that exposures to observable macroeconomic variables explain a relatively small fraction of the stock-bond correlations over time, and suggest that risk premiums drive a significant part of the comovement. Therefore, it is imperative for us to use this risk premium shocks along with the shocks of growth news and monetary news which are known to affect the returns.

1.2 Types of Shocks

We decompose daily innovations in stock returns and yield changes into orthogonal sources of news. We refer to the direction of the comovement of stocks returns with yield changes rather than with bond returns. Negative comovement of stocks returns with yield changes implies a positive comovement of stock and bond returns.

$$\omega = \begin{pmatrix} \omega^{g} & \textbf{growth news} \text{ (cash-flow risk)} \\ \omega^{m} & \textbf{monetary news} \text{ (pure discount-rate risk via short rate)} \\ \omega^{p+} & \textbf{hedging premium news} \text{ (compensation for cash-flow risk)} \\ \omega^{p-} & \textbf{common premium news} \text{ (compensation for discount-rate risk)} \end{pmatrix}$$

Figure 1: Decomposing Shocks

- Growth: Good news about the real activity in the economy (i.e. positive news about growth in general, like GDP increase expectations) increases both stock prices and yields
- Monetary: Good monetary news (news of monetary easing resulting in influx of cash in the economy) increases stock prices but depresses yields.
- Hedging premium ω_p+: It is a popularly known fact that bonds are instruments that are used to hedge growth or cash-flow risks present in stocks. So the premium in bonds existing because of this effect is the hedging premium. Any shock to this premium is hedging premium shock.
- Common premium ω_p-: Othe than the hedging premium, both stocks and bonds exposed to discount-rate risk like monetary and discount rate uncertainty in a similar manner and shocks of this kind affect both stocks and bond preices in the dsame direction.

Shocks that produce a common variation in equity and bond risk premium reflect the fact that stocks and bonds are both exposed to the pure discount rate news.

Shocks that drive risk premiums on stocks and bonds in opposite directions arise from bonds providing a hedge for cash-flow risk in stocks. We refer to these shocks as the common premium and the hedging premium, respectively.

Both premium shocks work to affect stock prices in the same direction (positive shocks lower stock prices), but they have opposite effects on bonds (a positive common-premium shock lowers bond prices and raises yields, while a positive hedging-premium shock does the opposite).

2 Modelling

2.1 Structural VAR Model

We first layout a general structure of modeling multi-asset universe through a structural Vector AutoRegression(VAR) model and discuss how we can recover shocks from the adapted model. In section 3, we go in further details of implementation methods and nuances of different approaches to reach to the desired recovered shocks.

Asset prices are modelled as affine functions of state variables.

$$Y_t = a + A * F_t \qquad rank(A) = dim(F_t) \tag{1}$$

$$F_t = \mu_F + \phi * F_{t-1} + \Sigma_F \omega_t \tag{2}$$

F_t beliefs about growth, monetary policy, uncertainty, time-varying risk aversion. We usually do not observe F directly, but we observe Y

$$Y_t = \mu_y + \psi(L) Y_{t-1} + u_t \tag{3}$$

Where ψ is the Lag operator. We can back out structural shocks ω_t from u_t and restrictions.

$$\omega_t = (A\Sigma_F)^{-1} u_t \tag{4}$$

Estimate VAR(1) in the yield changes Δy_t and log stock returns Δs_t to obtain the reduced-form shocks u_t

$$z_t = \Delta Y_t = (\Delta y_t^2, \Delta y_t^5, \Delta y_t^{10}, \Delta s_t)$$

$$Y_t = \mu_Y + \Psi(L) Y_t + u_t,$$

$$F_t = \mu_F + \Phi(L) F_t + \nu_t$$

$$u_t = \tilde{A}\omega_t, \quad \text{with} \quad \tilde{A} = A\Sigma_F.$$

We can obtain residuals from the reduced=form VAR equation(4), but to identify the matrix of $\tilde{A}$, which can be directly used to identify structural shocks $\omega = (\omega_g, \omega_m, \omega_{p+})$, we need some additional restrictions on the matrix. Typically, these restrictions were applied in the form of zeros of coefficients in traditional structural VAR models. As those restrictions do not make any economical sense in terms of shocks, as we know for a fact and y definition that all shocks have impact on all assets on any given day, without any consistent of null effect, we cannot simply apply the zero restrictions typically adopted for structural VAR models. We discuss the assumed restrictions to be applied in further and how to apply them in section 3.

2.2 Restriction to the Model

To have a set of realistic restrictions which can resemble with the definitions and the impact of the common shocks under consideration, we exploit the fact that the structure of $\tilde{A}$ is the interaction between the cross-section of assets and the common shocks. From empirical and intuitive understanding of impact of each individual shock on the cross section of assets, we can develop a set of restrictions which can be used to recover the shocks later.

Shocks that we identify are innovations to the information set of investors. We categorize our set of restrictions in 2 broad categories, namely, Sign Restrictions and Monotonicity Restrictions. Even after a comprehensive set of restrictions that we can impose, our approach leads to a set (as opposed to a point) identification of $\tilde{A}$, and has both advantages and costs. Although our model is simpler and less rigorous, we can recover shocks at daily frequency, which enriches the analysis of our outcome by getting rid of the limitation of event studies i.e. limited study of only selected macro-economic events or monitory policy announcements. Hence we can study continous evolution of investors expectations through these recovered shocks or innovations.

Restrictions on shocks to growth expectations: A positive growth expectations shock increases both stocks prices and yields. A number of empirical models predict that growth shocks move stocks and yields in the same direction due to any kind of growth expectations impact. Moreover, the impact yields at short-to-intermediate maturities are expected to be impacted much more than at long maturities as documented by a number of empirical studies such as Balduzzi, P., [4]. A detailed study of the updates of expectations about the GDP growth and the cross sectional impact on assets to verify this assumptions is done by the authors in the original publication by regressing the deltas on Bluechip Economic Indicators (BCEI) monthly survey [1].

Restrictions on monetary shocks: A positive monetary tightening shock decreases stocks prices and increases yields. Yields are simply increases due to the increase in rates and stocks are reduced due to the pronounced effect of the discounting factor of the cashflows in valuation The effect on yields declines in strength with yield maturity. This common understanding has been verified empirically by Rigobon, R [5]. In the cross-section of bonds, the response of the two-year yield is typically 2-3 times larger than the response of the ten-year yield as studies by Poole, W.[6]

Risk-premium shocks: Risk-premium shocks move the longer-end of the yield curve more than the short end. This understanding is supported empirically by teh study of Bansal, R., and I. Shaliastovich. 2013 [7]. The two shocks differ in the direction of the comovement between stocks and yields that they generate. We denote restrictions on risk-premium shocks that induce a positive comovement between yields and stocks as R^{p+} and those that induce a negative comovement as R^{p}. The estimates in this literature suggest that a one-standard deviation risk-premium shock moves the ten-year yield more than twice as much as the two-year yield.

The matrix of innovations of asset prices to structural shocks is related by the equation, $\tilde{A} = A\Sigma_F$, where the matrix $\tilde{A}$ is given by

$$\tilde{A} = \begin{pmatrix} A_g^2 & A_m^2 & A_{p+}^2 & A_{p-}^2 \\ A_g^5 & A_m^5 & A_{p+}^5 & A_{p-}^5 \\ A_g^{10} & A_m^{10} & A_{p+}^{10} & A_{p-}^{10} \\ A_g^s & A_m^s & A_{p+}^s & A_{p-}^s \end{pmatrix} \begin{pmatrix} \sigma_g & 0 & 0 & 0 \\ 0 & \sigma_m & 0 & 0 \\ 0 & 0 & \sigma_{p+} & 0 \\ 0 & 0 & 0 & \sigma_{p-} \end{pmatrix} \tag{5}$$

Sign Restrictions discussed above look like below after application:

$$\tilde{A} = \begin{pmatrix} + & + & - & + \\ + & + & - & + \\ + & + & - & + \\ + & - & - & - \end{pmatrix} \tag{6}$$

	Shocks			
	Short-rate expectations		*Risk premium*	
	growth $\omega^g \uparrow$	monetary $\omega^m \uparrow$	hedging $\omega^{p+} \uparrow$	common $\omega^{p-} \uparrow$
Yield changes	(+)	(+)	(−)	(+)
Stock returns	(+)	(−)	(−)	(−)
Stock-yield comovement	(+)	(−)	(+)	(−)

Figure 2: Sign Restrictions

Monotonicity Restrictions:
As it can be seen above, some shocks may have similar signs and it could be difficult to identify between each of them. Hence we discriminate between them through the following monotonicity restrictions. All below restrictions, depicted from Figure 3 have evidence based on literature and are quite intuitive. Equation 7 shows effect of monetary shocks and growth shocks over the term structure, as they are more prevalent on short term maturity. The equation 8 and 9 hold the same kind of relationship with magnitude relation such that it has an effect on conditional variance

$$A_m^2 > A_m^5 > A_m^{10}, A_g^2 > A_g^{10}, A_g^5 > A_g^{10} \tag{7}$$

$$(A_m^2 * \sigma_m)^2 + (A_g^2 * \sigma_g)^2 > (A_{p+}^2 * \sigma_{p+})^2 + (A_{p-}^2 * \sigma_{p-})^2 \tag{8}$$

$$(A_m^{10} * \sigma_m)^2 + (A_g^{10} * \sigma_g)^2 < (A_{p+}^2 * \sigma_{p+})^2 + (A_{p-}^2 * \sigma_{p-})^2 \tag{9}$$

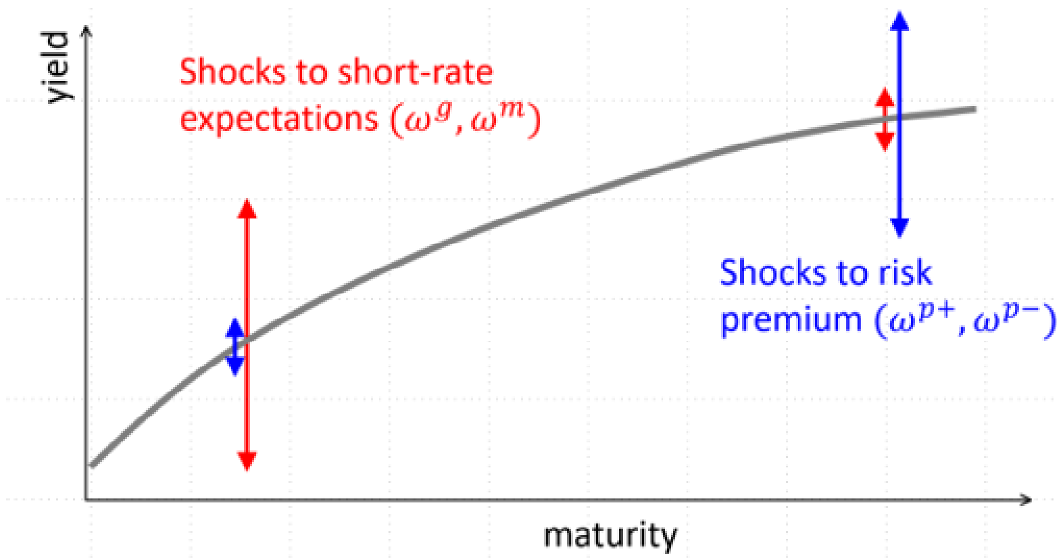

Figure 3: Monotonicity Restrictions

3 Implementation

We obtain reduced-form innovations to Y_t from a VAR(1) estimated on daily yield changes and daily stock returns, $z_t = Y_t = Y_t - Y_{t-1}$ for every day. We apply maximum likelihood on demeaned z_t. The lag length of one is already determined using the Bayesian information criterion(BIC) in the original paper, we directly use that fact to obtain a VAR trained model via using vars library in R. Using VAR(1) in changes implies a non-stationary dynamics of Y_t. While it is hard to argue theoretically that yields and price-dividend ratios have unit root, VAR(1) in changes is a convenient way of dealing with highly persistent dynamics in available data samples.

Then to recover the required stocks, we start from Cholesky decomposition of the reduced-form covariance matrix $A\Sigma_F$. Recovering the structural shocks requires identification of A matrix. Since

A matrix contains n^2 unknown elements, identification of A matrix requires at least n(n1)/2 restrictions to uniquely identify the elements of A. While it is difficult to impose sign restrictions directly on the coefficient matrix of the model, it is easy to impose them ex-post on a set of orthogonalised impulse response functions.

In our case, sign restrictions essentially explore the space of orthogonal decompositions of the shocks to see whether the responses conform with the imposed restrictions (Canova and DeNicolo, 2002). In addition to making a choice about the signs of the responses, we also specify monotonicity restrictions, which reduce the set of identifiable matrix and determine the distinction between all 4 shocks. For the ease of implementation and reduction of time complexity, we get rid of the orthogonality assumption and implement the following method. The steps involved in recovering the structural shocks, given a set of sign restrictions, can be summarised as follows

1. Run an unrestricted VAR in order to get A and E.
2. Extract the orthogonal innovations from the model using a Cholesky decomposition. The Cholesky decomposition here is just a way to orthogonalise shocks rather than an identification strategy.
3. Calculate the resulting impulse responses from Step 2
4. Randomly draw an orthogonal impulse vector α
5. Multiply the responses from Step 3 times α and check if they match the imposed signs.
6. If yes, keep the response. If not, drop the draw.
7. Repeat Steps 2-6.

Steps 4 and 5 need some further explanation. The impulse vector essentially sets the loading of the shock onto the variables (Doan, 2011). Uhlig (2005) shows that a vector is an impulse vector, iff there is an n-dimensional vector a of unit length, i.e. $||a|| = 1$ such that $\alpha = \beta a$ and $\beta\beta' = \Sigma$. Uhlig (2005) shows that, given an impulse vector $\alpha, onecansimplycalculatetheimpulseresponsesbymultiplyingtheimpuls$

$$\Sigma_u = PP'$$
$$u_t = P\omega_t*$$

P is lower triangular, ω_t* are correlated shocks with the property $Var(\omega_t*) = I$. Simulate rotation matrices Q such that $QQ = QQ = I$

Then we store 1000 (Q)'s for which $A'(Q) = PQ$ satisfies restrictions. Select the median-target (MT) solution with $\theta_i = vec(A'(Q_i))$ i.e., pick solution for which on-impact responses to are closest to the median of on-impact responses across solutions. Instead of the median target method, which is again computationally expensive, we use a method called median sampling, which simply samples the median values for each of the 1000 shocks we generated above for a given day. Note that because each shock has to be recovered using simulation 1000 times for every day from 1994 to 2016, we have to keep mind the complexity as the running time exceeds hours without the control on flexibility.

At last, we currently employ the above described model which is called partial identification model as each shock is extracted separately. This model is not necessarily worse than the direct methods applied by the authors of original method due to several reasons. Fry and Pagan explain the drawbacks of retrieving all shocks simultaneously in [8] and [9]. The primary reasons they mention is the assumption of apriori distribution in generating all shocks simultaneously and the local convergence of constraints due to the that. The separate shocks method implemented by us covers a larger space of possibilities and reduction in randomness of outcomes.

$$\theta^{MT} = \min_i \left[\frac{\theta_i - \text{median}(\theta_i)}{\text{std}(\theta_i)} \right]' \left[\frac{\theta_i - \text{median}(\theta_i)}{\text{std}(\theta_i)} \right]$$

4 Results

We have compared and contrasted our implementation methodology with the one employed in the original paper by authors. In this section we compare the results to the results displayed in the paper. Figure 4 shows the outcome of the median sampling technique followed by partial identification method. The figure 5 shows the direct method employed with median target method. Most of the results and general trends are expected to be similar in both of them, but will not have the same solutions. Primary reason is the magnification of variance on a particular shock because of the partial identification.

As we can see in figure 6 and 7 comparison, the growth shock is quite identically retrieved. Note the difference in scale, we can clearly see the reduced growth expectations during the periods of recession. The same trends are followed by all rest of the shocks in figure 4 and figure 5. We can see the trend is similar, while the scale in our results is a little bit higher due to the magnification. Another reason for differences in monetary shock and common premium shock towards the end of the graph is due to the fact that, the overall effect of variance in the figure 5 is decomposed over monetary and common premium shocks, while our results have more pronounced effect of both of them due to the partial identification. Overall, the shocks recovered by us are quite similar to the original ones in terms of analyzing trends or the mean prediction of the market. We explain the support study of events in the Section 5 using the original results for the same reason of a more complete and orthogonal decomposition of variance done by the authors and to show the evidence of the overall idea working.

We can observe from the results of the paper in Fig 7, that the growth shocks superimposes with the forecast updates of real GDP growth expectations from the BCEI survey. The shocks and survey updates are cumulative over a 12-month period. Survey updates are for the current quarter. Both variables are standardized to have a zero mean and unit standard deviation. Such closely related comovement in our recovered growth shocks and BCEI survey confirms the accuracy of our results and tests of our hypothesis that the shocks are apt innovations to the investors the growth expectations.

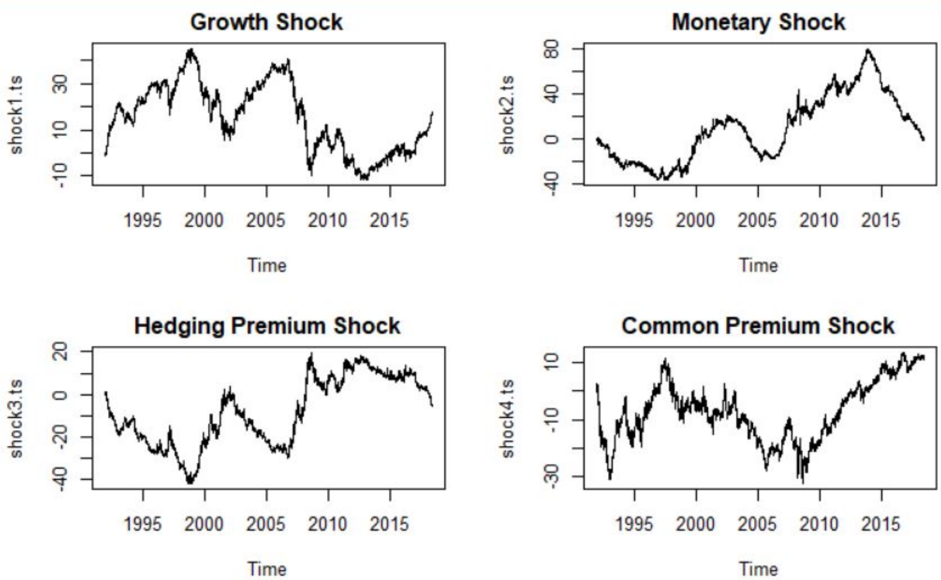

Figure 4: Decomposing Shocks

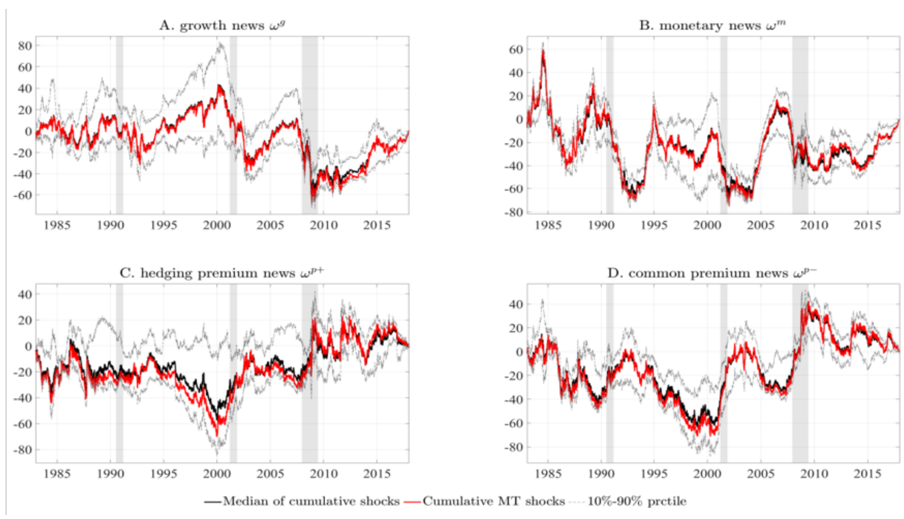

Figure 5: Decomposing Shocks by the paper

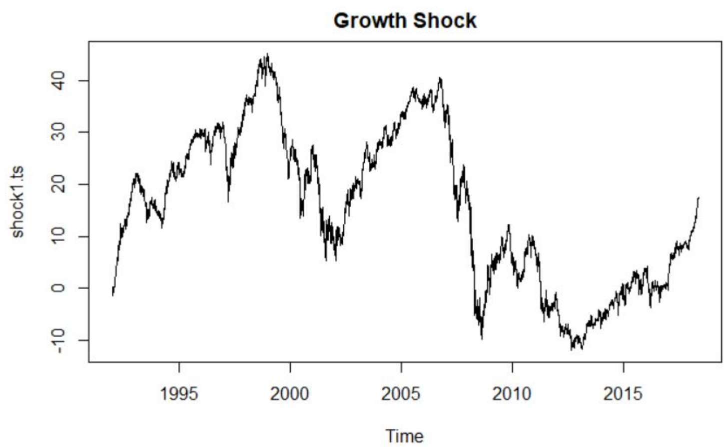

Figure 6: Growth Shocks from our improved model

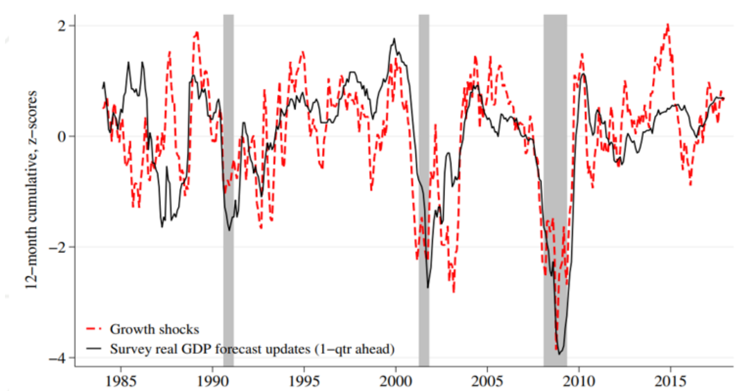

Figure 7: Growth Shock Results from the paper

5 Event Study

The channels of Fed's policy transmission occur in three channels:

- Conventional monetary channel – where Fed exogenously changes short rate
- Information channel – where Fed reveals information about growth that investors didn't have
- Risk-premium channel – where Fed influences the amount of risk perceived by investors

Let us now look into few event studies such as the FOMC announcement days and non-farm payroll announcements.

5.1 News on FOMC days

Using regression analysis performed on 192 scheduled FOMC meetings during 1994-2017, we can notice that the stock returns are positive and significant whereas the Yield changes for both 2-year and 10-year bonds are not significant during the FOMC announcement days.

Here the dependent variable is the overall return or yield change. It is the overall variation of each shock. We can also see that the impact of growth shock is not significant for both stocks and bonds. Almost 70% of the increase in stock returns is from the risk premium shocks.

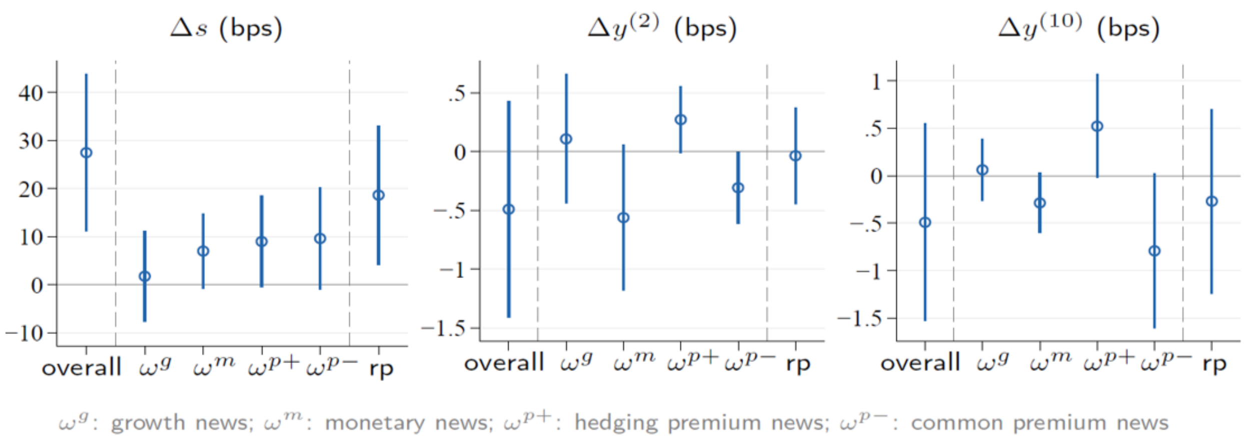

Figure 8: Stock returns and yield changes on scheduled FOMC announcement days

When it comes to FOMC cycle, it was observed from the literature that the excess stock returns are significantly higher in even weeks 0, 2, 4 and 6 of the FOMC cycle. The same cannot be said about the bonds. From the table, we can see that common premium shock has large impact causing high return in even weeks. We observed that the impact of hedging risk shock on FOMC announcement day is higher than during the even weeks of FOMC cycle indicating that the hedging risk premium dissipates over time during the FOMC cycle. Similar to the FOMC announcement day scenario, even here we can observe that the impact of the shocks on bonds are much weaker and are only significant in case of week 0 of 10-year bond.

	(1)	(2)	(3)	(4)	(5)	(6)
	Overall	Of which due to shock:				
	A. Log stock returns (bps)					
	Δs	ω^g	ω^m	ω^{p+}	ω^{p-}	ω^{p+}, ω^{p-}
Week 0 dummy	13.4***	4.23**	0.88	0.63	7.68***	8.31***
	(3.09)	(1.99)	(0.52)	(0.25)	(3.76)	(2.58)
Week 2, 4, 6 dummy	10.2***	1.29	2.04	2.66	4.25***	6.91***
	(3.03)	(0.82)	(1.64)	(1.45)	(3.02)	(2.97)
Constant	-5.89***	-0.96	-1.21*	-1.03	-2.69***	-3.72***
	(-3.03)	(-1.02)	(-1.65)	(-0.95)	(-3.25)	(-2.75)
N	6053	6053	6053	6053	6053	6053
	B. Two-year yield changes (bps)					
	$\Delta y^{(2)}$	ω^g	ω^m	ω^{p+}	ω^{p-}	ω^{p+}, ω^{p-}
Week 0 dummy	-0.030	0.26**	-0.075	0.021	-0.24***	-0.22**
	(-0.15)	(2.08)	(-0.56)	(0.27)	(-4.01)	(-2.25)
Week 2, 4, 6 dummy	-0.13	0.083	-0.16*	0.083	-0.13***	-0.049
	(-0.84)	(0.88)	(-1.67)	(1.50)	(-3.21)	(-0.72)
Constant	0.091	-0.060	0.10*	-0.032	0.083***	0.051
	(1.00)	(-1.05)	(1.72)	(-0.99)	(3.45)	(1.24)
	C. Ten-year yield changes (bps)					
	$\Delta y^{(10)}$	ω^g	ω^m	ω^{p+}	ω^{p-}	ω^{p+}, ω^{p-}
Week 0 dummy	-0.46**	0.15**	-0.039	0.040	-0.62***	-0.58***
	(-2.00)	(2.07)	(-0.58)	(0.28)	(-3.91)	(-2.67)
Week 2, 4, 6 dummy	-0.22	0.049	-0.084*	0.16	-0.34***	-0.18
	(-1.27)	(0.87)	(-1.68)	(1.51)	(-3.13)	(-1.20)
Constant	0.17*	-0.035	0.052*	-0.063	0.22***	0.15*
	(1.66)	(-1.05)	(1.75)	(-0.99)	(3.37)	(1.68)

Figure 9: FOMC cycle regressions

5.2 Non-farm payroll announcements

Let us now look into another event study which is the non-farm payroll announcement. We can describe the state of the economy into three classes which are (i) good, (ii) neutral and (iii) bad based on the current employment rates. When the non-farm payroll news is bad, we can notice that the stock returns are negative in case of bad and neutral economies and positive in case of good economy.

Although the impact of growth news is negative, the investors belief of the beginning of monetary easing results in positive stock returns. The negative effect of monetary news on stocks is visible when the state of the economy is good and neutral. The combined impact of the risk premium news on stocks is insignificant across the six scenarios. Hence, we can conclude that risk premia do not move on non-farm payroll news. From these event studies, we can say that our recovered shocks are empirically supported.

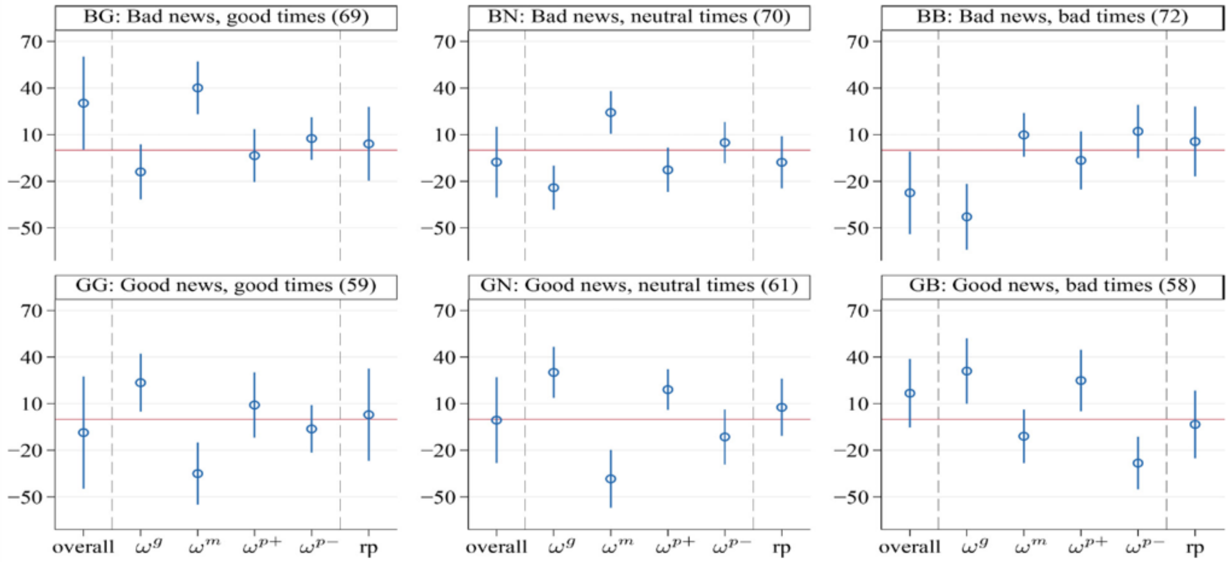

Figure 10: Stock returns on non-farm payroll announcement days

6 Conclusion and Discussion

We introduce a novel technique to analyze the source of variation in asset prices and reduce the variations in 4 shocks the the economy of 4 state variables, namely, growth expectations, monetary policy expectations, risk premiums. We further discriminate between common risk premium and hedging risk premium which primarily differs in terms of the comovement of yields and stocks, which is more nuanced study of the daily innovations. We make use of the standard structural VAR representation of economy, to recover shocks on daily basis, which is contrast to the traditional event studies and provides a daily set of information on the updates of investors expectations.

We discuss the advantages and drawbacks of various methods in the implementation section, and contrast their results in section 4. As the technical differences are covered in section 3, the comparison of results provide a further understanding of the analytical impact of using both the methods on the undertaken problem statement. The identification of shocks is economically intuitive and empirically driven through literature. The approach is verified later through event studies, supporting the intuition of the shocks and providing further analysis of the event studies. As there is no clear answer as to which method should be employed, we contrast both methodology and results of the techniques, one can weigh the factors according to the purpose of the analysis.

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