Expected inflation, real rates, and stock-bond comovement

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Abstract

This paper documents that the correlation between quarterly excess stock returns and contemporaneous changes in short-term real rates varies widely over the 1969–2017 period. The variation aligns with the well-known variation in the correlation between stock returns and changes in long-term nominal bonds. Stock returns and changes in real rates are projected on survey-based news about the macroeconomy, producing macro-spanned stock returns and real-rate changes, as well as residuals. The variation over time in stock returns–real rate comovement is entirely driven by the covariances of residual components. The covariances of the macro-spanned components are positive and stable over time. This result casts considerable doubt on attempts to explain time-varying comovement with time-varying macroeconomic dynamics.

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1 Introduction

The correlation between stock and nominal bond returns varies widely over time, occasionally switching sign. Figure 1 illustrates patterns first identified by Li (2002) and Fleming, Kirby, and Ostdiek (2003). Daily stock returns and contemporaneous daily changes in long-term nominal Treasury yields move together in the early 1960s. They are strongly negatively correlated from the 1970s through the late 1990s. After an abrupt sign change around 1997, the correlation remains positive through much of the 21st century. (Recall that correlations between stock and bond returns have the opposite sign of those in Figure 1.) This time-variation in daily comovement also holds for monthly, quarterly, and annual horizons.

As economists, we want to understand this evidence using intuition grounded in our standard dynamic frameworks of the macroeconomy and asset pricing. Much of the existing research focuses on time-variation in the conditional correlation between expected inflation and expected aggregate cash flows to equity. For example, Burkhardt and Hasseltoft (2012) and David and Veronesi (2013) allow macroeconomic dynamics to swing from countercyclical expected inflation—stagflation—to procyclical expected inflation. These regimes can in turn be tied to changes in the monetary policy rule, as in Song (2017) and Campbell, Pflueger, and Viceira (2015).

I take the perspective that the behavior of real rates, rather than that of expected inflation, is central to the changing dynamics of stock returns and nominal bond yields. This approach has its roots in two strands of recent empirical work. First, Duffee (2018) shows that conditional volatilities of long-horizon inflation expectations are small. Innovations in nominal yields are attributable mostly to news about expected future real rates and news about expected excess bond returns. An obvious corollary is that since there is not much news about expected inflation, conditional covariances of this news with news about future cash flows cannot vary much over time. Second, Campbell, Shiller, and Viceira (2009), Campbell, Sunderam, and Viceira (2017), and Liu (2017) all observe that the conditional comovement between stock returns and long-term inflation-indexed yields is roughly similar to the conditional comovement between stock returns and long-term nominal yields.

This evidence is intriguing but leaves two questions open. First, is the similarity between stock-nominal bond comovement and stock-real bond comovement just an artifact of the short sample period during which inflation-indexed government yields are observed? Second, is the similarity driven by dynamics of short-term real rates or common dynamics of real and nominal risk premia?

I examine empirically the comovement between quarterly changes in short-term (three-month and one-year) ex ante real rates and quarterly excess stock returns. Real rates are constructed by subtracting survey forecasts of inflation from nominal yields. This methodology allows me to study comovement from 1969 through 2017. The analysis begins with the observation, consistent with Figure 1, that correlations between stock returns and changes in short-term nominal yields were substantially higher after 1996. For example, the correlation with changes in one-year real rates rose from -0.13 to 0.36.

Our dynamic macroeconomic models tell us that both real rates and stock returns respond to macroeconomic news, thus the time-varying second moments should be connected to time-varying reactions to such news. I test this intuition. Macroeconomic news is inferred from quarterly revisions in survey forecasts of future output growth and inflation. I regress stock returns and changes in real rates on this news, producing news-linked components and residual components.

The first surprising result is that time variation in second moments is driven by the residual components, not the news-linked components. Over the entire sample, news about current and future GDP growth and inflation produces a positive covariance between stock returns and changes in real rates. This covariance varies little between the early and late parts of the sample period. By contrast, the covariance between the residual components is negative and large in the early part of the sample, and roughly zero since the late 1990s. A similar pattern holds for the covariance between stock returns and changes in long-term nominal yields.

In other words, the action in the stock-bond covariance is driven by variation orthogonal to macro news. Naturally, this evidence is difficult to reconcile with dynamic macro models of time-varying comovement, which puts macro news at the heart of variations of stock prices and interest rates. Nor can it be explained by models that emphasize time-varying risk premia dynamics, which are irrelevant to short-maturity real rates.

The second surprising result is that changes in real rates are more closely associated with news about current output than with news about expected future output. Real rates tell us how investors trade off consumption today for consumption in the future. Thus our macro-finance models typically link real-rate news to news about expected changes in future output rather than shocks to current output. Evidence supporting this typical channel is difficult to find in the 1969 through 2017 sample.

The next section describes the empirical approach and the data. Section 3 presents results for comovement between stock returns and changes in real rates. Section 4 incorporates changes in long-term nominal bonds. Section 5 briefly connects the empirical results to a New Keynesian dynamic model. Section 6 concludes.

2 The Data and the Methodology

In brief, I decompose both quarterly excess stock returns and quarterly changes in ex-ante real rates into a components spanned by macro news and components orthogonal to macro news. I then study the properties of the covariances produced by this decomposition.

2.1 Ex ante real rates and other asset information

The ex ante j-quarter real rate is the difference between the j-quarter nominal rate and expected inflation over the next j quarters. Beginning with Pennacchi (1991), researchers studying real-rate behavior often use survey forecasts of inflation to infer expectations.

In the middle of the second month of every quarter, respondents to the Survey of Professional Forecasters (SPF) provide forecasts of future values of the GDP deflator. Respondents also forecast future values of GDP, which I discuss in the next subsection. I use cross-sectional mean forecasts ("consensus" forecasts) for quarter t to construct $quarter - t$ forecasts of inflation during quarters t, $t+1$, $t+2$, $t+3$, and $t+4$. Note that quarter-t inflation is forecasted rather than known; it is not announced until sometime during quarter $t+1$.[1] The first observation is 1968Q4. I use data through 2017Q4.

Quarter t's ex ante three-month real rate is the quarter-t yield on a one-quarter Treasury bill less the quarter-t consensus forecast of one-quarter-ahead inflation. I use nominal yields from the middle of the second month of the quarter to match survey's timing.[2] Similarly, the ex ante one-year real rate is the one-year nominal Treasury yield less the mean of consensus

[1] Cross-sectional mean calculations drop outliers, as in Bansal and Shaliastovich (2013).

[2] The yield is for the 15th of the second month in the quarter. If the 15th is not a trading day, yields are observed on the last trading day prior to the 15th.

forecasts of inflation from one to four quarters ahead.[3]

This methodology presumes that consensus survey forecasts correspond to subjective forecasts of marginal investors. We do not observe forecasts of marginal investors. However, substantial research supports the view that consensus forecasts are, from an econometric perspective, as accurate as any other type of forecast. Duffee (2018) discusses the evidence of Ang, Bekaert, and Wei (2007), Faust and Wright (2009), Croushore (2010), Chernov and Mueller (2012), and Faust and Wright (2013). frontier of our forecasting ability." An alternative view, advocated by Coibion and Gorodnichenko (2012), is that consensus inflation forecasts are sticky owing to some inattentive respondents. The on line appendix to Duffee (2018) argues their results are more likely attributable to specific unforecastable events that produce in-sample patterns that look like stickiness.

The empirical analysis to follow also uses stock returns and long-term nominal yields. Like real rates, quarterly excess stock returns are aligned with survey forecasts. The quarter-t raw return, constructed from the CRSP daily value-weighted index, is from the middle of the second month of the previous quarter through the middle of the second month of quarter t. The excess return is constructed by subtracting the return to a one-quarter Treasury bill over the same time period. The mid-quarter yield on a ten-year nominal Treasury coupon bond is drawn from the CRSP Daily Fixed Income file.

Armed with these data, we can take a first look at real rate comovement. Recall from Figure 1 the sharp break around 1997 in the correlation between daily stock returns and daily changes in long-term nominal bond yields. We have quarterly rather than daily observations of ex ante real rates, thus this high-frequency methodology is unhelpful here. Instead, we ask two questions that motivate the empirical work that follows. First, do we see the same shift in comovement using *quarterly* stock returns and changes in nominal yields? Second, do we see a similar shift in comovement between quarterly stock returns and changes in ex ante real rates?

Panel A of Table 1 answers these questions by splitting the quarterly sample in a couple of places. The correlation between excess stock returns and changes in the ten-year nominal Treasury yield rose from −0.22 during 1969 through 1996 to 0.24 during 1997 to 2017. This latter sample includes both the pre-crisis period and the crisis/aftermath period. During

[3]The surveys of 1969Q1, 1969Q2, 1969Q3, 1970Q1, and 1974Q3 do not have forecasts of inflation for quarter $t + 4$. For these dates I use $t + 3$ forecasts as proxies for $t + 4$ forecasts.

both—splitting the sample at the end of 2017—the correlation is much higher than it is in the pre-1997 period.

The levels of the correlations between stock returns and ex-ante real rates are higher than those involving nominal bond yields, but exhibit similar changes. For the three-month (one-year) rate the correlation rose from zero (−0.13) before 1997 to 0.32 (0.36) after 1997. Correlations with real rates were particularly high just before the crisis, exceeding 0.4, and remain high during the crisis and the aftermath, exceeding 0.2.

Panel B reports corresponding information for covariances. The empirical work that follows uses covariances rather than correlations because the math of covariances is cleaner. The two panels, of course, tell the same tales.

The remainder of this paper focuses primarily on comovement between stock returns and real rates. This comovement is interesting in its own right. In addition, applying Occam's razor, what we learn about this comovement is likely informative about the comovement between stock returns and long-term nominal yields. It is more plausible that a common explanation underlies their joint variation through time rather than two separate explanations.

2.2 The empirical approach: I

The methodology of Baele, Bekaert, and Inghelbrecht (2010) is close in spirit to my approach. They also study quarterly-level data in their analysis of time-varying second moments of stock returns and long-term nominal Treasury bond returns. In their setting, stock and bond returns are driven by specified "macro" factors, "risk premium" factors, and "liquidity" factors. Formally,

$$\begin{pmatrix} \text{excess stock ret} \\ \text{excess bond ret} \end{pmatrix}_t = \mu + F_1 \tilde{X}_{macro,t} + F_2 \tilde{X}_{risk,t} + F_3 \tilde{X}_{liquid,t} + \eta_t, \tag{1}$$

where the parameters of factor loadings are in the F matrices and tildes represent shocks to the factors. The macro factors are

$$X_{macro,t} = \begin{pmatrix} \text{current output gap} \\ \text{expected quarter-ahead output gap} \\ \text{current inflation} \\ \text{expected quarter-ahead inflation} \\ \text{nominal 3-month Treasury rate} \\ \text{aggregate equity cash flows} \end{pmatrix}_t , \tag{2}$$

Note that their macro factor vector effectively contains the ex ante three-month real rate. Without loss of generality we could rotate the macro factor vector to include this real rate, dropping the nominal rate.

Baele et al. (2010) infer the macroeconomic expectations in (2) from consensus SPF forecasts of next quarter's real GDP and GDP deflator. Shocks to the macro factors are constructed by fitting the macro variables (other than aggregate cash flows) to a New Keynesian structural model. They use a regime-shifting model of factors' first and second moments to explain the dynamics of stock and bond return comovement.

I deviate from Baele et al. (2010) in four important ways. First, rather than burying the real-rate shock on the right side of (1), I highlight it by putting it on the left side, replacing the excess nominal bond return on the left. Second, I drop the risk premia and liquidity factors. Since neither risk premia nor illiquidity should affect short-term ex-ante real rates, they should not affect the covariance between changes in real rates and stock returns. Third, rather than constructing macro shocks by forcing the macro dynamics to be consistent with a New Keynesian model, I read the shocks directly off of successive quarters' SPF forecasts. Fourth, I do not estimate any type of regime-shifting model of second moments. I simply contrast results for two sample periods.

2.3 Macro news

Macroeconomic news is defined as news about current and expected future output and inflation. Formally,

$$\epsilon^x_{t,t+\tau} = E_t(x_{t+\tau}) - E_{t-1}(x_{t+\tau}), \qquad x \in \{y, \pi\}, \tag{3}$$

where y and π denote real GDP growth and inflation respectively. Revisions in survey forecasts proxy for this macroeconomic news. For example, in 1998Q2, there is a consensus forecast of inflation as of 1999Q1. One quarter later, in 1998Q3, there is different consensus forecast of inflation in 1991Q1. The change in the forecast from 1998Q2 to 1998Q3 is ϵ^π for 1998Q3. Since SPF forecasters predict output and inflation for the current quarter through four quarters ahead, the horizon τ in (3) ranges from zero to three quarters.

Naturally, the macro news at t for horizon τ_1 is not orthogonal to the news at t about horizon τ_2. Principal components (PC) analysis, summarized in Table 2, reveals that two factors account for almost all of the inflation news (more than 94 percent of the joint variation), and a large majority of the output news (87 percent prior to 1997, and more than 96 percent in the 1997 through 2017 period).

Figure 2 displays the loadings of the first two PCs for both macro variables and both time periods. The loadings are largely invariant to the sample period. The first PC of GDP growth has the largest effect on forecasts of current GDP growth, declining steadily to three-quarter-ahead forecasts. The second PC has opposite effects on forecasts of current and future GDP growth. The PCs of innovations in expected inflation appear qualitatively like those for GDP growth.

Since the first two PCs dominate the variation in GDP growth and inflation, I reduce the dimension of the macro news to increase estimation precision. All of the empirical analysis that follows uses news about current output and inflation ($\tau = 0$) and two-quarter-ahead news about output and inflation ($\tau = 2$). Alternative versions that add $\tau = 1$ do not reveal any additional interesting results.

2.4 The empirical approach: II

Stack the relevant macro shocks into a vector,

$$\epsilon_t \equiv \left(\begin{array}{cccc} \epsilon^y_{t,t} & \epsilon^y_{t,t+2} & \epsilon^\pi_{t,t} & \epsilon^\pi_{t,t+2} \end{array} \right)'. \tag{4}$$

Contemporaneous changes in real rates, as well as excess stock returns, are regressed on these shocks. The specification is

$$\left(\begin{array}{c} \Delta r_t^{(1)} \\ \Delta r_t^{(4)} \\ ex_t \end{array} \right) = \mu + F\epsilon_t + \eta_t, \tag{5}$$

where $\Delta r_t^{(j)}$ refers to the quarterly change in the j-quarter ex-ante real rate and ex is the excess aggregate stock return.

The comovement among changes in real rates and stock returns is

$$\text{Cov}_{t-1} \left(\begin{array}{c} \Delta r_t^{(1)} \\ \Delta r_t^{(4)} \\ ex_t \end{array} \right) = \underbrace{F\text{Cov}_{t-1}(\epsilon_t)F'}_{\text{macro covariance}} + \underbrace{\text{Cov}_{t-1}(\eta_t)}_{\text{residual covariance}}. \tag{6}$$

The part of the covariance spanned by macro news is labeled "macro covariance," and the unspanned part is labeled "residual covariance."

It is important to recognize that (5) is not a structural or quasi-structural description of how macroeconomic forces affect interest rates and stock returns. The idea behind (5) is simply that all macroeconomic shocks that move stock and bond prices (the left side of (5)) also affect current and/or expected future output and inflation (the right side). Equation (5), with four shocks to expectations on the right side, is consistent with a dynamic macro model that has four types of fundamental macroeconomic shocks. The key assumption is that the macro shock vector uniquely pins down the response of real rates and stock prices. For example, there cannot be two structural shocks that have the same effect on current and expected future output and inflation, yet have opposite effects on real rates. If there were two such shocks, (5) will put some macro-driven variation of real rates into the residual.

The functional form (1) of Baele et al. (2010), which puts real rates on the right side, is more familiar to some readers. The short-term nominal rate (and given inflation expectations, the short-term real rate) is typically viewed as a monetary policy instrument that is just as relevant to macroeconomic dynamics as output and inflation shocks. However, monetary policy shocks appear in (5) as well, since such a shock does not just move short-term nominal and real rates. It also affects expectations of future output and inflation.

One limitation of (5) is worth highlighting. The equation says there are no predictable changes in real rates from quarter to quarter, nor any predictable variation in excess stock returns. This assumption is undoubtedly false for real rates. The Fed often signals future changes in short-term nominal rates, and those anticipated changes do not precisely line up with changes in expected inflation. I do not attempt to model the conditional means because the sample periods are short. Parameters will not be estimated with high precision, hence some part of the true shock η_t will likely be absorbed by an estimated conditional mean.

Predictable variation in quarterly excess stock returns is swamped by the unpredictable variation. Hence the assumption of constant conditional means of changes in real rates will have little effect on the covariances of interest. The logic is straightforward. Unmodeled but true predictable changes in real rates are known by agents at $t-1$, and are therefore orthogonal to macro news at t. These predictable variations therefore show up in the residual of (5) rather than in news loadings F. This means misspecification does not affect estimates of the macro covariance matrix. Misspecification affects estimates of the diagonal of the residual covariance matrix, but our focus is on the off-diagonal elements. When the predictable variation in quarterly excess stock returns is small, its covariance with the predictable variation changes in real rates is also small.

2.5 A vector autoregression comparison

Vector autoregressions (VARs) are widely used in the macroeconomic literature. This section explains how to think about the methodology of Section 2.4 in a VAR setting.

Let the n-vector X_t contain typical variables included in a macroeconomic VAR, including measures of output growth, inflation, and short-term nominal interest rates. Write the VAR in first-order companion form with demeaned variables,

$$X_t = KX_{t-1} + \eta_t, \qquad \mathrm{Var}(\eta_t) = \Sigma. \tag{7}$$

Standard VAR math allows us to write j-ahead expectations of the vector and their associated innovations as

$$E_t\left(X_{t+j}\right) = K^j X_t. \tag{8}$$

The one-step-ahead forecast of inflation from this technique, combined with the nominal short rate, produces the ex ante real short rate.

This framework implies that innovations to the state vector are spanned by innovations to expectations of future values of the state vector. The innovation from $t-1$ to t in the expected value of the state at $t+j$ is

$$E_t\left(X_{t+j}\right) - E_{t-1}\left(X_{t+j}\right) = K^j \eta_t. \tag{9}$$

For example, stack in the vector θ_t the innovations to the j-ahead forecasts of output growth, for $j = 0$ through $n-1$. Assuming that output growth is the first element of X_t, the vector is

$$\theta_t^y = \begin{pmatrix} K_{1,.}^{0}{}' & K_{1,.}^{1}{}' & \dots & K_{1,.}^{n-1}{}' \end{pmatrix}' \eta_t, \tag{10}$$

where the subscript $(1,.)$ refers to the first row of a matrix and the superscript y indicates news about expected output. The covariance matrix of news at these different forecast horizons is

$$\operatorname{Var}(\theta_t^y) = \begin{pmatrix} K_{1,.}^{0}{}' & K_{1,.}^{1}{}' & \dots & K_{1,.}^{n-1}{}' \end{pmatrix}' \Sigma \begin{pmatrix} K_{1,.}^{0}{}' & K_{1,.}^{1}{}' & \dots & K_{1,.}^{n-1}{}' \end{pmatrix}. \tag{11}$$

Absent parameter restrictions on K, the matrix in (10) is invertible, allowing us to write the innovations to X_t as

$$\eta_t = \begin{pmatrix} K_{1,.}^{0} \\ K_{1,.}^{1} \\ \vdots \\ K_{1,.}^{n-1} \end{pmatrix}^{-1} \theta_t^y. \tag{12}$$

Taken literally, equation (12) invalidates the logic of Section 2.4. The equation says that the innovation to any variable in X_t, including the short-term nominal rate, is a linear combination of innovations to expected output at various horizons. (Or innovations to expected inflation, or expected money growth, or whatever else is included in X_t.) Since inflation is in X_t, the innovation to the ex-ante real rate is also a linear combination of these expectation innovations. In the language of Section 2.4, there is no residual component to real rates, and therefore no residual covariance between stock returns and changes in real rates.

Although this result is analytically correct it is not economically interesting. Our economic intuition tells us big macroeconomic news must be more important than small news in driving changes in asset prices. That principle is not imposed in (12). For example, this VAR math allows changes in time-t's short-term real rate to be more highly correlated with tiny innovations in year-ahead expected output than large changes in quarter-ahead expected output.

A more sensible approach is to focus on the variation in real rates explained just by big macroeconomic news, where "big" is defined statistically. In line with the approach of Section 2.4, explain innovations in real rates with only the most important principal components of news about expected output and the most important principal components of news about expected inflation. The principal components are determined by (11) and its counterpart for news about expected inflation. This approach puts us back into the setting of (5) and (6).

Of course, the major advantage of Section2.4's methodology is that news about expected output and inflation is observed directly rather than inferred from the dynamics of an estimated VAR. Even if we assume that the structure of the VAR is known—the variables and the lag length—uncertainty in the estimated parameters would make statistical inference problematic.

3 Comovement with Real Rates

3.1 Baseline estimates

I estimate (5) with ordinary least-squares (OLS) over the two sample periods 1969 through 1996 and 1997 through 2017. I assume that the covariance matrix of macro shocks (4) and the covariance matrix of the residuals are fixed throughout each sample period. In other words, the conditional covariances on the right side of (6) are replaced with fixed covariances. Parameters of the covariances are estimated with Generalized Method of Moments (GMM).

Standard errors are also calculated with GMM.[4]

The important results are in Table 3. Panel A reports the R^2s for the three individual regressions that comprise (5). For both samples, about 30 percent of the variation in three-month and one-year ex ante real rates is explained by contemporaneous macro news. The R^2 for excess stock returns is less than 10 percent in the early period, rising to almost 35 percent in the late period.

The low explanatory power of macro shocks for short-term real rates is consistent with the macro-finance literature. See, e.g., the handbook discussion of Duffee (2013). However, recall from the previous section that variation in conditional means shows up in the residual of (5). Since any sensible dynamic macro model will generate predictable variations in real rates, an R^2 of one is not a useful benchmark. Similarly, stock returns are not driven only by news about output and inflation. For example, shocks to risk premia (perhaps owing to volatility shocks) also matter.

Panel B decomposes covariances between stock returns and real rates into components spanned by macroeconomic news and residual components. I highlight two results. First, the macro covariance terms are uniformly positive. In other words, point estimates imply that macroeconomic shocks drive a positive covariance between stock returns and real rates for both periods and both real-rate maturities. The statistical significance of this positive relation is very strong in the later sample. The point estimates are larger in the early sample, but the standard errors are as well, thus the statistical significance is weaker. There is no statistically significant evidence that the magnitude of the macro covariance components has changed over time.

Second, the residual covariance terms switch sign between the two periods. They are negative and large in the early sample, although only the point estimate for the one-year rate differs from zero at the five percent level. For this early sample we can easily reject the hypothesis that the macro and residual covariance terms are equal. The negative residual covariance terms outweigh the positive macro covariance terms, producing an overall negative relation between stock returns and changes in real rates.

In the later period the residual covariance terms are positive, although a more robust

[4]All moment conditions (OLS moments for the two sample periods of (5), covariance moments for the two sample periods of (6)) are combined for this exercise. Therefore the standard errors of the covariance matrices take into account the uncertainty in the parameters of regression (5).

interpretation is that they are economically and statistically close to zero. For this sample, the macro covariances drive the overall positive relation between stock returns and changes in real rates.

Figure 3 illustrates the striking change from the first part of the sample to the second. It displays, for each quarter from 1969 through 2017, the product of the fitted innovations of changes and one-year real rates and stock returns. We can think of these as "realized macro covariances," in the sense that the covariance is the expected value of these products. It also displays for each quarter the product of the residual innovations, or realized residual covariances. The innovations are produced by the split-sample regressions summarized in Table 3.

Thoughout the entire period, the realized macro covariances are consistently positive. Through approximately 1995, realized residual covariances are almost always negative, and the largest spikes are all negative. After 1995, the realized residual covariances are much more muted.

These results are surprising and either encouraging or discouraging, depending on your perspective. The good news is that in the past 50 years there appears to be no regime shift in the relation between macroeconomic innovations and the comovement between stock returns and real rates. Macro innovations induce a positive correlation. The bad news is that macro regime shifts appear to be an unlikely explanation for the variation over time in the comovement between stock returns and real rates.

3.2 A vector autoregression perspective

I use typical macro VAR as a plausibility check on these results. I estimate a VAR(2) with quarterly data. The nine variables are the log change in real per capita GDP, the log change in real pre capita consumption on nondurables and services, the log change in real per capital physical capital (i.e., investment in physical capital), the log change in real per capita wages and salaries, the log change in a labor productivity index, the log change in nominal M2, GDP deflator inflation, the quarter-end three-month nominal Treasury yield, and the quarter-end one-year nominal Treasury yield. The number of free parameters comfortably exceeds the number of time series observations. Thus the only objective here is to compare properties of the model implied by the point estimates to the properties of the survey-based regressions.

Following (12), the parameters imply a covariance matrix of news about expected GDP growth for quarters 0 to 8 months ahead. The first two principal components of this matrix explain 85% (97%) of the total variance for the 1969–1996 (1997–2017) sample. The corresponding percentage for news about expected inflation is 97% (93%). Therefore I restrict my attention to the first two principal components of news about expected GDP growth and inflation.

Panel A of Table 4 reports R^2 of regressions of real rates on contemporaneous macro news. Recall that the regressions summarized in Table 3 have changes in real rates on the left side; conditional means are ignored. Here the VAR generates conditional means, therefore the left sides of the regressions have VAR-implied innovations in real rates rather than changes. The R^2s for these VARs are considerably higher than the R^2s reported in Table 3 that use survey versions of macroeconomic news. By contrast, the R^2 for stock returns is lower in Table 4 than Table 3.

Panel B reports the decomposition of covariances between stock returns and real rates into macro covariances and residual covariances. Qualitatively, these results are identical to those based on survey news. For both sample periods, macro news generates a positive covariance between stock returns and real rates. The residual covariance switches sign, from large and negative in the early period to small(er) and positive in the later period. Nothing in these results leads us to doubt the results based on survey evidence.

3.3 Under a microscope

It helps to take a close look at a few of the observations that stand out in Figure 3. Table 5 contains detailed information for the five quarters with the largest absolute realized quarterly residual covariance between stock returns and one-year real rates for the period 1969 through 1996. Table 6 does the same for the later sample 1997 through 2017.

The first two observations listed in Table 5 are those with the largest absolute realized covariances. Panel A shows that these two observations—both in 1982—have similar macroeconomic news. Current output unexpectedly declines substantially, while two-quarter-ahead expected output slightly increases. Current and expected future inflation both drop substantially.

Panel B reports the OLS-projected values of excess stock returns and changes in real rates given this macro news. Projected excess stock returns are around three to four percent and real rates are projected to drop in the neighborhood of 25 basis points at the one-quarter horizon and 40 basis points at the one-year horizon. Realizations, also reported in Panel B, differ wildly from these projections. During 1982Q1 stock prices fall while real rates spike. During 1982Q4 stock prices leap up while the one-year real rate (although not the one-quarter rate) drops substantially.

In both periods the changes in real rates are driven primarily by changes in nominal rates. The three-month Treasury bill rises by about four percent during 1982Q1.[5] Fed funds overnight interest rates rose as well during this period, by about two percent. In 1982Q4, the one-year bill yield falls by about 1.7 percent. The Fed funds rate falls about one percent.

Some readers will look to the behavior of the Fed funds rate during these quarters and conclude that the changes in stock prices and real rates as driven by macroeconomic news rather than unexplained "residuals." Macro models often regard the Fed funds rate as a target under the control of the central bank. Here, however, the focus is on investors. The central bank is powerful but cannot repeal agents' first-order conditions. Standard macro models allow the central bank to affect real rates only through channels where central bank actions affect the dynamics of real output, consumption, and investment.

Put differently, why do these quarters differ so much in the realized changes in one-year real rates, when the news that New Keynesian models say should matter—news about expected output and inflation—is almost the same in the two quarters? In a mechanical sense, one possibility is that the correct dynamic model of the macroeconomy has more than four important sources of uncertainty. If so, the news defined by (3) does not span the macroeconomic news that accounts for large changes in asset prices.

For example, consider many-shock interpretation of the next observation listed in Table 5. Investors revised upward their forecasts of current and expected future inflation during 1971Q1. They revised upward their forecast of current GDP growth and revised downward their forecast of expected future GDP growth. The OLS projection of excess stock returns

[5] Readers with an encyclopedic knowledge of quarterly Treasury yields may be surprised by this number because standard datasets do not report such a large increase. Recall that here, observations are mid-quarter. The 1982Q1 stock returns and changes in real rates are measured from mid-November 1981 until mid-February 1982. Measurements from quarter-end 1981Q4 to quarter-end 1982Q1 pick up the decline in the three-month yield of more than two percent during the second half of February.

and real rates predicts an excess stock return of two percent and fairly large increases in real rates of around half a percent. The realized excess stock return is close to 20 percent as real rates falls nearly two percent. The Fed funds rate falls about 1.7 percent.

One potential way to explain this joint behavior of stock returns and real rates is with a shock to the marginal investor's time rate of preference, modeled along the lines of Albuquerque, Eichenbaum, Luo, and Rebelo (2016). Investors, for whatever reason, suddenly prefer to save more. Real discount rates fall and long-lived assets such as stocks increase in price. In a production economy with endogenous capital, this shock will immediately raise investment and reduce consumption. Since the news defined by (3) does not break down output growth into consumption and investment, discount rate shocks can easily be labeled as residual shocks rather than macroeconomic news. Of course, such a story requires that the central bank accommodate shocks to the time rate of preference by adjusting the Fed funds rate accordingly.

Such a discount rate story could account for the observations listed in Table 5. But the observations in Table 6, the largest absolute realized covariances in the later sample, are difficult to reconcile with an important role for discount rate shocks. In 2004Q4, both output and inflation forecasts unexpectedly dropped. Real rates increase more than 50 basis points when OLS projections point to flat real rates. At the same time that the stock market rose 13 percent. In 2002Q3, OLS projections of real rates point to a drop of 25 basis points. The one-year real rate falls by 60 basis points, yet stock prices drop by more than 15 percent. Of the observations listed in Table 6, only one fits the pattern of stock prices and real rates moving in opposite directions.

4 Real and nominal rates

Recall that Table 1 reports covariances between stock returns and changes in long-term nominal rates as well as covariances between stock returns and real rates. This section discusses two properties of this table. First, for both the 1969–1996 and 1997–2017 samples, the nominal bond covariance is less than the one-year real rate covariance. Second, the gap between the nominal bond covariance and the one-year real rate covariance shrinks from the early sample to the later sample.

4.1 Cholesky decompositions and macro news in the early sample

The analysis here focuses on the covariance matrix of seven variables: the length-four vector of macro news (3), the change in the one-quarter and one-year real rates, and the change in the yield on a ten-year nominal bond. Table 7 reports Cholesky decompositions of the covariance matrix for the samples 1969–1996 and 1997-2017. The macro news comes first in the decompositions, giving the macro variables the maximum explanatory power for contemporaneous variation in real rates and the nominal yield.

With this decomposition, news about current output growth is the most important driver of the "macro covariance" with real rates—the first covariance on the right side of (6). The role of this news is worth a detailed discussion.

The first column of Panel A in Table 7 contains contemporaneous reactions during the early period. Good news about expected current output corresponds to good news about expected output growth two quarters out (second row), as well as higher stock prices (bottom row). The good news raises real rates, with the one-quarter rate (fifth row) increasing by more than the one-year rate (sixth row). Good news about output also corresponds to lower expected inflation, both immediately (third row) and in the future (fourth row). The inverse relation between news about output growth and expected inflation matches the empirical results of the stagflation literature. See, e.g., Song (2017).

The response of the ten-year nominal yield is in the seventh row. But ignore this for the moment, and consider what effects the real-rate and the expected-inflation news should have on the ten-year nominal yield. The increase in real rates declines with maturity (from one quarter to one year), thus it should have a smaller positive effect at the ten-year horizon than the one-year horizon. The decrease in expected inflation should induce a negative reaction of nominal yields to the good output news.

The table reports that actual response of the ten-year nominal yield is qualitatively consistent with this intuition. The yield increases with good news about output, but the increase is only half the size of the increase in the one-year real rate. Thus this first component of macroeconomic news generates a much larger covariance between stock returns and real rates than it does between stock returns and the ten-year nominal rate. (Precise numbers are in Table 8, which is discussed below.)

Similar stories can be told about the second and third columns of the early-sample decomposition. The sensitivities of the nominal yield differ from those of real rates in the direction of expected inflation. For example, in the third column, an unexpected increase in expected current inflation corresponds to lower real rates but a higher ten-year yield. Stories about the fourth column are more difficult to tell, but the overall importance of the orthogonal shock to expected future inflation is low.

Panel A of Table 8 summarizes the contributions of each shock to early-sample covariances between stock returns and real/nominal yields. The sum of each row is the total covariance in Panel B of Table 1. Given the ordering of the Cholesky decomposition, news about current GDP is by far the most important of the macro shocks in explaining the positive macro covariance between stock returns and real rates. The macro covariance between stock returns and the ten-year nominal yield is smaller (in fact, negative, at -0.04) because for the first three macro shocks, expected inflation moves in the opposite direction of real rates.

4.2 Macro news in the later sample

Macro dynamics in the later period differ from those in the early period, with implications for the joint behavior of output and nominal yields. As the first column in Panel B of Table 7 shows, good news about current output corresponds to higher expected inflation rather than the lower expected inflation observed in Panel A. This change in sign is consistent with the evidence of Song (2017). A similar change in magnitude, although not sign, appears in the second column. Good news about expected future output lowers expected inflation, but the decline is much smaller than it is in Panel A. Therefore the macro covariance between stock returns and the ten-year yield is 0.43, substantially larger in this later sample than in the early sample. Panel B of Table 8 contains the decomposition of this covariance.

Taken at face value, these results imply that about a quarter of the increase from the early to later period in the covariance between stock returns and the ten-year nominal yield is attributable to changing macro dynamics. The total change, from Table 1, is 1.95, and the portion attributable to changes in the macro covariance is 0.47.

4.3 Residual covariances

Columns five through seven of the Cholesky decompositions determine the "residual covariances" in (6). These are shocks to the components of real rates and the nominal yield that are orthogonal to the macro news. In the early period (Panel A of Table 7), each positive shock to real rates and the nominal yield corresponds to a decline in stock prices. In the later period (Panel B), each positive shock to real rates and the nominal yield corresponds to an increase in stock prices, although the absolute response of stock prices is smaller.

Thus the residual covariance for the ten-year nominal bond yield, like those for real rates, is large and negative in the early period and small and positive in the later period. Of the total change in the covariance between stock returns and changes in the nominal yield that we see in Panel B of Table 1, three-quarters is attributable to the residual covariance.

5 Macro models and macro covariances

Explaining the biggest puzzle uncovered by the previous results—the large swings in residual covariances—is well beyond the scope of this paper. This section asks a question that is easier to answer. Are the estimated macro covariances consistent with a state of the art dynamic New Keynesian model?

I take a close look at the New Keynesian model of stochastic endogeneous growth in Kung (2015). As I discuss in Duffee (2018), our standard models with endowment economies generate little variation in short-term real rates. In the data, as shown both here and in Duffee (2018), short term real rates exhibit substantial volatility. I examine Kung's model because the endogenous growth component generates a much higher volatility of short-term real rates than we see in standard models with endowment economies. Therefore it is a plausible candidate for explaining observed macro covariances.

The representative agent has recursive utility preferences in the model. Aggregate uncertainty is created by transitory productivity shocks, shocks to the volatility of productivity shocks, and monetary policy shocks. Transitory productivity shocks have long-run effects that are endogenously generated by investment in both physical capital and R&D. Stagflation also arises endogenously. Positive shocks to productivity raise investment, raise expected productivity growth, and lower marginal costs so that monopolistically competitive firms cut prices in order to capture business.

I simulate a long time series of quarterly data from the model.[6] I construct multi-quarter forecasts of output growth and inflation with OLS projections, and use the forecasts to produce macro news. I then replicate Tables 7 and 8 using the population covariance matrix

[6] Howard graciously provided his Dynare++ code.

of macro news, changes in ex-ante real rates, changes in the ten-year nominal bond yield, and excess stock returns. The results are in Table 9.

The first column of Panel B in the table reports that model-implied covariances between excess stock returns and changes in real rates are positive. Productivity shocks drive stock returns, investment, and real rates in the same direction. The magnitudes are a little more than a third of the empirical macro covariances of Table 3. At first glance this looks like a qualitative success, but a closer look at the table is discouraging.

Panel B reports that in the model, news about current GDP drives a negative covariance between stock returns and real rates, while news about future GDP growth drives a much larger positive covariance. In the data, as discussed extensively in Section 4.1, news about current GDP growth drives almost all of the positive covariance between stock returns and real rates.

The model properties are embedded in standard dynamics of consumption-based models with representative agents. Real rates respond to news about aggregate consumption growth, not news about a level shock to aggregate consumption. A positive shock to productivity initially lowers consumption because investment demand is high. Expected consumption growth is steep for a few quarters (thus high real rates), then tapers off and turns negative. This is why, in the model, real rates react much more to news about future growth of GDP than news that current GDP is higher than expected. The Cholesky decomposition in Panel A of Table 9 reports that a positive shock to current GDP modestly lowers real rates. A positive shock to expected future GDP strongly raises real rates.

The other significant disconnect between the model and the data is the macro covariance for the 10-year bond yield. The model-implied covariance is strongly negative, close to -0.94. Yet even during the early sample, which exhibits stagflation, the empirical covariance is only slightly less than zero. Cholesky decompositions show that the strength of the inverse relation between output growth and inflation is much larger in Table 9 (the model) than in Table 7 (the early sample). Of course, in the later sample, there is no evidence of stagflation at all.

These results add to the large body of evidence that real-rate behavior does not connect with aggregate dynamics in ways consistent with representative agent models. Kaplan, Moll, and Violante(2018) (2018) and Kaplan and Violante (2018) review this evidence as they argue that observed macroeconomic dynamics are more consistent with heterogeneous agent models.

6 Concluding comments

Time-varying comovement between stock returns and long-term nominal yields was first recognized almost twenty years ago. Explaining this behavior with dynamic macro-finance models has proven difficult. The evidence presented here is both helpful and discouraging. The good news is that this time-varying comovement is tied to comovement with short-term real rates. It is easier to build dynamic models of short-term real rates than long-term nominal yields. The bad news is that macroeconomic dynamics appear to have almost nothing to do with this time-varying comovement.

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Table 1. Comovement of interest rates and stock returns

The table reports correlations and covariances of quarterly changes in Treasury yields with the aggregate excess return to the U.S. stock market. The ten-year nominal yield is from the CRSP Fixed Term File. Ex ante three-month and one-year real rates are nominal Treasury yields less mean forecasts of inflation from the Survey of Professional Forecasters. Yields are measured in percent per year and stock returns are in percent per quarter.

Panel A. Correlations With Excess Stock Returns

Sample [Num Obs]	Three Month Real Rate	One Year Real Rate	Ten Year Nominal Yield
1969Q1 – 1996Q4 [112]	0.00	−0.13	−0.22
1997Q1 – 2007Q4 [44]	0.43	0.45	0.20
2008Q1 – 2017Q4 [40]	0.23	0.28	0.28
1997Q1 – 2017Q4 [84]	0.32	0.36	0.24

Panel B. Covariances With Excess Stock Returns

Sample [Num Obs]	Three Month Real Rate	One Year Real Rate	Ten Year Nominal Yield
1969Q1 – 1996Q4 [112]	−0.03	−1.19	−1.26
1997Q1 – 2007Q4 [44]	1.34	1.26	0.53
2008Q1 – 2017Q4 [40]	0.86	0.72	0.86
1997Q1 – 2017Q4 [84]	1.11	1.00	0.69

Table 2. Principal components decomposition of macroeconomic news

Panel A reports the contribution of each principal component to the overall variance of quarterly innovations in consensus survey forecasts of real GDP growth. Panel B reports the same information for forecasts of inflation. The original forecasts, at quarter $t-1$, are for one to four quarters ahead. The updated forecasts, as of quarter t, are for zero to three quarters ahead.

Panel A. Real GDP growth

	Contribution (percent)			
Sample	1st PC	2nd PC	3rd PC	4th PC
1969Q1 – 1996Q4 (107 obs)	57.8	29.3	10.4	2.5
1997Q1 – 2007Q4 (84 obs)	90.0	6.4	2.5	1.1

Panel B. Inflation

	Contribution (percent)			
Sample	1st PC	2nd PC	3rd PC	4th PC
1969Q1 – 1996Q4 (107 obs)	85.3	8.7	3.6	2.4
1997Q1 – 2007Q4 (84 obs)	84.4	10.0	3.8	1.8

Table 3. Survey-based decompositions of covariances between real rates and stock returns

Ex ante real rates are nominal Treasury yields less survey forecasts of inflation. Quarterly changes in these yields and the quarterly excess return to the aggregate stock market are regressed on contemporaneous innovations to survey forecasts of real GDP growth and inflation. Two forecast horizons are used for both GDP growth and inflation, for a total of four explanatory variables. Details are in the text. Panel A reports R^2s. Panel B reports covariances among the fitted values from these regressions (spanned by forecast innovations) and the residuals from these regressions (orthogonal to forecast innovations). Asymptotic GMM standard errors are in parentheses. Yields and inflation are in percent per year, while stock returns are in percent per quarter.

Panel A. R^2s

Sample [Num Obs]	Variable	Std Dev	R^2
1969Q1 – 1996Q4	3-month rate	1.03	0.30
[112]	1-year rate	0.92	0.29
	stock return	8.09	0.09
1997Q1 – 2016Q4	3-month rate	0.46	0.31
[84]	1-year rate	0.37	0.30
	stock return	7.63	0.34

Panel B. Contemporaneous covariances with stock returns

Sample [Num Obs]	Variable	Spanned by Expectation Innovs	Orthogonal to to Expectation Innovs	Test of Equality
1969Q1 – 1996Q4	3-month rate	1.27*	−1.30	2.58**
[112]		(0.77)	(0.85)	(1.17)
	1-year rate	0.89	−2.07**	2.96***
		(0.67)	(0.85)	(1.10)
1997Q1 – 2017Q4	3-month rate	1.00**	0.11	0.88*
[84]		(0.50)	(0.23)	(0.50)
	1-year rate	0.81***	0.19	0.62*
		(0.30)	(0.17)	(0.33)
Test of Equality	3-month rate	0.28	−1.42	
Across Samples		(0.92)	(0.88)	
	1-year rate	0.08	−2.26***	
		(0.73)	(0.87)	

Table 4. VAR-based decompositions of covariances between real rates and stock returns

Quarterly VAR(2)s are estimated for the period 1968Q3 through 1996Q4 and the period 1997Q1 through 2017Q4. Seven observables are log changes in real GDP, real aggregate consumption, real investment in physical capital, real wages, a labor productivity index, nominal M2, and the GDP deflator. Two other observables are the quarter-end three-month and one-year Treasury bill yields. The VAR parameters are used to infer covariances matrices of innovations to expected GDP and inflation over various horizons. The first two principal components of expected GDP innovations and expected inflation innovations are defined as "macroeconomic news."

Model-implied innovations in one-quarter and one-year ex ante real rates, as excess stock returns, are regressed on model-implied macroeconomic news. Panel A reports the R^2s. Panel B reports covariances among the fitted values from these regressions (spanned by forecast innovations) and the residuals from these regressions (orthogonal to forecast innovations). Yields and inflation are in percent per year, while stock returns are in percent per quarter.

Panel A. R^2s

Sample	Variable	Std Dev	R^2
1968Q4– 1996Q4	3-month rate	1.23	0.68
	1-year rate	1.15	0.55
	stock return	8.57	0.04
1997Q1 – 2016Q4	3-month rate	0.33	0.45
	1-year rate	0.31	0.11
	stock return	8.76	0.22

Panel B. Contemporaneous covariances between real rates and stock returns

Sample	Variable	Spanned by Expectation Innovs	Orthogonal to to Expectation Innovs
1968Q4– 1996Q4	3-month rate	0.48	−1.13
	1-year rate	0.36	−2.21
1997Q1 – 2016Q4	3-month rate	0.28	0.21
	1-year rate	0.30	0.51

Table 5. Macroeconomic forecast revisions, stock returns, and changes in real rates, 1969 – 1996

The table reports information about the five quarters in the 1969Q1 to 1996Q4 sample that have the largest product of unexplained stock market returns and one-year real rate changes.

Panel A. Revisions in mean survey forecasts (percent)

	Revision for Quarter t		Revision for Quarter $t+2$	
Quarter t	GDP Growth	Inflation	GDP Growth	Inflation
1982Q4	−0.35	−1.29	0.04	−0.54
1982Q1	−0.44	−0.91	0.09	−0.37
1971Q1	0.23	0.10	−0.18	0.40
1978Q4	0.19	−0.45	−0.05	0.64
1987Q4	−0.19	−1.06	−0.14	−0.67

Panel B. Real interest rates and stock returns (percent)

	———Predicted———			———Actual———		
Quarter t	Stock Return	Change in 1 Quarter Rate	Change in 1 Year Rate	Stock Return	Change in 1 Quarter Rate	Change in 1 Year Rate
1982Q4	3.9	−0.12	−0.33	33.9	0.08	−2.15
1982Q1	3.0	−0.39	−0.54	−8.7	4.27	3.04
1971Q1	2.2	0.64	0.42	19.4	−1.75	−1.84
1978Q4	4.8	0.78	0.18	−13.0	1.45	1.88
1987Q4	2.6	0.11	0.07	−27.7	0.82	0.82

Table 6. Macroeconomic forecast revisions, stock returns, and changes in real rates, 1997 – 2017

The table reports information about the five quarters in the 1996Q1 to 2017Q4 sample that have the largest product of unexplained stock market returns and one-year real rate changes.

Panel A. Revisions in mean survey forecasts (percent)

	Revision for Quarter t		Revision for Quarter $t+2$	
Quarter t	GDP Growth	Inflation	GDP Growth	Inflation
2004Q4	−0.10	−0.23	−0.06	−0.10
2002Q3	−0.19	0.03	0.01	−0.12
2007Q3	−0.01	−0.29	−0.07	0.08
2007Q4	−0.22	−0.12	−0.10	0.06
2008Q2	−0.37	−0.02	−0.04	−0.05

Panel B. Real interest rates and stock returns (percent)

	Predicted			Actual		
Quarter t	Stock Return	Change in 1 Quarter Rate	Change in 1 Year Rate	Stock Return	Change in 1 Quarter Rate	Change in 1 Year Rate
2004Q4	1.9	0.04	0.05	13.0	0.57	0.64
2002Q3	0.6	−0.23	−0.24	−15.5	−0.15	−0.61
2007Q3	1.8	0.13	0.08	−7.2	−0.60	−0.49
2007Q4	−2.0	−0.21	−0.18	4.0	−1.14	−1.03
2008Q2	−2.6	−0.35	−0.38	−7.1	−0.82	−1.44

Table 7. Cholesky decompositions

The table reports Cholesky decompositions of covariance matrices for two samples of quarterly data. The variables are revisions in survey forecasts of GDP growth and inflation for the current quarter t and the future quarter $t+2$, changes in ex-ante three-month and one-year real rates, changes in the 10-year nominal Treasury yield, and the excess return to the aggregate U.S. stock market. Inflation and yields are expressed in percent per year. GDP growth and stock returns are expressed in percent per quarter.

	———Forecast Revisions———				Ex Ante —Real Rates—		Ten Yr	Excess
	Current GDP	Future GDP	Current Inflation	Future Inflation	3 Mon	1 Yr	Nominal Yield	Stock Return
Panel A. 1969Q1 through 1996Q4								
GDP, t	0.336							
GDP, $t+2$	0.025	0.186						
Inflation, t	−0.146	−0.341	0.608					
Inflation, $t+2$	−0.026	−0.228	0.280	0.278				
1 Quarter	0.649	0.044	−0.169	0.050	1.029			
1 Year	0.563	0.012	−0.074	−0.113	0.795	0.455		
10 Year	0.264	−0.149	0.173	0.010	0.373	0.292	0.354	
Stock Return	1.487	1.421	−1.296	0.550	−1.266	−2.346	−0.184	7.637
Panel B. 1997Q1 through 2017Q4								
GDP, t	0.228							
GDP, $t+2$	0.063	0.059						
Inflation, t	0.087	−0.036	0.308					
Inflation, $t+2$	0.032	−0.017	0.099	0.104				
1 Quarter	0.178	0.058	−0.174	0.030	0.384			
1 Year	0.187	−0.012	−0.077	0.009	0.226	0.207		
10 Year	0.138	−0.034	0.066	−0.070	−0.003	0.175	0.290	
Stock Return	3.986	1.601	−1.155	−0.106	0.298	0.592	0.550	6.137

Table 8. Contributions of macroeconomic shocks to the covariance between stock returns and changes in yields

The table reports components of covariances between excess aggregate stock returns and changes in real rates and a ten-year nominal yield. The components are calculated using the Cholesky decompositions of Table 5.

		Forecast Revisions				
	Total Covar	Current GDP	Future GDP	Current Inflation	Future Inflation	All Else
Panel A. 1969Q1 through 1996Q4						
3 Mon Real Rate	−0.028	0.965	0.063	0.219	0.028	−1.303
1 Yr Real Rate	−1.185	0.837	0.016	0.096	−0.062	−2.073
10 Year Nom Yield	−1.261	0.392	−0.212	−0.224	0.005	−1.222
Panel B. 1997Q1 through 2017Q4						
3 Mon Real Rate	1.113	0.708	0.092	0.201	−0.003	0.114
1 Yr Real Rate	1.002	0.744	−0.019	0.089	−0.001	0.190
10 Year Nom Yield	0.689	0.549	−0.054	−0.076	0.007	0.263

Table 9. Properties of covariances in the model of Kung (2015)

Panel A reports a Cholesky decomposition of a population covariance matrix for the model of Kung (2015). The variables are structured as they are for constructing the sample Cholesky decompositions in Table 6. Panel B reports the contributions of macroeconomic shocks to covariances between excess stock returns and changes in real and nominal yields. Its structure follows the sample versions in Table 7.

Panel A. Cholesky Decomposition

	———Forecast Revisions———				—Real Rates—		Ten Yr	Excess
	Current GDP	Future GDP	Current Inflation	Future Inflation	3 Mon	1 Yr	Nominal Yield	Stock Return
GDP, t	1.158							
GDP, $t+2$	0.007	0.194						
Inflation, t	−0.099	−1.380	0.152					
Inflation, $t+2$	−0.412	−0.537	0.018	0.027				
1 Quarter	−0.302	1.078	−0.165	0.018	0.719			
1 Year	−0.072	0.452	−0.086	0.010	0.283	0.019		
10 Year	−0.258	−0.161	0.021	−0.003	0.021	−0.038	0.022	
Stock Return	2.905	1.172	−0.158	−0.102	−0.283	−0.006	0.264	0.421

Panel B. Macroeconomic Contributions to Stock Return Covariances

		———Forecast Revisions———				
	Total Covar	Current GDP	Future GDP	Current Inflation	Future Inflation	All Else
1 Q Real Rate	0.400	−0.876	1.252	0.026	−0.002	−0.203
1 Yr Real Rate	0.333	−0.210	0.530	0.014	−0.001	−0.080
10 Year Nom Yield	-0.940	−0.748	−0.189	−0.003	0.000	0.000

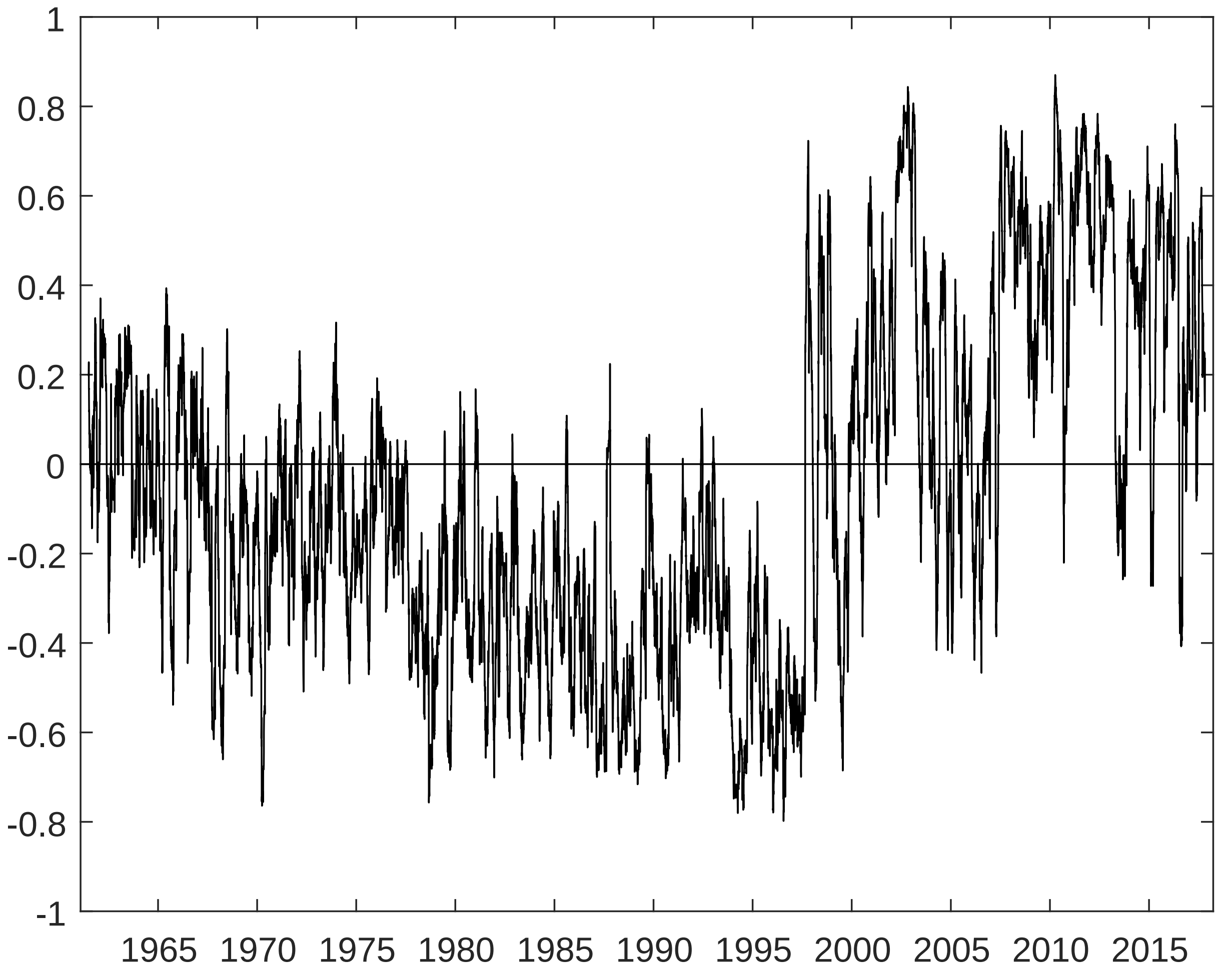

Figure 1. Rolling sample correlations between daily stock returns and changes in ten-year nominal Treasury yields

Contemporaneous correlations between the daily return to the U.S. aggregate stock market and the daily change in the yield on a ten-year Treasury coupon bond are constructed with overlapping 44-day (two-month) samples. The sample range is July 1961 through December 2017.

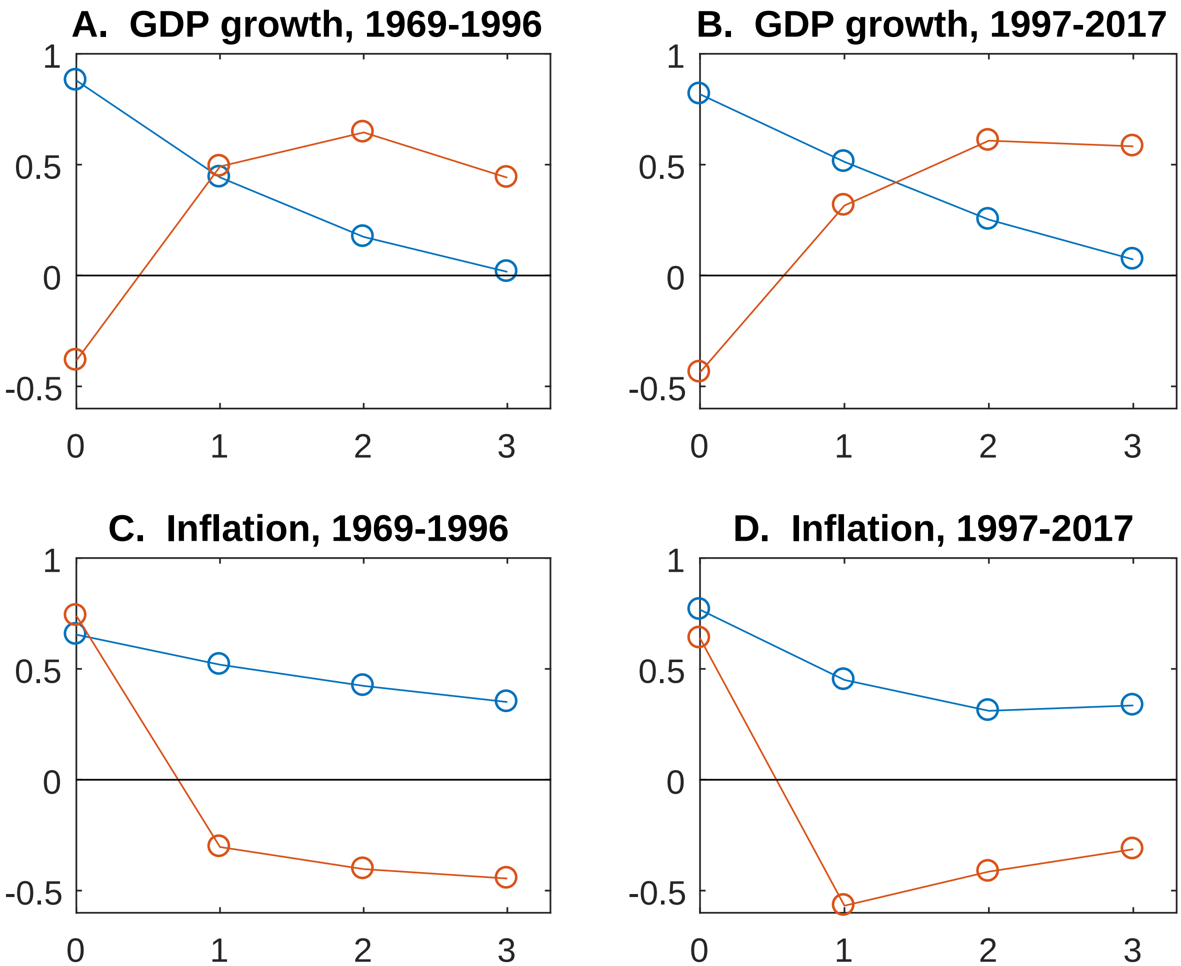

Figure 2. Loadings of innovations in survey expectations on their first two principal components

Each quarter there are four innovations to consensus survey forecasts of GDP growth and inflation, for quarterly horizons $j = 0$ through $j = 3$. Four principal component decompositions are performed, for each combination of macroeconomic variable and sample period (prior to 1997 and after 1996). The panels report loadings on the first two PCs.

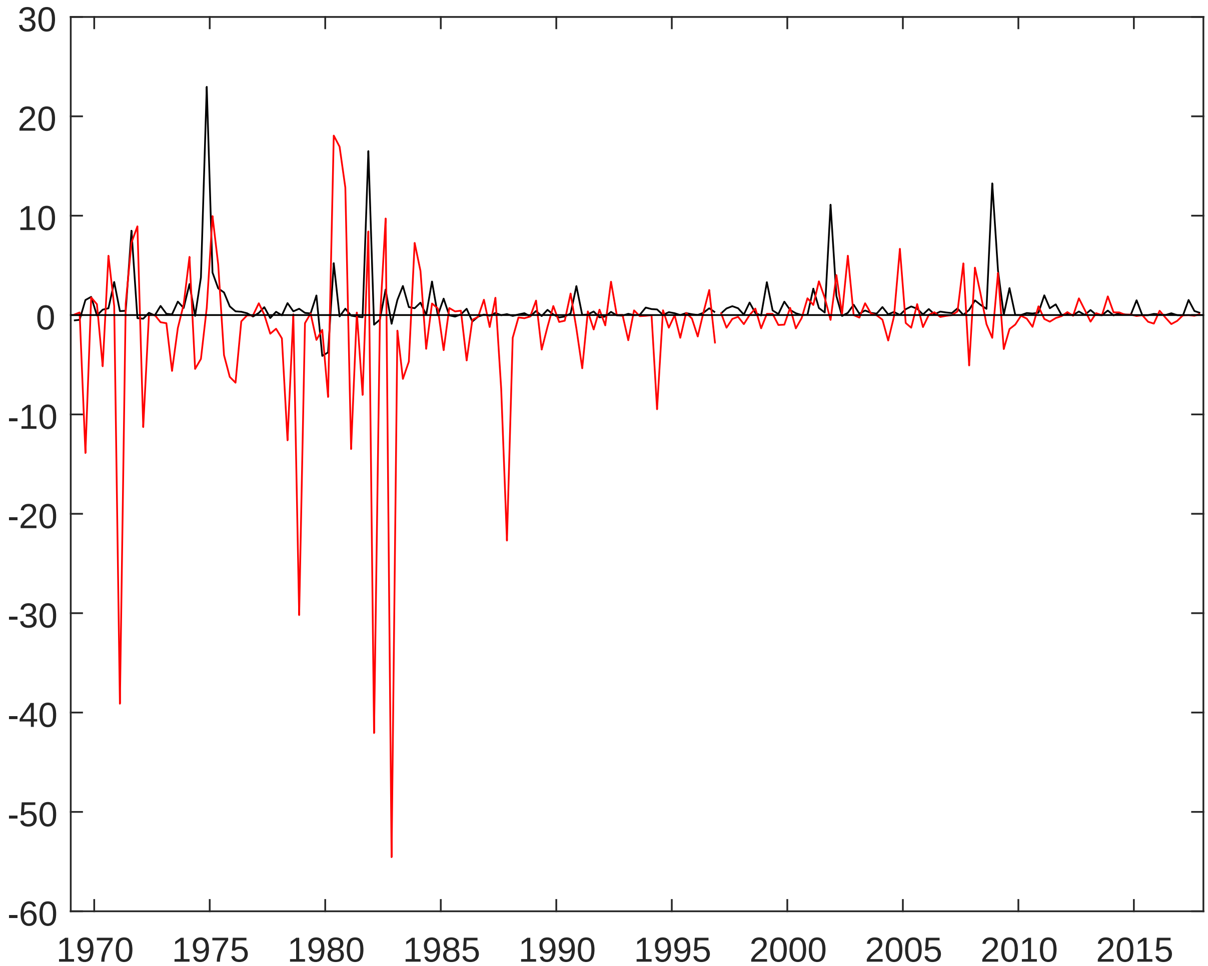

Figure 3. Quarterly products of excess stock returns and changes in one-year real rates

The excess stock return is for the U.S. stock market, in percent. The ex ante one-year real rate is the nominal Treasury yield less the mean forecast of inflation from the Survey of Professional Forecasters, in annual percentage points. Both the stock return and quarterly changes in the real rate are regressed on contemporaneous shocks to survey forecasts of GDP growth and inflation. Details are in the text. The black line is the product of (demeaned) fitted values from the regressions and the red line is the product of residuals from the regressions.