Inflation Expectations and Stock Returns *

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Abstract

How do inflation expectations affect stock returns, and what accounts for this relationship? We directly measure investors' expectations using traded inflation-indexed contracts and show that, post-2000, stocks offer positive returns in response to higher expected inflation: unconditionally, a 10 basis point increase in 10-year breakeven inflation is associated with a 1.1% increase in the value-weighted stock index. Using a wide range of approaches, we show that this positive relationship is almost entirely due to aggregate variations in expected excess returns rather than changes in firm cash flows (e.g., due to higher mark-ups) or fluctuations in risk-free rates (e.g., due to expected monetary policy response). Overall, a risk premium "proxy" mechanism appears to explain this dominant role of expected excess returns: higher long-term inflation expectations signal stronger future economic growth and reduced volatility.

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1 Introduction

Do stock prices rise or fall when inflation expectations increase and if so, why? A novice investor may notice that inflation expectations enter the nominal discount rate and conclude that stock prices must fall when expectations rise. A sophisticated investor may push back that stocks are ultimately a claim on income generated by real assets. As a result, dividends should rise with inflation, canceling out the effect of the discount rate. Finally, an even more sophisticated investor may argue that it is not so straightforward, as risk-premia and real interest rates could also change when inflation expectations move. For example, stock prices may fall if the central bank tightens monetary policy in response to rising expectations. Understanding the response of stock prices to changes in inflation expectations calls for careful empirical study.

Consistent with previous works (Campbell et al., 2009; Viceira, 2013; Gourio and Ngo, 2020; Duffee, 2023) documenting a positive correlation between aggregate stock returns and inflation expectations, we first show that stock prices unambiguously rise when inflation expectations increase, and that this relationship is highly stable and invariant characteristic of the asset class. We regress daily stock returns on changes in the 10-year breakeven inflation rate measured using Treasury Inflation-Protected Securities (TIPS), and find that a 1 basis point increase in the 10-year breakeven inflation rate is associated with an 11 basis point increase in the overall stock market value. Given that the standard deviation of daily changes in the 10-year breakeven inflation rate is around 3.6 basis points, the magnitude is non-trivial. This positive relationship is stable across time sub-samples and the cross-section of stocks, and the results are virtually unchanged when we use inflation swaps, rather than TIPS, to measure expectations. The positive relationship remains intact even in the post-pandemic high inflation episode, when stock returns and realized inflation appeared to move in opposite directions. While the positive comovement establishes that stocks are a hedge against changes in inflation expectations, it does not explain why stocks provide this hedge. The remainder of the paper focuses on this question.

We zoom in on CPI release dates to better understand the causal effect of investors updating their inflation expectations on stock prices. CPI release dates help us identify the causal effect for two reasons. First, we can attribute changes in stock returns and expectations on CPI days to the inflation information released in the print (high-frequency identification assumption). Second, since the CPI print contains only direct information about inflation, it seems reasonable that any effect of the information shock on beliefs about other variables works through the agents' revision of inflation expectations (exclusion restriction). In other words, we are assuming that agents use the information contained in the inflation print to revise their beliefs about future inflation, which they may then use to update their beliefs about other relevant economic variables such as economic growth and the path of monetary policy. Assuming the high-frequency identification assumption and the exclusion restriction are satisfied, regressing returns on the unanticipated changes in expectations reveals the causal effect. The CPI-day regression estimates mirror closely the results from the unconditional daily regression. We find that a 1 basis point increase in the 10-year breakeven inflation rate causes a 12 basis point increase in the overall stock market value. This relationship is also positive and stable across the cross-section of stocks, over sub-samples, and is essentially unchanged for alternative expectation measures. While these estimates are silent about the precise conclusions investors may draw about the macroeconomy after updating their future inflation beliefs, the sharp parallel between the unconditional relationship and the causal estimates suggests that the hedging property is a structural feature of equities.

Next, we decompose the channels driving the positive causal effect of the high inflation information shock. Asset pricing identities imply that positive returns must be driven by some combination of higher real cashflows, lower risk-free rates, or lower expected excess returns. We employ four different approaches that together point to the primacy of the expected excess return channel. We first sort stocks in portfolios by their market beta, and find that stocks with larger market beta have monotonically higher loadings on inflation expectations. Under a factor model where market return is the only factor, we derive a simple estimator for how portfolios should respond to changes in inflation expectations. We find that the two-stage estimates from this approach mirror the direct cross-sectional estimates; in other words, our results are consistent with a model where returns are solely driven by innovations to the market factor implied SDF. The next two approaches attempt to directly quantify the contribution of cashflow, risk-free rate and excess return expectation channels. Following Bernanke and Kuttner (2005), in the first approach we estimate a six-variable, six-lag VAR to decompose the return response into the three channels. Nearly the entire effect of inflation expectations on stock returns is attributed to expected excess returns, with the contribution from future real rate and future dividends statistically indistinguishable from zero. Our third approach takes advantage of the high-frequency setting to directly control the mediating channels. Controlling for contemporaneous changes in treasury yields and market-based cash-flow expectation measures (from Gormsen and Koijen (2020)) does little to change the response to inflation expectations. Of the 12 basis point rise in aggregate market value in response to a 1 basis point rise in expectations, (i) 10 basis points are from changes in expected excess returns, (ii) 2 basis points are from changes in cash flow expectations, and (iii) there is essentially no effect from changes in future risk-free rate expectations. Our final approach looks at the cross-section of returns. We estimate the cross-sectional responses over a battery of accounting variables that we would expect to be associated with the real value of cashflows. We find virtually no patterns based on a firm's leverage, profitability, or relative share of real and nominal assets. Moreover, the positive relationship is significant and consistent across all industries, indicating that it is likely driven by broader factors like risk premia, rather than specific firm cash flows. While all three methods have shortcomings, they jointly provide heuristic evidence that the effect works primarily through changes in expected excess returns.

Reduced-form results—even causal ones—do not speak to underlying economic mechanisms. For example, our results do not explain *why* rising inflation expectations cause expected excess returns to decline, and if this decline in expected returns reflects changes to risk premia or simply non-fundamental price impacts. We argue that the positive relationship reflects fundamental changes in risk, as information about higher future inflation signals higher future output. In other words, when investors develop higher inflation expectations, they assign lower probabilities to bad states of the world.[1] This improved outlook would reduce risk premia and thus raise stock prices (David and Veronesi, 2013).[2]

To assess the plausibility of the economic mechanism, we test if positive information about future inflation does in fact predict higher future output. The empirical challenge in uncovering this relationship is that the dynamics of aggregate output take several months (or years) to realize after the information shock, and their behavior depends on the evolution of other macroeconomic and financial variables. To overcome this challenge, we estimate a monthly frequency VAR containing output and other relevant endogenous variables such as the price level, inflation expectations, and the central bank's policy rate. We then include our high frequency shock measure as an exogenous variable (justified by the same identification assumptions we used in the CPI-day stock return regressions). We find that the behavior of the variables is broadly consistent with the information shock revealing higher future inflation: (i) the realized price level rises in response and stays elevated, and (ii) the central bank raises rates in the short-run and brings them back down in the long-run. Most importantly, consistent with our economic mechanism, positive information about future inflation predicts higher output and lower risk. An unexpected 10 basis point rise in the 10-year breakeven expected inflation predicts a 0.7% increase in output over the following year. The dynamics of VIX, and future realized variance of stock returns, show that higher expected inflation is associated with reduced volatility as well. Overall, this finding is consistent with investors using information about higher future inflation to revise their probabilities of future good states of the world.

[1] The effect on equities is largest for negative inflation expectations shocks in low-inflation economies, suggesting that expected disinflation may raise the probability of bad states of the world more than expected inflation raises the probability of good states.

[2] This interpretation is consistent with higher inflation being associated with higher output since the 2000s (Campbell et al., 2020).

Our paper contributes most directly to the literature studying the relationship between stock returns and inflation expectations (Fama and Schwert, 1977; Fama, 1981; Chen et al., 1986). This older literature found a negative correlation between stock returns and expected inflation, i.e., stocks did not provide a hedge against changes in inflation expectations. We build on these studies in several ways. First, since there have been many economic changes over the past few decades, most notably in the joint distribution of inflation and output (Campbell et al., 2020), the sample periods of the past studies are no longer representative of the current economic regime. Our paper is among the first to document the relationship between inflation expectations and stock returns for the post-2000s period. Second, past studies typically measured expectations using either econometric models or survey-based measures. Model-based approaches make strong assumptions about the expectations process of investors, while survey-based measures are often infrequent and may not represent the expectations of the aggregate investor class. We overcome these limitations by using market-based inflation expectations measures, which provide a better quality and higher frequency proxy for changes in investor beliefs. As a result, we achieve significantly higher statistical power than past methods. Finally, the high-frequency (daily) nature of these contracts reduces the risk of confounders leading to misspecification by allowing us to focus on CPI release days.

Several asset pricing models disagree about the sign and magnitude of the relationship between inflation expectations and equity prices (David and Veronesi, 2013; Campbell et al., 2017, 2020; Bhamra et al., 2021). Our results provide a yardstick for assessing these predictions. Furthermore, while our decomposition result—that the causal effect predominantly functions through the expected excess return channel—does not reveal the underlying economic mechanism, it does provide a guiding principle for the channels through which this underlying mechanism must function. For example, given that the effect is positive and the risk-free rate channel plays a limited role, it is unlikely that an explanation based on monetary policy reaction can reconcile the relationship between equity returns and changes in inflation expectations.

Our work is also linked to the broader empirical literature studying the relationship between stock returns and realized inflation (Lintner, 1975; Bodie, 1976; Jaffe and Mandelker, 1976; Nelson, 1976; Fama and Schwert, 1977; Fama, 1981; Chen et al., 1986; Bekaert et al., 2010; Ang et al., 2012; Boons et al., 2020; Roussanov et al., 2021). Theoretically, the predicted effect of realized inflation and stock returns, while not clear cut, is less ambiguous that the effect of expected inflation. Unlike inflation expectations, realized inflation does not appear in the nominal discount rate. Hence, prima facie, we would expect realized inflation to affect (nominal) returns positively to the extent that dividends are claims on real goods, and so rise with inflation. Contrary to this prediction, the literature has overwhelmingly documented a negative exposure of stock returns to realized inflation.[3] That said, the negative relationship between stock returns and realized inflation has turned positive since the 2000s—David and Veronesi (2013); Campbell et al. (2020); Boons et al. (2020) models suggest that the sign flip is consistent with higher inflation now proxying for higher growth. Roussanov et al. (2021) shed further light on the positive sign flip, showing that it is predominantly due to the correlation of returns and energy inflation changing sign, and not the correlation of returns and core inflation, which continues to be negative.[4] A final advantage of using inflation expectations is that, by virtue of being expectations, they strip out much of idiosyncratic noise that appears ex-post in realized inflation series, allowing greater statistical power.

Our paper also relates to the recent literature attempting to determine if investors are aware of and are trying to insure against specific risk factors. Our revealed preferences approach complements the Chinco et al. (2021) survey-based method. By looking at price changes in response to high-frequency shocks to specific risk factors, we can show whether investors are trying to insure against those risks. Our paper also contributes to a growing literature emphasizing the importance of using subjective expectations, rather than objective realizations, in models of asset pricing (De La O and Myers (2021), Nagel and Xu (2022)).

Finally, our paper provides a new method for decomposing the response of prices to high-frequency shocks into contributions from changes in expected excess returns, changes in cash flow expectations, and changes in the risk-free rate using market-based expectation measures. Our method is complementary to the existing VAR methodology proposed by Bernanke and Kuttner (2005). Our method directly controls for mediating factors to determine their contribution; this does not suffer from the bad control problem due to the stronger identification assumptions the high-frequency setting allows. Similar methods have been used in epidemiology and psychology but not in financial economics as far as we know (MacKinnon et al., 2002).

The remainder of the paper is structured as follows. Section 2 discusses the data used in our analysis. Section 3 provides the top-line result of the relationship between stock returns and changes in inflation expectations. Section 4 zooms in on scheduled CPI releases to estimate the causal effect of changes in inflation expectations on stock returns. Section 5 assesses the contributions of the various channels driving the stock price response. Section 6 provides a economic interpretation of our results, relating inflation expectations to output growth. Section

[3] Fama (1981) suggested the negative relationship could be due to high inflation proxying for low growth, whereas Modigliani and Cohn (1979) suggested that the negative correlation could be a result of investors incorrectly using nominal discount rates for valuing real cash flows (money illusion).

[4] Related to this literature that directly looks at the relationship between returns and inflation, Weber (2015) shows that inflation risk affects equity returns via a sticky-price channel, namely, firms that adjust their product prices infrequently carry a return premium.

7 concludes the paper.

2 Data

In this section, we describe data sources, the construction of our measures, and present summary statistics.

Inflation expectations: Our primary measure of inflation expectations uses yields on treasuries and treasury-implied protected securities (TIPS) to back out the breakeven inflation rate. These securities adjust principal and coupon payments on government-issued treasuries by the realized change in the consumer price index over the corresponding period. Investors holding TIPS thus earn the real (inflation-adjusted) yield on treasuries, and the difference between these yields and the yields on nominal US treasuries of the same maturity pins down risk-neutral expectations of inflation over the time period. We obtain daily data on TIPS-implied breakeven inflation expectation from the Federal Reserve Board's TIPS file (for more detail, see Gürkaynak et al. (2010)), and compute daily changes in the daily inflation expectation as our primary variable of interest. Our series comprises 5,276 daily observations on each annual maturity of 2 to 20 years from January 5, 1999 to January 1, 2022.

Since the market for TIPS sometimes suffers from limited liquidity, we also use inflation expectations derived from swaps as a robustness check for all our results. We obtain inflation swaps at 1, 5, and 10 year maturities from Bloomberg. Collectively these have a shorter history than TIPS, and span 4,481 daily observations from July 21, 2004 to November 21, 2021. Our two inflation expectations measures are highly correlated in both levels ($corr(\mathbb{E}_t[\pi_t^{TIPS,10Y}], \mathbb{E}_t[\pi_t^{Swap,10Y}]) = 0.96$) and changes ($corr(\Delta\mathbb{E}_t[\pi_t^{TIPS,10Y}], \Delta\mathbb{E}_t[\pi_t^{Swap,10Y}]) = 0.74$).

Returns: Daily stock returns on the value-weighted US stock index are collected from the Center for Research in Security and Prices (CRSP). We augment this dataset with several other sources of equity returns. For the November 2021-2022 period analyzed at the end of Section 3, we use daily returns on the SP500 Total Return Index, accessed from Yahoo Finance. For portfolio constructions, we use firm characteristics from Compustat, the set of anomaly portfolios from the Open Source Asset Pricing Database (Chen and Zimmermann, 2022), and Fama-French 30 industry portfolios and monthly risk-free rates from Ken French's website.

Dates: We separately analyze the inflation expectation - stock return relationship on sample dates corresponding to inflation news releases. We collect dates of Consumer Price Index (CPI) releases from the Bureau of Labor Statistics.

Other Measures: We obtain real yields from GSW TIPS file (Gürkaynak et al., 2010), and cash flow growth expectations from changes in dividend strips (Gormsen and Koijen, 2020).

Table 1 presents summary statistics on the main inflation expectations measures, the value-weighted stock return, and the real 10-year yield.

Table 1: Summary statistics of main measures

	Mean (basis points)	Standard deviation (basis points)	Observations
$\Delta\mathbb{E}_t\left[\pi_t^{TIPS,10Y}\right]$	-0.0	3.6	5028
ret_t	3.6	123.5	5536
$\Delta\mathbb{E}_t\left[\pi_t^{Swap,10Y}\right]$	-0.0	3.8	4295
$r_t^{TIPS,10Y}$	-0.1	4.7	5028

This table shows the summary statistics for measure of daily changes in inflation expectations and returns. Changes in both TIPS- and Swap-implied measured of inflation expectations are mean 0 over the sample. The sample period is 2000-2021 for TIPS measures, and 2004-2021 for Swap-implied measures.

3 Stocks prices rise hand-in-hand with inflation expectations

In this section we verify and show the robustness of the findings that stocks prices rise when inflation expectations rise. To capture the overall effect of changes in inflation expectation on returns, we regress daily CRSP value-weighted returns on daily changes in the TIPS implied 10-year breakeven inflation rate:

$$ret_t = \alpha + \beta_\pi \Delta\mathbb{E}_t\left[\pi_t^{10Y}\right] + \varepsilon_t \tag{1}$$

We choose TIPS over swaps for our baseline measure due to its longer history. Furthermore, we use the 10-year tenor because it aggregates inflation expectations across the term structure. The longer horizon also suggests a cleaner measure of inflation expectations: as documented by Bahaj et al. (2023), so-called fundamental expectations – i.e., as opposed to liquidity shocks –

account for the majority of price variation of inflation-linked products at longer horizons. As we later show, the overall conclusion is unchanged if we use alternative expectations measures or tenors.

Column 1 of table 2 presents the estimates for our baseline regression using the full post-2000 sample. For a 1 basis point increase in inflation expectations, stocks on average provide an 11.2 basis point return. The estimate is highly significant. Since the standard deviation of the change in 10-year TIPS expectations is 3.6 basis points, these results imply that a one standard-deviation increase in daily inflation expectations is associated with a nearly one third standard deviation in daily stock returns. In Column 3, we re-estimate equation 1 using inflation swaps to measure inflation expectations and obtain very similar estimates.

Our baseline estimate in column 1 uses the 10-year measures of inflation expectation. In column 2, we explore the relevant horizon at which expectations operate by examining innovations to short-dated and long-dated inflation-linked contracts separately. Specifically, we decompose the 10-year breakeven rate into the 5-year breakeven rate, $\mathbb{E}_t\left[\pi_t^{0-5Y}\right]$, and the component from the forward 5-to-10 year breakeven rate $\Delta\mathbb{E}_t\left[\pi_t^{5-10Y}\right]$. Column 2 shows that higher expected inflation is associated with higher returns at both the short and long ends of the term structure. There is some evidence that the effect is stronger in the short end ($\hat{\beta} = 11.40$) than the long end ($\hat{\beta} = 7.44$). Nevertheless, more relevant to our paper, the positive exposure of stock to changes in inflation expectations is not limited to a single expectations horizon but is robust across the term structure. Column 4 repeats the exercise using the swap-based inflation expectation measures and confirms the findings of column 2.

Next, we explore whether the stable positive relationship observed for stock market returns is also present in the cross-section of stock returns. To test this, we re-estimate equation 1 on the value-weighted return of each of 30 Fama-French industries. Figure 1 plots the industry-portfolio specific coefficients β_π. While there is heterogeneity among industries, all 30 industries have positive and significant exposure to inflation expectations that are similar in magnitude to the market portfolio. Hence, the positive exposure of market returns to inflation expectations does not seem to be driven by a few stocks but rather is a trait across stocks. The observed heterogeneity is consistent with Roussanov et al. (2021): we find that coal, chemicals, and oil—all energy-adjacent industries—are among the most sensitive to changes in expected inflation.

Given the dynamic macroeconomic environment post-2000—including changing nominal-real covariance, a recession, and a zero-lower bound period—a natural concern in studying the conditional effect of inflation is whether it is driven by a specific sub-period. We therefore check

Table 2: The exposure of stocks to changes in inflation expectations

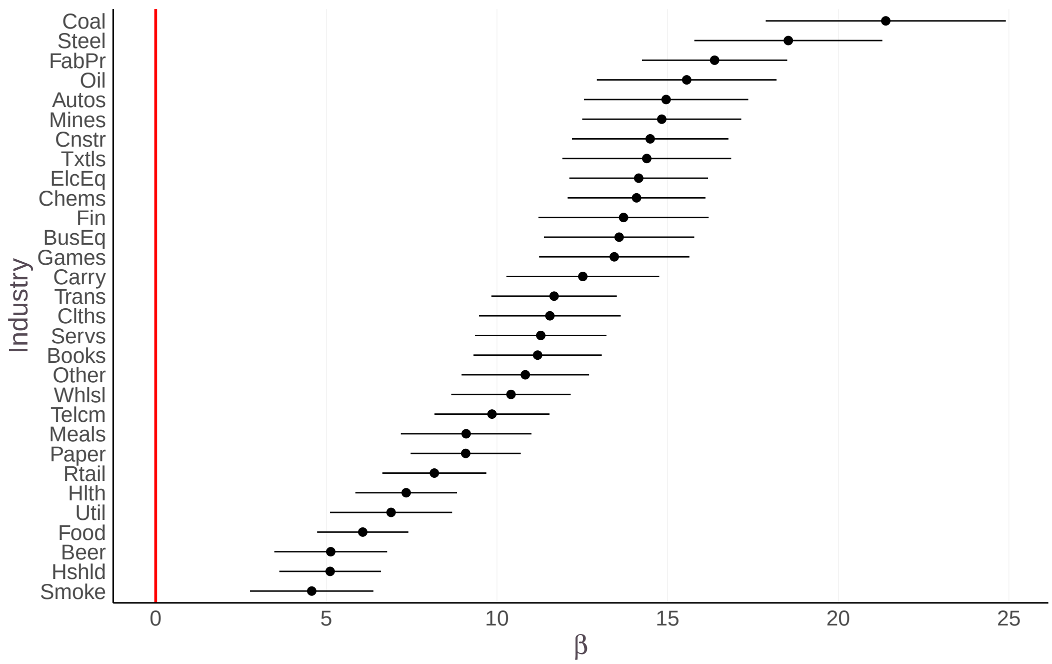
	TIPS		Inflation Swaps	
	(1)	(2)	(3)	(4)
	$ret_{market,t}$	$ret_{market,t}$	$ret_{market,t}$	$ret_{market,t}$
$\Delta\mathbb{E}_t[\pi^{10year}_{t,TIPS}]$	11.16^{***}			
	(13.03)			
$\Delta\mathbb{E}_t[\pi^{0-5years}_{t,TIPS}]$		11.40^{***}		
		(13.45)		
$\Delta\mathbb{E}_t[\pi^{5-10years}_{t,TIPS}]$		7.44^{***}		
		(5.01)		
$\Delta\mathbb{E}_t[\pi^{10year}_{t,Swap}]$			10.25^{***}	
			(8.16)	
$\Delta\mathbb{E}_t[\pi^{0-5years}_{t,Swap}]$				10.93^{***}
				(9.08)
$\Delta\mathbb{E}_t[\pi^{5-10years}_{t,Swap}]$				7.36^{***}
				(4.25)
N	5,021	5,021	4,155	4,086
R^2	0.11	0.11	0.11	0.12

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

This table displays the results from a regression of the daily value-weighted stock return on change in daily 10 year breakeven inflation expectations. Columns (1) and (2) measure breakeven inflation expectations using TIPS, while columns (3) and (4) use inflation swaps. Units of both the dependent and independent variable are in basis points, i.e. a coefficient of 10 indicates that a 1 basis point increase in inflation expectations is associated with a 10 basis point increase in daily stock returns. t-statistics are based on HAC standard errors with 4-lags.

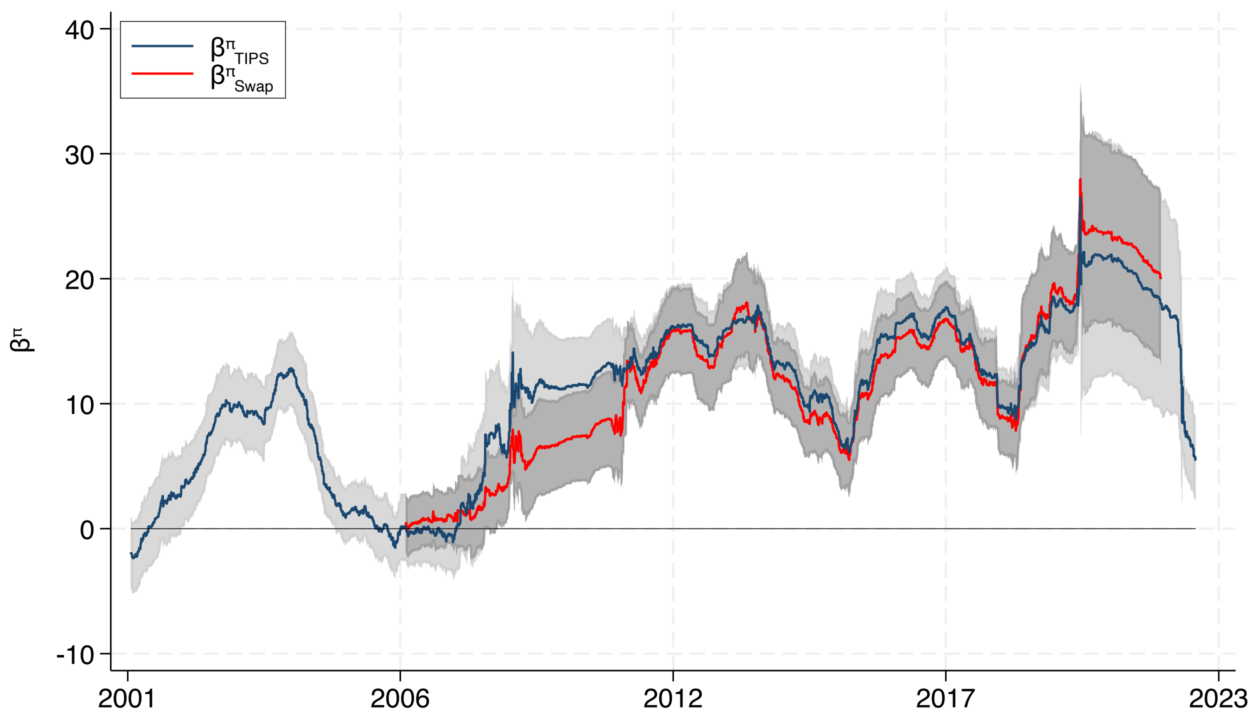
Figure 1: Inflation Betas Across 30 Fama-French Industries



This figure illustrates the response of industry portfolios to changes in expected inflation. Each point represents the coefficient from the bivariate regression of the value-weighted stock return in the corresponding industry on the daily change in 10-year TIPS-implied expected inflation. Point estimates and 95% robust confidence intervals are plotted for each of the Fama-French 30 industries.

whether the positive results are robust across the time series. We estimate a 750 calendar day (approximately two years) rolling window of equation 1 and plot the coefficients in figure 2. Despite the relatively short rolling window used for the analysis, the stability and significance of the estimates are striking. Apart from a brief period during the financial crisis, the relationship has been positive and robust since 2000. Additionally, the rolling regression using swap-implied inflation expectations yields an essentially identical conclusion to the TIPS-based results.

Figure 2: Rolling Inflation Expectations Beta



This figure shows the coefficients from daily rolling regressions with 750-calendar day windows of value weighted stock returns on changes in daily inflation expectations. The blue line uses TIPS-based measures, while the red line uses swap-based measures. The shaded areas represent 95% robust confidence intervals.

4 Causal Effect of Changes in Inflation Expectations

We now estimate the causal effect of inflation expectations on stock returns. The estimates in the previous section summarized the joint behavior of stock returns and inflation expectations we observe in equilibrium. While valuable for assessing if stocks hedge changes in inflation expectations, the results from the unconditional analysis do not reveal the underlying structural relationship.

To properly identify the causal effect of inflation expectations, an ideal experiment would shock investor beliefs about inflation and then trace out the subsequent effect on returns. The obvious empirical challenge is that we cannot selectively shock investors' expectations. Zooming in on CPI dates offers a quasi-experimental setting that approximates randomly shocking investors' beliefs about future inflation.

4.1 Identification

Our main approach to causal analysis is to re-run our main specification (see equation 1) on CPI days. This approach will reveal the causal relationship if the following two identification assumptions are satisfied,

1. **High-frequency identification assumption**: the only shock that drives changes in inflation expectations and stock returns in the estimation window is the CPI information shock.

2. **Exclusion restriction**: any effect of the information shock on other variables works through inflation expectations.

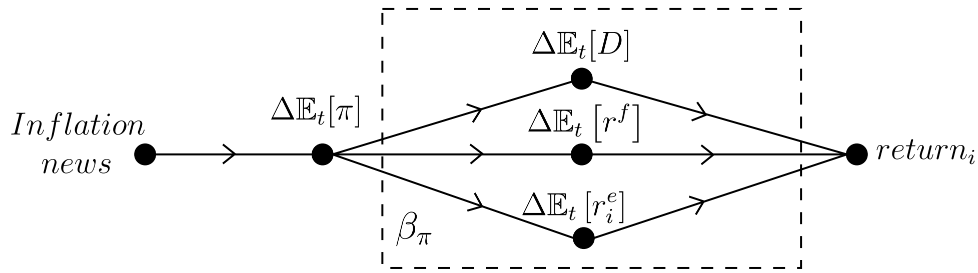
The high-frequency identification assumption is needed to ensure that our observed effect is due only to the CPI information shock and not other confounders. We use daily, rather than intraday, windows to ensure sufficient time for stock prices to fully adjust to the inflation information shock.[5] The exclusion restriction is needed to ensure that the observed return response is attributable to the change in inflation expectations. The exclusion restriction assumes that agents use the CPI print only to infer information about inflation, and so any subsequent outcomes are a result of changes in inflation expectations. Crucially, the assumption does *not* imply that agents do not update their beliefs about other macroeconomic variables, only that these updates are due to revisions in inflation expectations. For example, after a CPI print agents update their inflation expectations, as a result of which, they may also update other beliefs (e.g., monetary policy, growth, etc.). This exclusion restriction seems plausible given the limited nature of the information contained in CPI reports—it contains only descriptive information about aggregated prices with essentially no analysis.

The causal structure implied by these two identifying assumptions is captured by the DAG in figure 3. First, the inflation news shock is the sole driver of the causal effect—reflecting the high-frequency identification assumption. Second, changes in inflation expectations mediate the effect of the shock on all other variables—reflecting the exclusion restriction. Assuming the assumptions are satisfied, the β_π obtained from estimating our main specification on CPI

[5] We do not believe our results will be significantly impacted by using intraday data. Since the estimates are highly significant and robust under various sub-samples, any intra-day confounders would need to be present for almost every sub-sample to explain away the day-level result.

days will give the total causal effect of the change in inflation expectations. The total effect aggregates the direct and indirect effects from the mediating channels of changing (i) cash flow expectations, (ii) interest rate expectations, and (iii) excess return expectations.

Figure 3: CPI day regression DAG



4.2 CPI release day summary statistics

CPI announcement days are scheduled monthly and released by the Bureau of Labor Statistics. The dates of these announcements are known in advance, and the announcement occurs at 8:30am before market open. In our sample from January 2000 to December 2021, we have 274 CPI releases.

Table 3 compares the changes in inflation expectation on CPI days to non-CPI days. As a first sense check of the identification strategy, we find that the average change in inflation expectations is approximately zero, and it is no different on CPI vs. non-CPI days. The zero estimate is consistent with the CPI release leading to unanticipated changes in inflation expectations. As a second sense check, we find that the standard deviation of changes in inflation expectations is significantly higher on CPI release days. If CPI releases contain information of particular relevance for inflation expectations, then we would expect to see higher variance in inflation expectations on CPI release days.[6]

4.3 Causal estimates

In table 4, we present the results from the CPI day regressions. Column 1 presents our baseline specification. We find a positive and statistically significant coefficient of 11.88 ($t = 4.43$). In other words, a 1 basis point increase in inflation expectations causes a nearly 12 basis point rise in stock prices. Since the standard deviation of the change in 10-year TIPS expectations on CPI days is 4.3 basis points, these magnitudes are large even on news days. As before, column 3 confirms that the estimates are broadly similar when we use swaps to measure inflation

[6]Barring periods of significant market stress in 2008 Q3/4 and 2020 Q1, of the five largest single day changes in 10-year breakeven inflation expectations, three occurred on CPI release days.

Table 3: Inflation expectation measures CPI vs non-CPI days

	All	Non-CPI	CPI	Diff	p-value (Diff)
$\Delta \mathbb{E}_t \left[\pi_t^{TIPS,10Y}\right]$					
Mean	-0.025	-0.022	-0.087	-0.066	0.8
St. Deviation	3.6	3.6	4.3	0.66	5.1e-05***
Observations	5021	4747	274		
$\Delta \mathbb{E}_t \left[\pi_t^{Swap,10Y}\right]$					
Mean	7.9e-05	8e-03	-0.14	-0.15	0.63
St. Deviation	3.9	3.9	4.5	0.62	0.0014**
Observations	4155	3937	218		

The units are in basis points. The final two columns report the difference in mean and standard deviations for the given measure on CPI vs. non-CPI days. For means, the p-value is associated with a standard t-test test statistic. For standard deviations, the p-value is associated with an F test for equal variances.

expectations.

Columns 2 and 3 decompose the effect across the term structure. We lose statistical power; however, the estimates are still positive and have a similar magnitude both on the short-end and long-end of the expectations term structure. Overall, the positive exposure of stock to changes in inflation expectations is not limited to operating at a single horizon.

Columns 5 and 6 present the sensitivity of the estimates to using different sub-samples. We split the observations in half around the midpoint of November 2010. Hence, each of the two sub-samples has 137 observations. Column 5 presents the estimates for pre-November 2010, and column 6 presents the estimates for post-November 2010 (including November). The estimates in the two sub-samples are remarkably similar and significantly positive. Hence, a few outliers do not seem to be driving our estimates.

Like the unconditional analysis, we re-estimate our baseline specification for each of the 30 Fama-French industry portfolios. Figure 4 plots the industry-specific β_π. The individual coefficients are in the neighborhood of the estimate for overall market returns. While there is some heterogeneity, all 30 industries have positive and significant exposure to changes in inflation expectations. The positive effect of higher expected inflation on stock prices does not appear to depend on the industry or sector analyzed.

We next check for evidence of a reversal in the stock returns following the initial response to changes in the inflation expectations. If the price increase reflects fundamental information,

Table 4: CPI day effect of changes in inflation expectations on returns

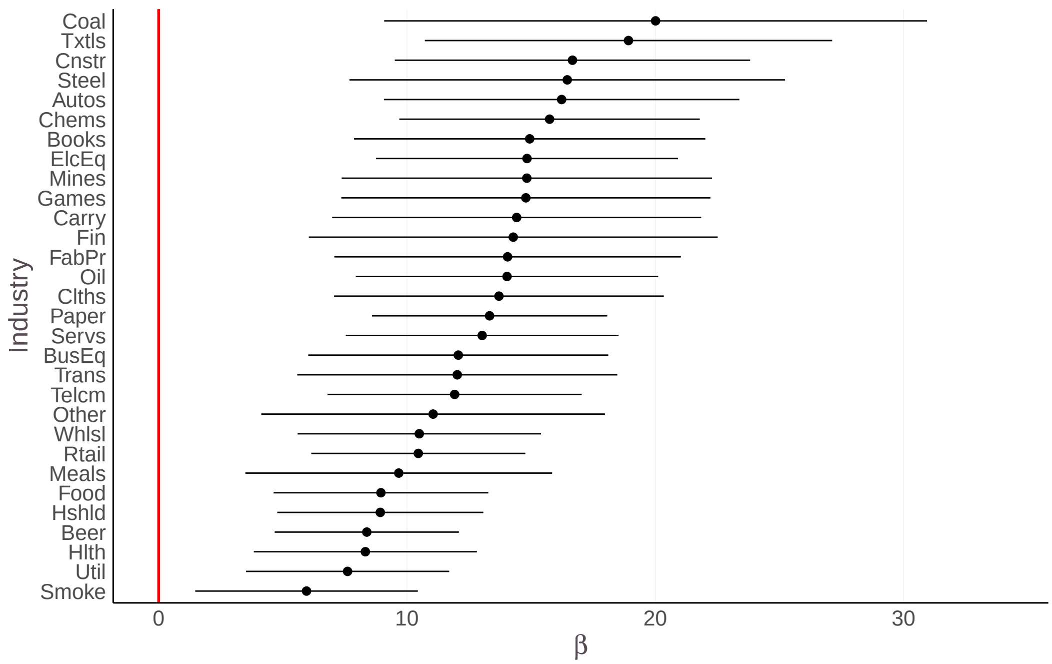
	TIPS		Inflation Swaps		Sample Split	
	(1)	(2)	(3)	(4)	(5)	(6)
	$ret_{market,t}$	$ret_{market,t}$	$ret_{market,t}$	$ret_{market,t}$	$ret_{market,t}$	$ret_{market,t}$
$\Delta\mathbb{E}_t[\pi_{t,TIPS}^{10year}]$	11.88***				11.13**	12.96***
	(4.43)				(2.92)	(3.57)
$\Delta\mathbb{E}_t[\pi_{t,TIPS}^{0-5years}]$		12.07***				
		(4.32)				
$\Delta\mathbb{E}_t[\pi_{t,TIPS}^{5-10years}]$		9.80				
		(1.97)				
$\Delta\mathbb{E}_t[\pi_{t,Swap}^{10year}]$			10.53**			
			(3.22)			
$\Delta\mathbb{E}_t[\pi_{t,Swap}^{0-5years}]$				10.51**		
				(3.27)		
$\Delta\mathbb{E}_t[\pi_{t,Swap}^{5-10years}]$				10.95*		
				(2.23)		
N	274	274	218	216	137	137
R^2	0.17	0.17	0.17	0.17	0.12	0.28

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

This table displays the results from a regression of the CPI day value-weighted stock return on change in daily 10 year breakeven inflation expectations. Columns (1) and (2) measure breakeven inflation expectations using TIPS, while columns (3) and (4) use inflation swaps. Columns (5) and (6) run the TIPS baseline specification but split the sample in half, pre and post Nov 2010 respectively. Units of both the dependent and independent variable are in basis points, i.e., a coefficient of 10 indicates that a 1 basis point increase in inflation expectations is associated with a 10 basis point increase in daily stock returns. t-statistics are based on HAC standard errors with 4-lags.

Figure 4: Inflation Betas Across 30 Fama-French Industries



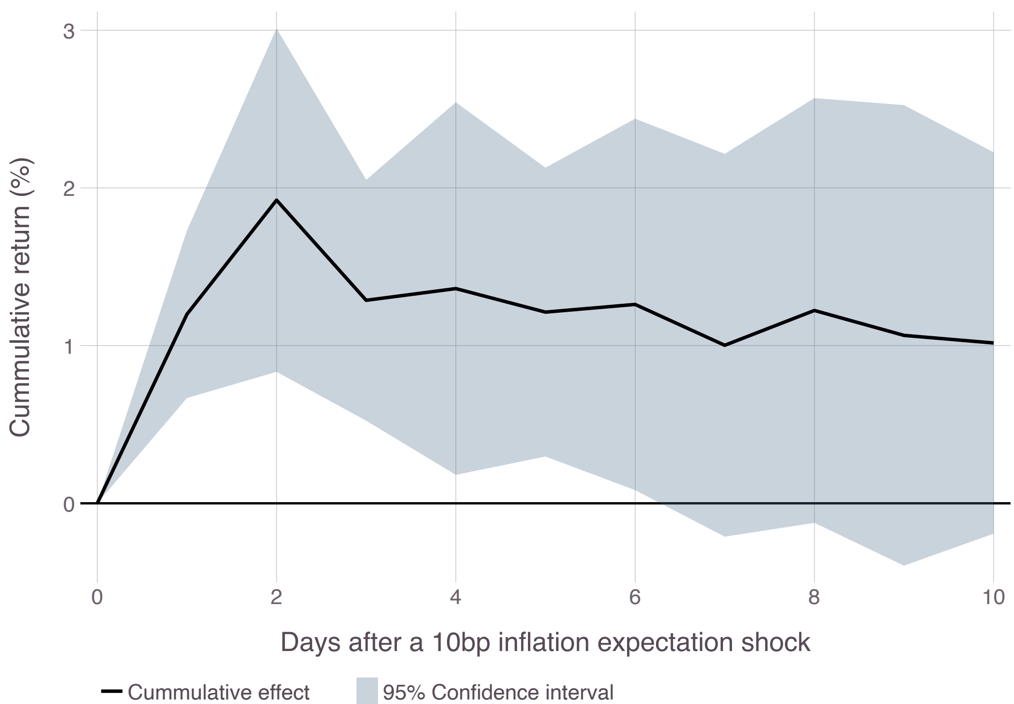
This figure illustrates the response of industry portfolios to changes in expected inflation. Each point represents the coefficient from the bivariate regression of the value-weighted stock return in the corresponding industry on the daily change in 10-year TIPS-implied expected inflation on CPI release dates. Point estimates and 95% robust confidence intervals are plotted for each of the Fama-French 30 industries.

prices should stay elevated after changes in inflation expectations. However, if the price change is for non-fundamental reasons — such as temporary mispricings — we would see the price eventually reverse. We check for reversal by regressing cumulative returns h days after the CPI release on the change in inflation expectations on CPI dates,

$$ret_{t+h} = \alpha + \beta_{\pi}^{h} \Delta \mathbb{E}_t \left[\pi_t^{10Y}\right] + \varepsilon_t, \quad h \in \{0, 1, 2, 3, ...\} \tag{2}$$

Figure 5 plots the cumulative forward return. If anything, the cumulative return in the day following the CPI release date is even higher, not lower. At a horizon of 10 days, the point estimates are in line with the same-day effect and show no evidence of reversal. This persistence suggests that CPI releases reveal fundamental information.

Figure 5: Reversal



This figure illustrates the persistent effects of the inflation insurance premium at horizons up to 10-days. The black line represents cumulative forward returns n days after a change in inflation expectations (i.e., it connects the point-estimates of β_{π}^{h} from equation 2), while the shaded area shows the 95% robust confidence interval. The sample comprises CPI release dates.

Our baseline results indicate that higher inflation expectations cause equity prices to rise. Furthermore, this effect is highly robust—the effect is significantly positive regardless of the measure of inflation expectations, the date sample analyzed, the horizon of expectations, and the sector of focus.

4.4 Asymmetric Responses: Disinflation Risk

A natural question to ask is whether the effect of inflation expectations on stock returns is asymmetric. Several papers have identified that household inflation expectations are more responsive to inflation than to disinflation ((Nagel and Yan, 2022), (Baqaee, 2020)), and a longer literature has identified the asymmetric role of inflation on economic fundamentals (for example, due to downward nominal wage rigidity). It is plausible that the effect of inflation on stock returns could vary heterogeneously – both by the current expected inflation environment, and by the sign of the innovation in inflation expectations. To motivate this analysis, we begin by splitting the sample into one of four categories based on the level of expected inflation and the sign of the change in daily breakevens. We classify each CPI day as above or below median in 10 year inflation expectations, and as a positive or negative change in expected inflation on the CPI day. The intersection of these categories provides four subgroups over which to separately estimate the effects.

Table 5 shows the results from this analysis. While all coefficients load positively, the effect is strongest for reductions in inflation expectations in environments where the level of expected inflation over the next 10 years is already low; the effect is more than twice as large as the unconditional average. For both high and low expected inflation environments, negative innovations to expected inflation have a larger (i.e. more negative) effect on stock prices than positive innovations to expectations. And for both positive and negative changes in expected inflation, the effect is stronger in low expected inflation environments than in high ones. These patterns are robust to using inflation swaps in place of TIPS, omitting the financial crisis period (2008-2009), and considering all days rather than restricting to CPI days alone.

Table 5: Inflation Beta by 2x2 Sort

	(1)	(2)	(3)	(4)	(5)
		High, +	High, -	Low, +	Low, -
$\Delta\mathbb{E}_t[\pi^{10year}_{t,TIPS}]$	11.73***	7.19	11.53*	9.10	24.27**
	(4.40)	(1.81)	(2.27)	(1.93)	(3.03)
N	277	71	67	65	74
R^2	0.16	0.04	0.12	0.06	0.27

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

This table shows the coefficients from regressions of value-weighted returns on changes in daily breakeven over four subsamples of CPI release days. “High” (“Low”) days are ones in which the 10-year expected inflation is greater (less) than its median. "+" ("-") are CPI days in which the change inflation expectations was positive (negative). Robust t-statistics are in parentheses.

These results may also shed light on the specific pricing risks that investors incorporate when adjusting inflation expectations. While the analysis has framed positive inflation as good news about economic growth, Table 5 suggests that the primary effect is through avoiding a *deflationary* environment. Environments in which the economy move closer to deflation – when expected inflation is already low, and moves lower – is when the stock market prices the largest effect. There are a number of reasons why deflation could be a pertinent risk, including recession risk and zero-lower bound risk. For example, Bok et al. (2022) develop a model in which the prospect of a binding zero-lower bound makes a low interest rate (low inflation) more costly, as the central bank is unable to lower rates further. This mechanism could give rise to asymmetry featured in table 5 if the ZLB constrains the central bank from stimulating the economy. However, in appendix section A.3, we control directly for changes in the option-implied (i.e., risk-neutral) probability of hitting the zero-lower bound, and verify that including this control does little to change the expected inflation beta. We revisit the implications of inflation for economic growth and interest rates in section 6.

4.5 Inflation Surprises vs. Inflation Expectation Surprises

Why is it that stocks appear to fall in response to high inflation news, but respond positively to positive innovations in inflation expectations? Indeed previous literature has documented a negative relationship between shocks to inflation and stock returns. For example, Gil de Rubio Cruz et al. (2022) document a robust negative relationship between inflation surprises – calculated as the difference between realized CPI and survey-based expectations – and the cross-section of equity returns. In this subsection, we reconcile the opposite signs on inflation surprises and inflation *expectations* surprises on stock returns. We argue that these opposite signs are consistent, as the positive impact of breakeven changes on stock returns is driven by the part of the change that is orthogonal to the inflation surprise.

In Table 7, we measure the effect of CPI surprises on aggregate stock returns. We calculate CPI surprises using the actual reported CPI less the survey-based expectation of the CPI announcement. We explore five measures of CPI – total CPI (both year-over-year and month-over-month); CPI ex-food and energy (also YoY and MoM); and seasonally-adjusted CPI. Consistent with prior literature, all inflation surprises are associated with a negative impact on stock returns, though the statistical significance is marginal.

That stock returns covary positively with changes to inflation expectations and negatively with inflation surprises could suggest that inflation surprises and changes in breakeven are negatively correlated. In Panel B of table 7, we show that this is not the case. Positive CPI surprises are associated with statistically significant increases in expected inflation for virtually all CPI surprise measures. In other words, when the CPI reading exceeds the survey-based expectation, investors tend to revise upwards their expectations of future inflation. An implication of these opposite signed results is that the positive impact of inflation expectations on stock returns is not primarily driven by the impact of inflation surprises on stock returns, but rather contains distinct informational content relevant to equities. To see this, observe that we can express changes in breakeven as linear in the CPI surprise and a component orthogonal to CPI surprise:

$$\Delta\mathbb{E}[\pi_t] = \beta Surprise_t + \eta_t$$

Taking covariances with returns, we have:

$$\underbrace{Cov(\Delta\mathbb{E}[\pi_t], ret_t)}_{(+)} = \underbrace{\beta}_{(+)} \underbrace{Cov(Surprise_t, ret_t)}_{(-)} + \underbrace{Cov(\eta_t, ret_t)}_{(+)}$$

where the signs of the first three terms are from tables 4 and 7, and the positive sign on $Cov(\eta_t, ret_t)$ follows by requirement. To sustain the positive covariance between changes to expected inflation and stock returns, stocks must respond very positively to the component of inflation expectations uncorrelated with surprises. Our paper is therefore consistent with the literature documenting a negative inflation-stock return gap: changes to inflation expectations contain information distinct from inflation surprises that more than compensate for the negative impact of these surprises. These results also explain the challenge in finding large and statistically robust impacts of inflation shocks on stock returns. The direct channel of inflation shocks on stock returns is negative, but is mitigated by the indirect channel of inflation shocks on expectations.

The distinctive effects of inflation and inflation expectations can also explain the response of equities to inflation news in the post-Covid period. During 2021-2023, realized inflation in the US alone has risen above 6%, with some months witnessing year-over-year changes as large as 9%. More pertinently, during this period, when realized inflation has surprised to the upside, stock prices have tended to decline sharply. A natural question is whether the relationship between stock returns and expected inflation has now turned negative.

While equities have responded negatively to realized inflation, we show that this effect is not driven by long-term inflation expectations. In fact, the 2 to 10 year forward inflation rate is a positive and significant predictor of stock returns. To show this, we repeat the analysis from the previous section, restricting our sample to the last two years (November 2021 through October 2023), when inflation was high.[7]

[7] To focus on the most recent stock return data possible, we use daily returns of the S&P500 Total Return index from Yahoo Finance. We continue to measure inflation expectations using treasury-implied breakeven rates.

Table 6 presents the results from this exercise. Columns (1) and (2) show the coefficients from a regression of stock returns on the unconditional daily changes in inflation expectations at 10-year and 2-year tenors. While the coefficients are smaller and insignificant, the point estimates are positive. Columns (3) and (4) provide evidence that the lower point estimates are not due to a changing relationship between long-term inflation expectations and stock returns. In column (3), we show that changes in the 2-10 year forward rate are significant and positive predictors of stock returns. And restricting to the 25 CPI days in the post-2021 sample, the point estimate rises to a (marginally insignificant) 14.69.

Why have the coefficients remained positive in the post-pandemic high inflation episode? And why are the responses stronger with forward rates than with spot rates? We argue that both of these results are consistent with the negative relationship between inflation and equity returns and the positive relationship between inflation expectations and stock returns. The short-end of the inflation expectations term structure is highly correlated with realized inflation. If realized inflation, in turn, has a negative impact on equities, then changes in inflation expectations associated with changes in inflation may offset, leading to coefficients close to zero. Forward inflation expectations, by contrast, net out the near term changes in realized inflation, and instead focus on the longer-term inflation expectations. These forward expectations may better capture the economic regime. To illustrate this, Figure 6 plots the year-on-year change in headline CPI against the 2-year, 5-year and 10-year instantaneous inflation forwards constructed using TIPS and treasuries. The figure shows that, despite realized inflation rising to 9%, inflation expectations have remained anchored at around 2%. The forward rates for the three tenors are virtually indistinguishable, suggesting that the recent increase in inflation is perceived by the market as a purely temporary phenomenon operating in the same inflation regime. Changes in inflation expectations isolated from spot realized inflation – the forward expected inflation – continue to have a significant and positive effect on stock returns.

4.6 Changes in beliefs about future expectations or changes in term premia?

A natural question when using market-based rather than survey-based inflation expectations is to what extent the measure is contaminated by changes in term premia. For example, when new information about inflation is published on CPI days, do changes in market-based inflation expectations predominantly reflect changes in investor beliefs about future inflation, or changes in term premium?

In the appendix A.2 we conduct three exercises that suggest that changes in term premia are not driving our results. First, using Fama and Bliss (1987) regressions, we show

Table 6: Baseline Regression for November 2021 to October 2023 Sample

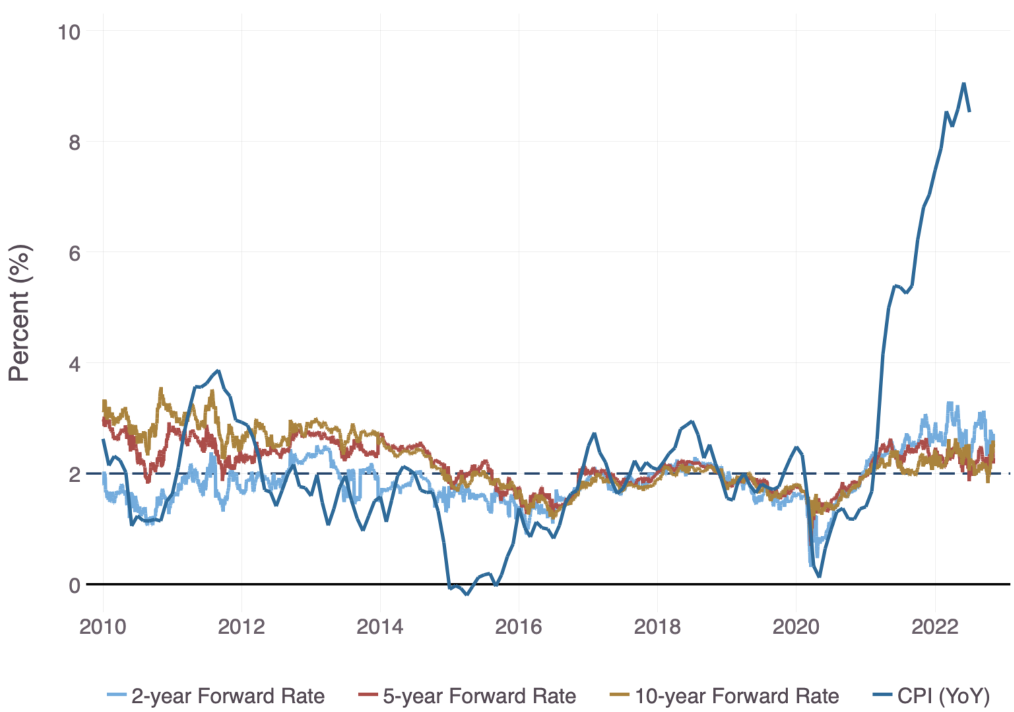
	(1)	(2)	(3)	(4)
$\Delta\mathbb{E}_t[\pi^{10year}_{t,TIPS}]$	2.06			
	(1.60)			
$\Delta\mathbb{E}_t[\pi^{2year}_{t,TIPS}]$		0.23		
		(0.23)		
$\Delta\mathbb{E}_t[\pi^{2-10year}_{t,TIPS}]$			2.36^{*}	14.69
			(1.98)	(1.44)
CPI days	No	No	No	Yes
N	475	475	475	25
R^2	0.01	0.00	0.01	0.09

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

This table shows the regression of the S&P500 returns on breakeven inflation expectations of different tenors. t-statistics are based on HAC standard errors with 4-lags.

Figure 6: Realized Inflation vs Inflation Expectations



This figure shows the time series of forward rates on breakeven inflation across different tenors. 2-year, 5-year, and 10-year forward rates are calculated using the differences in implied breakevens for corresponding TIPS contracts. For comparison, we also plot the year-over-year realized inflation series in dark blue.

Table 7: Inflation Surprises vs. Inflation Expectation Surprises

	MoM	YoY	Core (MoM)	Core (YoY)	Core (SA)
	(1)	(2)	(3)	(4)	(5)
Panel A: CPI Surprises and Stock Returns					
	Dep. Variable: $ret_{market,t}$				
CPI Surprise	-0.950	-0.126	-1.902*	-0.520	-0.396
	(0.905)	(0.848)	(0.750)	(0.848)	(0.369)
Observations	302	220	300	219	108
Panel B: CPI Surprises and Changes in Exp. Inflation					
	Dep. Variable: $\Delta\mathbb{E}_t[\pi^{10Y}_{t,TIPS}]$				
CPI Surprise	3.169	4.871*	10.31***	9.659***	3.909***
	(2.783)	(2.227)	(2.663)	(2.485)	(1.121)
Observations	279	222	278	221	110

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

This table contrasts the relationship between inflation surprises and stock returns with the relationship between changes in inflation expectations and stock returns. Panel A shows the results of a regression of value-weighted stock returns on 5 different measures of CPI surprises: month-over-month CPI (MoM), year-over-year CPI (YoY), CPI ex-Food and Energy month-over-month (Core (MoM)), CPI ex-Food and Energy year-over-year (Core (YoY)), and Core CPI Seasonally Adjusted (Core (SA)). Surprises are calculated using survey data from Bloomberg. Panel B shows the results from a regression of changes in TIPS-implied breakeven on each of these same 5 CPI surprise measures. Robust standard errors are in parentheses.

that unconditionally changes in term premia do not play a substantial role in driving changes breakeven-inflation rates. Second, we directly control for changes in term premia, estimated using Kim and Wright (2005) three-factor affine term structure model, and find that they do not significantly alter our estimates. In terms of the direct effect of term premia changes on stock prices, while it is significant for the full sample, it is insignificant when we condition on CPI days. Finally, consistent with investor beliefs changing, we show that changes in market-based inflation expectations are a significant predictor of inflation forecast revisions by analysts.

5 Disentangling the Channels

The estimates in the previous section establish that changes in inflation expectations cause stock prices to rise. However, the estimates do not reveal the channel by which the causal relationship works. According to the present discount identity (Campbell and Shiller, 1988), the stock price rise must be due to changes in expectations about (i) dividends, (ii) real rates, or (iii) excess returns. In this section, we use three different approaches to assess the prominence of these three channels. While each of the methods has its shortcomings, all suggest that the rise in stock prices following higher inflation expectations is mainly due to lower future expected excess returns.

We start by providing heuristic evidence showing that a using the market's β^{π}_{mkt} and a stocks i's β^{mkt}_i is a good predictor of the stocks β^{π}_i. Our next two methods take advantage of the exogeneity of our inflation expectations shock to decompose the response of market returns. We first apply the VAR method proposed by Bernanke and Kuttner (2005) to decompose the response of stock returns into the three channels. We find the effect is almost entirely driven by changes in future excess returns. Next, we use market based measures of dividend and real rate expectations to decompose the response of β_π into its respective channel. This exercise also suggests the primacy of changes in expected excess returns driving the price response. The final method assess if variables typically associated with firm-payout policy can explain the cross-sectional variation in β_π. We find little-to-no relationship, suggesting changes in dividend expectations do not seem to be an important channel.

5.1 Market factor implied β_π

Our first approach provides heuristic evidence for the role of changes in expected excess returns in driving the observed cross-sectional variation in β_π. We study the estimates that should be observed if returns are driven solely by innovations to the market factor; this is an exercise similar in spirit to the one done by Bernanke and Kuttner (2005) for monetary policy shocks.

In and of itself, our empirical exercise is atheoretic, as it does not take a stance of whether or not the market factor reflects risk compensation. It only asks if changes in the market factor can explain the observed heterogeneity in β_π. However, if CAPM were the *true* risk model, our exercise can be interpreted as assessing if changes in risk premia explain the response of stock prices to changes in inflation expectation.

To that end, suppose that returns are described by the one-factor model,

$$r_{i,t} = \alpha + \beta_i^{mkt}(r_{mkt,t} - r_t^f) + \varepsilon_{i,t}$$

If changes in inflation expectations only affect prices through market returns, then stock i's response to inflation expectation is given by,

$$\hat{\beta}_i^\pi = \hat{\beta}_i^{mkt} \cdot \hat{\beta}_{mkt}^\pi$$

where $\hat{\beta}_{mkt}^\pi$ is the response of market returns to changes in inflation expectations. In other words, the response of stock i to changes in inflation expectations should be directly proportional to the aggregate market response to those changes. Due to estimation and approximation noise, this equation will not hold exactly; however, if the magnitudes of $\hat{\beta}_i^\pi$ and $\hat{\beta}_i^{mkt}\hat{\beta}_{mkt}^\pi$ are close, it provides indicative evidence for the underlying assumptions.

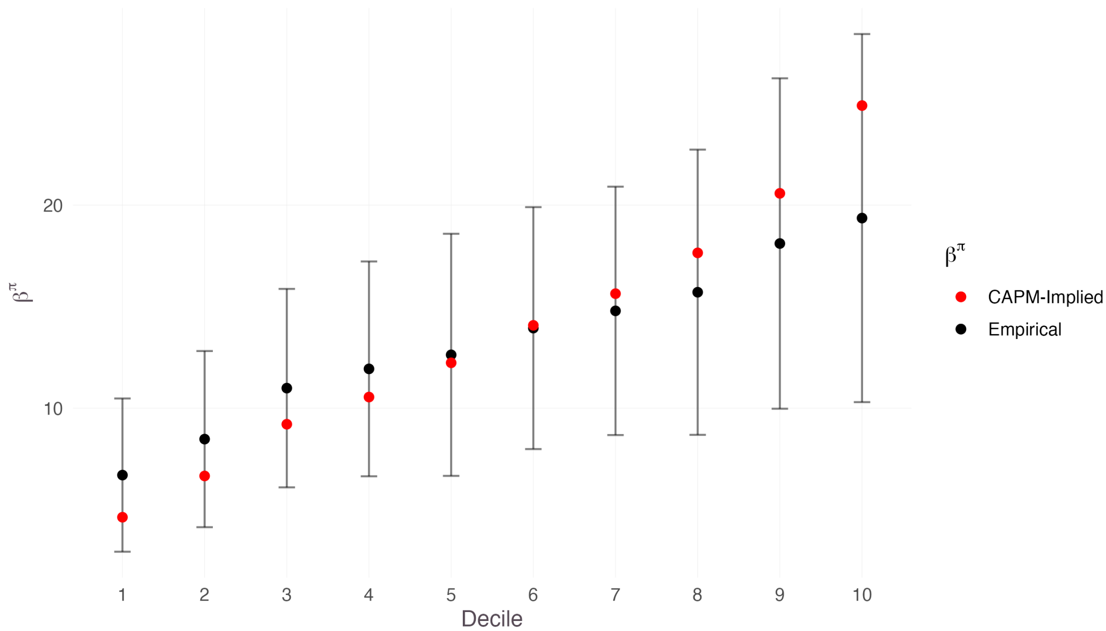
Figure 7 compares the two estimates across the deciles of inflation beta. Consistent with the role of expected excess returns, the market beta implied estimates are close to those obtained through the direct regression. (In all cases, the market beta implied estimates are well within the 95% robust confidence intervals of the direct estimates).

5.2 VAR decomposition of β_π

We employ a VAR to decompose the market return to inflation expectation shocks into contributions from changes in expectations of (i) dividends, (ii) real rates, and (iii) excess returns. This exercise is akin to those first employed by Campbell and Ammer (1993) to decompose stock returns and then modified by Bernanke and Kuttner (2005) to decompose the response of stock prices to monetary policy shocks.

The exercise relies on the Campbell and Shiller (1988) insight that we can express changes in excess equity returns as the sum of the expectations of discounted future dividends, the real

Figure 7: Market beta implied estimates vs. direct estimates of β^{π}



This figure shows the comparison of directly-estimated expected inflation betas with market beta implied expected inflation betas. The black dots (direct estimates, $\hat{\beta}_i^{\pi}$) show the coefficients from regressing the daily stock returns of the given portfolio on changes in 10-year breakeven on CPI days. Each point represents a different decile of stocks by market beta, and the associated error bars show 95% robust confidence intervals. The red dots (market beta implied estimates, $\hat{\beta}_i^{mkt} \cdot \hat{\beta}_{mkt}^{\pi}$) show the product of each portfolio's market beta with the aggregate response of the value-weighted market portfolio to changes in expected inflation (i.e., 11.88). Sorted market portfolios are obtained from Open Asset Pricing Data (Chen and Zimmermann, 2022), and the market Beta for each portfolio is estimated using monthly data post-2000. Inflation expectations are measured using TIPS.

interest rate, and future excess returns:

$$e^y_{t+1} = \tilde{e}^d_{t+1} - \tilde{e}^r_{t+1} - \tilde{e}^y_{t+1}$$

where $\tilde{e}^x_{t+1} := \mathbb{E}_{t+1}\left[\sum_{j=0}^{\infty} \rho^j \Delta x_{t+1+j}\right] - \mathbb{E}_t\left[\sum_{j=0}^{\infty} \rho^j \Delta x_{t+1+j}\right]$ for variable x, and ρ is the intertemporal discount factor. Under a given value for the intertemporal discount factor, we can decompose the response of stock prices into their three channels by estimating the response of various expectations to changes in inflation expectations.

For our empirical exercise, we follow the standard implementation. We set $\rho = 0.9962$, and use a monthly frequency six-variable and six-lag VAR. The VAR includes CRSP value-weighted excess returns and 1-month real rates (measured as the 1-month T-bill return deflated using CPI), and treats dividends as a residual. In addition to excess returns and real rates, we include four predictor variables: 1-year treasury yield, log CPI, log IP, and smoothed price-dividend ratio for the CRSP value-weighted index.[8]

As in Bernanke and Kuttner (2005), we first estimate the unconditional VAR. We begin estimation in 1990 to take account of the recent structural break in the correlation between bond and equity returns (Campbell et al., 2020). We then regress the one-step ahead forecast errors from the VAR on the CPI day changes in inflation expectations. We adhere to the Bernanke and Kuttner (2005) two-step estimation procedure as it allows us to achieve more stable estimates for the unconditional VAR in spite of a shorter time series for our shock measure. We then use the parameter estimates to decompose the response of stock prices to our inflation expectation shock into contributions from changes in (i) expected excess returns, (ii) expected real rates, and (iii) expected dividends. Finally, we evaluate standard errors using block bootstrap.

Table 8 summarizes the results from the VAR decomposition exercise. Consistent with our univariate regressions, current excess returns rise by 14bp in response to to a 1pp CPI-day change in inflation expectations. Almost all of this rise can be attributed to a fall in future expected returns. In fact the estimated contribution from changes in expected real rates and expected dividends cannot be distinguished from zero. This finding is particularly stark given that we treated dividends as a residual in the VAR.

Overall, the VAR decomposition suggests that the main driver of the stock price response to changes in inflation expectations is due to changes in expected future excess returns.

[8]Dividends are smoothed using a three month backward looking moving average. The price dividend ratio is also linearly de-trended to factor in changes in payout policy overtime.

Table 8: VAR decomposition of excess return response

	Total effect	Contribution		
	Current excess return	Future excess returns	Future real rates	Future dividends
Estimates	14.11***	14.27***	0.16	-0.32
	(13.91)	(2.80)	(0.07)	(-0.15)
N first step	383	383	383	383
N second step	264	264	264	264

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

This table shows the VAR decomposition of the excess return response to changes in inflation expectations. Following the method of Bernanke and Kuttner (2005), excess returns are predicted using monthly data on a six-lag, six-variable VAR. The variables are excess stock returns, real interest rates, 1-year treasury yields, log CPI, lop IP, and a smoothed price-dividend ratio for the CRSP value-weighted index. Estimation begins in 1990 and runs through 2022. Block-bootstrap t-statistics in parentheses.

5.3 Mediation Regression Decomposition of β_π

Next, we use market-based measures for the cash flow growth expectations and real rates to control for the mediating channels directly. We run the following three specifications,

$$ret_t = \alpha_0 + \beta_\pi \Delta\mathbb{E}_t[\pi_t^{10year}] + \varepsilon_{0,t} \tag{3}$$

$$ret_t = \alpha_1 + \beta_\pi^{cf+er} \Delta\mathbb{E}_t[\pi_t^{10year}] + \gamma\Delta r_t + \varepsilon_{1,t} \tag{4}$$

$$ret_t = \alpha_1 + \beta_\pi^{er} \Delta\mathbb{E}_t[\pi_t^{10year}] + \gamma\Delta r_t + \lambda\Delta\mathbb{E}_t[cf_t] + \varepsilon_{2,t} \tag{5}$$

Equation 3 is identical to our main specification. In this, β_π captures the total effect from channels (as shown in the DAG in figure 3 and estimated empirically in the previous section). Equation 4 controls the change in the real interest rate, which we measure using the TIPS implied 10-year zero coupon bond rate. By controlling for the real rate channel, the coefficient on inflation in this regression captures the effect of inflation not associated with changes in the real interest rate. Thus this coefficient, β_π^{cf+er}, reflects the combined effects of changes in expected dividends and expected excess returns. Finally, equation 5 additionally controls for changes in dividend growth expectations, which we measure using 24-month dividend strips for the S&P500 (Gormsen and Koijen, 2020).[9] Overall, controlling for changes in real rates and changes in dividend growth expectations restricts β_π^{er} to operate only through the remaining channel, the expected excess return channel.

Comparing coefficients across the three regressions allows us to recover the effect from each

[9]Ideally, we would like to use longer horizon growth expectations, but these are unavailable. That said, longer-term growth rates are notoriously difficult to forecast, so investors likely assume they are equal to their unconditional mean. We would not expect long-run dividend growth expectations to move around significantly.

channel. The cash flow effect is identified as the difference between the combined cash flow and excess return effect and the individual excess return effect: $(\beta_\pi^{cf+er} - \beta_\pi^{er})$. Likewise, the interest rate effect is identified as the difference between the cumulative effect of inflation and the combined cash flow and excess return channel: $(\beta_\pi - \beta_\pi^{cf+er})$. Together these provide estimates of the three channels:

$$\beta_\pi^{r} = \beta_\pi - \beta_\pi^{cf+er} \tag{6}$$

$$\beta_\pi^{cf} = \beta_\pi^{cf+er} - \beta_\pi^{er} \tag{7}$$

$$\beta_\pi^{er} = \beta_\pi^{er} \tag{8}$$

We provide a proof for the consistency of these estimators in appendix A.1. Note that the constituent effects sum to the total effect

$$\begin{aligned} \beta_\pi^{r} + \beta_\pi^{cf} + \beta_\pi^{er} &= (\beta_\pi - \beta_\pi^{cf+er}) + (\beta_\pi^{cf+er} - \beta_\pi^{er}) + (\beta_\pi^{er}) \\ &= \beta_\pi, \end{aligned}$$

so that we divide each coefficient by the total effect to compute the share of the cumulative inflation premium attributed to each channel.

Before turning to the results, several clarifying points merit discussion. As a caveat on the interpretation, since our dividend growth measure is taken under the risk-neutral measure, and since the real rate measure includes term premia, including them as controls at least partially controls for changes in risk premia also. We may therefore introduce some attenuation bias in β_π^{er}. However, changes in term premium do not seem to be associated with stock returns on CPI release days (see appendix section A.2). Second, to successfully control the mediating channels, we require the high-frequency identification assumption and the exclusion restriction to be satisfied—which is why we focus on CPI days for this formal decomposition exercise. In fact, the high-frequency setting is critically what allows us to avoid the bad control problem (see appendix section A.1).

In table 9, we show the results from this decomposition for both TIPS-based and swap-based inflation expectations measures on CPI announcement dates. Reading across columns (1)-(3), adding in controls for interest rates and changes in expected cash flows slightly attenuates the cumulative inflation coefficient from 11.98 to 9.80. Using our decomposition, the interest rate channel accounts for 0.313 of the 11.98 coefficient, the cash flow channel accounts for 1.872 of the 11.98, and the remainder we attribute to the expecetd excess return channel. These correspond to shares of 2.6%, 15.6%, and 81.8% for the interest rate, cash flow, and expected excess return effects, respectively.

As a robustness check, in columns (4)-(6), we perform the same decomposition with the swap-based inflation expectations measure. Although the point estimates are different, we obtain shares of 3.5%, 0.6%, and 95.7% for interest rates, cash flows, and expected excess returns. For both measures, the coefficient on expected excess returns—i.e., the component of returns not due to changes in expected cash flows or interest rates—is significantly different from 0. At the same time, we cannot reject the zero effect null hypothesis for the cash flow and interest rate channels. This decomposition provides strong evidence that high inflation expectations increase returns by reducing future expected excess returns and complement the results in the previous subsections.

Table 9: Decomposition of Inflation Premium by Channel

	TIPS			Swap		
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\mathbb{E}_t[\pi_t^{10year,TIPS}]$	11.98***	11.67***	9.80**			
	(4.42)	(4.39)	(3.32)			
$\Delta\mathbb{E}_t[\pi_t^{10year,swaps}]$				10.63**	10.25**	10.18**
				(3.23)	(2.84)	(2.64)
$\Delta r_t^{TIPS,10year}$		-1.17	-2.33		-1.64	-2.24
		(-0.70)	(-1.33)		(-0.80)	(-1.22)
$\Delta\mathbb{E}_t[cf_t]$			0.14**			0.18
			(2.63)			(1.30)
β_r			0.313			0.375
β_{cf}			1.872			0.074
β_{rp}			9.799**			10.177**
N	274	274	217	218	213	162
R^2	0.17	0.17	0.24	0.17	0.18	0.22

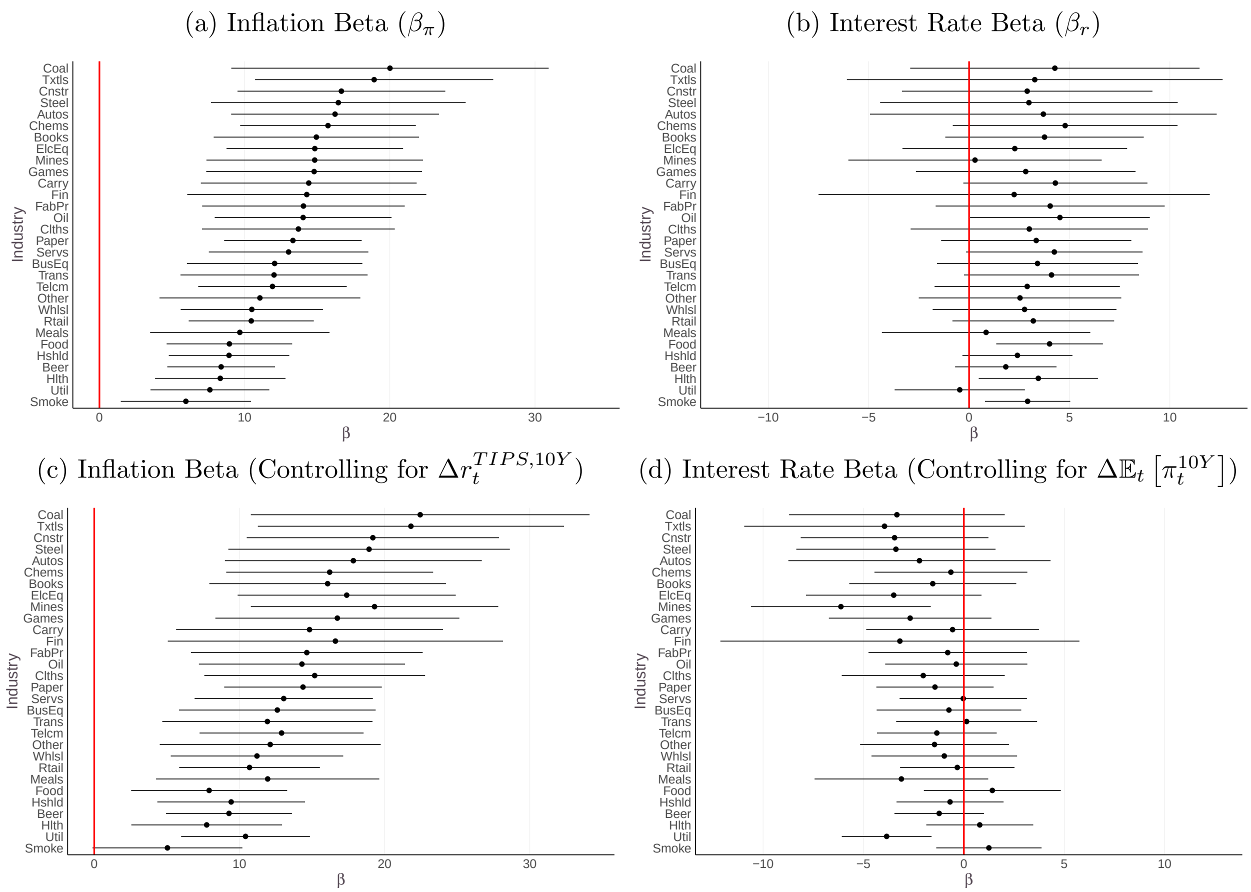
t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

This table shows the decomposition of the cumulative inflation expectation premium, β_π, into the interest rate, cash flow, and risk premium channels—β^r, β^{cf}, and β^{er} respectively. Columns (1)-(3) estimate equations (3)-(3), with the β's in the table notes formed according to equations (6)-(8). For the derived coefficients, the test statistics are derived using the Seemingly Unrelated Regressions (SUR) model.

Since industries differ in their duration (i.e., their response to changes in interest rates), it is helpful to consider whether the decomposition explored above applies cross-sectionally. In figure 8, we re-estimate the inflation betas on the 30 Fama-French industries with and without controlling for changes in 10-year real interest rates on these CPI days. The point estimates and ordering of industries is almost entirely unchanged, and all 30 industries retain a significant inflation premium—due to data limitations, we do not have stock-specific dividend growth expectation measures. For completeness, we show an analogous approach showing the unconditional *interest* rate betas (i.e., the coefficients from a bivariate regression of industry returns on changes in 10-year interest rates). These two exercises demonstrate that even in the cross-section, the path of future interest rates is not responsible for the positive causal effect.

Figure 8: Inflation Betas By Fama-French Industries with and without Interest Rate Controls



This figure illustrates the response of industry portfolios to changes in expected inflation, with and without controlling for changes in interest rates. The top left replicates the results from figure 4, showing the inflation betas from a bivariate regression of industry-level value-weighted stock returns on changes in 10-year TIPS breakevens. In the figure below (bottom left), we plot those same inflation betas after controlling for interest rates. The right two figures show the betas on interest rates in the bivariate regression of value weighted industry returns on changes in 10-year rates (top right) and the coefficients on the interest rate changes after controlling for inflation. In all figures, the sample comprises CPI release dates. Point estimates and 95% robust confidence intervals are plotted for each of the Fama-French 30 industries.

5.4 Expected dividend channel and cross-sectional β_π

Our final approach assesses the importance of the expected dividend channel by seeing if variables typically associated with firm-payout policy can explain the cross-sectional variation in β_π. We examine returns on portfolios sorted on a large number of firm characteristics that capture leverage, coverage, profitability, and other characteristics.[10]. For each characteristic, we sort firms into deciles as of each CPI date, construct the value-weighted daily returns within each decile, and regress those returns on changes in daily inflation expectations across the CPI sample.

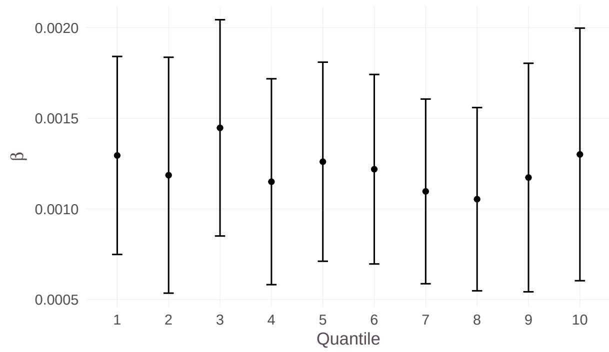
Figure 9 shows the coefficients and point estimates across six specific characteristics: asset tangibility, total payout ratio, book leverage, market leverage, cash ratio, and profit margin. We selected these characteristics because they relate to common conceptions about which types of companies are likely to be "winners" from higher inflation. Ceteris paribus, equity holders of firms with high leverage should disproportionately benefit because higher inflation erodes the real value of nominal debt. However, we do not find this in the data—there is little evidence that the estimated β_π is higher for firms with higher leverage regardless of if we measure it as book or market leverage. Similarly, asset tangibility and cash ratio—which measure the firm's relative quantity of real and nominal assets— have no discernible pattern. We also look at heterogeneity by firm profitability, where we measure profitability as net income over sales. For several reasons, profitability may be relevant to inflation's effect on equity value. Firms with higher profit margins can capture a larger share of sales; since sales reflect revenue from goods and services sold at nominal prices, high profitability firms may serve as a better hedge. Additionally, profitability may serve as a rough proxy for market power. According to popular wisdom, firms with high market power may be better able to pass higher costs to consumers and so can better withstand inflationary shocks (although there is little academic evidence for this channel). Despite these arguments, we find no clear pattern in stock responses across deciles of profitability.

The only pattern that shows some degree of monotonicity is the total payout ratio. Firms with higher payout ratios appear to have smaller increases in returns in response to an increase in inflation expectations. This evidence is consistent with the total payout ratio proxying a firm's stock's "cash likeness". Higher inflation deteriorates the real value of nominally denominated payouts; hence, ceteris paribus, the price of these higher payout ratio firms should decline relatively more. Nonetheless, the large standard errors do no long allow us to reject the null

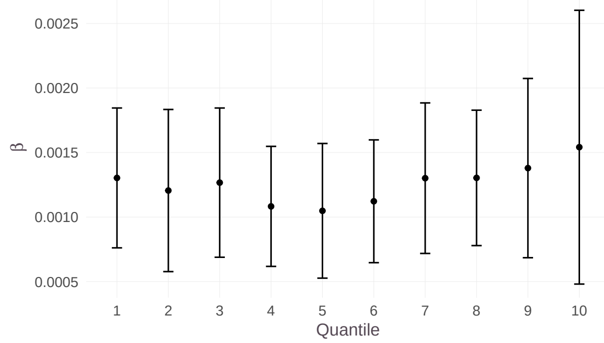
[10]We look at asset tangibility, book leverage (debt/assets), book leverage (debt/(debt + shareholders equity), common equity, current ratio, debt/ebitda, dividend payout ratio, ebit coverage, ebitda coverage, ebitda ratio, interest ratio, market leverage (long term, short term, and total), profit margin, return on equity, and total payout ratio.

Figure 9: Inflation Betas by Total Payout Ratio and Leverage

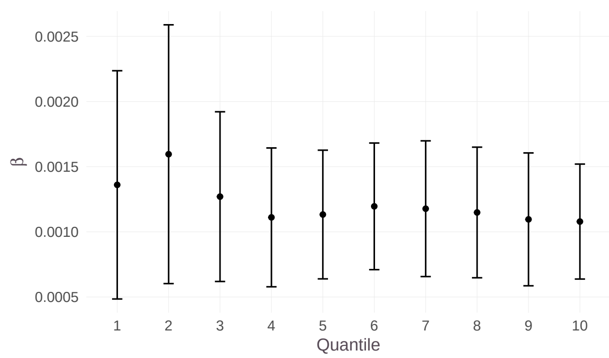
(a) Book Leverage



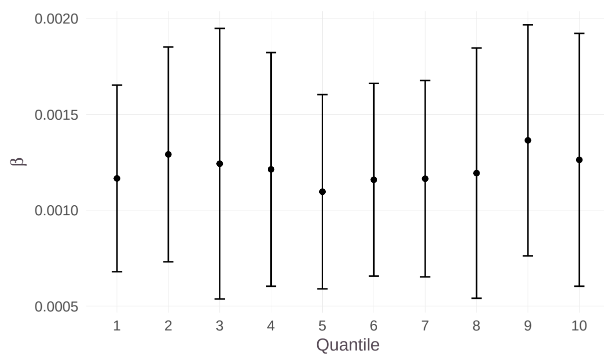
(b) Market Leverage



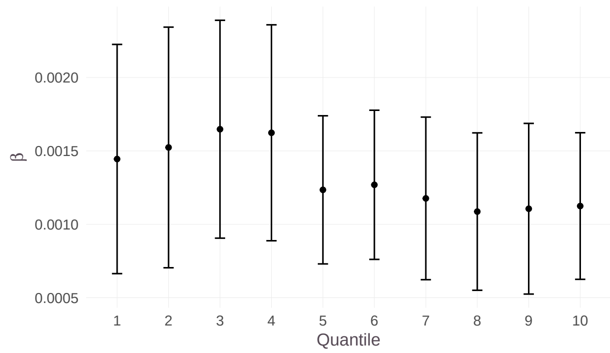
(c) Asset Tangibility



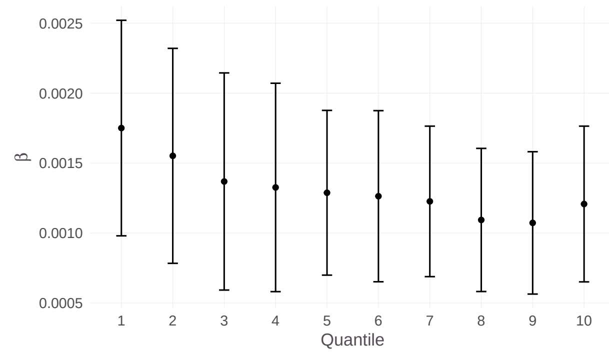
(d) Cash Ratio



(e) Profit Margin



(f) Total Payout Ratio



These figures show inflation betas on decile sorts of various firm-level financial characteristics. Portfolios for each characteristic are formed as of each CPI day and split into deciles. The points in the figure represent the estimated coefficient and 95% robust confidence intervals from a regression of value-weighted stock returns within each decile on changes in daily inflation expectations. The regression sample comprises CPI release dates, with TIPS-implied inflation measures. Book leverage is defined as debt/assets; market leverage is debt/(debt+share repurchases + common equity); Asset tangibility is defined as PPE/assets; cash ratio is cash and short term investments over assets; profit margin is net income/sales; and total payout ratio is (dividends + share repurchases)/net income.

that the highest and lowest decile have different returns.

In short, while every decile portfolio has a positive inflation beta significantly different from zero, it is difficult to conclude that differences in firm financial characteristics account for differences in return response. The chosen firm characteristics reflect variables related to cash flow, and in turn their future dividends. The absence of significant results suggests that changes in expected dividends are not the main driver of the positive effect of inflation expectations on stock returns.

6 Towards an Economic Interpretation

The preceding results have established that increases in expected inflation lead to an increase in stock prices, and that this increase is driven by a decline in expected future excess returns. However, the analysis thus far has been model agnostic. That is, while we establish the relationships in reduced-form, we have carefully avoided attaching any structural interpretation to the results.

In this section, we attempt to go a step further and provide an economic interpretation of our results. We argue that our results are consistent with information about higher future inflation, signalling higher future output. In other words, higher inflation expectations result in investors lowering the probabilities they assign to bad states of the world, which in turn lowers risk premia and raises stock prices (David and Veronesi, 2013). Furthermore, we show that the central mechanism underpinning this economic mechanism does in fact obtain in the data, namely, information about higher future inflation strongly predicts higher future output.

6.1 Inflation Expectations and Future Output

The economic interpretation described above provides a clear and testable empirical prediction: if information shocks lead investors to revise their inflation expectations upwards, we should expect higher output in the future as well. The challenge in testing this prediction is that (i) the time series evolution of output is determined through the joint dynamic behavior of several macroeconomic variables, and (ii) an initial exogenous information shock about future inflation is required to trace out the causal response. We solve the former by using a VAR to model the endogenous dynamics of macroeconomic variables, and we solve the latter by leveraging our high-frequency inflation information shock.

Specifically, we estimate a monthly frequency VAR with five endogenous variables and twelve lags, and we estimate it for the sample period of January 2000 through December 2021. For endogenous variables, we include: (i) output, measured using log industrial production (ii) price level, measured using log CPI (iii) inflation expectations, measured using the 10-year breakeven rate, and (iv) policy rate, measured using the 1-year ZCB treasury rate, and (v) and implied volatility, measured using the VIX.[11] Finally, we include unanticipated changes in the 10-year breakeven inflation rate on CPI days (cumulated to monthly frequency) as an exogenous variable in the VAR. We represent the VAR as:

$$Y_t = \phi z_t + \sum_{j=1}^{12} A_j Y_{t-j} + u_t \tag{9}$$

where Y_t is a vector containing our five endogenous variables and z_t is the unanticipated changes in the 10-year breakeven inflation rate on CPI days, cumulated up to monthly frequency.

Figure 10 displays the response of endogenous variables for a 10 basis point, information-induced shock to inflation expectations—assuming our shock satisfies the high frequency identification and exclusion assumptions, these IRFs can be interpreted as the causal response to the information shock. Mechanically, expected inflation rises instantly by approximately 10 basis points. Consistent with rational expectations, higher (realized) inflation appears over the following months, with the price level rising approximately 0.25 percentage point and remaining at that level for several months. We also observe the reaction of monetary policy to elevated inflation; the short-term interest rate rises by roughly 12 basis over the subsequent year, after which it declines back to steady state.

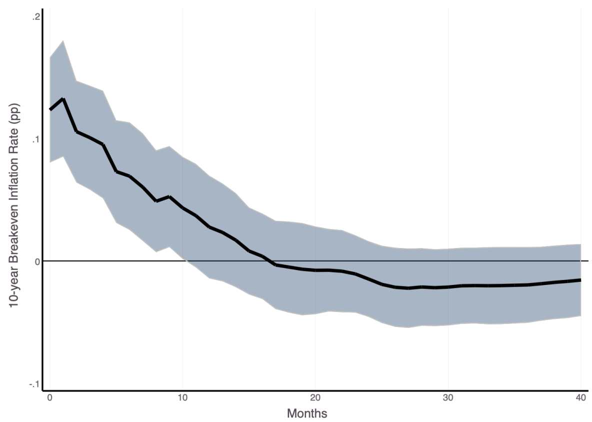
The most relevant figure for the proposed economic mechanism is captured in the response of output and volatility to the rise in inflation expectations. Panel (d) of figure 10 traces the response of industrial production to a 10 basis point increase in inflation expectations. Output rises by 0.7% over the next year, and stays above steady state for at least three years. At the same time, implied volatility, measured with VIX, drops more than 2 percentage points immediately, and remains depressed for nearly 18 months. In other words, higher inflation expectations positively predict higher growth and negatively predicts future volatility.

Overall, our finding is consistent with investors using information about higher future inflation, to revise up their probabilities of future good states of the world, thus reducing the compensation they demand for holding risk. This explanation is in line with David and Veronesi

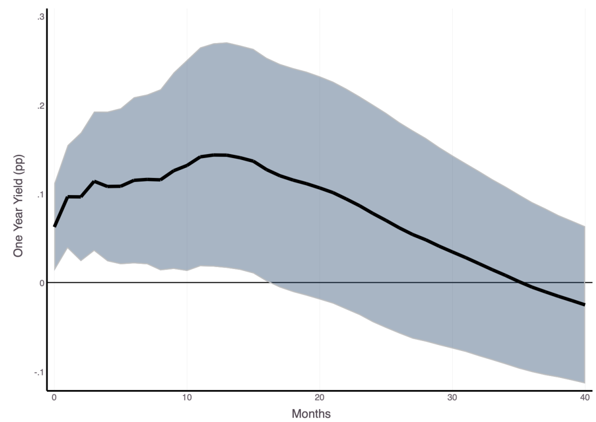
[11] We use the 1-year treasury rather than the Fed Funds rate because for a large portion of the sample, the Fed Funds was at the zero lower bound and hence had little to no variation. We use industrial production to measure output, rather than GDP, because it is available at the monthly level (GDP is only available quarterly). We use VIX to measure volatility since it best represents investors' expectations of future volatility. However, since VIX is a risk-neutral measure, in Appendix section A.4 we re-estimate the IRF using realized volatility to show that the change in VIX is not driven by CPI-day changes in the variance risk premium.

Figure 10: Impulse Responses to an Increase in Expected Inflation

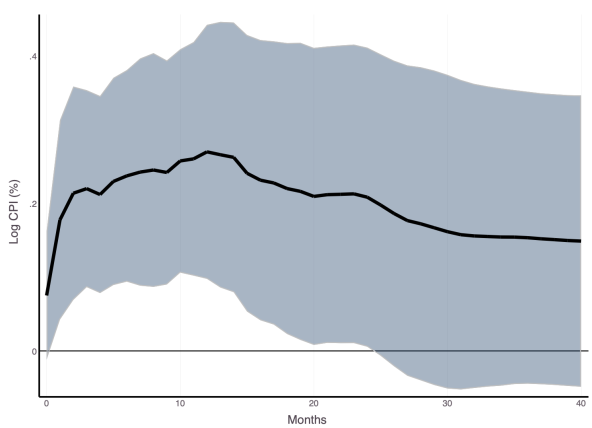
(a) Expected Inflation



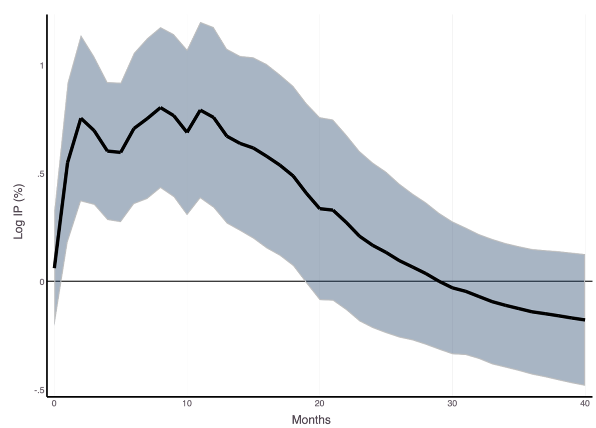
(b) Interest Rates



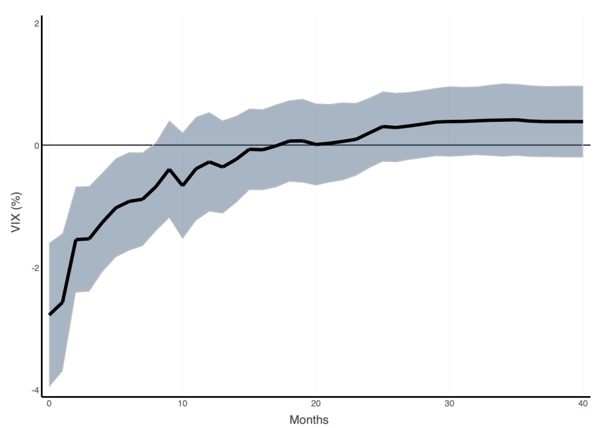
(c) Inflation



(d) Output



(e) VIX



This figure shows the IRF for a response to a 10 basis point exogenous increase in CPI day inflation expectations. The top row shows the response of the level of 10-year breakevens and one-year treasury yields; the second row shows the response of log CPI and log industrial production, and panel (e) shows the response of VIX. The results are based on a 12-lag monthly VAR spanning January 2000 to December 2021.

(2013), but also Fama (1981) "proxy" explanation for why higher realized inflation generated negative stock returns during the stagflation era—higher inflation at the time predicted lower future output. It also sheds light on the persistent positive correlation even in the post-pandemic high inflation episodes. While the anchored long-term expectations illustrated in figure 6 do not directly speak to the inflation-growth covariance, they suggest that investors expect a similar inflation regime in the future.

7 Conclusion

This paper documents that since the 2000s, stocks have provided a hedge against changes in inflation expectations. A 1 basis point positive change in inflation expectations is associated with an 11 basis point higher return. This relationship is highly significant and robust to the choice of the inflation expectations measure and estimation period, and the effect is present across the cross-section of stocks. The positive relationship remains intact in the post-pandemic high inflation episode.

Zooming in on CPI releases dates, we find that the positive association is causal. Information about higher future inflation causes investors to raise their inflation expectations; stock prices, in turn, rise as well. Furthermore, using several complementary approaches, we find the rise in prices is driven by investors lowering their expectations about future excess returns. First, Bernanke and Kuttner (2005) style VAR decomposition and also high-frequency mediation regressions attribute the rise in stock market returns almost entirely to changes in expected excess returns. Secondly, variables traditionally associated with firm cashflows are not systematically associated with stocks' cross-sectional response to changes in inflation expectations.

Overall, our findings are consistent with investors using information about higher future inflation to revise up their probabilities of future good states of the world, thus reducing the compensation they demand for holding risk (David and Veronesi, 2013). This mechanism reconciles (i) why there is positive association between changes in inflation expectations and stock returns, (ii) why information about higher future inflation causes stock prices to rise, and (iii) why price response is explained by lowering future excess returns (which from the mechanism's lens reflects a decline in risk premium). Finally, consistent with the economic mechanism, we show that information about future inflation predicts higher future output.

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A Appendix

A.1 Decomposition Result

Suppose x effects y through mediating variables $z_1, \ldots, z_n$ such that,

$$
\begin{aligned}
z_1 =& \alpha_1 + \beta_1 x + \varepsilon_1 \\
z_2 =& \alpha_2 + \beta_2 x + \varepsilon_2 \\
&\vdots \\
z_n =& \alpha_n + \beta_n x + \varepsilon_3 \\
y =& \gamma_0 + \sum_{i=1}^{n} \gamma_n z_n + \eta
\end{aligned}
$$

We can substitute all the mediating effects into the final equation to see the total effect (reduced form effect) of y on x,

$$y = a + bx + \epsilon$$

where $a = \gamma_0 + \sum_{i=1}^{n} \alpha_i \gamma_i$, $b = \sum_{i=1}^{n} \beta_i \gamma_i$, and $\epsilon = \eta + \sum_{i=1}^{n} \varepsilon_i \gamma_i$.

Proposition: If $\mathbb{E}[x\epsilon] = 0$ then OLS consistently estimates the total effect b of x on y.

Corollary: If x is a shock that is orthogonal to y then OLS consistently estimates the total effect b of x on y.

Proposition: The mediated effect of x on y through z_1 (i.e. $\beta_1 \gamma_1$ can be consistently estimated by regressing y on x and controlling for $z_2, \ldots, z_n$ if,

1. $\mathbb{E}[x(\varepsilon_1, \eta)'] = 0$
2. $\mathbb{E}[z_i(\varepsilon_1, \eta)'] = 0$ *for all* $i \geq 2$

Proof. Suppose you run the following regression,

$$y = \delta_0 + \delta_1 x + \sum_{i=2}^{N} \delta_i z_i + u$$

Substituting in the true model we can see that: $\delta_0 = \gamma_0 + \alpha_1 \gamma_1$, $\delta_1 = \beta_1 \gamma_1$, $\delta_i = \gamma_i$ for all $i \geq 2$, and $u = \varepsilon_1 + \eta$. OLS consistently estimates the parameters if $\mathbb{E}[(x, z_2, \ldots z_n)' u] = 0$. This is guaranteed if the moment conditions in the proposition are satisfied. □

Corollary: If x is orthogonal to y and the only shock to occur, then all mediating effects $\beta_i \gamma_i$ can be estimated.

If x is the only shock to occur, then all changes in the mediating variables can be attributed to x i.e. $\varepsilon_i \approx 0$. Hence, orthogonality of errors across different mediating variables is satisfied. Note this assumption is stronger than only assuming orthogonality. If we were only to assume orthogonality then controlling for mediating factors would introduce a bad control bias (Angrist and Pischke, 2009).

In most quasi-experimental studies, the only shock assumption is too strong. However, for high-frequency identification the assumption is plausible. In fact, this is typically how we think of high-frequency identification. We focus on a narrow window of time, where we believe the only piece of information released.

A.2 Robustness to Changes in Term Premium

In this section, we show that the positive response of stock prices to inflation information is (predominantly) driven by changes in inflation expectations and not changes in term premia. Changes in breakeven inflation rates can be driven by changes in inflation expectations or changes in term premia embedded in treasuries and TIPS. We begin by using Fama and Bliss (1987) style regressions to assess the extent to which unconditional changes in breakeven rates reflect changes in expectations vs. term premia. We find that the role inflation expectations is large, and for longer horizons it is difficult to rule out all the variation is driven by changes in inflation expectations. Next, we turn to assess if term premium changes can explain away our baseline result for CPI days. Unfortunately, we cannot use the Fama and Bliss (1987) regressions to assess the CPI-day drivers, instead we include changes in Kim and Wright (2005) term premium measure as a control in our CPI day regressions and find our point estimates are essentially unchanged.

A.2.1 Expectation Hypothesis

The expectations hypothesis (EH) for bonds states that the expected excess returns on long-term bonds over short-term bonds are constant over-time. We can then link the EH for nominal treasuries and TIPS to breakeven inflation using the following definition,[12]

$$y^{\pi}_{nt} := y^{n}_{nt} - y^{r}_{nt} \qquad \text{(breakeven inflation rate)}$$

where y^k_{nt} and f^k_{nt} are the time t yields and forward rates for ZCB bonds maturity in n periods, respectively. And $k = n$ refers to nominal bonds, $k = r$ refers to real bonds, and $k = \pi$ refers to break-even inflation.

More formally EH can be stated as,

$$\mathbb{E}_t \left[y^k_{tn} - \frac{1}{n} \sum_{i=0}^{n-1} y^k_{1,t+i} \right] = \theta^k_n \tag{10}$$

From the perspective of breakeven inflation, this says that the current breakeven inflation rate is equal the expected path of one-period realized inflation plus a time-invariant constant. As should be apparent from the definitions above, a failure of EH amounts to there being an

[12] As is standard in the bond literature testing EH, we will work with log returns.

additional time varying error term. For example, EH would fail if in practice we have,

$$\mathbb{E}_t\left[y^k_{tn} - \frac{1}{n}\sum_{i=0}^{n-1} y^k_{1,t+i}\right] = \theta^k_n + \varepsilon^k_{n,t} \quad \text{s.t.} \quad Var(\varepsilon^k_{n,t}) > 0$$

This error term is often referred to as term premium, and could reflect rational risk premium or non-fundamental drivers such as sentiment. The definitions above also highlight why the failure of EH for nominal treasuries and TIPS do not necessarily imply a failure of EH for breakeven inflation. For example, if $\varepsilon^r_{n,t} = \varepsilon^y_{n,t}$, EH will fail for nominal treasuries and TIPS, but will be satisfied for breakeven inflation. To this point, in our paper we use changes in breakeven inflation expectations to proxy for changes in investor beliefs about future inflation. This would be correct if,

$$Var(\Delta\varepsilon^\pi_t) = Var(\Delta\varepsilon^n_{n,t} - \Delta\varepsilon^r_{n,t}) \approx 0$$

A.2.2 Fama-Bliss Regressions

While there are numerous tests for EH, a common approach is to test for dynamic constraints imposed on bond prices by EH—Fama and Bliss (1987) is one such test. To develop this test, we need to define the one-period ahead breakeven forward,

$$f^\pi_{nt} = (n+1)y^\pi_{n+1,t} - ny^\pi_{nt} \tag{11}$$

By combining the forward rate identity with the definition of EH we can get a dynamic constraint between breakeven forwards and the expected future one-period ahead breakeven rate.

Proposition: *Under EH the breakeven inflation forward rate is the expected future one-period ahead breakeven rate in the future (plus a constant),*

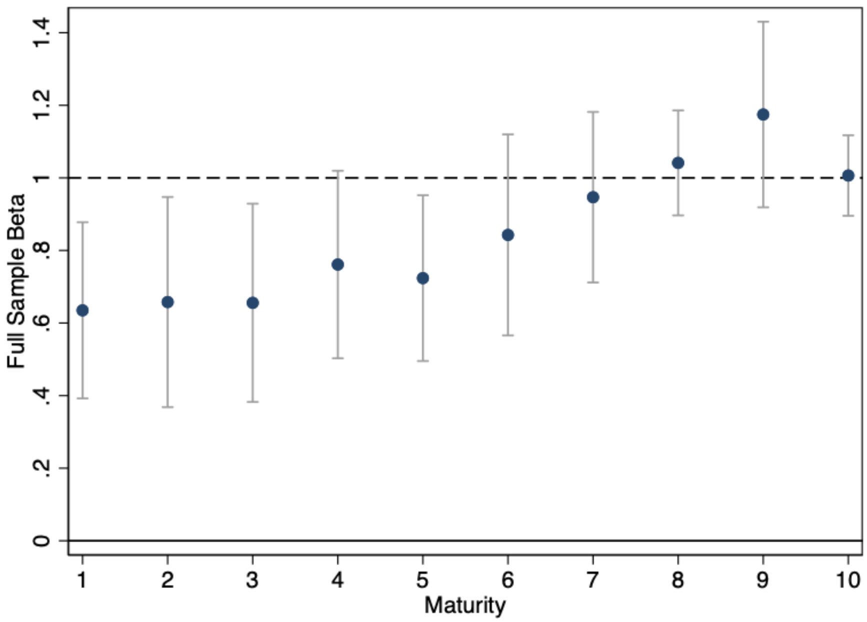
$$f^\pi_{nt} = \phi^\pi_n + \mathbb{E}_t[y^\pi_{1,t+n}] \tag{12}$$

Proof:

$$\begin{aligned}
f^\pi_{nt} =& (n+1)y^\pi_{n+1,t} - ny^\pi_{nt} && \text{(equation 11)}\\
f^\pi_{nt} =& (n+1)\mathbb{E}_t[y^\pi_{n+1,t}] - n\mathbb{E}_t[y^\pi_{nt}] && \text{(take expectations)}\\
f^\pi_{nt} =& \underbrace{(n+1)\theta^\pi_{n_1} - n\theta^\pi_n}_{:=\phi^\pi_n} + \mathbb{E}_t\left[\sum_{i=0}^{n} y^\pi_{1,t+i} - \sum_{i=0}^{n-1} y^\pi_{1,t+i}\right] && \text{(by equation 10)}
\end{aligned}$$

After subtracting the current one-period breakeven rate from both sides of 12, we can run the following time-series regression to test if breakeven inflation satisfies the expectations

Figure A1: Breakeven inflation Fama-Bliss regressions



hypothesis,

$$y^{\pi}_{1,t+n} - y^{\pi}_{1t} = \alpha_n + \beta_n(f^{\pi}_{nt} - y^{\pi}_{1t}) + u^{\pi}_{t+n} \tag{13}$$

If EH is satisfied we will find $\beta_n = 1$.

We run regression 13 at monthly frequency for maturities $n = 1, 2, \ldots, 10$ years. As our short-rate rate we use the one-year breakeven inflation rate. As figure A1 shows, overall we find that β is close to 1. While for maturities less than 5-years we can reject the $\beta = 1$, we cannot do so for longer maturities. In spite of that, the coefficients are generally close to one, and much closer to one that found in the literature for nominal treasuries and TIPS. Hence, overall it seems like majority of the changes in the 10-year breakeven inflation rate reflect changes in investor beliefs, rather than changes in premia.

A.2.3 Controlling for term premium

We look at both measures of inflation expectations (TIPS and Swaps) and both sample periods (all days post-2000 and CPI release days alone). In columns (1)-(4), we first look unconditionally across the full post-2000s sample. In the first column, we re-estimate our main regression specification from equation (1), and add a control for changes in the Kim and Wright (2005) 10-year term premium in column 2. As expected, changes in term premia are positively associated with changes in stock returns. However changes in term premia do not themselves explain the response of equities to inflation expectations: for both TIPS and swaps, the inflation betas remain positive and significant, though smaller in magnitude.

In columns (5)-(8) we zoom in on CPI days. Under our identification assumption, on these days all changes in stock returns should operate through inflation expectations and so the contribution from the term premium should be small. Consistent with this assumption we find that controlling for the term premium does virtually nothing to the point estimates of inflation expectations. Moreover, the point estimates on term premia are insignificant and close to 0. These suggest that changes in term premia are not driving the return response.

Table A1: Inflation Expectations Premium After Controlling for Term Premium

	All Days				CPI Days			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta\mathbb{E}_t[\pi^{10year}_{t,TIPS}]$	11.16***	7.69***			11.88***	12.60***		
	(12.82)	(7.31)			(4.43)	(3.90)		
$\Delta\mathbb{E}_t[\pi^{10year}_{t,Swap}]$			10.25***	7.78***			10.53**	10.34**
			(9.06)	(6.42)			(3.22)	(2.98)
ΔTerm Premium$^{10year}_t$		9.15***		12.62***		-2.19		0.49
		(6.89)		(8.11)		(-0.55)		(0.12)
N	5,021	5,020	4,155	3,953	274	274	218	214
R^2	0.11	0.14	0.11	0.17	0.17	0.17	0.17	0.16

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

This table shows the effect of changes on inflation expectations of the stock returns after controlling for changes in the term premium. We use the daily change in 10-year term premium on zero coupon bonds, based on the three-factor model in Kim and Wright (2005). The dependent variable is daily value-weighted stock returns. Changes in inflation expectations are measured using both TIPS (columns 1, 2, 5, and 6) or Swaps (columns 3, 4, 7, and 8). Columns (1)-(4) use the full post-2000 daily sample, while columns (5)-(8) restrict to CPI days. The sample period is 2000-2021. Robust t-statistics are in parentheses.

A.3 Robustness to Changes in Probability of Hitting Zero Lower Bound

Given the results on deflation in low inflationary periods, we ask if the results could be generated by the probability of hitting the ZLB, as in (Bok et al., 2022). We use the probability of hitting the ZLB, extracted from options prices, as in (Bauer et al., 2019).[13] Matching the data available from Bauer et al. (2019) restricts us to the Jan 2018- September 2019 sample period. Controlling for changes in the risk-neutral probability of hitting the zero-lower bound does little to change the coefficient on changes in expected inflation. The point estimate on the interaction suggests that perhaps the change in probability could augment it, but it is statistically insignificant.

[13]We are grateful to Michael Bauer for sharing with us his data.

Table A2: Expected Inflation Beta by Change in ZLB Proability (2018-2019)

	All Days			CPI Days		
	(1)	(2)	(3)	(4)	(5)	(6)
	$ret_{market,t}$	$ret_{market,t}$	$ret_{market,t}$	$ret_{market,t}$	$ret_{market,t}$	$ret_{market,t}$
$\Delta\mathbb{E}_t[\pi^{10year}_{t,TIPS}]$	18.94***	14.66***	14.57***	20.74**	16.80*	15.33
	(7.41)	(5.51)	(5.41)	(2.88)	(2.11)	(1.83)
$\Delta Pr^{3Y}_t(ZLB)$		-0.20**	-0.20**		-0.19	-0.46
		(-3.03)	(-2.93)		(-1.47)	(-1.85)
$\Delta\mathbb{E}_t[\pi^{10year}_{t,TIPS}] \times \Delta Pr^{3Y}_t(ZLB)$			0.72			15.37
			(0.40)			(1.35)
N	408	407	407	22	22	22
R^2	0.15	0.18	0.18	0.36	0.40	0.47

t statistics in parentheses

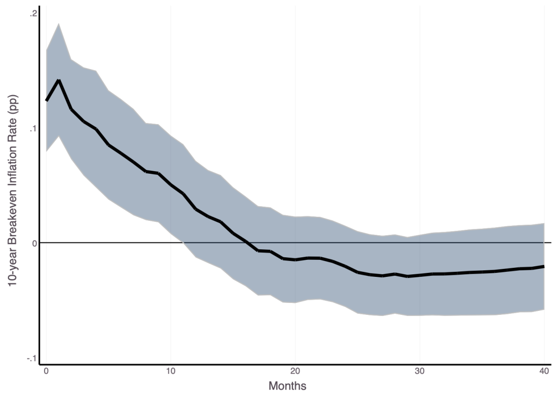
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

This table shows the results from a regression of value-weighted stock returns on changes in expected inflation, changes in the probability of hitting the zero lower bound, and their interaction. Construction of the ZLB is described in detail in (Bauer et al., 2019). The sample period is January 1, 2018 through September 17, 2019. Robust t-statistics are in parentheses.

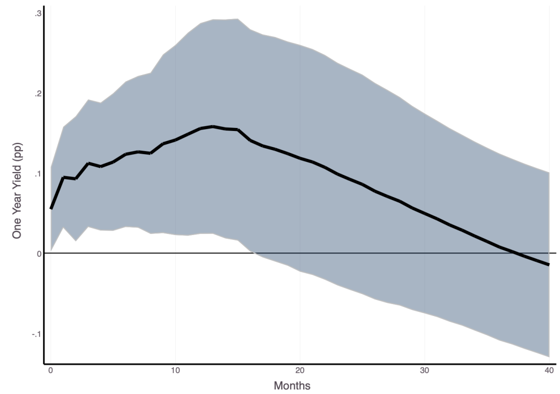
A.4 Robustness of Volatility Response to Inflation Expectations

Figure A2: Impulse Responses to an Increase in Expected Inflation

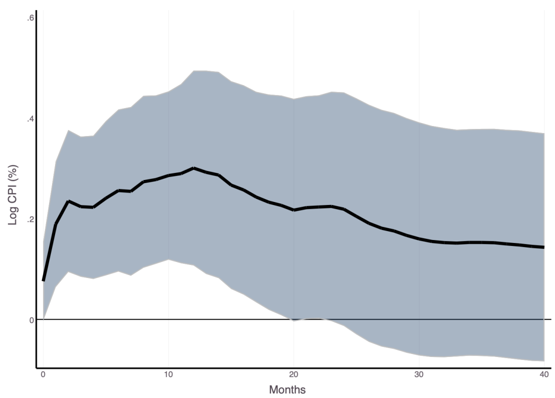
(a) Expected Inflation



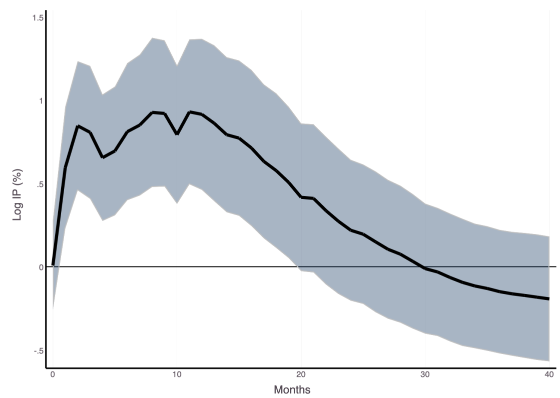
(b) Interest Rates



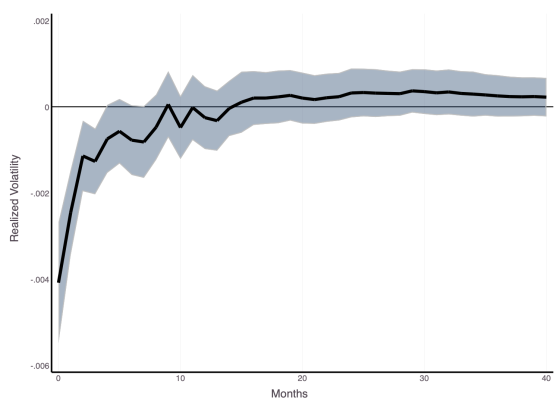
(c) Inflation



(d) Output



(e) Realized Volatility



This figure shows the IRF for a response to a 10 basis point exogenous increase in CPI day inflation expectations. The top row shows the response of the level of 10-year breakevens and one-year treasury yields; the second row shows the response of log CPI and log industrial production, and panel (e) shows the response of realized volatility, measured as the time-series standard deviation of daily returns in the CRSP value-weighted index. The results are based on a 12-lag monthly VAR spanning January 2000 to December 2021.

A.5 Survey Expectation Changes and Inflation

In this subsection, we show that changes in inflation expectations reflect changes in investor beliefs about future inflation. To do so, we regress inflation forecast revisions on changes in break-even inflation. If changes in breakeven inflation reflect changes in the inflation expectations of investors, then we should see that these changes should predict changes in surveyed inflation expectations.

In terms of constructing forecast revisions, we use the mean CPI forecasts from the Survey of Professional Forecasters (SPF). Denote the forecast made in period t for the average inflation between periods $t+h$ and $t+h+f$ as $F_t^f \pi_{t+h}$, for example, $F_t^4 \pi_{t+h}$ is the forecast made at time t of the average inflation from quarter $t+h$ to quarter $t+h+4$. Using this notation, we define the forecast revision as,

$$\eta_t^f(\pi_{t+h}) := F_t^f \pi_{t+h} - F_{t-1}^f \pi_{t+h}$$

Since SPF is conducted quarterly, we can exactly calculate forecast revisions for $f=1$, but not for $f>1$. Given this data limitation, we can approximate the revisions for $f>1$ using the approximation $\eta_t^f(y_{t+h}) \approx F_t^f \pi_{t+h} - F_{t-1}^f \pi_{t+h-1}$. For large f, the $F_{t-1}^f \pi_{t+h-1} \approx F_{t-1}^f \pi_{t+h}$, since a single quarter has a small impact on the overall forecast.

To measure new inflation information made available to forecasters in between surveys, we use changes in the 10-year break-even inflation rate. In terms of timing, the SPF is conducted quarterly, and the respondents receive the survey at the end of the first month of a given quarter, e.g., the survey conducted in Q2, is filled out by the respondents in May (at the earliest). Hence, to measure new information in the interim, we use changes in the breakeven rate between the beginning of the second months of each quarter; e.g., for the Q2 survey, we consider the change in the breakeven rate between February 1st and April 30th. We also construct a measure only using changes in the breakeven rate on CPI release days that fall in the interim between survey dates.

Using our measures, we run the regression,

$$\eta_t^f(y_t + h) = \alpha_h^f + \beta_h^f \Delta \mathbb{E}_t[\pi_{t,TIPS}^{10years}] + \varepsilon_{h,t}^f$$

If changes in breakeven expectations contain information on future inflation, we would expect $\beta > 0$.

Table A3 presents the results of this expression. First, in spite of the small number of quarterly frequency observations we find significant evidence of realized innovations in breakeven inflation predicted forecast revisions; consistent with breakeven inflation changing in response to changes in investor beliefs about future inflation. Second, for many of the horizons, innovations explain a large proportion of the changes in forecasts (with the exception of three-quarter ahead forecast, they explain around 20% to 30% of the variation). Third, higher f forecasts reflect a larger segment of the inflation belief term structure; hence, all else equal revisions of larger f forecasts should respond more strongly to changes in the 10-year breakeven rate. Consistent with this prediction, changes in the breakeven rate have particularly high predictive power for $\eta_t^f(\pi_{t+4})$. Finally, only using innovations from CPI days, while we lose power the passthroughs are larger, and significant for the one-quarter ahead and one-year ahead revisions.

Table A3: Response of SPF Forecast Revisions to Innovations in Inflation Expectations

	All days				CPI days			
	$\eta_t^1(\pi_{t+1})$	$\eta_t^1(\pi_{t+2})$	$\eta_t^1(\pi_{t+3})$	$\eta_t^4(\pi_{t+4})$	$\eta_t^1(\pi_{t+1})$	$\eta_t^1(\pi_{t+2})$	$\eta_t^3(\pi_{t+3})$	$\eta_t^4(\pi_{t+4})$
$\Delta\mathbb{E}_t[\pi_{t,TIPS}^{10year}]$	2.00**	0.57*	0.21*	0.36***	4.99*	1.14	0.42	0.82*
	(2.95)	(2.11)	(2.41)	(4.51)	(2.19)	(1.63)	(1.26)	(2.52)
N	84	84	84	84	84	84	84	84
R^2	0.22	0.22	0.09	0.29	0.10	0.06	0.03	0.11

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

This table shows the results from a regression SPF forecast innovations on changes in 10-year breakeven inflation in the interim between forecasts. Columns (1) to (4) use all changes in breakeven inflation rates, whereas columns (5) to (8) use changes in breakeven inflation only from CPI days. Robust t-statistics in parentheses.