Sorting out the time-varying inflation risk premium*

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ABSTRACT

This paper finds that the inflation risk premium (IRP) in the stock market has reversed over time. In both portfolio sorts and cross-sectional regressions, the unconditional estimate of the IRP is marginally negative, but masks a reversal from a significant -8.0% in the sixties to an insignificant 5.5% in recent years. We identify the proximate causes of this time-variation. First and foremost, the reversal is driven by the growth in the relative market share of TIPS, which were introduced in 1997 and are the preferred hedge against inflation risk. Second, the IRP is particularly large in recessions. Finally, a pronounced upward shift in the nominal-real covariance at the end of the 90s has contributed to the reversal in isolation, but our evidence suggests this predictability is not easily disentangled from TIPS.

JEL Classification Codes: G11, G12, G13

Keywords: Inflation Risk, Time-Varying Inflation Risk Premium, Inflation Hedging, Business Cycle, TIPS, Nominal-Real Covariance.

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Introduction

Inflation is an important risk factor for investors, consumers, and producers alike, because it threatens the real value of investments, erodes purchasing power, and redistributes wealth unexpectedly. Therefore, a natural question is whether this macroeconomic risk is priced.[1] We follow Ang et al. (2012) and sort all US stocks on inflation risk, measured as beta with respect to $ARMA$-innovations in inflation. We are the first to uncover a reversal in the inflation risk premium (IRP) in the stock market, from a significant -8.0% in the sixties to an insignificant 5.5% in recent years. Consistent with previous work, however, we estimate an unconditional IRP that is only marginally negative.[2]

In this paper, we identify the proximate causes of this time-variation. First and foremost, the IRP increases with the market share of Treasury Inflation-Protected Securities (TIPS). We argue that this result is due to the fact that TIPS allow investors to hedge inflation more efficiently than the cross-section of stocks. Second, the IRP is larger in recessions, which confirms early, albeit weak, evidence in Chen et al. (1986) and Ferson and Harvey (1991). These dynamics are robust and obtain in cross-sectional regressions when we (i) add an inflation mimicking portfolio to either of the traditional portfolio return-based asset pricing models, (ii) add the non-traded inflation innovations instead, (iii) use either portfolios or individual stocks as test assets, and (iv) control for characteristics.

Finally, in isolation, the IRP is also predictable by various proxies of the nominal-real covariance, i.e., the relation between inflation and macroeconomic activity, which extends evidence

[1] Early theoretical work on the pricing of inflation risk includes, for instance, Roll (1973), Long (1974), Friend et al. (1976) and Elton et al. (1983). Previous empirical work on the pricing of inflation risk in the stock market, includes, for instance, Chen et al. (1986), Ferson and Harvey (1991) and Ang et al. (2012).

[2] Chen et al. (1986) and Ferson and Harvey (1991) estimate a negative IRP among a small set of stock portfolios. Consistent with the fact that bonds are negative inflation beta assets, Buraschi and Jiltsov (2005), Ang et al. (2008), Gurkaynak et al. (2007) and D'Amico et al. (2008) estimate a positive IRP in the bond market.

from the bond market in Campbell et al. (2013). However, the contribution of this channel to the reversal in the IRP is not easily disentangled from the contribution of TIPS, because TIPS were introduced around the same time the proxies experienced a pronounced upward shift at the end of the nineties.

We write down an asset pricing model with time-varying inflation risk to explain these results. In our framework, inflation may enter the investor's portfolio optimization for a number of reasons. For instance, inflation is an exogenous risk for many investors, including pension funds and insurance companies with real liabilities and individuals with nominal wages. Also, inflation is relevant as a state variable for future consumption-investment opportunties in an Intertemporal CAPM (along the lines of Merton (1973), Fama (1996) and Cochrane (2001, Ch.9)), as inflation forecasts negative changes in macroeconomic activity on average (Bekaert and Wang (2010) and Campbell et al. (2013)).

Historically, investors exposed to inflation risk are forced to hedge partly in the stock market, because real bonds are not available and nominal bonds are negatively exposed to inflation. We present empirical evidence that inflation beta-sorted stock portfolios are indeed an useful component of the investor's optimal hedge portfolio for inflation risk. Because inflation is typically bad news, this finding is consistent with the observed outperformance of low inflation beta stocks. Since 1997, however, TIPS are the most important component of the inflation hedge portfolio. Accordingly, TIPS market size has grown dramatically from $30 billion at the end of 1997 to $800 billion in 2011. In turn, this growth has spurred the development of inflation derivative contracts, which could satisfy more complex inflation–linked hedging demands as well (Bekaert and Wang (2010)).

Assuming TIPS are a perfect hedge, the model indicates a zero IRP post-TIPS, if TIPS are used to hedge exclusively. If TIPS are sufficiently attractive from a diversification (speculative) point of view, however, the model indicates a reversal in the IRP. Indeed, the incentive to hedge this speculative demand for TIPS will then dominate in the stock market. Previous literature suggests a reasonable lower-bound for the diversification benefits of TIPS is zero, consistent with our reversal to an insignificant positive risk premium in recent years.[3]

Time-varying risk aversion allows the model to fit the business cycle variation we document. In recessions, risk aversion is large, which increases the incentive to hedge the negative exposure Pre-TIPS and the non-negative exposure Post-TIPS. Further, the model suggests a possible channel through which the investor's fundamental exposure to inflation risk may vary over time, that is whether inflation shocks represent good or bad news about future macroeconomic activity. For instance, Bekaert and Wang (2010) and Campbell et al. (2013) find that this nominal-real covariance has in fact reversed around the turn of the century, thus contributing to the reversal in the IRP.

Finally, in our model, the inflation risk premium in the stock market must be consistent with the pricing of exposure to TIPS, and thus also realized TIPS returns. Preliminary empirical evidence using the short sample of (noisy) TIPS returns suggests that pricing is indeed increasingly consistent as the TIPS market grows and matures. First, the stock market risk premium for exposure to TIPS converges to average TIPS returns towards the end of the sample. Relatedly, in cross-sectional regressions, a model with TIPS as risk factor predicts a cross-section of expected returns that is increasingly similar to a model with inflation as risk factor.

Our main contribution is in establishing that the IRP in the stock market is time-varying and has reversed sign around the turn of the century. Duarte and Blomberger (2012) also note

[3]See, for instance, Roll (2004), Khotari and Shanken (2004), Mamun and Visaltanachoti (2006), Briere and Signori (2009), Fleckenstein et al. (2013) and Campbell et al. (2009).

this reversal, but do not investigate its proximate causes, as their focus is on the question of why inflation betas vary cross-sectionally. Campbell et al. (2013) find that term premiums in the nominal bond market have also changed sign around the turn of the century and ascribe this change to a reversal in the nominal-real covariance, proxied by the stock market beta of the long-term nominal bond. We extend this evidence to the stock market, using two additional proxies of the nominal-real covariance. That is, the time-varying relation between inflation and future industrial production or consumption growth.

In conclusion, however, our results suggest that the introduction of TIPS is the most important driver of the reversal in the stock market. We argue that changing hedging preferences are an important channel through which an expansion of the menu of assets impacts risk premiums in the stock market. This argument is reminiscent of the diversification-channel through which emerging market risk premiums are varying over time with the level of integration of these markets with the world stock market (see Bekaert and Harvey (2000) and De Jong and De Roon (2005)). Finally, the business cycle variation we document is consistent with countercyclical variation in the market risk premium.[4]

A second contribution is in establishing that stocks can be an important component of an inflation hedge portfolio. Traditional studies focus on the time series of aggregate stock and bond returns and find that these standard asset classes are poor hedges against inflation, especially at the monthly frequency (see, e.g., Fama (1981), Schotman and Schweitzer (2000) and Bekaert and Wang (2010)). We find that portfolios of individual stocks, which exploit heterogeneity in inflation betas, hedge more adequately. This finding obtains even though inflation betas are hard-to-estimate and vary substantially over time, as shown in Ang et al. (2012), and extends when we

[4] See, e.g., Shiller (1984); Campbell and Shiller (1988); Fama and French (1989); Ferson and Harvey (1991); Campbell and Cochrane (1999); Lettau and Ludvigson (2001).

perform a truly out-of-sample sort using real-time vintage inflation.

In the next section we derive an asset pricing model with inflation risk and present the main testable implications. Section II presents the methods used to estimate inflation exposures and the IRP. Section III presents the cross-section of inflation beta-sorted portfolios. Section IV presents the first tests of a time-varying IRP. Section V presents unconditional and conditional cross-sectional regressions. Section VI asks which assets are the best hedges against inflation risk over our sample period. Section VII analyzes the role of the nominal-real covariance. Section VIII concludes.

I Model and empirical content

We derive a simple asset pricing model with inflation risk that indicates a time-varying inflation risk premium in the stock market. Appendix A presents the model in full detail. Here we highlight the main testable implications and their empirical content. In its basic form, the model is conceptually similar to Fama (1996). In its extended form, we introduce a hedge asset to model the introduction of TIPS, which yields a rich set of new predictions.

A A CAPM with inflation risks

Consider a general one period mean-variance Markowitz (1959) problem for risk-averse agents faced with inflation risk. Denote the 'return' on the risk factor π_{t+1}, and denote each agent j's predetermined exposure (as a fraction of wealth $X_{j,t}$) $q_{j,t}$. Thus, the total return on agent j's portfolio, with investments in risky assets $w_{j,t}^{A\prime}$, equals

$$R_{j,t+1}^{p} = R_t^f + w_{j,t}^{A\prime} r_{t+1}^{A} + q_{j,t}^{\prime} \pi_{t+1}, \tag{1}$$

where $r^A_{n,t+1} = R^A_{n,t+1} - R^f_t$, the excess return on each of N risky assets, with expected return vector $\mu_{A,t}$ and covariance matrix Σ_{AA}, respectively.[5]

Most of the time and for many investors the exposure $q_{j,t}$ is negative, consistent with three non-exclusive interpretations.[6] First, inflation is an exogenous risk that hurts, for instance, pension funds and insurance companies with real liabilities or individuals with nominal wages. Second, inflation is relevant as a state variable in an Intertemporal-CAPM (see, e.g., Merton (1973), Chen et al. (1986) and Cochrane (2001, Ch. 9)), because it predicts real economic activity and consumption growth with a negative sign (Bekaert and Wang (2010), Duarte (2011) and Campbell et al. (2013)).[7] Finally, for investors that desire to maximize mean-variance utility over real returns, the portfolio problem is approximated by setting $q_{j,t} = -1$. In the former two cases, it is natural to allow for time-variation in this exposure. Indexation policies of pension funds are usually conditional on funding ratios and, among others, Campbell et al. (2013) find that the relation between inflation and real activity is time-varying.

Assuming that the portfolio problem for every agent j only depends on the mean and variance of this portfolio return and aggregating over all agents, we show in Appendix A.1 that the wealth-weighted market portfolio combines a standard speculative demand with a minimum-variance hedge demand

$$w^A_{m,t} = \gamma^{-1}_{m,t}\Sigma^{-1}_{AA}\mu_{A,t} - \Sigma^{-1}_{AA}\Sigma_{A\pi}q_{m,t}, \tag{2}$$

as in Merton (1973) and Anderson and Danthine (1981), for instance. Here, $\gamma_{m,t}$ is the wealth-weighted risk aversion; $\Sigma_{A\pi}$ is the N-vector of covariances with inflation; and, $q_{m,t}$ is the wealth-

[5] Throughout, we work with the version of the model in which only risk premia vary over time but not the covariances. The testable implications and empirical results are unchanged using time-varying (co-) variances.

[6] In fact, a negative exposure is also generally implied by the anxiety consumers expressed about inflation in the survey of Shiller (1996).

[7] In Panel A of Table VII we replicate some of this evidence.

weighted exposure. With $q_{m,t} < 0$, this market portfolio implies that agents adjusts upward the demand for stocks that move in-sync with inflation in order to hedge.

B Introducing a (perfect) hedge asset

Suppose there exists an additional asset that is perfectly correlated with π_{t+1}, with returns r^0_{t+1}. We only need a perfect correlation for expositional purposes. As long as the new asset is a better hedge than the available assets, the hedge demand will tilt towards the new asset and the same predictions obtain. We think of this asset to be an inflation-linked bond. There is a wide spectrum of assets that are considered potential inflation hedges, such as nominal bonds, commodities and real estate. In theory, however, TIPS are most adequate, because both coupons and principal are indexed to realized CPI inflation (albeit with a three month lag), whereas the latter is generally also guaranteed in case of deflation. In Section VI we ascertain that TIPS are nowadays a crucial component of the optimal hedge portfolio for inflation risk.

Denoting the $(N+1)$-vector of excess returns on the expanded set of assets $r^X_{t+1} = (r^0_{t+1}\; r^{A\prime}_{t+1})'$, we show in Appendix A.2 that the total demand for assets, separated in a speculative and a hedge demand, can be written as

$$w^X_{j,t} = \begin{pmatrix} w^0_{j,t} \\ w^A_{j,t} \end{pmatrix} = \begin{pmatrix} w^0_{spec} \\ \gamma^{-1}_{j,t}\Sigma^{-1}_{AA}\mu_{A,t} - \Sigma^{-1}_{AA}\Sigma_{A\pi}w^0_{spec} \end{pmatrix} - \begin{pmatrix} q_{j,t} \\ 0_N \end{pmatrix}, \tag{3}$$

where $w^0_{spec} = \gamma^{-1}_{j,t}\sigma^{-1}_{ee}a_0$ comes from the auxiliary regression $r^0_{t+1} = a_0 + b_0' r^A_{t+1} + e_{0,t+1}$ with $Var(e_{0,t+1}) = \sigma_{ee}$. The individual components of this demand have a natural interpretation. First, the hedge demand, $(q_{j,t}\; 0_N')'$, focuses completely on the hedge asset, because it is perfectly correlated with the risk. Second, agents want an additional investment in the hedge asset, w^0_{spec}, if it provides an abnormal return over the risky assets.

Third, the optimal demand for risky assets, $w_{j,t}^A$, adjusts the tangency portfolio with a minimum-variance hedge demand for w_{spec}^0, instead of the exposure $q_{j,t}$ in Equation (2). Thus, if the agent seeks additional exposure to the hedge asset beyond the hedge demand $q_{j,t}$ when $a_0 > 0$, he will hedge this exposure among the N risky assets. This result follows directly from the speculative demand for the extended set of assets (see also Stevens (1998)). Importantly, the composition of this hedge portfolio is determined by $\Sigma_{AA}^{-1}\Sigma_{A\pi}$, as in the basic framework.

C Asset pricing with two types of investors

In this subsection, we analyze what it means for the inflation risk premium in the stock market when the fraction of investors that are able to invest in the hedge asset varies over time. We assume there are two types of investors: a fraction $\varphi_{b,t}$ $(= 1 - \varphi_{e,t})$ of investors ('basic') that is unable to invest in the hedge asset and a fraction $\varphi_{e,t}$ of investors ('extended') that is able to do so. These time-varying fractions can be motivated by noting that investors will not add a new asset to their portfolio over night. Rather the final investment decision is typically conditional on observing market performance and liquidity reaching a critical level. In the case of TIPS, affirmation of commitment to the program by the Treasury was particularly important. In addition, Sack and Elsasser (2004) argue that investors had a benign outlook for inflation in the late nineties, thus lowering demand initially. Consequently, TIPS market size grew only slowly after the Treasury first auctioned \$7 billion of 10-year TIPS on January 29, 1997. After the Treasury affirmed its commitment in 2002, market size increased rapidly from \$168 billion to \$800 billion at the end of 2011.

On aggregate, the two investors do not differ in their exposure to the risk factor, i.e., $q_{b,t} = q_{e,t} = q_{m,t}$. Using the optimal portfolios given in Equations (2) and (3) and the procedure outlined in Appendix A.1, we find that the wealth-weighted (market) portfolio of the N assets in r^A_{t+1} is given by

$$w_{m,t} = \gamma^{-1}_{m,t}\Sigma^{-1}_{AA}\mu_{A,t} - \gamma^{-1}_{m,t}\Sigma^{-1}_{AA}\Sigma_{A\pi}Q_t. \tag{4}$$

This portfolio adjusts the Markowitz demand with a hedge demand over the aggregate exposure $Q_t = \gamma_{m,t}((1-\varphi_{e,t})q_{m,t} + \varphi_{e,t}w^0_{spec})$. As in the basic framework, the exposure $q_{m,t}$ is hedged with the risky assets by a fraction $(1-\varphi_{e,t})$ of investors. As in the extended framework, the exposure $q_{m,t}$ is hedged with the hedge asset by a fraction $\varphi_{e,t}$ of investors, which leaves them the speculative investment in this hedge asset (w^0_{spec}) to be hedged with the risky assets.

From the two-factor asset pricing model that is implied by this demand, it is easily seen that the inflation risk premium is time-varying with Q_t,

$$E_t(r^A_{n,t+1}) = \gamma_{m,t}Cov(r^A_{n,t+1}, r_{m,t+1}) + Q_tCov(r^A_{n,t+1}, \pi_{t+1}), \tag{5}$$

Appendix A.3 shows that this two-factor model can be equivalently written in beta form:

$$E_t(r^A_{n,t+1}) = \beta_{n,m}E_t(r_{m,t+1}) + \beta_{n,H}E_t(r_{H,t+1}), \tag{6}$$

where $r_{H,t+1}$ is a return on a hedge portfolio that is long high and short low inflation beta stocks with expected excess return $E_t(r_{H,t+1})$ determined by the value of Q_t. In our empirical work, we assume that portfolio sorts and cross-sectional regressions make $r_{H,t+1}$ observable.

C.1 A note on integration

The asset pricing pricing model in Equation (6) follows from focusing on the expected returns of the initial set of N risky assets (stocks) only. We do not assume that the market for the risky asset and the hedge asset are segmented, however. In Appendix A.4, we derive the model that jointly prices the extended set of assets, with risk premiums for the N risky assets that are identical to Equation (6). When $\varphi_{e,t}$ approaches one, this joint model collapses to the model implied by Equation (3), containing the market portfolio of the extended set of assets and the hedge asset itself:

$$E_t(r^A_{n,t+1}) = \beta_{n,m^X} E_t(r_{m^X,t+1}) + \beta_{n,0} E_t(r_{0,t+1}). \tag{7}$$

D Testable implications and empirical content

To derive the main testable implications for a time-varying inflation risk premium in the stock market, we focus on two elements of the aggregate exposure: the fraction of investors with access to the hedge asset $\varphi_{e,t}$ and the market's coefficient of relative risk aversion $\gamma_{m,t}$. This focus is motivated by the introduction of TIPS and evidence suggestive of a procyclical inflation risk premium in Chen et al. (1986) and Ferson and Harvey (1991).[8] Appendix A.5 expands $Q_t = \gamma_{m,t}((1-\varphi_{e,t})q_{m,t} + \varphi_{e,t} w^0_{spec})$ around $\varphi_{e,t} = 0$ and $\gamma_{m,t} = 1$, so as to mimic the basic framework with log utility. We consider two specifications of the aggregate exposure Q_t to guide our empirical analysis, which are nested in the model

$$Q_t = \theta_0 + \theta_1 \varphi_{e,t} + \theta_2 \gamma_{m,t} + \theta_3 (\varphi_{e,t} \times \gamma_{m,t}). \tag{8}$$

[8] Albeit weak, their evidence, respectively, suggests the inflation risk premium is most negative when inflation is most volatile and when the Default Spread and the Dividend Yield are large. Both coincide with recessions.

First, we focus on the role of TIPS and restrict $\theta_2 = \theta_3 = 0$. Thus, when TIPS are not available (i.e., $\varphi_{e,t} = 0$), the aggregate exposure to inflation is negative, i.e., $Q_t = \gamma_{m,t} q_{m,t} < 0$. In this setting, investors pay high prices for stocks that covary with inflation risk to hedge and therefore we predict $\theta_0 < 0$ in Equation (8). When TIPS are introduced and $\varphi_{e,t}$ increases, the inflation risk premium increases as well, provided that the diversification benefits of TIPS are not too low (as shown in Equation (48) in the appendix). The intuition is that fewer investors are hedging $q_{m,t}$ in the stock market.

When all investors have access to TIPS ($\varphi_{e,t} = 1$), the aggrate exposure collapses to $Q_t = \gamma_{m,t} w^0_{spec}$. Now suppose that TIPS provide positive diversification benefits, i.e., $w^0_{spec} > 0$. In this setting, the inflation risk premium will reverse to being positive, because the incentive to hedge this speculative investment will dominate in the stock market. In case $w^0_{spec} = 0$, inflation risk is not priced in the stock market directly, but indirectly, through the exposure of the market portfolio to π_{t+1}. This result is clear from Equation (3), where the demand for stocks collapses to the tangency portfolio of stocks, thus leading to the one-factor CAPM.

Evidence in Roll (2004), Khotari and Shanken (2004), Mamun and Visaltanachoti (2006) and Briere and Signori (2009) suggests that a reasonable lower bound for the diversification benefits of TIPS is zero. Also, positive diversification benefits are consistent with Fleckenstein et al. (2013), who find that TIPS are grossly underpriced, and Campbell et al. (2009), who find that the stock market beta of TIPS is negative, whereas realized returns have been positive. Thus, we predict $\theta_1 > 0$ and $Q_t \geq 0$ in Equation (8), such that the inflation risk premium is non-negative Post-TIPS.

Our second specification incorporates time-variation in the market's coefficient of relative risk aversion $\gamma_{m,t}$. When TIPS are not available, the aggregate exposure to inflation is negative and decreases further with $\gamma_{m,t}$, as this strenghtens the incentive to hedge. Further, the marginal effect of $\varphi_{e,t}$ on the inflation risk premium is increasing with $\gamma_{m,t}$, provided that w^0_{spec} is not too low (see Equation (50) in the appendix). The intuition is that when the share of investors that hedge with TIPS increases ($\varphi_{e,t} \to 1$), Q_t approaches $\gamma_{m,t} w^0_{spec}$. Thus, only the (non-negative) speculative investment in TIPS needs to be hedged in the stock market and the incentive to do so is increasing in risk aversion. Combining, the additional predictions for the model in Equation (8) are: $\theta_2 < 0$ and $\theta_3 > 0$.

As argued before, our model is derived under the assumption of market integration, which means that the inflation risk premium must be consistent with expected TIPS returns. This consistency is testable only when $\varphi_{e,t}$ approaches 1, however (see Equation (43) in the appendix). For this reason, we test in Section V whether the risk premium for exposure to TIPS in the stock market converges to the average realized return on TIPS towards the end of our sample.

II Methodology

This section presents our measures of inflation risk and the sorting procedure that is performed to estimate the time-varing inflation risk premium.

A Inflation risk

We measure inflation using the seasonally adjusted Consumer Price Index for All Urban Consumers (CPI) available from the Bureau of Labor Statistics. We measure risk as beta with respect to inflation innovations, because the expected component of inflation is easily hedged with nominal bonds and irrelevant for cross-sectional asset pricing. Similar to Fama and Gibbons (1984), Vassalou (2000) and Campbell and Viceira (2001), we filter the time-series of monthly inflation rates using an $ARMA(1,1)$-model ($I_t = \gamma I_{t-1} + \pi_t - \delta\pi_{t-1}$, with $\widehat{\gamma} = 0.903$ and $\widehat{\delta} = 0.580$) and use in our tests the monthly innovations denoted π_t. Our conclusions are not sensitive to the specific method of extracting the innovations.[9] Also, we ascertain below that our conclusions are robust for a truly out-of-sample exercise that uses inflation in the real-time vintage CPI series (I_t^{rv}), as in Ang et al. (2012).[10]

To fix ideas, it is important to note that the innovations π_t represent the unexpected component of inflation as well as changes in expected inflation from the model.[11] As argued in Brennan and Xia (2002), this model is the relevant case for investors when expected inflation is not observable and must be inferred from the price level itself. This dual information is exactly why our monthly horizon is relevant. On one hand, unexpected inflation is more variable than changes in expected inflation at the monthly frequency (Nelson and Schwert (1977) and Fama and Gibbons (1984)). On the other hand, (expected) inflation is persistent, which means that if a stock hedges the innovation this month, it is also hedging inflation a number of months ahead.

B Inflation betas

We sort all ordinary common stocks traded on NYSE, AMEX and NASDAQ (excluding firms with negative book equity) on their inflation betas and form portfolios at the end of each month t. We require that stocks have at least two out of the last five years of returns available. The

[9] Similar results obtain for $ARIMA(0,1,1)$-innovations, the difference between inflation and the short-term t-bill return (following Fama and Schwert (1977) and Gorton and Rouwenhorst (2006)) and the monthly change in annual inflation (following Erb and Harvey (2006) and Hong and Yogo (2012)). These results are available upon request. We can not use survey-based measures of expected inflation, because these gauge expectations over the (semi-) annual horizon only.

[10] Available from http://alfred.stlouisfed.org/.

[11] Taking expectations in the $ARMA(1,1)$-model, we see that the change in expected inflation over month $t-1$ is perfectly correlated to the innovation π_{t-1}:

$$E_{t-1}(I_t) - E_{t-2}(I_t) = [\gamma I_{t-1} - \delta\pi_{t-1}] - [\gamma E_{t-2}(I_{t-1})] =$$

$$[\gamma(\gamma I_{t-2} + \pi_{t-1} - \delta\pi_{t-2}) - \delta\pi_{t-1}] - [\gamma(\gamma I_{t-2} - \delta\pi_{t-2})] = (\gamma - \delta)\pi_{t-1}$$

(see also Fama and Gibbons (1984)).

sample period runs from August 1964 to December 2011, which is often the focus in empirical work and coincides with the introduction of AMEX stocks in the CRSP file.

We follow Duarte (2011) and estimate betas using a weighted least-squares regression over all observations in the interval $[1:t]$.[12] The expanding window ensures that we use as much information as possible, whereas exponentially decaying weights ensure timeliness of the estimated beta. Thus, for each stock i the estimator of $\beta_{i,t}$ is given by

$$\left(\widehat{\alpha_{i,t}}, \widehat{\beta_{i,t}}\right) = \underset{\alpha_{i,t},\beta_{i,t}}{\arg\min} \sum_{\tau=1}^{t} K(\tau)\left(R_{i,\tau} - RF_{\tau} - \alpha_{i,t} - \beta_{i,t}\pi_{\tau}\right)^2 \tag{9}$$

$$\text{with weights } K(\tau) = \frac{\exp(-|t-\tau|\ h)}{\sum_{\tau=1}^{t-1}\exp(-|t-\tau|\ h)}, \tag{10}$$

with $h = \frac{\log(2)}{60}$, such that the half-life converges to 60 months for large t. We transform the estimated $\widehat{\beta_{i,t}}$ using the Vasicek (1973) adjustment

$$\widehat{\beta_{i,t}^{v}} = \widehat{\beta_{i,t}} + \frac{var_{TS}(\widehat{\beta_{i,t}})}{\left[var_{TS}(\widehat{\beta_{i,t}}) + var_{CS}(\widehat{\beta_{i,t}})\right]}\left[mean_{CS}(\widehat{\beta_{i,t}}) - \widehat{\beta_{i,t}}\right], \tag{11}$$

where the subscripts TS and CS denote means and variances taken over the time-series and cross-sectional dimension, respectively. In this way, $\widehat{\beta_{i,t}^{v}}$ is a weighted average of the estimated beta in the time series and the cross-sectional average beta, where the former receives a larger weight when it is estimated more precisely. For instance, Elton et al. (1978) show that this adjustment makes ex-ante exposures better predictors of ex-post exposures. Indeed, we find the usual rolling window betas to be more noisy, although they provide us with largely similar results. Also, we ascertain below that our conclusions are robust to including the benchmark factors MKT, SMB, HML and MOM in Equation (9).

[12] For the out-of-sample exercise, we omit month t as inflation is not announced until the middle of month $t+1$.

C Inflation risk premium

This subsection explains how we bring the model with a time-varying inflation risk premium to the data. To be consistent with extant asset pricing literature, we focus on the beta asset pricing model in Equation (6), where expected returns of the market portfolio and the hedge portfolio for inflation risk satisfy

$$\begin{pmatrix} \mu_{m,t} \\ \mu_{h,t} \end{pmatrix} = \begin{pmatrix} \sigma_M^2 & \Sigma_{MH} \\ \Sigma_{HM} & \sigma_H^2 \end{pmatrix} \begin{pmatrix} \gamma_{m,t} \\ z_{m,t} \end{pmatrix},$$

with $z_{m,t} = Q_t(\iota_N' \Sigma_{AA}^{-1} \Sigma_{A\pi})$ (see Equation (33)). Thus, both $\mu_{m,t} = E_t(r_{m,t+1})$ and $\mu_{h,t} = E_t(r_{h,t+1})$ are time-varying as linear functions of $\gamma_{m,t}$ and Q_t. If the correlation between $r_{m,t+1}$ and $r_{h,t+1}$ is zero, Q_t solely determines the expected return of the inflation hedge portfolio. If the correlation is not zero or time-varying, we can still back out the linear relation between $r_{h,t+1}$ and Q_t by controlling for the market in either time-series or cross-sectional regressions.[13] Similarly, we control for the three-factor model of Fama and French (1993; denoted FF3M) and the four-factor model of Carhart (1997; denoted FFCM), which factors can be motivated as hedge portfolios for additional risks.

C.1 Hedge portfolio returns

We use two standard approaches to obtain returns on the inflation hedge portfolio $r_{h,t+1}$: portfolio sorts and cross-sectional regressions. The two approaches have in common that the implied hedge portfolio is a zero-investment portfolio that is one dollar long in high beta stocks and one dollar

[13] Note, the correlation between the aggregate stock market and inflation has changed from negative (the famous failure of the Fisher hypothesis) to positive around the turn of the century (Campbell et al. (2013)). In Section VII we analyze directly how this reversal impacts the inflation risk premium.

short in low beta stocks.

To start, we construct 30 market-value weighted portfolios that are at the intersection of a two-way sort in ten inflation beta groups and three Size groups (denoted UI1S30). Our choice for Size as control variable responds to Ang et al. (2012), who find that the best inflation hedgers are the smallest stocks. The main take-away of a time-varying inflation risk premium is robust to controlling for Book-to-Market or Momentum instead.[14] We measure Size as market cap at the end of month t and split as in Fama and French (2008): micro stocks have market cap below the 20th NYSE percentile, small stocks are between the 20th and 50th percentiles, and big stocks are above the 50th percentile. Thus, our first estimates of the inflation risk premium are the High minus Low (HLIB) spreading portfolios derived from this two-way sort. In particular, we will focus on the Size-controlled HLIB portfolio that averages over the three Size groups.

The second set of estimates of the inflation risk premium is found by estimating cross-sectional regressions for various sets of portfolios and individual stocks. For these regressions, we construct a traded inflation factor INF. Similar to SMB and HML, we sort all CRSP stocks independently into three inflation beta groups (split at the terciles of ranked values) and two Size groups (split at NYSE median market cap). Then, the factor INF that captures the common variation in returns related to inflation betas is the average of the portfolios "low beta, small" and "low beta, big" minus the average of the portfolios "high beta, small" and "high beta, big". In a number of robustness checks, we use the non-traded inflation innovations as risk factor instead. Finally, we run cross-sectional regressions using TIPS returns as a risk factor, to analyze whether TIPS exposure is priced in the stock market consistent with realized TIPS returns.

We do not consider dividend yields as an alternative measure of expected returns (see, e.g.,

[14] These results are available upon request.

Bekaert and Harvey (2000) and De Jong and De Roon (2005)). The motivation is that dividend yields are not particularly informative about expected returns in the cross-section of inflation beta-sorted portfolios Pre- versus Post-TIPS. According to the present-value identity of Campbell and Shiller (1988), dividend yields must predict either returns or dividend growth rates or both. Cochrane (2008) finds that the evidence is in favor of return predictability for the aggregate stock market. Maio and Santa-Clara (2013), however, find that this conclusion applies only to Big and Growth stocks. Similarly, we find that high inflation beta stocks are characterized by return predictability, but low beta stocks by dividend growth predictability. Moreover, dividend growth rates differ between high and low beta stocks and this difference is strongly time-varying, which further complicates making inferences.[15]

C.2 Proxy variables

This subsection describes the proxies we use to bring the unobservable model parameters $\varphi_{e,t}$ and $\gamma_{m,t}$ to the data. For $\varphi_{e,t}$ we use the relative market share of TIPS (denoted $TIPS_t$), measured as the total value of outstanding TIPS (from Barclays) over the total market value of all stocks in the CRSP file. This proxy takes into account that institutions cannot change their investment practices overnight, whereas small investments in TIPS will likely have little effect on pricing in the stock market. For $\gamma_{m,t}$ we use the Chicago FED National Activity Index (denoted $CFNAI_t$).[16] Our choice of a business cycle indicator is consistent with countercyclical risk aversion in Campbell and Cochrane (1999) and Brandt and Wang (2003), for instance.

[15] These results are available upon request.

[16] Specifically, we use the 3-month moving average of the index: CFNAI-MA3, available at: http://www.chicagofed.org/webpages/publications/cfnai. Our results are similar for NBER dating, but we prefer the CFNAI because it is available in real-time (since 2001) and is known to be a good predictor of inflation.

To sum up, we have two empirical specifications

$$r_{h,t+1} = \lambda_0 + \lambda_1 TIPS_t + u_{t+1} \text{ and} \tag{12}$$

$$r_{h,t+1} = \lambda_0 + \lambda_1 TIPS_t + \lambda_2 CFNAI_t + \lambda_3 (TIPS_t \times CFNAI_t) + u_{t+1}. \tag{13}$$

Since risk aversion is countercyclical, the hypotheses developed in Section I.D translate to the predictions: $\lambda_0 < 0$, $\lambda_1 > 0$, $\lambda_2 > 0$ and $\lambda_3 < 0$. In our cross-sectional regressions, we allow the risk premiums of all factors to vary over time. The null hypothesis here is that neither $TIPS_t$ nor $TIPS_t \times CFNAI_t$ predicts, because the factor risk premiums are the returns on artifical portfolios that have no exposure to inflation risk. On the other hand, time-varying risk aversion, as proxied by $CFNAI_t$, may well be relevant for all factors.

III Inflation beta sorted portfolios

Table I describes the set of Inflation beta and Size-sorted portfolios. To conserve space, we present results for only four beta groups (High, four, seven and Low) and the HLIB spreading portfolios. We report pre- and post-ranking inflation exposures as well as annualized average return and standard deviation in Panels A to C.

Panel A demonstrates that there exist stocks across a wide spectrum of ex ante exposures ranging from -10.9 to 5.3. The post-ranking betas line up monotonically and average out to 2.9 for the Size-controlled HLIB portfolio. This exposure is significant and economically large, translating to an incremental monthly return of 73 basis points when π_t increases by one standard deviation (2.9×0.25). In contrast, the inflation beta of the aggregate stock market is -2.3, such that it loses over 50 basis points on the same occassion. Thus, we have created portfolios that are exposed to inflation risk, which implies inflation is not a useless factor in the sense of Kan and Zhang (1999) and is a necessary and sufficient condition for the portfolios to carry the risk premium. In fact, Table VI demonstrates that these portfolios are present in the optimal inflation hedge portfolio historically.

Next, we see that average returns decrease with inflation beta, but the relation is not strictly monotonic. The HLIB spreads are significant, except among Micro stocks, averageing out to -4.28% ($t = -2.12$) for the Size-controlled HLIB portfolio.[17] A negative unconditional inflation risk premium is consistent with previous estimates in Chen et al. (1986) and Ferson and Harvey (1991), in a small set of stock portfolios, and Buraschi and Jiltsov (2005), Ang et al. (2008), Gurkaynak et al. (2007) and D'Amico et al. (2008), in the bond market. The estimate is sensitive to the exact specification, however, and weakens when we control for the benchmark factors MKT, SMB, HML and MOM when estimating inflation betas in Panel B. This finding could be due to substantial variation over time, as hypothesized in Section I. Moreover, Ang et al. (2012) estimate an insignificant positive risk premium among individual stocks over the same sample period. The discrepancy is due to differences in the sorting methodology, because the conclusions from Panel A extend in the truly out-of-sample sort on betas with respect to I_t^{rv} in Panel C.[18] Importantly, the conditional evidence we present below is not sensitive to these differences.

Panel D reports average portfolio characteristics: Size, Book-to-market and Momentum.[19] If these characteristics explain the cross-section of expected returns completely, one would expect

[17] Note, this estimate is insignificant when considering the data mining-corrected t-statistic cutoffs in Harvey et al. (2013).

[18] To be precise, Ang et al. (2012) (i) use 60 month rolling window betas, (ii) sort in five beta groups and (iii) do not control for Size.

[19] Size is market cap in billions of dollars. Book-to-Market (BM) is calculated in June as the ratio of the most recently available book-value of equity in Compustat (assumed to be available six months after the fiscal year-end) divided by Market Capitalization from CRSP (Size) at previous year-end. Prior return is defined as $\prod_{j=12}^{2}(1+r_{i,t+1-j})$.

a positive unconditional inflation risk premium, because our strategy loads on Small, Value and Winner stocks on average. Further, one would expect the inflation risk premium to increase post-TIPS, because in these years, the tilt towards Small and Winner stocks is stronger. In the cross-sectional regressions of Table V, we test whether the inflation risk premium is separate to these characteristics.

In Panel A of Table B1 (Appendix B) we characterize these portfolios further in terms of industry composition (based on 48 industries available from Kenneth French's Web Site). In short, we find that industry composition needs to vary substantially over time to be maximally exposed to inflation (see also Ang et al. (2012)). Nevertheless, Panel B demonstrates that an industry-neutral strategy, which exploits only within-industry variation in inflation betas, is also useful as an inflation hedge.

IV Time-series regressions

This section presents the first formal tests of a time-varying inflation risk premium, which hypotheses are derived in Section I and summarized in Equation (8). We regress returns of (Size-controlled) inflation beta-sorted portfolios on the relative market share of TIPS ($TIPS_t$) and the Chicago Fed National Activity Index ($CFNAI_t$). We consider three specifications and report the results in Table II. Specification (A) regresses returns on lagged $TIPS_t$, for which regression the model predicts a negative intercept λ_0 and a positive coefficient λ_1 (see Equation 12). Specification (B) adds $CFNAI_t$ and the interaction term $TIPS_t \times CFNAI_t$, for which the model, respectively, predicts a positive coefficient λ_2 and a negative coefficient λ_3 (see Equation 13). Model (C) adds four benchmark predictors: Dividend Yield (DY_t), Default Spread (DS_t), Risk-Free Rate (RF_t) and Term Spread (TS_t). All variables are standardized, except for $TIPS_t$, which is normalized to have standard deviation one only. This normalization ensures that the intercept measures the unconditional inflation risk premium before TIPS were introduced. For Models (B) and (C), the table presents the p-value of a Wald-test of the hypothesis that the inflation risk premium is not time-varying with $TIPS_t$, $CFNAI_t$ and $TIPS_t \times CFNAI_t$. The sample period is July 1967 to December 2011, dictated by data availability.

Let us focus initially on the HLIB portfolio in Panel A. First, the intercept λ_0 is negative and significant in each specification around -7.0%. A negative unconditional average return is consistent with our model and the idea that inflation is bad news on average. Second, λ_1 is positive and significant at 5.85 in Model (A), which suggests that $TIPS_t$ predicts HLIB portfolio returns to increase.[20] This finding is consistent with our model in that an increasing market share of TIPS, which are the preferred hedge for inflation risk, implies that fewer investors are hedging in the stock market. Thus, forcing the inflation risk premium in the stock market up from its historical negative value.

In Model (B), $TIPS_t$ is largely driven out by $CFNAI_t$ and the interaction term, which coefficients λ_2 and λ_3 are large and significant at 8.17 and -6.18, respectively. As a result, the Wald-test comfortably rejects the hypothesis of no time-variation. These coefficient estimates are consistent with the model in that risk aversion is larger in recessions, which implies for lower values of $CFNAI_t$: (i) a lower inflation risk premium Pre-TIPS and (ii) a stronger effect of increasing TIPS market share. Note also that Model (B) fits considerably better than Model (A) at an adjusted-R^2 of 4.21% relative to 1.22%, which is meaningful for a predictive regression of monthly returns. Plugging in the realized values of the independent variables in 1967 and

[20] Note, the correlation between $TIPS_t$ and a linear (post-1997) time trend is 0.95. In results that are available upon request, we find that $TIPS_t$ predicts with the hypothesized sign even when orthogonalized from this time trend.

2011, the coefficient estimates in Model (B) imply a reversal in the inflation risk premium from a significant -11.24% to an insignificant 7.36%. This positive, insignificant risk premium post-TIPS is consistent with the model in that investors that use TIPS to hedge inflation risk, have only the speculative investment in TIPS left to hedge in the stock market. Previous literature suggests this speculative investment is non-negative.

Two additional results stand out from Panel A. First, the coefficients $\lambda_0, \lambda_1, \lambda_2$ and λ_3 vary monotonically with Inflation Beta. Second, controlling for the benchmark predictors in Model (C) leaves these conclusions unchanged. Also, these conclusions are not affected much when excluding the financial crisis. The only difference is that λ_3 halves and is only marginally significant, which is likely due to the fact that we effectively only have the recent recession to identify this coefficient.[21]

Panel B shows that the time-variation in the inflation risk premium weakens when we control for a stock's exposure to the benchmark factors when estimating inflation beta. A possible explanation is that exposures to inflation, a non-traded factor, are relatively small and hard to estimate. We analyze the relation with the benchmark factors more closely below. For now it is important to note that these models do imply a similarly significant reversal from about -6% in 1967 to 10% in 2011. Panel C demonstrates largely similar time-variation in the risk premium from the truly out-of-sample sort on I_t^{rv}. The only difference with Panel A is a slightly smaller, although marginally significant, unconditional inflation risk premium.

The long-horizon regressions in Panel D further stress the economic significance of these results. We annualize returns over three forecasting horizons $k = 3, 12, 24$ (standard errors are Newey - West with lag length k). First, the estimated coefficients λ_0 and λ_1 are similar to the one-month horizon. In contrast, the coefficients λ_2 and λ_3 shrink as the horizon increases, which is likely

[21] In Panel B of Table B1 (Appendix B) we see that the industry-neutral strategy, which exploits only within-industry variation in inflation betas, obtains similar time-varying returns, as well.

due to the fact that turbulent economic times (measured by the lowest $CFNAI_t$-values) are relatively short-lived. Nevertheless, the coefficients are of the hypothesized sign at all horizons, which combines to clear rejections in the Wald-test. Finally, R^2 increases with the horizon, that is, from 4.21% for $k = 1$ to 28.93% for $k = 24$ in Model (B), which is similar to the aggregate stock market in (see Fama and French (1988) and Campbell (2001), for instance).

In conclusion, the inflation risk premium, as measured by returns on Inflation Beta-sorted portfolios, is varying over time in the predicted fashion with the market share of TIPS and over the business cycle. Table B2 analyzes whether this time-variation is robust to controlling for conditional exposures to the benchmark factors of the CAPM, FF3M and FFCM, similar to Ferson and Harvey (1999). We relegate this exercise to the appendix because it is not clear ex ante why betas with respect to the benchmark factors should vary over time, and, in particular, with $TIPS_t$. First, we see that the time-variation in Inflation Beta-sorted portfolio returns is not explained in unconditional factor models. Exposures to the benchmark factors are strongly varying over time, however, similar to the portfolio characteristics reported in Table I. In case of the CAPM and FF3M, these time-varying exposures are not enough to fully explain the observed time-variation in HLIB returns. In contrast, a FFCM that conditions exposures on $TIPS_t$,$CFNAI_t$ and $TIPS_t \times CFNAI_t$ completely eradicates the time-varying inflation risk premium. We find that this supreme fit is largely mechanical. Our WLS procedure to estimate inflation betas puts the largest weight on observations close to t, such that the strategy loads on winners when inflation innovations were high recently and vice versa.[22]

The cross-sectional regressions that follow explicitly control for the relation between Inflation

[22] Two additional pieces of information are necessary to fully understand the result. First, inflation innovations are typically low in recessions, such that we load on losers. Second, a regression of MOM on $CFNAI_t$ shows that MOM returns are similar in recessions and expansions Pre-TIPS, but extremely low in the recent financial crisis, when losers outperform winners by about 1.75% per month on average.

Beta and Momentum as well as other factors and characteristics. Thus, this exercise allows us to answer the ultimate question of whether inflation betas contain independent information for expected returns in the cross-section.

V Cross-sectional regressions

The previous section analyzed the inflation risk premium derived from the returns of Inflation Beta-sorted portfolios. We now turn to cross-sectional estimates of the inflation risk premium. Table III presents summary statistics and some predictability evidence for the benchmark factors that we use as well as the inflation factor INF. The unconditional average return on INF is negative at -1.60%, but insignificant and small compared to the other factors. As before, this unconditional estimate masks important time-variation. In the full model, the intercept as well as the coefficients on $CFNAI_t$ and $TIPS_t \times CFNAI_t$ are large and significant at -3.61, 5.85 and -3.51, respectively, which adds up to a reversal from a significant -6.72% in 1967 to an insignificant 5.61% in 2011. For the benchmark factors, the Wald-test of no time-variation only rejects in case of SMB, which returns are larger in recessions. Further, the R^2 of the full model stands out for Momentum at 7%, driven by a large and significant coefficient on $TIPS_t \times CFNAI_t$.

Table IV presents cross-sectional regressions where we allow risk premiums to vary over time. We consider three types of regressions. Type (A) is the standard Fama and MacBeth (1973) cross-sectional regression estimate of the unconditional risk premium (with Shanken (1992) standard errors). Type (B) and (C), respectively, condition the risk premiums on M instruments, that is either $Z_t = (1, TIPS_t)$ or $Z_t = (1, TIPS_t,\ CFNAI_t, TIPS_t \times CFNAI_t)$. We estimate the time-varying risk premium coefficients using the pooled time-series cross-sectional regression

$$R_{i,t+1} = \lambda'(\widehat{\beta_{i,t}} \otimes Z_t) + u_{i,t+1},$$

where $\widehat{\beta_{i,t-1}}$ is a $K - vector$ of estimated factor exposures for the benchmark models and models that add INF. λ is the $KM \times 1 - vector$ of parameters to be estimated. This pooled second stage gives identical estimates to a three-stage setup, where the second stage runs cross-sectional regressions in each month $t + 1$ and the third stage runs predictive regressions of the time-series of risk premium estimates on the instruments.[23] The three-stage approach is used in Ferson and Harvey (1991) and Cohen et al. (2005) and is consistent under the assumption that the measurement error in the betas is uncorrelated with the instruments. The pooled regression is consistent under the same assumption and is attractive, because it provides the standard errors in one go, which we cluster on time. The first-stage betas used as independent variable in the second stage are the usual constant, full sample betas. The regressions do not include an intercept to increase efficiency, but our conclusions are robust in this dimension.

In Panel A, we use 30 Inflation Beta and Size-sorted portfolios (UI1S30) as test assets. We present the estimated risk premiums (λ), the time-series average of the second-stage cross-sectional R_t^2, a Wald-test of the hypothesis that the inflation risk premium does not vary over time and the model-implied inflation risk premium at the beginning and the end of the sample period. The remaining Panels B to E present a range of robustness checks where we omit the estimated risk premiums for the sake of brevity. These can be found in Table B3 of Appendix B.

In short, Panel A demonstrates that exposure to inflation risk is compensated with a time-varying price that is consistent with realized returns of the inflation factor INF. First, the uncon-

[23] This identity extends the analysis of cross-sectional regressions in Cochrane (2001) to a conditional setting.

ditional inflation risk premium is an insignificant -2% when INF is added to the CAPM, FF3M and FFCM. Allowing for variation with the market share of TIPS in Model (B), $\lambda_{0,INF}$ turns significant at about -4% in each model, which is again consistent with the idea that inflation is bad news on average. In Model (B), $\lambda_{1,INF}$ is also significant, with the hypothesized sign, around 3.5. Increasing TIPS market share implies that fewer investors hedge inflation risk in the stock market, such that the premium that is required from low Inflation Beta stocks decreases.

Model (C) conditions further on the state of the business cycle, which results in $TIPS_t$ being driven out by $CFNAI_t$ and $TIPS_t \times CFNAI_t$, as before. The estimated coefficients $\lambda_{2,INF}$ and $\lambda_{3,INF}$ are large and significant at 7 and -4, respectively, and imply that the inflation risk premium is largest (in absolute value) in recessions. In sum, these cross-sectional regressions imply a reversal from -8% to 5.5%, which is consistent with the model where investors hedge inflation risk in the stock market pre-TIPS, but hedge a non-negative speculative investment in TIPS in the stock market once TIPS are introduced.

Finally, we see that adding INF improves the average cross-sectional R_t^2 considerably: from 4% to 21% in the CAPM, 36% to 44% in the FF3M and 40% to 47% in the FFCM. The unconditional risk premiums for MKT, SMB and HML are quite similar to the average realized returns of these factors. MOM is an exception, however, with a small and insignificant unconditional risk premium. In unreported results, we find that the time-variation in the SMB, HML and MOM risk premiums weakens considerably whenever INF is included.

Although the set of Inflation Beta-sorted portfolios is hard-wired to attribute any "common" variation to INF, this choice is not driving our results. Indeed, Panel B presents largely similar results when we expend the set of test assets with 17 industry (IND17) and 25 Size and Book-to-

Market (25SBM) portfolios.[24] To show that our results are not specific to constructing the traded factor INF either, Panel C uses as measure of inflation risk the non-traded inflation innovations π_t. In this case, the implied reversals are slightly weaker in absolute value, which is likely due to larger noise in the estimated exposures.[25] Panel D shows that our conclusions also survive a simple test of model misspecification, that is the inclusion of characteristics (Berk (1995) and Jagannathan and Wang (1996)).[26]

As another chck of robustness, Panel E presents firm-level cross-sectional regressions. Here we use a three-stage setup and estimate the conditional risk premiums by regressing the second stage Fama and MacBeth (1973) estimates (that use the time-varying betas that were previously used to sort) on the instruments. We present results for two models: FF3M+π_t and FFCM+π_t, both ex- and including characteristics, which are standardized cross-sectionally.[27] Note, consistent with previous literature, the average cross-sectional R^2 is small compared to using portfolios (see, e.g., Fama and French (2008)).

Without characteristics, the Wald-test of no time-variation in the inflation risk premium in Model (C) rejects marginally. All coefficients for the time-varying inflation risk premium have the hypothesized sign, but the coefficients are less significant and imply a reversal that is scaled differently: from an insignificant -2.5% in 1967 to an insignificant 10% in 2011.[28] The discrepancy with the evidence shrinks when we include characteristics, with an implied reversal that runs from a large and significant -5% in 1967 to a marginally significant 11% in 2011.

[24] Both available from Kenneth French's Web site.

[25] To calculate implied risk premiums that are comparable to Panel A and B, we scale the coefficient estimates from Panel C by the post-ranking beta of the HLIB portfolios from Panel B of Table I.

[26] These characteristics are standardized cross-sectionally at each time t. For IND17 and SBM25, Prior return is estimated using the returns on the portfolios, not the stocks inside.

[27] Note, these cross-sectional regressions are biased in favor of characteristics, which unlike betas, can be measured without error.

[28] To calculate implied risk premiums that are comparable to the previous panels, we scale the coefficient estimates from Panel E by the average pre-ranking beta of the HLIB portfolios in 1967 and 2011, which is about 13.

In the end, all specifications provide us with evidence of an inflation risk premium that varies with both the market share of TIPS and over the business cycle. In cross-sectional regressions, the inflation risk premium cannot be explained by the benchmark factors and characteristics, which suggests that inflation beta contains orthogonal information about expected returns. The exact magnitude of the implied reversal does vary across specifications, which is likely due to two problems. First, exposures to a non-traded factor are relative difficult to estimate. Second, the cross-sectional distribution of inflation exposures is varying over time. Both problems are most severe for the case of individual stocks analyzed in Panel E.

A Joint pricing of stocks and TIPS

This subsection presents preliminary evidence that the pricing of inflation risk in the stock market is consistent with expected TIPS returns, using the available 15 year sample of realized TIPS returns. To be precise, our model suggests that the risk premium in the stock market for a unit exposure to TIPS converges to the expected return on TIPS towards the end of the sample.

In Panel A of Table V, we present cross-sectional regressions using the set of 30 Inflation Beta and Size-sorted portfolios (UI1S30) as test assets. The asset pricing model includes the CRSP VW market portfolio and a portfolio of TIPS (an index of all maturity TIPS available from Barclays Capital) as factors.[29] To alleviate concerns about noisy TIPS prices in the market's early years, we use a 60 month rolling window to estimate betas and impute the first set of estimated betas in February 2002 for the five years before.

In short, we find that the estimated risk premium for exposure to TIPS in the stock market (λ_{TIPS}) is indeed converging to the average excess return on TIPS (r_{TIPS}), which is presented

[29] In contrast to what is implied by our model, our proxy of the market portfolio does not include TIPS. The motivation is that the relative market value of TIPS is small.

as well. In the first five-year period from 1997 to 2001, the two risk premiums differ by a large 8.72% (λ_{TIPS} = 10.17% versus r_{TIPS} = 1.45%), which is significant at the 5%-level. In the two subsequent five-year periods, the difference is small and insignificant at -0.41% and 0.11%, respectively.[30]

Another way to test this convergence is by asking whether the model with TIPS predicts a cross-section of expected returns that is similar to predictions from the original model, which includes the inflation factor INF. To this end, Panel B presents the same set of cross-sectional regressions for this original model and, in the last column, the cross-sectional correlation between expected returns for the set of 30 portfolios predicted by these two competing models.[31] Expected returns are calculated in each month t by multiplying the rolling window betas with the ex-post average factor risk premiums in each five-year period. We find that the average cross-sectional correlation is increasing from -0.03 in the first five-year period, to 0.60 and 0.65 in the two subsequent five-year periods. Although preliminary, this evidence suggests that the pricing of inflation risk in the stock market is increasingly consistent with realized TIPS returns as this market grows and matures.

VI Do stock portfolios and TIPS hedge inflation risk?

This section asks whether our stock portfolios as well as TIPS are an important component of the portfolio that optimally hedges inflation risk. TIPS hedging ability is necessary for our model

[30] This conclusion is largely robust to including SMB, HML and MOM and using the larger set of 72 portfolios. These results are available upon request.

[31] Note that TIPS returns are less time-varying than returns on the inflation factor INF. This finding is not inconsistent with the model. Consider Equation (40) of Appendix 4, which equates supply (fixed at $w^0_{m,t}$) and demand in the TIPS market: $w^0_{m,t} = \varphi_{e,t}(w^0_{spec} - q_{m,t})$. We see that the hedge demand for TIPS (that is, $q_{m,t}$) is not likely to cause a strong upward pressure on TIPS prices through the equilibrium quantity w^0_{spec}. The reason is that $\varphi_{e,t}$ is small when TIPS are introduced and increases gradually over the sample period as does the supply of TIPS by the Treasury.

to have economic content, but is not a given in practice. For instance, TIPS hedging ability may be hampered by a three month indexation lag, illiquidity in the market's early years and volatile prices in the recent financial crisis. For this reason, Table VI presents regressions of $ARMA(1,1)$-innovations in inflation (Panel A) and inflation itself (Panel B) on gross returns of the one-month t-bill (TB1, from CRSP), the 10 year constant maturity treasury bond (CMT10, from CRSP), the inflation factor (INF, a zero-investment strategy) and the portfolio of TIPS.[32]

In the period before TIPS, TB1 and INF, with long positions, and CMT10, with a short position, are significant components of the optimal inflation hedge portfolio with a joint R^2 of 7.34%. Out of these three assets, INF obtains the highest R^2 in isolation at 4.07% with a coefficient of 0.020 ($t = 3.94$).[33]

Post-TIPS, both CMT10 and INF are marginally significant in isolation, but little variation is explained at R^2's of 3.22% and 1.06%, respectively. Combining a short position in CMT10 with TIPS improves the fit considerably to an R^2 of 11.32%. In fact, only CMT10 and TIPS are significant in the joint regression with similarly large positions of -0.07 and 0.07. This combination intuitively captures an innovation in inflation, i.e., unexpected inflation plus changes in expected inflation. On one hand, TIPS compensate the investor for realized inflation. On the other hand, the investor pays expected inflation on the short position in CMT10, which asset loads negatively on changes in expected inflation.

Panel B demonstrates that these results are robust to hedging total inflation instead. Pre-TIPS, TB1 is the best hedge at an R^2 of 23.94%, which confirms Ang (2012). INF is, however, a significant component of the joint hedge portfolio that obtains an R^2 of 26.91%. Post-TIPS, TB1

[32] Results are similar when we use the sort in ten inflation beta groups and when we substitute CMT10 with the Merrill Lynch U.S. Treasury bond Index from Datastream.

[33] The aggregate stock market achieves a similar R^2 of 4.74%. However, the required position is negative (-0.011, $t = -3.64$), consistent with the historical failure of the Fisher hypothesis.

and INF are driven out by the long-short combination of TIPS and CMT10, with the joint model achieving an R^2 of 11.12% relative to 0.20% for TB1 in isolation. In unreported results we find that these conclusions extend for inflation (innovations) compounded up to three months in the future, after which the hedging ability of both INF and TIPS starts to weaken.

To conclude, we find that our inflation beta-sorted stock portfolios were present in the optimal hedge portfolio for inflation risk historically. However, after the introduction of TIPS, this asset provides for a much better hedge when combined with a short position in nominal bonds. This finding means that substituting part of an existing position in nominal bonds, which have a negative exposure to inflation, with TIPS is desirable for many institutions. In terms of our model, such reallocation implies that investors can unwind their hedge positions in the stock market post-1997, which leads to the documented reversal in the inflation risk premium.

VII The inflation risk premium and the nominal-real covariance

So far we have focused on TIPS to explain the reversal in the inflation risk premium. Now, we ask whether a time-varying nominal-real covariance has also contributed to this reversal. This question is motivated by a reversal in the relation between inflation and future macroeconomic activity, the nominal-real covariance, around the end of the nineties. In related work, Campbell et al. (2013) use this nominal-real covariance as a state variable that governs time-variation in nominal bond returns and estimate a consequent reversal in term premia over the recent decade.

Panel A of Table VII summarizes the evidence for a reversal in the nominal-real covariance. We regress inflation (from $t-2$ to $t-1$) on future (log) industrial production growth and (log) non-durables and services consumption growth. We denote the coefficients b^1_{IP} and b^1_{CG}, when using the growth rate from t to $t+1$, and b^{12}_{IP} and b^{12}_{CG}, for twelve month cumulative growth rates from t to $t+12$. For comparison to Campbell et al. (2013), we also present the negative of the stock market beta of the 10 year constant maturity government bond bond (b_B^1). In short, we see that over the second half of the last decade inflation largely predicts negative changes in macroeconomic activity, whereas in the recent decade inflation predicts positive changes. Indeed, both inflation and real activity were low in the recent crisis.

A Testable implications, empirical content and proxy variables

In the model of Section I, the investor's fundamental exposure to inflation $q_{m,t}$ can be motivated by noting that inflation is a state variable for consumption-investment opportunities in an Intertemporal CAPM along the lines of Cochrane (2001, Ch. 9), Vassalou (2003) and Koijen et al. (2013), for instance. Indeed, inflation shocks can be either good or bad news for investors, depending on how inflation predicts macroeconomic activity.

To set the stage, we go back to the model outlined in Section I and consider the second-order Taylor expansion using one additional element of the aggregate exposure: the market's exposure to inflation risk $q_{m,t}$. Starting from $Q_t = \gamma_{m,t}((1-\varphi_{e,t})q_{m,t} + \varphi_{e,t}w^0_{spec})$, Appendix A.6 derives the following extended model for the aggregate exposure

$$\begin{aligned} Q_t &= \theta_0 + \theta_1\varphi_{e,t} + \theta_2\gamma_{m,t} + \theta_3(\varphi_{e,t}\times\gamma_{m,t}) + \\ &\quad \theta_4 q_{m,t} + \theta_5(q_{m,t}\times\gamma_{m,t}) + \theta_6(\varphi_{e,t}\times\gamma_{m,t}), \end{aligned} \tag{14}$$

where we predict $\theta_4 > 0, \theta_5 > 0$ and $\theta_6 < 0$, in addition to $\theta_0 < 0$, $\theta_1 > 0$, $\theta_2 < 0$ and $\theta_3 > 0$, which were derived before. First, the inflation risk premium increases with $q_{m,t}$. The intuition is that when a shock to inflation contains less adverse news about macroeconomic activity, for instance, in the recent decade, the investor's incentive to hedge weakens and the inflation risk premium will adjust accordingly. Second, the marginal effect of $q_{m,t}$ is increasing with $\gamma_{m,t}$, when the investor's incentive to hedge is larger. Finally, the marginal effect of $q_{m,t}$ is decreasing with $\varphi_{e,t}$. For if all investors hedge using TIPS, no one is hedging the exposure $q_{m,t}$ in the stock market.

We follow a simple, but flexible approach and use backward-looking estimates of the relation between inflation and real activity, consumption and stock returns to proxy for $q_{m,t}$. These running estimates are obtained by running the regressions in Panel A of VII using historical data only in each month t. The specification is similar to the inflation betas of Equation (9): using an expanding window and Weighted Least Squares.[34] Thus, we regress returns (or twelve month ahead compounded returns) of the inflation factor INF on the running measures $b^1_{IP,t}$, $b^1_{CG,t}$ and $b^1_{B,t}$ (or $b^{12}_{IP,t}$, $b^{12}_{CG,t}$ and $b^1_{B,t}$) and the control variables:

$$\begin{aligned} r_{INF,t+1} \;=\;& \lambda_0 + \lambda_1 TIPS_t + \lambda_2 CFNAI_t + \lambda_3 (TIPS_t \times CFNAI_t) + \\ & \lambda_4 b_{IP,t} + \lambda_5 (b^1_{IP,t} \times CFNAI_t) + \lambda_6 (b^1_{IP,t} \times TIPS_t) + u_{t+1}, \end{aligned} \tag{15}$$

where the additional hypotheses are $\lambda_4 > 0$, $\lambda_5 < 0$ and $\lambda_6 < 0$.

B Empirical evidence

In Panel B of Table VII we consider three versions of Equation (15). Model (A) focuses on the nominal real-covariance and restricts $\lambda_1 = \lambda_2 = \lambda_3 = \lambda_5 = \lambda_6 = 0$. Model (B) allows for business cycle variation and restricts $\lambda_1 = \lambda_3 = \lambda_6 = 0$. Model (C) is the full specification for which we also present a Wald test of the hypothesis that the nominal-real covariance does not add anything

[34] The expanding window starts in February 1959, dictated by consumption data availability. The WLS procedure uses an exponential weighting scheme with a half-life of 60 months.

to the model analyzed in previous sections, i.e., $\lambda_4 = \lambda_5 = \lambda_6 = 0$.

In short, we see that our proxies of the nominal-real covariance, which are all standardized, predict largely with the right sign unless we control for $TIPS_t$. Focusing on the first proxy $b_{IP,t}$, we see that λ_4 is significant at 3.73 in Model (A). In Model (B), both $b^1_{IP,t}$ and its interaction with $CFNAI_t$ are significant with the hypothesized sign ($\lambda_4 > 0$ and $\lambda_5 < 0$). These findings are consistent with the model and suggest that as the macroeconomic news contained in inflation shocks becomes more positive, the risk premium increases and particularly so in recessions. Intuitively, in this scenario, high inflation beta stocks become less attractive as a hedge and therefore have lower prices (higher expected returns), whereas these effects are particularly strong when risk aversion is large. In Model (C) all coefficients related to $b_{IP,t}$ turn insignificant, however, and the Wald-test cannot reject. In contrast, both $CFNAI_t$ and $TIPS_t \times CFNAI_t$ are similarly large and significant to Table III.

For twelve month compounded returns, λ_4 and λ_5 become more significant in Model (A) and (B). This is consistent with idea that the nominal-real covariance captures a slow-moving component of the inflation risk premium. This is also clear from the R^2's, which are much larger at 18% versus 3% in Model (B), for instance. However, again, the Wald-test cannot reject that the nominal-real covariance is superfluous in Model (C). Results for the alternative proxies $b_{CG,t}$ and $b_{B,t}$ are by and large similar.

In summary, we find that the inflation risk premium is predictable with various proxies of the nominal-real covariance, which extends the bond market evidence in Campbell et al. (2013). Our evidence suggests, however, that the nominal-real covariance has little to add to a model that already includes the market share of TIPS. A possible explanation for the difficulty in disentangling the two effects follows from observing that (i) the Post-TIPS sample is short and (ii) the admittedly noisy proxies of the nominal-real covariance have seen a very pronounced upward shift that roughly coincides with the introduction of TIPS in 1997.[35] Indeed, Panel C shows that bIP_t^1 predicts with a large coefficient only in the Post-TIPS period.

VIII Conclusion

This paper follows a long tradition of papers at the intersection of macroeconomics and asset pricing and finds that there exists an inflation risk premium (IRP) in the cross-section of US stocks that reverses from -8.0% in the sixties to an insignificant 5.5% in recent years. We uncover three forces that guide this time-variation. First and foremost important for the reversal is that the IRP is increasing in the market share of TIPS. Second, the IRP is particularly large in recessions. Finally, a time-varying nominal-real covariance contributes to the reversing IRP in isolation. This predictability is largely driven out by TIPS, however, which could be due to the fact that our noisy proxies of the nominal-real covariance experience a pronounced upward shift around the same time TIPS were introduced.

We derive a simple asset pricing model to motivate the reversal. Inflation may enter the model as an exogenous risk or as a state variable. In either case, it is natural to assume that inflation is typically bad news for the average investor. Historically, real bonds are not available and nominal bonds are exposed with a negative sign. Consequently, investors are forced to hedge partly in the stock market, consistent with the negative IRP pre-TIPS, because high inflation beta stocks are attractive as a hedge. Since 1997, however, TIPS allow the investor to hedge inflation more efficiently, leaving only the speculative investment in TIPS to be hedged in the stock market. Previous literature suggests that this investment is non-negative, in which case our

[35] In the time-series the correlation between various measures of the nominal-real covariance and $TIPS_t$ is about 0.70.

model indicates that the IRP reverses, because high inflation beta stocks are not attractive as a hedge anymore.

An alternative explanation for the reversal focuses on the role of inflation as a state variable, with inflation shocks predicting negative changes in macroeconomic activity until the end of the nineties. In contrast, inflation shocks predict positive changes over the recent decade, such that inflation is not necessarily bad news anymore. Our evidence surely favors the market share of TIPS as driving factor of the reversal, however.

A number of extensions come to mind. First, a thorough investigation of the nominal-real covariance and the independent information this variable contains for the IRP in the stock market may benefit from directly modelling the stochastic discount factor in the economy, as in Campbell et al. (2013). Relatedly, Campbell et al. (2009) note that the nominal-real covariance may well change sign again, which could present an ideal opportunity to test our model out-of-sample. Furthermore, we leave open the question of why firm's inflation exposures differ in the cross-section, which is analyzed in Duarte and Blomberger (2012). Finally, because we have a short sample of TIPS returns, our evidence is only suggestive that the pricing of inflation risk in the stock market is consistent with TIPS.

Appendix A: Derivations

1. Basic framework

This section presents a detailed derivation of the basic framework of the model outlined in Section I.A. Defining as $\mu_{\pi,t}$ and σ_{π}^2 the expected 'return' and variance of the risk factor, respectively, the expected return and variance of agent j's portfolio can be written as

$$E_t(R^p_{j,t+1}) = R^f + w^{A\prime}_{j,t}\mu_{A,t} + q'_{j,t}\mu_{\pi,t} \text{ and} \quad (16)$$

$$Var_t(R^p_{j,t+1}) = w^{A\prime}_{j,t}\Sigma_{AA}w^A_{j,t} + q'_{j,t}\sigma^2_\pi q_{j,t} + 2w^A_{j,t}\Sigma_{A\pi}q_{j,t}, \quad (17)$$

where $\Sigma_{A\pi}$ is the $N \times 1$ covariance matrix of the risky assets and the risk factor. Although we assume constant covariances the model can be extended to incorporate time-varying (co-) variances.

With the assumption that the portfolio problem of the agent depends only on the mean and variance of portfolio returns, the problem that agent j (with risk-aversion $\gamma_{j,t}$) has to solve is, using obvious notation,

$$\max_{w^A_{j,t}} \ E_t(R^p_{j,t+1}) - \frac{\gamma_{j,t}}{2}Var_t(R^p_{j,t+1}). \quad (18)$$

Plugging in equations (16) and (17) we obtain the following first-order condition for each agent j

$$\mu_{A,t} = \gamma_{j,t}\Sigma_{AA}w^A_{j,t} + \gamma_j\Sigma_{A\pi}q_{j,t}. \quad (19)$$

Aggregating over all agents $j = 1, ..., J$, weighting by their relative wealth $x_{j,t} = X_{j,t}/\sum_{j=1}^{J} X_{j,t}$, and rewriting we get

$$\sum_{j=1}^{J} x_{j,t}\gamma^{-1}_{j,t}\mu_{A,t} = \sum_{j=1}^{J} x_{j,t}\begin{pmatrix} \Sigma_{AA} & \Sigma_{A\pi} \end{pmatrix}\begin{pmatrix} w^A_{j,t} \\ q_{j,t} \end{pmatrix} \text{ such that} \quad (20)$$

$$\mu_{A,t} = \gamma_{m,t}\begin{pmatrix} \Sigma_{AA} & \Sigma_{A\pi} \end{pmatrix}\begin{pmatrix} w^A_{m,t} \\ q_{m,t} \end{pmatrix} \Leftrightarrow \quad (21)$$

$$w^A_{m,t} = \gamma^{-1}_{m,t}\Sigma^{-1}_{AA}\mu_{A,t} - \Sigma^{-1}_{AA}\Sigma_{A\pi}q_{m,t}. \quad (22)$$

where $\gamma_{m,t}^{-1}$, $w_{m,t}^{A}$ and $q_{m,t}$ are the wealth-weighted risk tolerance, investments in risky assets, and exposure to the risk factor, respectively, of the market m. This demand is easily rearranged to a standard two-factor asset pricing model

$$E_t(r_{n,t+1}^{A}) = \gamma_{m,t} Cov(r_{n,t+1}^{A}, r_{m,t+1}) + \gamma_{m,t} q_{m,t} Cov(r_{n,t+1}^{A}, \pi_{t+1}) \tag{23}$$

where both exposures to the market and inflation risk are priced.

2. Extended framework

This section presents a detailed derivation of the extended framework of the model, where we introduce an asset that hedges the risk factor perfectly as described in Section I.B.

Using the same notation as before, denote the expanded set of $N+1$ assets X, such that $\mu_{X,t} = \begin{pmatrix} \mu_{0,t} \\ \mu_{A,t} \end{pmatrix}$, a $(N+1) - vector$ of expected excess returns; $\Sigma_{XX} = \begin{pmatrix} \sigma_{00} & \Sigma_{0A} \\ \Sigma_{A0} & \Sigma_{AA} \end{pmatrix}$, a $(N+1) \times (N+1) - matrix$ of (co-) variances; and, $\Sigma_{X\pi} = \begin{pmatrix} \sigma_{0\pi} \\ \Sigma_{A\pi} \end{pmatrix}$, a $(N+1) - vector$ of covariances with the risk factor. From the optimization problem in equation (18), we obtain a familiar first-order condition and optimal demand for each agent j

$$\mu_{X,t} = \gamma_{j,t} \Sigma_{XX} w_{j,t}^{X} + \gamma_{j,t} \Sigma_{X\pi} q_{j,t} \Leftrightarrow \tag{24}$$

$$w_{j,t}^{X} = \gamma_{j,t}^{-1} \Sigma_{XX}^{-1} \mu_{X,t} - \Sigma_{XX}^{-1} \Sigma_{X\pi} q_{j,t}. \tag{25}$$

This appendix serves to define the total demand, separated in a speculative and a hedge demand, in more detail. Consider the auxiliary regression $r_{t+1}^{0} = a_0 + b_0^{'} r_{t+1}^{A} + e_{0,t+1}$, which 'hedges' the risk in the new asset, r^0_{t+1}, with the risky assets, r^A_{t+1}. Thus, a_0 is the hedged expected return on the hedge asset, b_0 are the minimum-variance hedge weights, and σ_{ee} is the idiosyncratic variance of the hedge asset. From the definition of a partitioned inverse the hedge demand will equal

$$\Sigma^{-1}_{XX}\Sigma_{X\pi} = \begin{pmatrix} \sigma^{-1}_{ee} & -\sigma^{-1}_{ee}b'_0 \\ -\sigma^{-1}_{ee}b_0 & \Sigma^{-1}_{AA} + \sigma^{-1}_{ee}b_0b'_0 \end{pmatrix} \begin{pmatrix} \sigma_{0\pi} \\ \Sigma_{A\pi} \end{pmatrix} \tag{26}$$

$$= \begin{pmatrix} \sigma^{-1}_{ee}b'_0\Sigma_{A\pi} + \sigma^{-1}_{ee}\sigma_{e\pi} - \sigma^{-1}_{ee}b'_0\Sigma_{A\pi} \\ -\sigma^{-1}_{ee}b_0b'_0\Sigma_{A\pi} - \sigma^{-1}_{ee}b_0\sigma_{e\pi} + \Sigma^{-1}_{AA}\Sigma_{A\pi} + \sigma^{-1}_{ee}b_0b'_0\Sigma_{A\pi} \end{pmatrix}, \tag{27}$$

where the second equality follows from defining $Cov(r^0_{t+1}, \pi_{t+1}) = b'_0\Sigma_{A\pi} + \sigma_{e\pi} = \sigma_{0\pi}$. If the asset r^0_{t+1} is indeed perfectly correlated to the risk factor π_{t+1}, we get that $\sigma^{-1}_{ee}\sigma_{e\pi} = 1$ and $b_0 = \Sigma^{-1}_{AA}\Sigma_{A\pi}$, such that the hedge demand can be written as

$$\Sigma^{-1}_{XX}\Sigma_{X\pi} = \begin{pmatrix} 1 \\ 0_N \end{pmatrix}. \tag{28}$$

An intuitive result, because with a perfect hedge asset available, agents will only use this asset to hedge.[36] Plugging this hedge demand into the total demand we get

$$w_{j,t}^X = \begin{pmatrix} w_{j,t}^0 \\ w_{j,t}^A \end{pmatrix} = \gamma_{j,t}^{-1} \begin{pmatrix} \sigma_{ee}^{-1} & -\sigma_{ee}^{-1} b_0' \\ -\sigma_{ee}^{-1} b_0 & \Sigma_{AA}^{-1} + \sigma_{ee}^{-1} b_0 b_0' \end{pmatrix} \begin{pmatrix} \mu_{0,t} \\ \mu_{A,t} \end{pmatrix} - \begin{pmatrix} q_{j,t} \\ 0_N \end{pmatrix} \tag{29}$$

$$= \begin{pmatrix} \gamma_{j,t}^{-1} \sigma_{ee}^{-1} a_0 \\ \gamma_j^{-1} \Sigma_{AA}^{-1} \mu_{A,t} - b_0 \gamma_j^{-1} \sigma_{ee}^{-1} a_0 \end{pmatrix} - \begin{pmatrix} q_{j,t} \\ 0_N \end{pmatrix} \tag{30}$$

$$= \begin{pmatrix} w_{spec}^0 \\ \gamma_{j,t}^{-1} \Sigma_{AA}^{-1} \mu_{A,t} - \Sigma_{AA}^{-1} \Sigma_{A\pi} w_{spec}^0 \end{pmatrix} - \begin{pmatrix} q_{j,t} \\ 0_N \end{pmatrix}, \tag{31}$$

where the last equality defines $w_{spec}^0 = \gamma_{j,t}^{-1} \sigma_{ee}^{-1} a_0$, a Markowitz demand for the hedge asset given that it is hedged using the auxiliary regressions. Initially, we focus on the stock market and derive from this demand the expected returns for the initial set of N risky assets only. In Appendix A.4, we derive the joint pricing model for the set of $N + 1$ assets.

3. A beta asset pricing model

In this section we rewrite the asset pricing model

$$E_t(r_{n,t+1}^A) = \gamma_{m,t} Cov(r_{n,t+1}^A, r_{m,t+1}) + Q_t Cov(r_{n,t+1}^A, \pi_{t+1}) \tag{32}$$

to a beta-form, that is, in terms of betas to and expected returns of the market portfolio and a hedge portfolio as in Fama (1996). Define the scaled exposure ($z_{m,t}$) and the hedge portfolio (H) for the risk factor as

$$z_{m,t} = Q_t(\iota_N' \Sigma_{AA}^{-1} \Sigma_{A\pi}) \text{ and} \tag{33}$$

[36] Note that the unit investment in the hedge asset can be scaled by the ratio $\frac{\sigma_\pi}{\sigma_0}$ if these standard deviations are unequal.

$$H = \frac{1}{\left(\iota_N' \Sigma_{AA}^{-1} \Sigma_{A\pi}\right)} \Sigma_{AA}^{-1} \Sigma_{A\pi}, \tag{34}$$

with $\iota_N' H = 1$, such that H is a vector of scaled regression coefficients from a regression of π_{t+1} on r_{t+1}^A, a hedge portfolio. Starting from equation (32) we have

$$\begin{aligned} \mu_{A,t} &= \gamma_{m,t} \Sigma_{Am} + \Sigma_{AA} \Sigma_{AA}^{-1} \Sigma_{A\pi} Q_t && (35) \\ &= \gamma_{m,t} \Sigma_{Am} + \Sigma_{AH} z_{m,t}. && (36) \end{aligned}$$

Using that the first-order conditions in equation (36) must also hold for the market portfolio and the hedge portfolio themselves, we get

$$\begin{pmatrix} \mu_{m,t} \\ \mu_{h,t} \end{pmatrix} = \begin{pmatrix} \sigma_M^2 & \Sigma_{MH} \\ \Sigma_{HM} & \sigma_H^2 \end{pmatrix} \begin{pmatrix} \gamma_{m,t} \\ z_{mt} \end{pmatrix}. \tag{37}$$

Inverting equation (37), which solves for $\gamma_{m,t}$ and $z_{m,t}$, and substituting in equation (36) gives

$$\begin{aligned} \mu_{A,t} &= \begin{pmatrix} \Sigma_{AM} & \Sigma_{AH} \end{pmatrix} \begin{pmatrix} \sigma_M^2 & \Sigma_{MH} \\ \Sigma_{HM} & \sigma_H^2 \end{pmatrix}^{-1} \begin{pmatrix} \mu_{m,t} \\ \mu_{h,t} \end{pmatrix}, \text{ or} && (38) \\ E_t(r_{n,t+1}^A) &= \beta_{n,m} E_t(r_{m,t+1}) + \beta_{n,H} E_t(r_{H,t+1}), && (39) \end{aligned}$$

that is, a simple beta-APM in exposures to and expected excess returns of the market portfolio and the hedge portfolio for non-tradable inflation risk.

4. A joint pricing model

In this appendix, we derive a joint pricing model for stocks and TIPS that gives expected returns for the N risky assets that are identical to Equation (6). We start by aggregating the demand for the initial set of N risky assets (stocks) and the $N+1$th hedge asset (TIPS) over the two types of investors. Naturally, for the basic investors (with wealth share $(1-\varphi_{e,t})$) the demand for the hedge asset is fixed to zero:

$$
\begin{aligned}
w_{m,t}^{X} &= \begin{pmatrix} w_{m,t}^{0} \\ w_{m,t}^{A} \end{pmatrix} && (40)\\
&= (1-\varphi_{e,t})\begin{pmatrix} 0 \\ \gamma_{m,t}^{-1}\Sigma_{AA}^{-1}\mu_{A,t} - \Sigma_{AA}^{-1}\Sigma_{A\pi}q_{m,t} \end{pmatrix} + \varphi_{e,t}\begin{pmatrix} w_{spec}^{0} - q_{m,t} \\ \gamma_{m,t}^{-1}\Sigma_{AA}^{-1}\mu_{A,t} - \Sigma_{AA}^{-1}\Sigma_{A\pi}w_{spec}^{0} \end{pmatrix} && (41)\\
&= \begin{pmatrix} \varphi_{e,t}(w_{spec}^{0} - q_{m,t}) \\ w_{T}^{A} - \varphi_{e,t}\Sigma_{AA}^{-1}\Sigma_{A\pi}w_{spec}^{0} - (1-\varphi_{e,t})\Sigma_{AA}^{-1}\Sigma_{A\pi}q_{m,t} \end{pmatrix} && (42)\\
&= w_{T,t}^{X} - \left(\begin{pmatrix} q_{m,t} \\ 0_N \end{pmatrix} + (1-\varphi_{e,t})(q_{m,t} - w_{spec}^{0})\begin{pmatrix} -1 \\ \Sigma_{AA}^{-1}\Sigma_{A\pi} \end{pmatrix}\right), && (43)
\end{aligned}
$$

where $w_{T,t}^{A} = \gamma_{m,t}^{-1}\Sigma_{AA}^{-1}\mu_{A,t}$ and $w_{T,t}^{X} = \gamma_{m,t}^{-1}\Sigma_{XX}^{-1}\mu_{X,t}$, the tangency portfolio of the set of N and $N+1$ assets, respectively. This demand can be rewritten to the beta asset pricing model

$$
E_t(r_{n,t+1}) = \beta_{n,m^X}E_t(r_{m^X,t+1}) + \beta_{n,H^X}E_t(r_{H^X,t+1}), \tag{44}
$$

where the two priced factors are the return on the extended market portfolio $r_{m^X,t+1}$ and the return on the pseudo hedge portfolio $r_{H^X,t+1}$. The latter portfolio is not a hedge portfolio in the usual sense, because it combines the minimum-variance hedge demands for investors without and with excess to the hedge asset. Because both factors may be partly invested in the hedge asset, this model is not testable, except when $\varphi_{e,t} = 1$. In this case, the joint pricing model collapses to

$$E_t(r_{n,t+1}) = \beta_{n,m^X} E_t(r_{m^X,t+1}) + \beta_{n,0} E_t(r_{0,t+1}), \tag{45}$$

where the hedge asset itself is the second priced factor.

5. Testable implications I

In this appendix we derive the main testable implications for the time-variation in the aggregate exposure Q_t driven by time-variation in $\gamma_{m,t}$ and $\varphi_{e,t}$. Start from $Q_t = f(\gamma_{m,t}, \varphi_{e,t}) = \gamma_{m,t}((1 - \varphi_{e,t})q_{m,t} + \varphi_{e,t} w^0_{spec})$ and expand around the base case scenario given by the point (1, 0). Then we have

$$f(1, 0) = q_{m,t}, \tag{46}$$

which means that in the base case scenario, the inflation risk premium equals $q_{m,t}$, which is assumed to be negative. The two first order derivatives are given by

$$f_{\gamma_{m,t}} = ((1 - \varphi_{e,t})q_{m,t} + \varphi_{e,t} w^0_{spec}) \Leftrightarrow f_{\gamma_{m,t}}(1, 0) = q_{m,t}, \tag{47}$$

$$f_{\varphi_{e,t}} = \gamma_{M,t}(-q_{m,t} + w^0_{spec}) \Leftrightarrow f_{\varphi_{e,t}}(1, 0) = -q_{m,t} + w^0_{spec}, \tag{48}$$

Thus, the inflation risk premium decreases with $\gamma_{m,t}$, but increases with both $q_{m,t}$, provided that w^0_{spec} is not too negative. The four second order terms are given by

$$f_{\gamma_{m,t}\gamma_{m,t}} = 0, f_{\varphi_{e,t}\varphi_{e,t}} = 0, \tag{49}$$

$$f_{\gamma_{m,t}\varphi_{e,t}} = f_{\varphi_{e,t}\gamma_{m,t}} = -q_{m,t} + w^0_{spec} \Leftrightarrow f_{\gamma_{m,t}\varphi_{e,t}}(1, 0, -1) = 1 + w^0_{spec}, \tag{50}$$

The second line implies that $f_{\varphi_{e,t}}$ increases with $\gamma_{M,t}$.

6. Testable implications II

In this appendix we derive additional testable implications when Q_t varies with $q_{m,t}$. In this case, we expand around $\gamma_{m,t} = 1$, $\varphi_{e,t} = 0$ and $q_{m,t} = -1$. Thus, start from $Q_t = f(\gamma_{m,t}, \varphi_{e,t}, q_{m,t}) = \gamma_{m,t}((1 - \varphi_{e,t})q_{m,t} + \varphi_{e,t} w^0_{spec})$ and expand around the base case scenario given by the point (1, $0, -1)$. We present only the with respect to $q_{m,t}$, because the derivatives for $\gamma_{m,t}$ and $\varphi_{e,t}$ are unchanged with $q_{m,t} = -1$.

The first order derivative is given by

$$f_{q_{m,t}} = \gamma_{M,t}(1 - \varphi_{e,t}) \Leftrightarrow f_{q_{m,t}}(1, 0, -1) = 1,$$

which means that the inflation risk premium increases with $q_{m,t}$. The relevant second order terms are

$$f_{q_{m,t}q_{m,t}} = 0, \tag{51}$$

$$f_{\gamma_{m,t}q_{m,t}} = f_{q_{m,t}\gamma_{m,t}} = (1 - \varphi_{e,t}) \Leftrightarrow f_{\gamma_{m,t}q_{m,t}}(1, 0, -1) = 1, \tag{52}$$

$$f_{\varphi_{e,t}q_{m,t}} = f_{q_{m,t}\varphi_{e,t}} = -\gamma_{M,t} \Leftrightarrow f_{q_{m,t}\varphi_{e,t}}(1, 0, -1) = -1. \tag{53}$$

The second line implies that $f_{q_{m,t}}$ increases with $\gamma_{M,t}$. The third line implies that $f_{q_{m,t}}$ decreases with $\varphi_{e,t}$.

Appendix B: Additional results

Table B1: Industry Composition and Industry-Neutral Strategy

Panel A of this table describes the Inflation Beta-sorted portfolios in terms of French's 48 Industry Portfolios. We use the sort in three groups that is performed to construct the inflation factor INF, which combines the three highest (High30), four middle (Mid40) and three lowest (Low30) Inflation beta deciles. We present the five industries that composed the largest share of the respective group from August 1964 to December 2011. The first row presents this average "Industry share". The following rows present the average and standard deviation of Relative share, i.e., the industry share divided by the share of that industry in the market portfolio. A number larger (smaller) than one indicates the industry is overweighted (underweighted) relative to the market. Panel B presents select results for an industry-neutral HLIB portfolio (HLIB_INTRL). The portfolio is constructed by sorting stocks in five groups within each industry and taking the equal weighted average of the resulting 48 HLIB (i.e., P1-P5) portfolios. We report (i) post-ranking inflation beta (β_{post}) and average return (μ), (ii) the hedge regression of inflation innovations u_t on $R_{HLIB\_INTRL,t}$ and (iii) the predictive regression of $R_{HLIB\_INTRL,t+1}$ on $TIPS_t$, $CFNAI_t$ and $TIPS_t \times CFNAI_t$. ***,**,* indicate significance at the 1, 5 and 10 percent level, respectively. The regressions use Newey-West standard errors with 1 lag.

Panel A: Industry composition of High30, Mid40 and Low30

				High30		
		Oil	Utilities	Telecom	Bus. Serv.	Computers
Industry share	Full	0.23	0.10	0.08	0.06	0.05
Relative share	Full	2.27	1.48	1.42	1.02	0.92
	Pre-TIPS	2.41	1.74	1.54	0.62	0.86
	Post-TIPS	1.96	0.90	1.17	1.89	1.05
	St.Dev.	1.48	0.85	0.84	1.03	0.81
				Mid40		
		Cons. Gds.	Computers	Oil	Drugs	Utilities
Industry share	Full	0.07	0.07	0.06	0.06	0.06
Relative share	Full	1.20	1.24	0.72	1.14	0.87
	Pre-TIPS	1.37	1.05	0.49	1.23	0.79
	Post-TIPS	0.84	1.66	1.23	0.95	1.06
	St.Dev.	0.51	0.69	0.60	0.49	0.49
				Low30		
		Retail	Banks	Trading	Drugs	Cons. Gds.
Industry share	Full	0.08	0.08	0.07	0.06	0.06
Relative share	Full	1.54	1.95	1.55	1.06	1.09
	Pre-TIPS	1.56	2.07	1.80	1.04	1.00
	Post-TIPS	1.49	1.68	1.01	1.10	1.30
	St.Dev.	0.68	1.22	0.88	0.69	0.59

Panel B: Industry-neutral HLIB portfolio (HLIB_INTRL)

(i) Descriptives		(ii) Hedging inflation innovations: $\pi_t = a + b_{HLIB\_INTRL} R_{HLIB\_INTRL,t} + e_t$			
β_{post}	μ		a	b_{HLIB_INTRL}	R^2
1.59***	-2.09*	Pre-TIPS	0.000***	0.018**	2.50
		Post-TIPS	0.000	0.019*	2.76

(iii) Forecasting: $R_{HLIB\_INTRL,t+1} = \lambda_0 + \lambda_1 TIPS_t + \lambda_2 CFNAI_t + \lambda_3(TIPS_t \times CFNAI_t) + u_{t+1}$

	λ_0	λ_1	λ_2	λ_3	R^2	$H_0: \lambda_1 = \lambda_2 = \lambda_3 = 0$
(A)	-3.26**	2.52			0.58	
(B)	-3.25**	0.90	3.44***	-2.98*	2.28	(0.021)

Table B2: Time-varying alphas and betas of Inflation Beta-sorted Portfolio

This table presents evidence that both alphas and betas of the Size-controlled HLIB portfolio vary over time. We focus on the usual benchmark factor models CAPM ($F_{t+1} = R_{MKT,t+1}$), FF3M ($F_{t+1} = (R_{MKT,t+1}, R_{SMB,t+1}, R_{HML,t+1})$) and FFCM ($F_{t+1} = (R_{MKT,t+1}, R_{SMB,t+1}, R_{HML,t+1}, R_{MOM,t+1})$). The conditioning information for α is either TIPS ($Z_t^\alpha = (1, TIPS_t)$) or the Full model ($Z_t^\alpha = (1, TIPS_t, CFNAI_t, TIPS_t \times CFNAI_t)$). The first six columns use unconditional exposures ("Constant betas"). The last six columns condition the factor exposures ("Time-varying betas") on the same information, i.e., $Z_t^\alpha = Z_t^\beta$. Row-wise we present the estimated coefficients, the adjusted-R^2 and the p-value (in brackets) of two Wald-tests. The first tests the hypothesis that α is not time-varying, the second tests the hypothesis that CAPM β is not time-varying. ***,**,* denote significance at the 1, 5 and 10 percent level, respectively, using Newey-West standard errors with 1 lag.

$$R_{t+1} = \alpha' Z_t^\alpha + \beta'(F_{t+1} \otimes Z_t^\beta) + e_{t+1}$$

	Constant betas						Time-varying betas					
	CAPM		FF3M		FFCM		CAPM		FF3M		FFCM	
	TIPS	Full	TIPS	Full	TIPS	Full	TIPS	Full	TIPS	Full	TIPS	Full
α_0	-6.69***	-6.84***	-5.71**	-5.73**	-4.58*	-5.07**	-5.55**	-6.37**	-3.92*	-5.03**	-3.82*	-3.82
α_1	5.85**	2.76	5.66*	2.34	5.12*	2.37	3.87	1.02	1.58	1.03	1.00	0.31
α_2		8.11***		8.12***		8.08***		8.71***		6.39***		1.82
α_3		-6.19**		-6.40**		-5.95**		-7.18***		-3.42		-0.18
$\beta_{MKT,0}$	-0.02	-0.01	-0.03	-0.03	-0.04	-0.04	-0.15***	-0.15***	-0.18***	-0.15***	-0.17***	-0.18***
$\beta_{MKT,1}$							0.20***	0.25***	0.25***	0.16***	0.23***	0.19***
$\beta_{MKT,2}$								-0.10*		-0.09*		0.01
$\beta_{MKT,3}$								0.08***		-0.03		-0.02
$\beta_{SMB,0}$			-0.08	-0.07	-0.08	-0.07			-0.19**	-0.22***	-0.19**	-0.26***
$\beta_{SMB,1}$									0.24**	0.39***	0.23**	0.36***
$\beta_{SMB,2}$										0.05		0.11
$\beta_{SMB,3}$										0.12		0.13
$\beta_{HML,0}$			-0.14	-0.15	-0.16	-0.17			-0.10	-0.06	-0.08	-0.06
$\beta_{HML,1}$									-0.33***	-0.42***	-0.37***	-0.36***
$\beta_{HML,2}$										0.09		0.21**
$\beta_{HML,3}$										-0.06		-0.06
$\beta_{MOM,0}$					-0.08	-0.05					0.01	-0.06
$\beta_{MOM,1}$											-0.06	0.13
$\beta_{MOM,2}$												0.26***
$\beta_{MOM,3}$												0.00
R^2	1.08	4.05	1.76	4.86	2.20	4.94	8.43	11.66	17.52	20.75	18.04	25.03
$H_0 : \alpha_1 = \alpha_2 = \alpha_3 = 0$		(0.001)		(0.001)		(0.001)		(0.001)		(0.039)		(0.947)
$H_0 : \beta_1 = \beta_2 = \beta_3 = 0$							(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Table B3: The time-varying inflation risk premium in cross-sectional regressions (Continued)

This table presents the estimated time-varying risk premium coefficients, which are omitted in Panels B to E of Table V. To be precise, Panel B to D present two-stage pooled time-series cross-sectional regressions. Panel B presents results for the extended set of 72 portfolios: 30 Inflation Beta and Size, 25 Size and Book-to-Market and 17 Industry portfolios; Panel C presents results for the non-traded measure of inflation risk π_t (instead of the traded factor INF); and Panel D presents results when including the characteristics Size, Book-to-Market and Prior Return (Momentum). Panel E presents results for three-stage cross-sectional regressions for individual stocks (both ex- and including characteristics). The cross-sectional regressions never include an intercept. ***,**,* indicate significance at the 1, 5 and 10 percent level, respectively.

Panel B: Extended set of 72 portfolios

		CAPM	CAPM+INF			FF3M	FF3M+INF			FFCM	FFCM+INF		
		(A)	(A)	(B)	(C)	(A)	(A)	(B)	(C)	(A)	(A)	(B)	(C)
MKT	λ_0	6.39**	6.14**	5.39*	6.58**	5.11**	5.12**	4.58*	5.42*	5.48**	5.47**	5.08*	5.83**
	λ_1			1.41	-1.31			1.03	-0.70			0.74	-0.59
	λ_2				-6.73**				-5.28**				-5.16**
	λ_3				-0.92				-0.26				0.16
SMB	λ_0					1.57	1.61	1.09	2.02	2.16	2.17	1.89	2.66
	λ_1							0.98	-1.04			0.52	-0.86
	λ_2								-5.51***				-5.32***
	λ_3								-0.51				0.15
HML	λ_0					4.11**	3.78**	4.20**	4.16**	4.23**	3.95**	4.45**	4.37**
	λ_1							-0.79	-1.55			-0.94	-1.50
	λ_2								2.05				2.11
	λ_3								-1.54				-1.33
MOM	λ_0									7.52*	7.28*	11.54***	8.92**
	λ_1											-8.03	3.47
	λ_2												2.87
	λ_3												12.23*
INF	λ_0		-3.16*	-4.70***	-5.18***		-2.22	-3.77**	-4.19**		-2.64*	-4.38***	-4.68***
	λ_1			2.89*	2.22			2.93*	1.87			3.28**	1.73
	λ_2				6.71***				6.82***				6.67***
	λ_3				-2.97**				-3.44***				-3.95***
Average	R_t^2 from 2nd stage	5.44	13.69	13.69	13.69	27.77	36.98	36.98	36.98	29.61	39.33	39.33	39.33
INF	$H_0 : \lambda_1 = \lambda_2 = \lambda_3 = 0$				(0.000)				(0.000)				(0.000)
INF	July 1967			-4.70***	-8.75***			-3.77**	-7.81***			-4.38***	-8.23***
INF	December 2011			6.92	4.69			8.01	4.64			8.80	4.00

Table B3 continued

Panel C: Cross-sectional regressions using non-traded inflation risk π_t

		30 Portfolios									72 Portfolios		
		CAPM+π_t			FF3M+π_t			FFCM+π_t			FFCM+π_t		
		(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)
MKT	L0	6.59**	6.02**	7.34**	5.16**	4.71*	5.57**	5.23**	5.24*	6.02**	5.46**	5.07*	5.82**
	L1		1.08	-1.80		0.85	-1.04		-0.01	-1.43		0.74	-0.60
	L2			-7.89***			-5.14**			-5.33**			-5.16**
	L3			-0.73			-0.49			0.11			0.15
SMB	L0				2.95	2.61	2.87	2.95	2.58	2.84	2.43	2.36	3.16
	L1					0.64	0.13		0.69	0.16		0.13	-1.01
	L2						-1.62			-1.61			-6.16***
	L3						-0.06			-0.09			0.70
HML	L0				0.75	0.51	2.64	1.11	2.99	4.76	3.88**	4.53**	4.52**
	L1					0.44	-4.83		-3.55	-6.66**		-1.23	-1.76
	L2						-11.36***			-12.24***			1.31
	L3						-2.33			0.43			-1.03
MOM	L0							-0.71	6.81	4.68	7.84*	12.74***	10.25**
	L1								-14.18**	-5.05		-9.23	2.87
	L2									2.78			0.13
	L3									9.54			13.82*
π_t	L0	-0.86	-1.67***	-1.64**	-0.93	-1.74***	-1.62***	-0.87*	-1.31**	-1.25**	-0.51	-0.91*	-0.98*
	L1		1.53**	0.41		1.54**	0.19		0.84	-0.13		0.75	0.32
	L2			2.06***			1.61***			1.46***			1.72***
	L3			-1.95***			-2.07***			-1.59**			-1.06**
Average R_t^2 from 2nd stage		15.76	15.76	15.76	41.10	41.10	41.10	43.34	43.34	43.34	38.47	38.47	38.47
π_t	$H_0: \lambda_1 = \lambda_2 = \lambda_3 = 0$			(0.001)			(0.001)			(0.001)			(0.001)
π_t	July 1967		-4.56***	-7.43***		-4.58***	-6.51***		-3.28**	-5.06***		-2.27*	-4.73***
π_t	December 2011		12.20	3.00		11.64	1.03		5.18	-2.11		5.27	1.91

Table B3 continued

Panel D: Cross-sectional regressions including characteristics

		30 Portfolios									72 Portfolios		
		CAPM+π_t			FF3M+π_t			FFCM+π_t			FFCM+π_t		
		(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)
MKT	L0	6.18**	5.42*	6.72**	5.62**	5.14*	5.62*	6.28**	5.94*	6.26**	5.96**	6.61**	7.14**
	L1		1.58	-1.59		0.46	-0.77		0.01	-1.08		0.56	-0.90
	L2			-7.08**			-4.78*			-4.57			-4.49*
	L3			-1.20			-0.18			-0.07			-0.16
SMB	L0				2.20	2.41	3.42	1.87	1.89	3.02	2.32	1.68	2.53
	L1					-0.54	-2.35		-0.28	-2.16		-0.14	-1.31
	L2						-5.07*			-5.24*			-6.01***
	L3						-0.31			-0.39			0.25
HML	L0				0.24	-2.03	-0.11	0.54	2.80	3.81	1.19	-2.44	-1.88
	L1					7.09**	1.51		3.57	-0.83		1.37	0.79
	L2						-1.76			-0.67			0.81
	L3						-4.45			-3.50			-0.72
MOM	L0							4.12	12.15	9.20	8.51**	13.39***	9.80**
	L1								-11.07*	-5.98		-8.43	2.72
	L2									3.28			4.83
	L3									3.92			8.94
INF	L0	-4.77***	-5.55***	-5.90***	-3.92**	-5.62***	-5.96***	-3.87**	-5.76***	-6.07***	-4.21***	-5.43***	-5.65***
	L1		4.31***	2.65*		4.77***	2.69*		4.80***	2.72*		3.77**	1.75
	L2			7.56***			7.74***			7.72***			6.24***
	L3			-1.84			-2.83			-2.86			-2.72**
Size	L0	-0.22	1.00	0.65	-0.18	1.13	1.29	-0.48	1.17	1.33	-0.06	-0.03	-0.07
	L1		-1.21*	-0.33		-0.30	-0.79		-0.41	-0.85		-0.55**	-0.39
	L2			0.31			-1.03			-1.06			-0.08
	L3			0.72			-0.05			-0.01			0.04
BM	L0	1.15**	2.96***	3.18***	0.65	2.91***	2.91***	0.90*	3.11***	3.06***	0.89**	2.58***	2.29***
	L1		-1.31**	-1.34**		-1.61***	-1.23**		-1.72***	-1.32**		-1.07**	-0.94*
	L2			-2.19**			-1.53*			-1.48			0.50
	L3			0.76			0.82			0.83			0.01
PRET	L0	1.15*	2.98***	3.15***	0.99*	3.00***	3.30***	0.86	2.91***	3.23***	1.18***	2.49***	2.63***
	L1		-1.99**	-0.51		-1.98**	-0.70		-1.93**	-0.68		-1.40**	-0.40
	L2			-0.46			-0.62			-0.64			-0.19
	L3			1.69			1.37			1.33			0.89*
Average	R_t^2 from 2nd stage	46.77	46.77	46.77	51.73	51.73	51.73	52.96	52.96	52.96	44.00	44.00	44.00
INF	$H_0 : \lambda_1 = \lambda_2 = \lambda_3 = 0$			(0.000)			(0.000)			(0.001)			(0.001)
INF	July 1967		-5.55***	-9.92***		-5.62***	-10.07***		-5.76***	-10.18***		-5.43***	-8.97***
INF	December 2011		11.77**	4.72		13.53**	5.51		13.52**	5.58		9.73	2.26

Table B3 continued

Panel E: Three-stage regressions using individual stocks

		FF3M+π_t						FFCM+π_t					
		Without			With			Without			With		
		(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)
	Average R_t^2	3.12	3.12	3.12	4.73	4.73	4.73	3.29	3.29	3.29	4.87	4.87	4.87
π_t	$H_0 : \lambda_1 = \lambda_2 = \lambda_3 = 0$			7.42			10.01			6.86			9.51
π_t	July 1967		-2.55*	-2.50		-4.80***	-5.26***		-2.42*	-2.51		-4.56***	-4.95***
π_t	December 2011		19.97**	9.72		11.98	10.61*		19.75**	9.70		11.66	10.63*
MKT	L0	5.94**	4.75*	6.32**	9.63***	9.25***	11.02***	5.73**	4.39	5.95**	9.66***	9.14***	10.91***
	L1		2.24	-2.43		0.73	-4.26		2.51	-2.21		0.98	-4.11
	L2			-6.63**			-8.08***			-6.36**			-7.90***
	L3			-3.19			-3.08			-3.33			-3.25
SMB	L0	2.56*	3.03	3.56*	-0.69	-0.86	-0.57	2.61*	3.10	3.65*	-0.67	-0.81	-0.49
	L1		-0.89	-1.08		0.31	0.53		-0.92	-1.19		0.25	0.34
	L2			-5.31***			-3.53**			-5.35***			-3.62**
	L3			1.52			1.40			1.44			1.28
HML	L0	2.77*	3.08**	3.04*	0.12	-0.16	-0.31	2.68*	2.95*	2.92*	-0.13	-0.43	-0.60
	L1		-0.57	-1.45		0.53	0.29		-0.50	-1.41		0.58	0.33
	L2			2.36			2.17*			2.31*			2.36**
	L3			-1.77			-0.98			-1.80			-1.05
MOM	L0							-4.08**	-4.12**	-4.84**	-2.74**	-2.29	-2.93*
	L1								0.07	1.79		-0.84	0.45
	L2									3.98			4.06*
	L3									0.67			0.15
π_t	L0	0.04	-0.20*	-0.15	-0.20**	-0.38***	-0.38***	0.05	-0.19*	-0.14	-0.18**	-0.35***	-0.35***
	L1		0.45**	0.17		0.34**	0.30**		0.45**	0.17		0.32**	0.30**
	L2			0.09			0.07			0.10			0.06
	L3			-0.35*			-0.06			-0.35*			-0.05
Size	L0				-5.43***	-5.87***	-6.51***				-5.43***	-5.87***	-6.50***
	L1					0.84	2.66***					0.82	2.62***
	L2						2.81***						2.82***
	L3						1.17*						1.14*
BM	L0				2.45***	3.15***	2.96***				2.42***	3.13***	2.94***
	L1					-1.32***	-1.17***					-1.35***	-1.21***
	L2						1.68***						1.78***
	L3						-0.37						-0.43
PRET	L0				2.71***	3.89***	3.46***				2.59***	3.82***	3.36***
	L1					-2.24**	-0.44					-2.33**	-0.40
	L2						0.68						0.76
	L3						1.84**						1.96***
Average R_t^2 from 2nd stage		3.12	3.12	3.12	4.73	4.73	4.73	3.29	3.29	3.29	4.87	4.87	4.87
π_t	$H_0 : \lambda_1 = \lambda_2 = \lambda_3 = 0$			(0.074)			(0.100)			(0.069)			(0.095)
π_t	July 1967	-2.55*	-2.50		-4.80***	-5.26***		-2.42*	-2.51		-4.56***	-4.95***	
π_t	December 2011		19.97**	9.72		11.98	10.61*		19.75**	9.70		11.66	10.63*

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Table I: Summary statistics for the two-way sort on Inflation Beta and Size

This table presents portfolios at the intersection of two independent sorts in ten inflation beta groups (row: High to Low) and three Size groups (column: Micro, Small and Big). The sample period is August 1964 to December 2011. To conserve space, we present results only for beta groups 1 (High), 4, 7 and 10 (Low) as well as a High minus Low spreading portfolio (HLIB). Columns headed "Size-ctr" present the average across size groups. Inflation betas come from a regression of a stock's past returns on inflation innovations π_t in Panel A and B and total inflation in the real-time vintage CPI series I_t^{rv} in Panel C. In Panel B this regression controls for exposure to the benchmark factors of the CAPM (MKT), FF3M (+SMB, HML) and FFCM (+MOM). Pre-ranking beta is the average inflation beta in a portfolio averaged over time. Post-ranking beta comes from a regression of portfolio returns on the relevant inflation measure (with controls in Panel B). Here, standard errors are Newey-West with 1 lag. Average return and standard deviation are annualized. Panel D presents the characteristics Size, Book-to-Market and Prior Return (averaged within group and over time) and tests these for the HLIB portfolio for the full sample period as well as Pre- and Post-TIPS. ***,**,* denote significance at the 1, 5 and 10 percent level.

Table I continued

Panel A: Inflation Innovation (π_t) Beta and Size

	Micro	Small	Big	Size-ctr	Micro	Small	Big	Size-ctr
	Pre-ranking Beta				Post-ranking Beta			
High	5.28	4.90	4.41	4.86	-0.42	-0.75	-0.55	-0.58
4	-1.54	-1.56	-1.56	-1.55	-1.66	-2.58	-2.68**	-2.31
7	-4.77	-4.77	-4.76	-4.77	-2.28	-2.70	-2.46*	-2.48
Low	-10.93	-10.90	-10.66	-10.83	-3.22	-4.25**	-2.94*	-3.47*
HLIB	16.20	15.81	15.07	15.69	2.80***	3.49***	2.39**	2.89***
	Average Return				Standard Deviation			
High	6.95**	6.11*	2.38	5.15	24.29	25.24	23.62	22.74
4	9.11***	7.73***	4.15*	7.00***	22.47	20.42	16.77	18.54
7	10.02***	9.07***	4.38*	7.82***	22.48	20.70	16.97	19.00
Low	9.71***	10.63***	7.94***	9.43***	25.21	23.97	20.47	22.10
HLIB	-2.76	-4.51*	-5.56**	-4.28**	12.03	16.78	19.40	13.92

Panel B: Sorts control for benchmark factors; Panel C: Inflation I_t^{rv}

	Panel B: Post-ranking Beta			Panel B: Average Return			Panel C: Post-ranking Beta	Panel C: Average Return
Size-ctr	CAPM	FF3M	FFCM	CAPM	FF3M	FFCM	No controls	
High	2.09***	1.92***	1.91***	6.20*	7.14**	7.38**	-0.81	6.55**
4	0.18	0.30*	0.16	8.27***	7.30***	7.88***	-1.76*	8.29***
7	-0.16	0.08	-0.02	7.86***	7.72***	7.58***	-1.91*	7.92***
Low	-0.63	-0.71**	-0.59**	9.71***	9.17***	9.20***	-2.15*	8.26**
HLIB	2.72***	2.63***	2.50***	-3.51*	-2.04	-1.82	1.34***	-1.70

Panel D: Characteristics

	Size			Book-to-Market			Prior return		
Size Ctr	Full	Pre-TIPS	Post-TIPS	Full	Pre-TIPS	Post-TIPS	Full	Pre-TIPS	Post-TIPS
High	1.28	0.66	2.63	0.96	1.05	0.76	17.01	11.97	28.09
4	1.81	0.84	3.92	0.93	1.02	0.72	11.19	9.43	15.07
7	1.92	0.63	4.75	0.88	0.95	0.73	11.20	11.42	10.71
Low	1.51	0.41	3.94	0.83	0.89	0.71	13.11	13.73	11.75
HLIB	-0.23***	0.25***	-1.30***	0.13***	0.16***	0.05	3.90***	-1.75	16.33***

Table II: Forecasting returns of Inflation Beta-sorted portfolios with $TIPS_t$ and $CFNAI_t$

This table presents evidence that returns of Inflation Beta-sorted portfolios vary over time with the market share of TIPS ($TIPS_t$) and over the business cycle ($CFNAI_t$). The sample period is July 1967 to December 2011. We consider three predictive regressions: Model (A) includes only $TIPS_t$; Model (B) adds $CFNAI_t$ and an interaction; and, Model (C) additionally controls for the standard predictors (Dividend Yield, Default Spread, Risk-Free Rate and Term Spread). In Panel A, we present results for five Size-controlled π_t-beta portfolios (High, 4, 7, Low and HLIB). Panel B presents results for sorts that control for the benchmark factors of the CAPM, FF3M and FFCM, whereas Panel C presents results for the truly out-of-sample sort on total inflation in the vintage CPI series I_t^{rv} I_t. Panel D presents long- horizon regressions for k-month compounded returns ($k = 3, 12, 24$). In each panel, the first nine columns present the estimated slope coefficients and adjusted-R^2 (x100). Column ten presents the p-value (in brackets) of a Wald-test of the hypothesis that $TIPS_t$, $CFNAI_t$ and $TIPS_t \times$ $CFNAI_t$ are insignificant in Models (B) and (C). ***,**,* denote significance at the 1, 5 and 10 percent level, respectively, using Newey-West standard errors with k lags.

Table II continued

$$R_{t+1} = \lambda_0 + \lambda_1 TIPS_t + \lambda_2 CFNAI_t + \lambda_3 (TIPS_t \times CFNAI_t) + (controls) + u_{t+1}$$

	λ_0	λ_1	λ_2	λ_3	c_{DY}	c_{DS}	c_{RF}	c_{TS}	R^2	$H_0: \lambda_1 = \lambda_2 = \lambda_3 = 0$
Panel A: Size-controlled π_t-beta portfolios										
High (A)	2.10	4.93							0.19	
(B)	3.55	-0.54	-3.60	-5.08					1.08	(0.424)
(C)	6.90	-5.51	-2.54	-2.59	16.35**	2.10	-24.16***	-4.10	2.88	(0.717)
4 (A)	5.51*	2.17							-0.08	
(B)	7.01**	-1.71	-7.62**	-1.96					1.36	(0.061)
(C)	9.31**	-5.14	-6.55**	-0.26	10.79**	1.38	-14.33*	0.99	2.86	(0.148)
7 (A)	6.91*	0.83							-0.17	
(B)	8.39**	-1.88	-9.94***	0.14					1.47	(0.031)
(C)	11.11***	-5.82	-8.26**	2.34	11.39**	3.31	-16.23**	0.46	3.30	(0.053)
Low (A)	8.87**	-0.92							-0.17	
(B)	10.45**	-3.31	-11.77***	1.10					1.39	(0.028)
(C)	13.90***	-8.67*	-10.18**	3.25	9.35	4.48	-17.30*	-0.71	2.36	(0.022)
HLIB (A)	-6.77***	5.85**							1.22	
(B)	-6.90***	2.77	8.17***	-6.18**					4.21	(0.001)
(C)	-7.01***	3.16	7.64***	-5.84**	7.00	-2.38	-6.86	-3.39	4.32	(0.005)
Panel B: Sorts control for benchmark factors										
					CAPM: MKT					
HLIB (A)	-6.15***	5.01*							1.02	
(B)	-6.04***	2.62	4.08	-4.06*					2.08	(0.085)
					FF3M: MKT, SMB and HML					
HLIB (A)	-4.80***	5.60**							1.98	
(B)	-4.43**	3.14	1.44	-3.29					2.83	(0.144)
					FFCM: MKT, SMB, HML and MOM					
HLIB (A)	-4.74***	5.96**							2.48	
(B)	-4.35***	3.30	1.60	-3.57					3.68	(0.076)
Panel C: Size-controlled I_t^{rv}-beta portfolios										
High (A)	3.18	5.52							0.29	
(B)	4.68	0.10	-4.20	-4.83					1.22	(0.384)
4 (A)	6.90**	2.10							-0.08	
(B)	8.46**	-2.13	-7.53**	-2.39					1.48	(0.066)
7 (A)	6.95*	0.51							-0.18	
(B)	8.33**	-1.85	-9.65***	0.44					1.21	(0.060)
Low (A)	7.95*	-1.19							-0.17	
(B)	9.52**	-2.61	-13.73***	2.85					1.60	(0.027)
HLIB (A)	-4.77*	6.70**							1.46	
(B)	-4.84*	2.71	9.52***	-7.68**					5.46	(0.001)
Panel D: Long-horizon regressions										
					$R_{t+1:t+3}$					
HLIB (A)	-6.82***	6.65**							4.27	
(B)	-6.77***	3.48	6.50***	-5.60***					10.28	(0.000)
					$R_{t+1:t+12}$					
HLIB (A)	-6.33***	7.64***							15.92	
(B)	-6.53***	6.67***	4.25**	-2.28**					21.09	(0.000)
					$R_{t+1:t+24}$					
HLIB (A)	-5.90***	8.46***							26.53	
(B)	-5.76***	6.93***	1.75	-1.68*					28.93	(0.000)

Table III: Summary statistics and predictability of asset-pricing factors
This table presents the factors we use in our cross-sectional asset pricing tests: INF, MKT, SMB, HML and MOM. The inflation factor INF is constructed similar to SMB, HML and MOM using an independent double sort in three Inflation innovation (π_t) beta groups and two Size groups. Panel A presents annualized average return and standard deviation. Panel B presents the usual forecasting exercise of returns on $TIPS_t$ in Model (A) and in addition on $CFNAI_t$ and their interaction in Model (B). For each factor, we also present the p-value (in brackets) of a Wald test of the hypothesis that the factor risk premium is not time-varying in Model (B). ***,**,* indicate significance at the 1, 5 and 10 percent level, respectively, using Newey-West standard errors with 1 lag.

Panel A: Summary statistics

	INF	MKT	SMB	HML	MOM
Avg. Ret.	-1.60	5.07**	2.49	4.60***	8.37***
St.Dev.	9.90	16.13	11.05	10.41	15.33

Panel B: $F_{t+1} = \lambda_0 + \lambda_1 TIPS_t + (\lambda_2 CFNAI_t + \lambda_3(TIPS_t \times CFNAI_t) + u_{t+1}$

	INF		MKT		SMB		HML		MOM	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
λ_0	-3.35**	-3.61**	4.95*	5.75**	1.86	2.60	5.71***	5.55***	11.78***	10.20***
λ_1	3.31**	1.91	0.23	-1.33	1.17	-0.07	-2.10	-2.60*	-6.42	1.62
λ_2		5.85***		-5.20*		-5.17***		2.88		-0.75
λ_3		-3.51***		-0.09		0.27		-1.52		9.46**
R^2	0.74	3.23	-0.19	0.25	-0.09	1.12	0.15	0.35	1.28	6.77
$H_0 : \alpha_1 =$										
$\alpha_2 = \alpha_3 = 0$		(0.000)		(0.248)		(0.008)		(0.110)		(0.151)

Table IV: The time-varying inflation risk premium in cross-sectional regressions

This table presents cross-sectional regressions for portfolios (in Panel A to D) and individual stocks (Panel E), where we allow for time-varying risk premiums. In case of portfolios, the first-stage betas used as independent variables in the second stage are the usual constant, full sample betas. In case of individual stocks, we use the time-varying betas that use only historical data and were used to sort. Column-wise we consider the benchmark factor models (CAPM, FF3M and FFCM) as well as models that add inflation risk. We consider three specifications of the risk premiums. Type (A) is the standard Fama-MacBeth cross-sectional regression estimate of the unconditional risk premium (standard errors are Shanken-corrected in Panels A to D and Fama-MacBeth in Panel E). Type (B) and (C), respectively, allow the risk premiums to vary over time with $TIPS_t$ and $TIPS_t$, $CFNAI_t$ and $TIPS_t \times CFNAI_t$. In Panels A to D these conditional risk premiums are estimated using the pooled time-series cross-sectional regression described in Section VI (with standard errors clustered on time). In Panel E the conditional risk premiums are estimated using a three stage regression procedure, where we regress the second stage Fama-MacBeth estimates on the instruments (standard errors are Newey-West with 1 lag). In Panel A, we use 30 Inflation Beta and Size-sorted portfolios as test assets. Panel B adds 17 industry portfolios and 25 Size and Book-to-Market portfolios to the set of test assets. Panel C replaces the traded inflation factor INF with the non-traded inflation innovation π_t. In Panel D and E we additionally control for the characteristics Size, Book-to-Market and Momentum (Prior return). In Panel A we present the full set of results: the estimated risk premiums (λ's, where $(\lambda_0, \lambda_1, \lambda_2, \lambda_3)$ refer to the instrument vector $(1, TIPS_t, CFNAI_t, TIPS_t \times CFNAI_t)$), the time-series average of the second stage cross-sectional regression R^2, a Wald test of the hypothesis that the inflation risk premium does not vary over time and the model-implied inflation risk premium at the beginning and the end of the sample period. For the sake of comparison, the implied risk premium in Panel C (Panel E) is scaled by the post-ranking (pre-ranking) inflation beta of the HLIB portfolio analyzed in Table 1. To conserve space, Panels B to E present everything but the estimated risk premiums, which are reported in Table B2 of Appendix B. The cross-sectional regressions never include an intercept. ***,**,* indicate significance at the 1, 5 and 10 percent level, respectively.

Table IV continued

Panel A: 30 Inflation beta and Size portfolios

		CAPM	CAPM+INF			FF3M	FF3M+INF			FFCM	FFCM+INF		
		(A)	(A)	(B)	(C)	(A)	(A)	(B)	(C)	(A)	(A)	(B)	(C)
MKT	λ_0	6.43**	6.31**	5.48*	6.79**	5.47**	5.38**	5.01*	5.84**	5.72**	5.61**	5.44*	6.14**
	λ_1			1.57	-1.61			0.70	-0.96			0.32	-0.97
	λ_2				-7.12**				-5.28**				-4.70*
	λ_3				-1.32				-0.18				0.06
SMB	λ_0					0.33	1.64	2.00	2.49	1.07	1.49	1.70	2.28
	λ_1							-0.66	-1.55			-0.41	-1.55
	λ_2								-3.34				-3.74*
	λ_3								0.07				-0.09
HML	λ_0					6.82	3.16	-0.15	1.50	6.67	4.97	3.25	3.89
	λ_1							6.24**	0.13			3.25	0.05
	λ_2								-4.34				0.20
	λ_3								-5.57**				-3.72
MOM	λ_0									3.27	2.06	6.99	4.06
	λ_1											-9.31	-0.25
	λ_2												11.68**
	λ_3												6.57
INF	λ_0		-2.52	-4.22**	-4.69***		-2.06	-4.04**	-4.29***		-2.07	-4.06**	-4.30***
	λ_1			3.21**	2.20			3.74**	1.98			3.76**	1.98
	λ_2				7.32***				6.53***				6.51***
	λ_3				-3.55***				-4.15***				-4.16***
Average	R_t^2 from 2nd stage	4.41	20.95	20.95	20.95	35.63	44.43	44.43	44.43	40.09	46.92	46.92	46.92
INF	$H_0 : \lambda_1 = \lambda_2 = \lambda_3 = 0$				(0.000)				(0.000)				(0.000)
INF	July 1967			-4.22**	-8.58***			-4.04**	-7.76***			-4.06**	-7.76***
INF	December 2011			8.68	5.44			10.99*	5.55			11.03*	5.55

Panel B: Extended set of 72 portfolios

		CAPM	CAPM+INF			FF3M	FF3M+INF			FFCM	FFCM+INF		
		(A)	(A)	(B)	(C)	(A)	(A)	(B)	(C)	(A)	(A)	(B)	(C)
Average	R_t^2 from 2nd stage	5.44	13.69	13.69	13.69	27.77	36.98	36.98	36.98	29.61	39.33	39.33	39.33
INF	$H_0 : \lambda_1 = \lambda_2 = \lambda_3 = 0$				(0.000)				(0.000)				(0.000)
INF	July 1967			-4.70***	-8.75***			-3.77**	-7.81***			-4.38***	-8.23***
INF	December 2011			6.92	4.69			8.01	4.64			8.80	4.00

Table IV continued

Panel C: Cross-sectional regressions using non-traded inflation risk π_t

		30 Portfolios									72 Portfolios		
		CAPM+π_t			FF3M+π_t			FFCM+π_t			FFCM+π_t		
		(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)
Average R_t^2 from 2nd stage		15.76	15.76	15.76	41.10	41.10	41.10	43.34	43.34	43.34	38.47	38.47	38.47
π_t	$H_0 : \lambda_1 = \lambda_2 = \lambda_3 = 0$			(0.001)			(0.001)			(0.009)			(0.005)
π_t	July 1967		-4.56***	-7.43***		-4.58***	-6.51***		-3.28**	-5.06***		-2.27*	-4.73***
π_t	December 2011		12.20	3.00		11.64	1.03		5.18	-2.11		5.27	1.91

Panel D: Cross-sectional regressions including characteristics

		30 Portfolios									72 Portfolios		
		CAPM+π_t			FF3M+π_t			FFCM+π_t			FFCM+π_t		
		(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)
Average R_t^2 from 2nd stage		46.77	46.77	46.77	51.73	51.73	51.73	52.96	52.96	52.96	44.00	44.00	44.00
π_t	$H_0 : \lambda_1 = \lambda_2 = \lambda_3 = 0$			(0.000)			(0.000)			(0.001)			(0.001)
π_t	July 1967		-5.55***	-9.92***		-5.62***	-10.07***		-5.76***	-10.18***		-5.43***	-8.97***
π_t	December 2011		11.77**	4.72		13.53**	5.51		13.52**	5.58		9.73	2.26

Panel E: Three-stage regressions using individual stocks

		FF3M+π_t						FFCM+π_t					
		Without			With			Without			With		
		(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)
Average R_t^2 from 2nd stage		3.12	3.12	3.12	4.73	4.73	4.73	3.29	3.29	3.29	4.87	4.87	4.87
π_t	$H_0 : \lambda_1 = \lambda_2 = \lambda_3 = 0$			(0.074)			(0.100)			(0.069)			(0.095)
π_t	July 1967		-2.55*	-2.50		-4.80***	-5.26***		-2.42*	-2.51		-4.56***	-4.95***
π_t	December 2011		19.97**	9.72		11.98	10.61*		19.75**	9.70		11.66	10.63*

Table V: Pricing of exposure to TIPS in the stock market relative to realized TIPS returns

This table presents a test of the hypothesis that the risk premium in the stock market for a unit exposure to TIPS converges to the realized returns of TIPS towards the end of the sample, as predicted by our model. Panel A presents Fama and MacBeth (1973) cross-sectional regressions using the 30 Inflation Beta and Size-sorted portfolios (UI1S30) as test assets. The factors are the CRSP VW market portfolio and a portfolio of TIPS. The exposures are estimated over 60 month rolling windows, to alleviate concerns about noisy TIPS prices in the market's early years. Over the full sample ('97-'11) and for each of three five-year subperiods, we report: average estimated risk premiums (e.g., $\lambda_{TIPS} = \frac{1}{T}\sum_{t=1}^{T} \lambda_{TIPS,t+1}$), Fama and MacBeth (1973) t-statistics (in parenthesis) and average cross-sectional R^2's. The fourth and fifth column, respectively, report average realized TIPS returns ($r_{TIPS} = \frac{1}{T}\sum_{t=1}^{T} r_{TIPS,t+1}$) and a test of the difference between TIPS returns and the estimated TIPS risk premium in the cross-sectional regression ($r_{TIPS} - \lambda_{TIPS}$). Panel B presents the same cross-sectional regressions, but with the inflation factor INF substituted for the portfolio of TIPS. The final column presents the time-series average of the cross-sectional correlation between the risk premiums predicted by the two models for the 30 portfolios: $corr(\widehat{r^{(1)}_{t,t+1}}, \widehat{r^{(2)}_{t,t+1}})$.

	Panel A: TIPS risk premium and TIPS returns					Panel B: Benchmark INF risk premium			
	(1) $r_{i,t+1} = \lambda_{MKT,t+1}\widehat{\beta_{MKT,t}} + \lambda_{TIPS,t+1}\widehat{\beta_{TIPS,t}} + u_{i,t+1}$			Realized	Difference	(2) $r_{i,t+1} = \lambda_{MKT,t+1}\widehat{\beta_{MKT,t}} + \lambda_{INF,t+1}\widehat{\beta_{INF,t}} + u_{i,t+1}$			
	λ_{MKT}	λ_{TIPS}	R^2	r_{TIPS}	$\lambda_{TIPS} - r_{TIPS}$	λ_{MKT}	λ_{INF}	R^2	$corr(\widehat{r^{(1)}_{i,t+1}}, \widehat{r^{(2)}_{i,t+1}})$
'97-'11	4.90	7.34	0.09	4.30	3.04	7.59	0.85	0.12	0.40
	(1.03)	(2.03)		(2.79)	(0.77)	(1.57)	(0.25)		
'97-'01	3.57	10.17	0.20	1.45	8.72	9.89	-8.75	0.11	-0.03
	(0.39)	(2.66)		(1.07)	(2.15)	(1.10)	(-1.06)		
'02-'06	7.57	5.26	-0.09	4.85	0.41	10.75	2.11	-0.06	0.60
	(1.32)	(0.88)		(1.68)	(0.06)	(1.59)	(0.67)		
'07-'11	3.54	6.56	0.18	6.66	-0.11	1.95	9.48	0.30	0.65
	(0.38)	(0.78)		(1.97)	(-0.01)	(0.21)	(1.89)		

Table VI: Do the inflation factor and TIPS really hedge inflation risk?
This table presents hedge regressions of $ARMA(1,1)$-innovations in inflation (π_t, Panel A) and total inflation (I_t, Panel B) on gross returns of (1) the one-month t-bill ($R_{TB1,t}$), (2) the 10 year constant maturity treasury bond ($R_{CMT10,t}$), (3) the inflation factor ($R_{INF,t}$) and (4) a portfolio of TIPS ($R_{TIPS,t}$). Multiple regressions (5) and (6) combine these assets in the optimal hedge portfolio. We present the regressions for two sub-periods: Pre-TIPS (1964-08 to 1997-02) and Post-TIPS (1997-03 to 2011-12). ***,**,* denote significance at the 1, 5 and 10 percent level, respectively, using Newey-West standard errors with 1 lag.

E.g., $\pi_t = a + b_{TB1}R_{TB1,t} + b_{CMT10}R_{CMT10,t} + b_{INF}R_{INF,t} + b_{TIPS}R_{TIPS,t} + e_t$

Model (#)	a	b_{TB1}	b_{CMT10}	b_{INF}	b_{TIPS}	R^2
Panel A: $ARMA(1,1)$-innovations in inflation (π_t)						
Pre-TIPS						
(1)	-0.001**	0.156***				2.17
(2)	0.000***		-0.011**			1.18
(3)	0.000***			0.020***		4.07
(5)	-0.001**	0.175***	-0.010*	0.019***		7.34
Post-TIPS						
(1)	0.000	0.025				-0.55
(2)	0.000		-0.028*			3.22
(3)	0.000			0.011*		1.06
(4)	0.000				0.017	0.32
(6)	0.000	0.081	-0.066**	0.004	0.073**	11.32
Panel B: Total Inflation (I_t)						
Pre-TIPS						
(1)	0.001	0.694***				23.94
(5)	0.001	0.722***	-0.017**	0.015**		26.91
Post-TIPS						
(1)	0.002***	0.157				0.20
(6)	0.001***	0.203	-0.068**	-0.001	0.072**	11.12

Table VII: The inflation risk premium and the nominal-real covariance

This table presents evidence linking the stock market-based inflation risk premium to the nominal-real covariance, as is done in Campbell et al. (2013) for nominal bonds. In Panel A, we present our proxies of the nominal-real covariance. We regress (cumulative) log future Industrial Production growth and Non-Durables and Services Consumption growth on lagged inflation, and calculate the negative of the stock market beta of the ten year constant maturity bond. We present the coefficients and R^2's for various sub-periods, starting from February 1959 (coinciding with the availiability of monthly consumption data) to December 2011. In Panel B, we forecast the inflation risk premium (measured by the return on the inflation factor INF) one month-ahead (or compounded twelve month-ahead) with running estimates of the nominal-real covariance. These running estimates use only historical data as described in Section VI.A. We present results for three models. Model (A) includes only the estimated running proxy of the nominal-real covariance ($\widehat{b_{IP,t}}$, $\widehat{b_{CG,t}}$ or $\widehat{b_{B,t}}$, which are standardized); Model (B) adds $CFNAI_t$ and an interaction term; and, Model (C) adds $TIPS_t$ and $TIPS_t \times CFNAI_t$. We present the estimated coefficients, adjusted R^2's and a Wald test of the hypothesis that the terms related to the nominal-real covariance are jointly insignificant in a model that includes $TIPS_t$, $CFNAI_t$ and $TIPS_t \times CFNAI_t$. In Panel C, we present select results for the Pre- and Post-TIPS period. ***,**,* indicate significance at the 1, 5 and 10 percent level, respectively, using Newey-West standard errors with k lags.

Table VI continued

Panel A: Time-varying nominal-real covariance

		$S_{t:t+k} = a + b_S I_{t-1} + e_{t:t+k}$				$R_{B10,t+1} = a + b_B(-R_{M,t+1}) + e_{t+1}$	
		S = Industrial production		S = Consumption		-Long-Term Bond Beta	
	k	b_{IP}	R^2	b_{CG}	R^2	bB	R^2
Full sample	1	-0.32	1.33	-0.09*	0.58	-0.07**	1.67
	12	-4.74***	9.61	-0.76	2.67		
1967-07 to	1	-0.80**	6.81	-0.35***	6.86	-0.16***	13.05
1979-12	12	-10.58***	26.60	-1.88***	14.29		
1980-01 to	1	-0.64**	7.47	-0.20*	2.52	-0.17*	6.13
1989-12	12	-5.37***	18.44	-1.90***	30.03		
1990-01 to	1	-1.15***	11.81	-0.27	2.05	-0.15**	9.70
1999-12	12	-7.68***	22.62	-3.69***	32.66		
2000-01 to	1	0.34	1.59	0.04	-0.41	0.13***	7.95
2011-12	12	-1.86	0.81	0.04	-0.75		

Panel B: Predicting the inflation risk premium using proxies for the nominal-real covariance

$$R_{INF,t:t+k} = \lambda_0 + \lambda_1 TIPS_t + \lambda_2 CFNAI_t + \lambda_3 (TIPS_t \times CFNAI_t) + \lambda_4 \widehat{b_{S,t}} + \lambda_5 (\widehat{b_{S,t}} \times CFNAI_t) + \lambda_6 (\widehat{b_{S,t}} \times TIPS_t) + u_{t:t+k}$$

	k		λ_0	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	R^2	$H_0: \lambda_4 = \lambda_5 = \lambda_6 = 0$
						S = Industrial Production ($\widehat{b_{IP,t}}$)					
INF	1	(A)	-1.60				3.73***			1.00	
		(B)	-1.89		2.01		2.97**	-3.06**		2.65	
		(C)	-2.65	-0.29	5.97**	-3.90**	2.38	0.41	0.20	2.92	(0.558)
	12	(A)	-1.40				3.17***			8.63	
		(B)	-1.89		1.68		3.56***	-2.32**		17.77	
		(C)	-2.73**	-3.69	4.73***	-2.11***	1.09	1.52	4.48*	27.75	(0.144)
						S = Consumption Growth ($\widehat{b_{CG,t}}$)					
INF	1	(A)	-1.60				2.45			0.32	
		(B)	-1.68		1.05		1.65	-3.26**		1.74	
		(C)	-3.28*	-2.41	6.46**	-4.15**	0.59	0.74	3.03	2.85	(0.835)
	12	(A)	-1.40				4.04***			14.15	
		(B)	-1.33		0.79		3.66***	-1.57		17.95	
		(C)	-2.77***	-2.29	3.79***	-1.91***	1.76*	0.79	3.63	28.69	(0.142)
						S = Bond beta ($\widehat{b_{B,t}}$)					
INF	1	(A)	-1.60				2.26*			0.25	
		(B)	-2.83*		3.51**		2.51**	-6.15***		3.18	
		(C)	-2.89	-1.88	4.96***	-2.26	1.69	-2.97	1.34	2.89	(0.839)
	12	(A)	-1.40				2.91***			7.24	
		(B)	-2.13*		2.55***		3.11***	-3.56***		20.07	
		(C)	-2.66**	-12.00	3.26**	-0.65	0.13	-1.01	9.18*	30.99	(0.223)

Panel C: Pre- versus Post-TIPS era (S = Industrial Production ($\widehat{b_{IP,t}}$))

	k		λ_0	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	R^2	$H_0: \lambda_4 = \lambda_5 = \lambda_6 = 0$
						Pre-TIPS					
UI1F	1	(A)	-2.20				2.19			0.34	
		(B)	-2.18		5.17**		1.43	-0.12		3.27	
		(C)									
						Post-TIPS					
UI1F	1	(A)	-0.38				6.29*			1.45	
		(B)	-1.86		0.40		5.55	-4.38		1.69	
		(C)	-6.19	5.29	14.10	-5.37	13.30	-3.60	-6.20	2.81	(0.410)