

Inflation Risk and the Labor Market: Beneath the Surface of a Flat Phillips Curve*

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While the Phillips curve appeared quiescent after the Great Financial Crisis (GFC), inflation risk, as gauged from option prices, remained sensitive to employment dynamics. Using Phillips-curve regressions centered on option-implied risk-neutral moments, I show that, in tight labor markets, a fall in the unemployment gap raises the risk that inflation overshoots expectations—even if realized inflation remains stable. In tight labor markets, implied moments convey valuable information, as shown by their ability to anticipate future patterns in inflation break-evens and wage growth. Being risk neutral, option-implied moments embed risk premia, which can make moments particularly informative about developments that matter the most to investors. The usefulness of inflation options in assessing risk, despite their illiquidity, is rooted in reputational incentives that dealers have to disseminate accurate quotes.

JEL Codes: G12, G14, G23.

1. Introduction

The weakening empirical link between inflation and the labor market has garnered considerable attention since the Great Financial Crisis (GFC). Two main economic forces stand behind the flattening of the Phillips curve.¹ The first is firmer anchoring of inflation expectations

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¹The increased responsiveness of monetary policy to job market dynamics can also flatten the slope of the reduced-form Phillips curve, even if the structural

(Ball and Mazumder 2011; Watson 2014; Blanchard 2016; Barnichon and Mesters 2021). The second is the decline in labor bargaining power, which has dampened the prices-wages amplification channel (Lombardi, Riggi, and Viviano 2020; Ratner and Sim 2020; Stansbury and Summers 2020).² Yet, there is evidence that the Phillips curve, while dormant, could resurface rapidly in an overheated job market (Hooper, Mishkin, and Sufi 2020).

In this paper, I study whether perceived upside risk to inflation becomes more sensitive to employment conditions as slack tightens, even if realized inflation does not respond. I do so by characterizing the link between the unemployment gap and option-implied moments of expected U.S. inflation, conditional on labor market tightness. The baseline proxy for tightness is changes in the labor force participation rate, which includes information not necessarily incorporated in the unemployment rate and in the unemployment gap (Erceg and Levin 2014 and Yellen 2014). For instance, the participation rate reflects the flow of discouraged workers in and out of the employment pool. The conclusions are robust to alternative proxies for labor market tightness, including a quadratic specification in the unemployment gap. While the sample excludes the pandemic to avoid the effects of large dislocations in financial markets, the appendix provides selected results from the sample that includes the pandemic.

The main results show that upside risk rises as the unemployment gap falls—but only if the labor market is tight. Importantly, these dynamics hold even as realized inflation remains flat. That is, option-implied inflation moments indicate that, while the Phillips curve may be quiescent, there are important shifts in perceived inflation risk under the surface. These shifts anticipate a number of subsequent developments, as discussed next.

relation is negatively sloped (Eser et al. 2020; Hooper, Mishkin, and Sufi 2020; McLeay and Tenreyro 2020). Additional factors include issues with measuring inflation expectations (Coibion and Gorodnichenko 2015; Coibion, Gorodnichenko, and Kamdar 2018) and the labor slack (Ball and Mazumder 2019).

²These elements are closely related to demographic changes that also affect low-frequency inflation dynamics, such as fluctuations in the working-age population (Juselius and Takáts 2021) and the higher participation rate of older workers (Mojon and Ragot 2019).

I use a two-pronged approach to assess whether the dynamics of option-implied moments convey relevant information. First, I evaluate whether they signal that inflation expectations are becoming unsettled.³ To do so, I consider the comovement between risk-neutral moments and future realized moments of daily break-even rates, which are market-based inflation expectations built from nominal and real government-bond yields. Second, I explore the link between option-implied moments and the future dispersion of wage growth across industries. The rationale is that upside risk to inflation is likely to result in faster wage growth in industries where employees have better bargaining power. Overall, the results indicate that option-implied moments provide useful insights.

The methodology used to extract inflation moments builds on the popular nonparametric approach of Aït-Sahalia and Duarte (2003) and Kitsul and Wright (2013). It is rooted in the work of Breeden and Litzenberger (1978), who derive the return distribution for the asset underlying a set of options from the prices of calls. Importantly, option-implied moments are risk neutral, meaning that they incorporate risk premia. The presence of risk premia, however, is not a hindrance to the analysis. Rather, it means that moments are particularly informative about developments that matter the most to investors and that affect their behavior, chiefly high-inflation states that command larger risk premia (Hilscher, Raviv, and Reis 2026). Elaborating on the arguments set forth by Feldman et al. (2015), Nagel (2016, p. 214) illustrates the usefulness of risk-neutral variables by writing that a “social-welfare maximizing policy should take into account . . . the price that the public is willing to pay to insure against . . . states of the world. Risk-neutral probabilities capture . . . these aspects.”

When studying option-implied inflation distributions, data quality is an important consideration. Available information suggests that these options were relatively liquid between the end of the GFC and the mid-2010s, when trading slowed down considerably and potentially dried up. Subsequently, prices have mostly reflected dealer quotes. Besides theoretical considerations that prices can be informative even in the absence of trading (Milgrom and Stokey

³Note that comparing moments with long-run realized inflation is impractical, since the sample starts just after the GFC.

1982 and Gizatulina and Hellman 2019), conversations with market participants suggest that quotes are useful because they are disseminated, in part, to facilitate the risk management of legacy option holdings by large intermediaries (see Section 2.2 for a detailed discussion). The question of price informativeness is also an empirical one. As discussed above, option-implied moments anticipate future realized moments of break-even rates and cross-industry dispersion in wage increases.

Option-implied moments and probabilities have been used extensively to characterize the behavior of inflation expectations and associated risk premia. The risk of long-lived deflation has been of particular interest to researchers, as in Fleckenstein, Longstaff, and Lustig (2017) and Hilscher, Raviv, and Reis (2026), who develop a method to gauge the risk of very high or very low inflation. Relatedly, Reis (2020) finds that disagreement among market participants, rather than risk premia, is the main determinant of discrepancies between survey-based and market-implied inflation expectations. The drivers of deflation probabilities are explored by Galati, Gorgi, and Zhou (2018), who find evidence of slight unanchoring in the euro area. Eser et al. (2020) highlight that more limited economic slack played an important role in the rightward shift of the euro-area inflation distribution before the COVID-19 pandemic. A separate strand of literature uses information extracted from options to characterize the interplay of inflation and macroeconomic aggregates. For instance, Mertens and Williams (2021) study how the distribution of inflation was affected by the zero lower bound, while Hilscher, Raviv, and Reis (2022) assess the likelihood that inflation can lower real U.S. public debt.

The analysis in this paper is related to research on predicted inflation distributions built using quantile regressions, which are often specified as Phillips curves (Manzan and Zerom 2013). Applications generally focus on the drivers of inflation tails (Busetti, Caivano, and Rodano 2015) and on inflation-at-risk, which quantifies the likelihood that inflation experiences large negative realizations (Banerjee et al. 2020 and López-Salido and Loria 2024). In this literature, Phillips-curve regressions are used to build expected distributions from the historical comovement of inflation with lagged macroeconomic factors. In contrast, inflation options span the full forward-looking distribution on each date,

and I use Phillips-curve regressions to understand the drivers of the risk-neutral distributions of expected inflation. Additionally, the wide set of options' strike prices allows to measure the perceived risk of events—typically rare disasters—that, while not observed in the data, are concerning enough to investors to affect asset prices and trading activity (see, among others, Krasker 1980 and Santa-Clara and Yan 2010 for a general discussion).

In the remainder of the article, Section 2 discusses the methodology to extract risk-neutral inflation distributions. Section 3 computes Phillips curves with realized and risk-neutral expected inflation, while Section 4 studies option-implied moments using Phillips-curve regressions, focusing on the impact of labor market developments on inflation risk. Section 5 evaluates the information content of implied inflation moments and Section 6 concludes.

2. Implied Inflation Distributions

The first step of the analysis consists of extracting risk-neutral distributions from option prices. The data used to build the densities are from Bloomberg and also include inflation swaps to measure point expectations and interest rates swaps as riskless rates. All variables have a five-year horizon and are available each day. As a result, the distributions refer to average annual inflation over the five years following the day in which they are computed.

The methodology used to extract densities is standard in the literature and originates from Breeden and Litzenberger (1978). They link the cumulative probability distribution for the values of the underlying asset (in this case, inflation) to the first derivative of call prices as a function of strike prices.⁴ Option prices are normally interpolated to obtain a dense set of strikes. Doing so typically introduces inflection points that can result in negative probabilities, a sign that the interpolated prices imply arbitrage opportunities. To address this issue, I follow the approach of Ait-Sahalia and Duarte

⁴The set of options includes puts (known as floors) with strikes equal to -1 percent, -0.5 percent, 0 percent, and 0.5 percent, and calls (known as caps) with strikes equal to 1 percent, 1.5 percent, 2 percent, 2.5 percent, 3 percent, 3.5 percent, 4 percent, 4.5 percent, 5 percent, and 6 percent. I convert caps prices into floors prices using the put-call parity (see Mercurio and Zhang 2017).

(2003). They first transform traded prices to satisfy selected slope and convexity restrictions, limiting the incidence of arbitrage. They then use kernel smoothing to obtain a dense set of prices that inherit the favorable properties of the transformed traded prices.

As in Kitsul and Wright (2013), call prices for a given strike can be obtained using the parameters $\{\hat{\beta}_0(k), \hat{\beta}_1(k)\}$ that minimize the following loss function:

$$L = \sum_{i=1}^N [m_i - \beta_0(k) - \beta_1(k)(k_i - k)]^2 \frac{1}{\hat{h}} K\left(\frac{k_i - k}{\hat{h}}\right), \quad (1)$$

where $\{m_i\}_{i=0}^N$ are the transformed prices, N is the number of strikes with a traded price, $K(u) = \exp(-u^2/2) / \sqrt{2\pi}$ is the Gaussian kernel, and \hat{h} is the estimated optimal bandwidth, computed according to Equation (3.23) in Ait-Sahalia and Duarte (2003).

After optimizing Equation (1) for each daily cross-section of traded prices, I compute cumulative probabilities corresponding to a grid of 10,000 equally spaced strikes between the minimum and maximum traded strikes (-1 percent and 6 percent). From this grid, I obtain percentiles that allow me to calculate higher moments robust to outliers (Bowley 1920 and Moors 1988; see Andrade, Ghysels, and Idier 2015 for an application to inflation skewness from survey data). Specifically, option-implied volatility, skewness, and kurtosis are defined as follows:

$$vol_t^{opt} = \frac{\pi_t^{75,opt} - \pi_t^{25,opt}}{\pi_t^{50,opt}}, \quad (2)$$

$$skew_t^{opt} = \frac{\pi_t^{75,opt} + \pi_t^{25,opt} - 2 \cdot \pi_t^{50,opt}}{\pi_t^{75,opt} - \pi_t^{25,opt}}, \quad (3)$$

$$kurt_t^{opt} = \frac{(\pi_t^{87.5,opt} - \pi_t^{62.5,opt}) + (\pi_t^{37.5,opt} - \pi_t^{12.5,opt})}{\pi_t^{75,opt} - \pi_t^{25,opt}}, \quad (4)$$

where $\pi_t^{n,opt}$ is the n^{th} percentile of the risk-neutral distribution of expected inflation on day t . These measures are the variables of interest in the analysis discussed in the remainder of the paper.

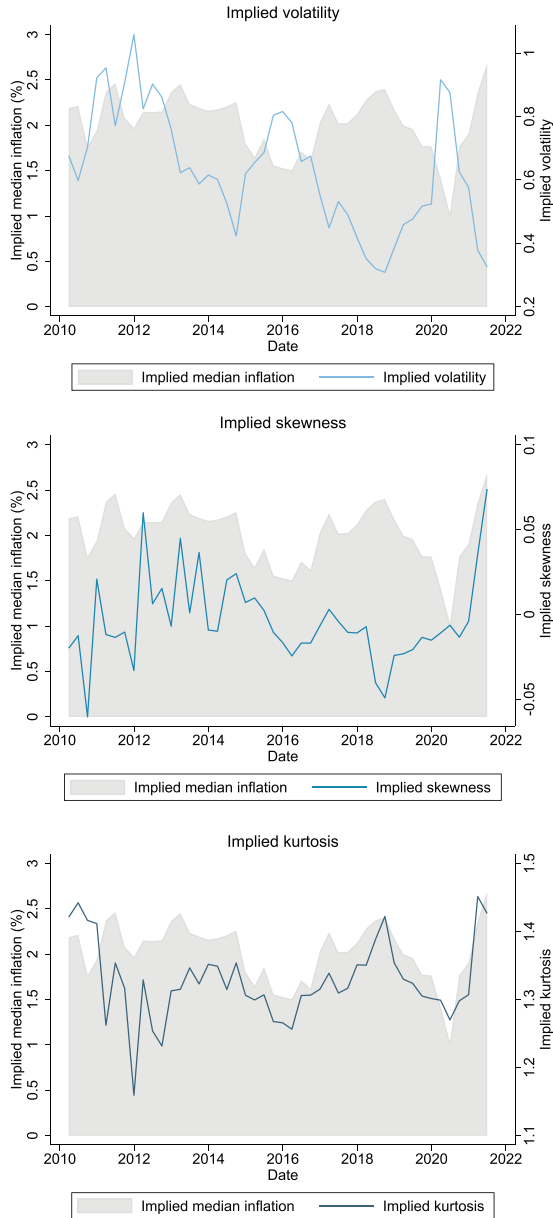
2.1 Empirical Properties of Risk-Neutral Inflation Moments

The three moments follow distinct time-series patterns, but they all tend to fluctuate more sharply in the first part of the sample, until U.S. monetary-policy normalization started in 2015 (Figure 1). From then onward, volatility tended to increase in periods of lower risk-neutral inflation expectations, with a particularly pronounced rise in early 2020 at the beginning of the COVID-19 pandemic. Kurtosis tracked risk-neutral inflation expectations quite closely, peaking at the end of the sample in early 2021. In contrast, the behavior of skewness was more nuanced. At first, it turned negative as risk-neutral expected inflation rose in 2018—implying a shift in the probability mass toward moderately higher inflation together with a higher tail risk of markedly lower inflation. However, higher risk-neutral expected inflation in early 2021 was accompanied by a rapid increase in skewness, signaling a higher chance of somewhat lower-than-expected price rises but a more pronounced tail risk of high inflation.

The three moments can be mapped into the probability of various future inflation scenarios. This exercise is especially useful because studying moments allows to understand nuanced changes in the structure of inflation risks, but evaluating the practical relevance of joint dynamics in moments is not immediately intuitive. To gauge upside risk, I consider the link between moments and the likelihood of an inflation “overshoot” (average annual inflation up to 0.5 percentage points above median option-implied inflation) and of an inflation “surge” (more than 2 percentage points above the median). Due to the nonparametric nature of the distributions extracted from Equation (1), I establish the link using regressions robust to outliers (Li 1985) rather than formulas. The dependent variable is the logit transformation of the probability of either scenario, while the independent variables are standardized moments (see Table 1; volatility is replaced by its natural logarithm).

The coefficients shown in the top panel of Table 1 indicate that higher volatility reduces the probability of an overshoot but increases that of a surge. Higher skewness—which reflects a leftward shift in probability mass but a thicker right tail—lowers the chance of an overshoot but heightens the risk of a surge. Kurtosis has a similar effect. The high adjusted R^2 s indicate that the link between

Figure 1. Implied Inflation Moments Over Time



Note: The three panels depict the time series of quarterly averages for option-implied (risk-neutral) inflation volatility, skewness, and kurtosis. Each panel also shows the median of the option-implied distribution in the background for reference. Data are quarterly and cover 2010 to 2021:Q2.

**Table 1. Risk-Neutral Moments
and Upside Risk to Inflation**

	Dependent Variable	
	Prob. Overshoot	Prob. Surge
vol^{opt}	-0.314*** (-20.22)	0.896*** (19.32)
$skew^{opt}$	-0.121*** (-9.00)	0.136*** (3.37)
$kurt^{opt}$	-0.051*** (-2.78)	0.386*** (7.05)
α	-1.286*** (-99.67)	-3.339*** (-86.56)
Obs.	119	119
Adj. R ²	0.829	0.791
	Probability Values	
	Prob. Overshoot	Prob. Surge
Prob. if All Moments at Mean	21.7%	3.4%
Δ Prob. if vol^{opt} is 1 σ Above Mean	-4.9%	4.6%
Δ Prob. if $skew^{opt}$ is 1 σ Above Mean	-2.0%	0.5%
Δ Prob. if $kurt^{opt}$ is 1 σ Above Mean	-0.9%	1.5%

Note: The table links risk-neutral moments to the likelihood that future inflation exceeds expectations by a moderate or substantial amount. Moments and probabilities are contemporaneous. In the upper panel, the variable of interest is the logit transformation ($y = \ln\left(\frac{p}{1-p}\right)$) of the probability that annual average realized inflation in the next five years is up to 0.5 percentage points above median expected inflation (“Prob. Overshoot”) or 2 percentage points or more above the median (“Prob. Surge”). The dependent variables are linked to standardized inflation moments using regressions robust to outliers (Li 1985). In the lower panel, the probabilities in the first line are computed with the inverse logit transformation applied to the coefficients α in the upper panel: $(1 + \exp(-\alpha))^{-1}$. Probability changes (Δ Prob) when moments are one standard deviation above the mean are computed as Δ Prob = $(1 + \exp(-(\alpha + mom^{opt})))^{-1} - (1 + \exp(-\alpha))^{-1}$, where mom^{opt} is one of the three option-implied moments. The sample covers 2010–19.

moments and probabilities is tight. When the moments are at their sample average, the probability of an overshoot is 21.7 percent and that of a surge is 3.4 percent (lower panel). One-standard-deviation increases in individual moments alter the two probabilities meaningfully. Changes in skewness affect the chance of an overshoot the

most (−2.0 percentage points), while kurtosis has a larger effect on the likelihood of an inflation surge (+1.5 percentage points).

2.2 How Informative Are the Prices of Inflation Options?

As discussed in Kitsul and Wright (2013), the market for U.S. inflation options developed after the GFC. In 2011, trading amounted to \$22 billion in notional value, which represented a threefold increase relative to 2010 but was still much less than the total for inflation-indexed bonds. Kitsul and Wright (2013) argue that large volumes are not crucial to price formation, pointing to the work Wolfers and Zitzewitz (2004) on markets characterized by small transactions. From a theoretical standpoint, the no-trade theorem illustrates how quoted prices can be informative even when trading does not occur at all (Milgrom and Stokey 1982 and Gizatulina and Hellman 2019).

While details on recent trading activity for inflation options are difficult to obtain, conversations with data providers and market participants paint the picture of instruments with very limited volume but with meaningful legacy open positions. Although the number of transactions fell rapidly around 2015, large financial institutions, reportedly including banks and insurance companies, hold inflation options that will not expire until at least the mid-2020s. The reason is that these instruments have always had long maturities, mostly expiring after 5 or 10 years.

Depending on the accounting and regulatory treatment of such positions, inflation options need to be marked-to-market regularly, possibly every day. Marking-to-market of illiquid instruments is a common industry practice that often relies on dealer quotes. A key reason why dealers provide frequent quotes for instruments that rarely trade is precisely to ensure that clients can value their positions daily. Quotes are often based on the prices of more liquid contracts that load on similar risks—such as interest rate derivatives in the case of inflation options—and on expert judgment.

Dealers that provide quotes for illiquid instruments have two main incentives to give unbiased estimates. The first is that these quotes are actionable, meaning that clients can ask to trade on them. While there is no obligation for a dealer to transact, a large discrepancy between the quote and the proposed trade price would be detrimental to the dealer's reputation. The second incentive relates

to the use of these quotes. To the extent that they are inputs to the calculation of regulatory capital—as they reportedly can be—they would be validated in a number of ways to ensure that they are of appropriately good quality. This process can include, among other steps, a comparison with available transaction prices and with consensus pricing data that aggregates estimates from a large set of market participants. Providing quotes that do not clear these hurdles would tarnish the reputation of a dealer and affect its business.

The appendix includes an empirical analysis of the informativeness of option-implied distributions.

3. Phillips Curves with Realized and Implied Inflation

Before exploring the link between risk-neutral inflation moments and the labor market, I estimate standard Phillips curves with realized inflation to provide an initial reference point. The specification is similar to the one in Hooper, Mishkin, and Sufi (2020), who measure inflation with the changes in the core personal consumption expenditures (PCE) index. The only difference is that I use changes in the consumer price index (CPI), since the payoff of U.S. inflation options is tied to CPI. The baseline specification, using data at the quarterly frequency, is

$$\pi_t = \alpha + \beta \cdot ugap_t + \sum_{j=1}^3 \eta_j \pi_{t-j} + \theta \cdot \pi_{t-1}^{e,frb} + \lambda \cdot \Delta RelImport_{t-1} + \epsilon_t, \quad (5)$$

where π is the period-on-period relative change in CPI, $ugap$ is the difference between the unemployment rate and the natural rate of unemployment, $\pi^{e,frb}$ is the inflation expectation series used in the Federal Reserve's FRB/US model, and $\Delta RelImport$ is the change in the relative price of import goods relative to domestic goods. Standard errors are based on Newey and West (1987) with four lags. The variable $\pi^{e,frb}$ is available from the Federal Reserve Board, while all others are from the Federal Reserve Economic Data (FRED) database of the Federal Reserve Bank of St. Louis. Regression coefficients are computed using data from 2010 to 2019, excluding the last 18 months of the sample to avoid the influence of the large dislocations

caused by the COVID-19 pandemic (see the appendix for selected results based on an extended sample).

The results in the first column of Table 2 can be compared with those in Table 2.5 of Hooper, Mishkin, and Sufi (2020), since the sample is nearly identical. The conclusions are quite similar, in that the slope of the Phillips curve relative to the unemployment gap is negative but not statistically significant, implying that the measured Phillips curve is flat. Early studies, such as Tobin (1972), recognized that this relation could be asymmetric and depend on the state of the labor market. As a result, the second column of the table shows coefficients from a specification where the effect of the unemployment gap is conditioned on the labor market. The conditioning variable is the 12-month trailing change in the labor force participation rate ($\Delta part$), which, as discussed in Section 1, is a broad measure of labor slack that reflects the flow of discouraged workers in and out of the labor pool. The regression is

$$\pi_t = \alpha + \beta \cdot ugap_t + \gamma \cdot \Delta part_{t-1} + \delta \cdot ugap_t \cdot \Delta part_{t-1} + \sum_{j=1}^3 \eta_j \pi_{t-j} + \theta \cdot \pi_{t-1}^{e,frb} + \lambda \cdot \Delta RelImport_{t-1} + \epsilon_t. \quad (6)$$

The coefficients are quite similar to those in the unconditional specification. In addition, the interaction term is not statistically significant, meaning that the marginal effect of the unemployment gap on inflation is statistically zero in both slack and tight labor markets (bottom panel of the table). In the two middle columns of Table 2, the sample focuses on the post-GFC period, for which inflation-option data are available. Once again, the Phillips curve is flat. In addition, the interaction term with the unemployment gap is not statistically significant, meaning that the slope of the Phillips curve does not depend on labor slack.

The positive coefficient on $\Delta part$ is consistent with the participation rate reflecting inflationary increases in labor demand rather than deflationary improvements in labor supply. Recent studies indicate that labor demand can raise the participation rate, especially for under-represented workers (Hobijn and Şahin 2021), even if labor supply shapes participation in subsets of the population (Mojon and Ragot 2019). Yellen (2014, p. 5) highlighted the role of labor demand

Table 2. Phillips Curve with Realized and Implied Inflation (Quarterly)

Period (Quarterly) →	1989–2019		2010–19		2010–19	
	π_t		π_t		$\pi_t^{e,opt}$	
Dep. Var. →						
$ugapt$	-0.180 (-1.54)	-0.279 (-1.22)	-0.144 (-0.61)	0.409 (1.50)	0.281* (1.91)	0.590*** (2.80)
$\Delta part_{t-1}$		-0.070 (-0.54)		0.585*** (4.00)		0.409*** (3.12)
$ugapt \cdot \Delta part_{t-1}$		-0.066 (-0.70)		-0.085 (-0.74)		0.108 (1.37)
π_{t-1}	-0.120 (-0.88)	-0.128 (-0.92)	0.113 (0.55)	0.086 (0.47)	0.473*** (2.93)	0.403** (2.48)
π_{t-2}	-0.220 (-0.91)	-0.211 (-0.92)	-0.041 (-0.20)	-0.034 (-0.17)	0.618** (2.22)	0.497* (1.90)
π_{t-3}	0.019 (0.22)	0.007 (0.08)	-0.340 (-1.66)	-0.271 (-1.55)	-0.028 (-0.11)	-0.029 (-0.11)
$\pi_{t-1}^{e,frb}$	0.411*** (2.68)	0.446** (2.36)	0.312 (1.64)	0.195 (1.25)	-0.277 (-1.24)	-0.314 (-1.47)
$\pi_{t-1}^{e,opt}$					0.618*** (5.18)	0.759*** (6.14)
$\Delta RelImport_{t-1}$	0.167 (0.92)	0.155 (0.88)	0.176 (0.88)	0.112 (0.50)	-0.310 (-1.30)	-0.350 (-1.33)
Obs.	123	123	40	40	39	39
R ²	0.117	0.124	0.132	0.266	0.621	0.667

(continued)

Table 2. (Continued)

Labor Market	Marginal Effect of $ugap_t$	
Slack ($\Delta part_{t-1} = -1\sigma$)	-0.213 (-1.26)	0.494 (1.57)
Tight ($\Delta part_{t-1} = +1\sigma$)	-0.345 (-1.13)	0.699*** (3.14)

Note: The table shows coefficients from Phillips curves similar to those in Hooper, Mishkin, and Sufi (2020), using quarterly data. When the dependent variable is realized inflation (π_t), the specification is $\pi_t = \alpha + \beta \cdot ugap_t + \gamma \cdot \Delta part_{t-1} + \delta \cdot ugap_t \cdot \Delta part_{t-1} + \sum_{j=1}^3 \eta_j \pi_{t-j} + \theta \cdot \pi_{t-1}^{e,frb} + \lambda \cdot \Delta RelImport_{t-1} + \epsilon_t$. When the dependent variable is option-implied expected inflation ($\pi_t^{e,opt}$), the specification is $\pi_t^{e,opt} = \alpha + \beta \cdot ugap_t + \gamma \cdot \Delta part_{t-1} + \delta \cdot ugap_t \cdot \Delta part_{t-1} + \sum_{j=1}^3 \eta_j \pi_{t-j} + \theta \cdot \pi_{t-1}^{e,frb} + \lambda \cdot \Delta RelImport_{t-1} + \epsilon_t$. The variables included in the regressions are the relative period-on-period change in the consumer price index (π), median expected inflation as implied from option prices ($\pi^{e,opt}$), the difference between the unemployment rate and the natural rate of unemployment ($ugap$), the four-quarter change in the labor force participation rate ($\Delta part$), the inflation expectation series used in the Federal Reserve's FRB/US model ($\pi^{e,frb}$), and the change in the relative price of import goods relative to domestic goods ($\Delta RelImport$). All variables are standardized and constants are unreported. t -statistics are calculated with standard errors based on Newey and West (1987) with four lags.

as a driving factor, writing that then-recent dynamics in “labor force participation . . . could partly reflect discouraged workers rejoining the labor force in response to the significant improvements . . . in labor market conditions.”

The closest specification to a Phillips curve that uses information from inflation derivatives is a regression of risk-neutral expected inflation on the unemployment gap and standard controls. Since these expectations are risk neutral, they embed inflation risk premia, which could themselves be linked to the state of the labor market. The last two columns of Table 2 show coefficients from Equations (5) and (6), respectively, where the left-hand variable is $\pi^{e,opt}$ instead of realized inflation. This variable is the median of the risk-neutral distribution of expected inflation extracted from option prices. Since inflation swaps are used to convert the prices of floors into those of caps, $\pi^{e,opt}$ closely tracks the inflation swap rate. The regressions include lagged $\pi^{e,opt}$ as a market-based counterpart to $\pi^{e,frb}$. The results indicate that the Phillips curve is *positively* sloped (upper panel), a finding that I discuss in detail in the next section. The slope is considerably larger in tight labor markets (lower panel).

As shown in Table 3, this pattern also holds with monthly rather than quarterly data. In addition, coefficients on lagged realized and risk-neutral expected inflation indicate short-term persistence in both variables. The monthly specification, reported below, does not include $\Delta RelImport_{t-1}$ as a regressor due to the higher data frequency:

$$\begin{aligned} \pi_t = & \alpha + \beta \cdot ugap_t + \gamma \cdot \Delta part_{t-1} + \delta \cdot ugap_t \cdot \Delta part_{t-1} \\ & + \sum_{j=1}^3 \eta_j \pi_{t-j} + \zeta \cdot \pi_{t-1}^{e,opt} + \epsilon_t. \end{aligned} \quad (7)$$

3.1 The Role of Monetary Policy Expectations

The observation that option-implied expected inflation rises when the unemployment gap widens appears counterintuitive, since Phillips curves normally have a negative slope. However, market-based inflation expectations, on which I focus in this part of the analysis, are different in key respects from realized inflation contemporaneous to the unemployment gap. Besides incorporating risk

Table 3. Phillips Curve with Realized and Implied Inflation (Monthly)

Period (Monthly) →	2010–19		2010–19	
Dep. Var. →	π_t		$\pi_t^{e,opt}$	
$ugap_t$	0.025 (0.41)	0.101 (1.10)	0.036 (0.98)	0.156** (2.47)
$\Delta part_{t-1}$		0.105 (1.18)		0.150** (2.38)
$ugap_t \cdot \Delta part_{t-1}$		-0.039 (-0.64)		0.059 (1.43)
π_{t-1}	0.429*** (4.88)	0.421*** (4.80)	0.182*** (3.31)	0.184*** (3.23)
π_{t-2}	-0.131* (-1.74)	-0.129* (-1.75)	-0.048 (-1.11)	-0.038 (-0.83)
π_{t-3}	-0.060 (-0.66)	-0.065 (-0.73)	-0.033 (-0.53)	-0.034 (-0.54)
$\pi_{t-1}^{e,opt}$	-0.008 (-0.16)	0.007 (0.15)	0.885*** (20.16)	0.902*** (24.20)
Obs.	119	119	119	119
R ²	0.168	0.180	0.836	0.845
Labor Market	Marginal Effect of $ugap_t$			
Slack ($\Delta part_{t-1} = -1\sigma$)	0.140 (1.10)		0.097 (1.41)	
Tight ($\Delta part_{t-1} = +1\sigma$)	0.061 (0.67)		0.215*** (2.64)	
<p>Note: The table shows coefficients on Phillips curves similar to those in Hooper, Mishkin, and Sufi (2020), using monthly data. The dependent variable y is either π or $\pi^{e,opt}$. The specification is $y_t = \alpha + \beta \cdot ugap_t + \gamma \cdot \Delta part_{t-1} + \delta \cdot ugap_t \cdot \Delta part_{t-1} + \sum_{j=1}^3 \eta_j \pi_{t-j} + \zeta \cdot \pi_{t-1}^{e,opt} + \epsilon_t$. The variables included in the specifications are defined in Table 2. Monthly natural rates are linearly interpolated from quarterly data. Constants are not reported. All variables are standardized. t-statistics are calculated with standard errors based on Newey and West (1987) with 12 lags.</p>				

premia, expectations refer to inflation that investors anticipate (in a risk-neutral sense) will be realized over the following five years. As a result, in linking current labor market conditions to expectations of future inflation, one needs to consider the effect of possible policy actions in response to the state of the labor market. Naturally, these

actions affect future inflation, as well as its current expectations, much more than they affect contemporaneous realized inflation. Can changes in expected monetary policy contribute to the positive coefficients on the unemployment gap in Tables 2 and 3?

In order to avoid endogeneity issues, I focus on an event study that, in the spirit of Phillips-curve regressions focused on inflation expectations, links inflation expectations to the state of the labor market while controlling for monetary policy expectations. Given the event-study setup, the variables are expressed in changes, except for the labor market variable, which, to address endogeneity, is expressed as surprises relative to consensus surveys. Specifically, the event study focuses on days when the unemployment rate is announced as part of scheduled Employment Situation report releases. Using the specification below, I condition the link between market-based inflation expectations and unemployment surprises on both expected monetary policy and the labor market:

$$\begin{aligned} \Delta\pi_t^{e,opt} = & \Delta vix_t + surp_t + \Delta part_{t-1} + \Delta ffr_t \\ & + surp_t \cdot \Delta part_{t-1} + surp_t \cdot \Delta ffr_t + \Delta part_{t-1} \cdot \Delta ffr_t \\ & + surp_t \cdot \Delta part_{t-1} \cdot \Delta ffr_t + \epsilon_t, \end{aligned} \quad (8)$$

where Δffr is the change in the expected federal funds rate one year ahead, and $surp$ is the difference between the announced unemployment rate and survey expectations from Thomson Reuters, divided by the natural rate of unemployment (linearly interpolated as needed). As in the rest of the paper, regressions are based on standardized variables, so that the coefficients can be interpreted as (i) the effect of a one-standard-deviation change in the independent variables (ii) in terms of standard deviations of the dependent variable.

As shown in panel A of Table 4, Δffr is an important explanatory variable for $\Delta\pi^{e,opt}$. Its interaction with $\Delta part$ is also negative and strongly statistically significant. The coefficients on $surp$ and on its interaction with $\Delta part$ are not statistically significant. However, given the size and the strong statistical significance of the other interactions, the marginal effect of a wider unemployment gap on option-implied expected inflation is positive and larger in tight labor markets (as in Tables 2 and 3, even if the test designs are completely different)—but only when investors expect looser monetary policy

Table 4. Expected Policy Rates and Implied-Inflation/Unemployment-Gap Link

A. Changes in Implied Inflation and <i>ugap</i> Surprises				
Dep. Var. →	$\Delta\pi_t^{e,opt}$	$\Delta\pi_t^{e,opt}$	$\Delta\pi_t^{e,opt}$	$\Delta\pi_t^{e,opt}$
Δvix_t				-0.142 (-1.37)
$surp_t$	0.158 (1.33)	0.129 (1.33)	0.075 (0.79)	0.083 (0.96)
$\Delta part_{t-1}$	0.170** (2.57)	0.122* (1.93)	0.122 (1.57)	0.111 (1.44)
Δffr_t		0.267* (1.87)	0.348*** (3.95)	0.323*** (3.66)
$surp_t \cdot \Delta part_{t-1}$			0.066 (1.17)	0.048 (0.80)
$surp_t \cdot \Delta ffr_t$			-0.086* (-1.67)	-0.097* (-1.79)
$\Delta part_{t-1} \cdot \Delta ffr_t$			-0.248*** (-2.91)	-0.252*** (-2.93)
$surp_t \cdot \Delta part_{t-1} \cdot \Delta ffr_t$			-0.009 (-0.12)	-0.030 (-0.39)
Obs.	116	116	116	116
R ²	0.057	0.125	0.215	0.234
B. Effect of <i>ugap</i> Surprise on Change in Implied Inflation, by Labor Tightness and Change in Expected Monetary Policy				
	Expected Monetary Policy			
	Expand		Contract	
Labor Market	$(\Delta ffr_t = -1\sigma)$		$(\Delta ffr_t = +1\sigma)$	
Slack $(\Delta part_{t-1} = -1\sigma)$	0.103 (1.65)		-0.032 (-0.14)	
Tight $(\Delta part_{t-1} = +1\sigma)$	0.258** (2.51)		0.004 (0.04)	
<p>Note: The table shows the result of an event study based on scheduled releases of the Employment Situation report. The variables Δvix_t and Δffr_t are changes in log-VIX and in the one-year-ahead federal funds rate (implied from futures) between day $t - 1$ and day t, where t is the date of the monthly release of the Employment Situation report. The variable $surp_t$ is the difference between the actual and expected unemployment rate (based on Thomson Reuters surveys) divided by the natural rate of unemployment measured in the previous month. Monthly natural rates are linearly interpolated from quarterly data. Other variables are defined in Table 2. Constants are not reported. All variables are standardized. t-statistics are calculated with standard errors based on Newey and West (1987) with 12 lags.</p>				

(panel B).⁵ This result confirms that policy actions are key determinants of the empirical link between inflation and the unemployment rate (McLeay and Tenreyro 2020).

4. Inflation Risk and the Labor Market

The Phillips-curve framework can be used to explore how the whole risk-neutral distribution of expected inflation relates to labor dynamics. Using option-implied moments as dependent variables, Phillips-curve regressions can link the state of the job market to different types of inflation risks (and embedded risk premia), from the dispersion of future changes to the incidence of extreme realizations. In turn, such risks can be expressed as the probabilities of relevant inflation scenarios (see Section 2.1). Ultimately, this analysis can shed light on the ebbs and flows of perceived inflationary pressures as employment opportunities change—even when realized inflation remains stable.

In practice, it is reasonable to expect that, as the labor market tightens, inflation risk changes from the possibility of relatively minor movements around expected inflation to a higher likelihood of unusually high inflation. In terms of inflation moments, this change corresponds to lower volatility (inflation risk becomes less symmetric), lower skewness (the probability mass moves toward higher inflation values), and higher kurtosis (more pronounced tail risk).

The empirical analysis builds on specifications similar to the Phillips curves used to study realized inflation at the quarterly and monthly frequencies, as detailed in Equations (6) and (7). Apart from the dependent variable (y_t) being one of volatility, skewness, or kurtosis, the only difference is that the set of regressors includes lagged values of y_t to account for autocorrelation in moments. At the quarterly frequency, the specification features the inflation-expectations series used in the Federal Reserve's FRB/US model

⁵The surprise variable has a standard deviation of 3 percent over the regression sample. Over the same period, daily changes in risk-neutral inflation expectations have a standard deviation of 3.91 basis points. Given the 0.258 coefficient corresponding to expansionary monetary policy expectations and tight labor markets, a one-standard-deviation surprise raises implied inflation by 1 basis point.

($\pi^{e,frb}$) and the change in the relative price of import goods relative to domestic goods ($\Delta RelImport$):

$$y_t = \alpha + \beta \cdot ugap_t + \gamma \cdot \Delta part_{t-1} + \delta \cdot ugap_t \cdot \Delta part_{t-1} + \zeta y_{t-1} + \sum_{j=1}^3 \eta_j \pi_{t-j} + \theta \cdot \pi_{t-1}^{e,frb} + \lambda \cdot \Delta RelImport_{t-1} + \epsilon_t. \quad (9)$$

At the monthly frequency, constraints on data availability mean that inflation expectations are measured with the median of the option-implied distribution ($\pi^{e,opt}$) and that $\Delta RelImport$ is not included:

$$y_t = \alpha + \beta \cdot ugap_t + \gamma \cdot \Delta part_{t-1} + \delta \cdot ugap_t \cdot \Delta part_{t-1} + \zeta y_{t-1} + \sum_{j=1}^3 \eta_j \pi_{t-j} + \zeta \cdot \pi_{t-1}^{e,opt} + \epsilon_t. \quad (10)$$

The results shown in Table 5 clearly indicate that the higher moments respond to the unemployment gap. For skewness, the coefficient on $ugap$ is positive, as is the one on the interaction between $ugap$ and $\Delta part$. The bottom panel shows marginal coefficients for $ugap$ when the labor market is slack or tight, obtained by combining the coefficients on $ugap$ and on the $ugap$ - $\Delta part$ interaction. These marginal coefficients indicate that a smaller unemployment gap is accompanied by lower skewness, that is by a shift in probability mass towards higher inflation—but only if the labor market is tight. For kurtosis, both the main and interaction coefficients are negative, as are the marginal coefficients corresponding to a tight labor market (bottom panel of the table). As a result, when the job market is already tight, a lower unemployment gap increases kurtosis and tail thickness. Volatility also declines as the unemployment gap shrinks, but the marginal coefficients are only statistically significant when using monthly data.

The three moments can be translated into probabilities of future inflation scenarios. Doing so is useful because individual moments can measure nuanced changes in the structure of inflation risks, but assessing the practical relevance of joint moment dynamics is not intuitive.

To better gauge the practical implications of these changes in implied moments, it is useful to translate these changes to changes

Table 5. Phillips-Curve Regressions with Option-Implied Inflation Moments

Period →	2010–19 (Quarterly)			2010–19 (Monthly)		
	vol_t^{opt}	$skew_t^{opt}$	$kurt_t^{opt}$	vol_t^{opt}	$skew_t^{opt}$	$kurt_t^{opt}$
$ugapt$	0.177 (0.79)	0.696*** (2.90)	-0.391* (-1.84)	0.184*** (2.77)	0.342*** (2.72)	-0.231 (-1.63)
$\Delta part_{t-1}$	0.036 (0.28)	0.463*** (3.23)	-0.242 (-1.57)	-0.021 (-0.55)	0.277** (2.36)	-0.198** (-2.57)
$ugapt \cdot \Delta part_{t-1}$	0.103 (1.36)	0.684*** (4.54)	-0.439*** (-3.34)	0.024 (0.64)	0.330*** (3.06)	-0.262*** (-3.68)
y_{t-1}	0.652*** (4.82)	0.030 (0.18)	0.145 (0.54)	0.774*** (11.84)	0.298*** (2.86)	0.377*** (3.90)
π_{t-1}	-0.091 (-0.73)	-0.376** (-2.09)	-0.005 (-0.03)	-0.036 (-0.85)	0.050 (0.44)	0.030 (0.46)
π_{t-2}	-0.412*** (-2.62)	0.516 (1.28)	-0.093 (-0.31)	0.092** (2.18)	-0.031 (-0.22)	-0.168* (-1.88)
π_{t-3}	-0.138 (-1.19)	-0.141 (-0.74)	0.018 (0.10)	0.039** (2.00)	-0.037 (-0.53)	-0.169** (-2.48)
$\pi_{t-1}^{e,frb}$	0.256*** (2.25)	-0.066 (-0.29)	-2.467 (-1.66)	-0.140*** (-2.99)	0.090 (1.12)	0.251*** (3.33)
$\Delta RelImport_{t-1}$	0.066 (0.39)	-0.335 (-0.99)	0.272 (1.00)			
Obs.	39	39	39	119	119	119
R ²	0.834	0.511	0.471	0.907	0.253	0.385
Labor Market	Marginal Effect of $ugapt$					
Slack ($\Delta part_{t-1} = -1\sigma$)	0.073 (0.37)	0.012 (0.04)	0.048 (0.33)	0.160** (2.14)	0.012 (0.11)	0.031 (0.19)
Tight ($\Delta part_{t-1} = +1\sigma$)	0.280 (1.03)	1.380*** (4.83)	-0.831** (-2.58)	0.208*** (2.71)	0.672*** (3.29)	-0.493*** (-3.16)

Note: The table shows coefficients from regressions similar to Phillips curves, where the dependent variables are option-implied moments (log-volatility, skewness, and kurtosis) for expected average inflation five years ahead. The variables included in the specifications are defined in Tables 2 and 3. Monthly natural rates are linearly interpolated from quarterly data. Constants are not reported. All variables are standardized. t -statistics are calculated with standard errors based on Newey and West (1987) with 12 lags. The sample covers 2010–19.

in the probabilities of different inflation scenarios. As discussed in Section 2.1, there is a tight empirical relation between implied moments and the probability of inflation overshooting (i.e., at most 0.5 percentage points above the median) or surging (i.e., at least 2.0 percentage points above the median). The coefficients in Table 5, which quantify how moments change with the labor market, can be combined with the results in panel A of Table 1, which connect moments and inflation probabilities. Using the coefficients in Table 5 from the monthly sample, a one-standard-deviation decline in *ugap* raises the overshoot probability by about a tenth from 21.7 percent to 23.6 percent (to 25.0 percent if using quarterly estimates), while the surge probability declines from 3.4 percent to 2.9 percent (to 2.8 percent with quarterly data). The risk of a surge dips because, as *ugap* compresses, the decline in volatility more than compensates for the increase in kurtosis.

The importance of job market conditions in determining the connection between option-implied inflation moments and the unemployment gap is not driven by the specific choice of how to measure labor tightness. In addition to changes in the participation rate, I consider two alternative proxies: the unemployment gap itself, which implies adding the squared *ugap* to the baseline regressions, and the under-employment rate, defined as the ratio of the under-employment level to the civilian labor force. In both cases, and in contrast to $\Delta part$, lower values correspond to better employment opportunities.

Table 6 shows the coefficients on *ugap* conditional on each of the two measures of labor-market tightness, using monthly data. These results should be juxtaposed to the monthly marginal effects in Table 5. Comparability is ensured because all variables are standardized. There is a remarkable correspondence between the baseline and alternative specifications. Crucially, the coefficients are always larger in tight labor markets. In addition, the only difference in terms of statistical significance pertains to skewness in slack markets, when the proxy is the unemployment gap. In this case, the *t*-statistic is close to -3 , while it is about nil in the baseline. Finally, the magnitude of the coefficients is quite similar to the main results when conditioning on the unemployment gap, while it is noticeably larger if using the under-employment rate.

Table 6. Phillips-Curve Regressions: Alternative Measures of Labor Market Slack

Labor Market	Unemployment Gap		
	vol^{opt}	$skew^{opt}$	$kurt^{opt}$
Slack ($ugap_t = +1\sigma$)	0.180** (2.59)	-0.223*** (-2.82)	0.139 (0.66)
Tight ($ugap_t = -1\sigma$)	0.229** (2.56)	0.503*** (3.86)	-0.301** (-2.18)
Labor Market	Underemployment Rate		
	vol^{opt}	$skew^{opt}$	$kurt^{opt}$
Slack ($underempl_t = +1\sigma$)	0.247 (1.18)	0.521 (1.50)	-0.521 (-1.56)
Tight ($underempl_t = -1\sigma$)	0.339 (0.96)	1.667*** (2.97)	-1.302*** (-2.72)
<p>Note: The table reports marginal coefficients on $ugap_t$ from monthly Phillips-curve regressions similar to those in Table 5. The specifications use two alternative measures of labor market slack: the unemployment gap (meaning that the regressions include a linear and squared term for $ugap_t$) and the underemployment rate ($underempl_t$), defined as the underemployment level divided by the civilian labor force. All variables are standardized. t-statistics are calculated with standard errors based on Newey and West (1987) with 12 lags. The sample covers 2010–19.</p>			

5. The Informative Content of Inflation Moments

The responsiveness of inflation moments to the labor market indicates that options quickly incorporate information, consistent with the discussion in Section 2.2 on why illiquidity does not prevent price formation. Since option-implied distributions are forward looking, moments should anticipate future inflation dynamics, especially—in light of the results so far—when the labor market is tight. In this section, I investigate whether such is indeed the case, using regressions of selected variables on lagged inflation moments. The relatively short sample, which is limited to the post-GFC period, implies that considering the moments of realized inflation as dependent variables is impractical. As a result, I focus on variables that are plausibly linked to lagged inflation moments, as long as option

prices contain useful information. These variables are, first, realized moments of daily risk-neutral inflation expectations and, second, wage-growth dispersion across industries. The following subsections discuss the variables and the results of the analysis.

5.1 *The Moments of Future Break-Even Rates*

I measure risk-neutral inflation expectations with five-year break-even rates, defined as the difference between nominal and real Treasury yields. Realized moments are calculated using daily break-evens over the three months after option-implied moments are measured. Focusing on volatility as an example, if high implied volatility in $t - 1$ correctly anticipates high volatility of realized inflation over the subsequent five years, it is likely that realized inflation will also be volatile over the horizon covered by the break-evens (five years from $t + 2$). As a result, break-evens between t and $t + 2$ are also likely to be volatile. Consequently, high implied volatility in $t - 1$ should anticipate high volatility for break-even rates between t and $t + 2$. Similar reasoning applies to skewness and kurtosis.

I compute the realized log-volatility, skewness, and kurtosis of daily five-year break-even rates (mom_t^{brk}) within a given quarter, half-year, or year. Each of these moments is then regressed on its lagged value and the corresponding lagged average option-implied moment (mom_t^{opt}):

$$mom_t^{brk} = \alpha + \beta \cdot mom_{t-1}^{opt} + \gamma \cdot mom_{t-1}^{brk} + \epsilon_t. \quad (11)$$

In the main specification, the coefficients are computed with ordinary least squares (OLS) and the standard errors are based on Newey and West (1987) with two lags. In an alternative specification, I consider the possibility that persistence in the regressors could yield biased coefficients, and use the procedure of Amihud, Hurvich, and Wang (2009) to correct for this potential bias.

The results are reported in Table 7. Starting with the quarterly horizon, the first three columns of panel A indicate that risk-neutral inflation volatility provides useful signals about future realized break-even volatility, which increases by 0.4 standard deviation for one standard-deviation increase in option-implied volatility. However, there is no effect in the case of skewness or kurtosis. As shown

Table 7. Option-Implied Moments and Future Break-Even Moments

		A. Newey-West											
Method	→	3 Months				6 Months				12 Months			
Horizon	→	vol_t^{brk}	$skew_t^{brk}$	$kurt_t^{brk}$	vol_t^{brk}	$skew_t^{brk}$	$kurt_t^{brk}$	vol_t^{brk}	$skew_t^{brk}$	$kurt_t^{brk}$	vol_t^{brk}	$skew_t^{brk}$	$kurt_t^{brk}$
Realized Moment	→												
$moment_{t-1}^{opt}$		0.368*** (2.89)	0.083 (0.95)	-0.004 (-0.05)	0.260 (1.58)	0.292*** (2.38)	-0.023 (-0.23)	0.040 (0.22)	0.159 (1.62)	-0.058 (-0.87)			
$moment_{t-1}^{brk}$		0.043 (0.32)	0.091 (1.21)	-0.001 (-0.02)	0.221 (1.56)	-0.103 (-1.26)	-0.005 (-0.05)	0.330 (1.30)	-0.210 (-1.59)	-0.158 (-1.47)			
Obs.		103	103	103	100	100	100	94	94	94			
R ²		0.147	0.015	0.000	0.155	0.094	0.001	0.115	0.075	0.030			
		B. Reduced Bias											
Method	→	3 Months				6 Months				12 Months			
Horizon	→	vol_t^{brk}	$skew_t^{brk}$	$kurt_t^{brk}$	vol_t^{brk}	$skew_t^{brk}$	$kurt_t^{brk}$	vol_t^{brk}	$skew_t^{brk}$	$kurt_t^{brk}$	vol_t^{brk}	$skew_t^{brk}$	$kurt_t^{brk}$
Realized Moment	→												
$moment_{t-1}^{opt}$		0.391*** (2.91)	0.080 (0.85)	-0.008 (-0.08)	0.273* (1.71)	0.296*** (2.84)	-0.025 (-0.26)	0.049 (0.26)	0.161 (1.38)	-0.058 (-0.86)			
$moment_{t-1}^{brk}$		0.021 (0.16)	0.095 (1.30)	-0.010 (-0.10)	0.210* (1.75)	-0.12 (-1.55)	-0.002 (-0.02)	0.319 (1.15)	-0.217* (-1.85)	-0.158 (-1.61)			

Note: The coefficients reported in the table are from the following regressions using monthly data: $mom_t^{brk} = \alpha + \beta \cdot mom_{t-1}^{opt} + \gamma \cdot mom_{t-1}^{brk} + \epsilon_t$, where mom_t^{brk} is either option-implied log-volatility, skewness, or kurtosis. The variable mom_t^{brk} is either realized log-volatility, skewness, or kurtosis of daily five-year break-even inflation rates over the horizon indicated in the table starting from t . Similarly, the variable mom_{t-1}^{brk} is calculated over the horizon indicated in the table up to and including $t - 1$. In panel A, the coefficients and t -statistics are based on Newey and West (1987) with lags equal to double the horizon. In panel B, the results are based on the methodology of Amihud, Hurvich, and Wang (2009) for persistent regressors. All variables are standardized. The sample covers 2010 to 2019.

in panel B, the reduced-bias methodology of Amihud, Hurvich, and Wang (2009) yields similar coefficients to those based on OLS.

At the half-yearly horizon, the magnitude and statistical significance of the coefficient on volatility start to fade, while risk-neutral skewness is clearly linked to future break-even skewness. Once more, there is little difference between the computations based on OLS and Amihud, Hurvich, and Wang (2009). The connection between break-even and lagged option-implied moments disappears when considering a one-year horizon.

To take the state of the labor market into account, the marginal effect of inflation moments is computed from the coefficients β and λ in the following regression:

$$\begin{aligned} mom_t^{brk} = & \alpha + \beta \cdot mom_{t-1}^{opt} + \gamma \cdot mom_{t-1}^{brk} + \delta \cdot \Delta part_{t-1} \\ & + \lambda \cdot mom_{t-1}^{opt} \cdot \Delta part_{t-1} + \epsilon_t, \end{aligned} \quad (12)$$

where standard errors are based on Newey and West (1987) with two lags. The results are presented in Table 8, which shows marginal effects when the labor market is tight or slack, defined on the basis of $\Delta part_{t-1}$ being one standard deviation above or below average.

At the quarterly horizon, volatility remains the only option-implied moment to comove with its equivalent computed from break-even rates. The picture becomes richer starting with the six-month frequency: labor tightness means that all option-implied moments anticipate their realized counterparts. A similar pattern holds at the one-year horizon, although magnitudes and statistical significance decline for skewness and kurtosis. Interestingly, coefficient signs indicate that inflation risk is persistent in tight labor markets, while it tends to revert in slack ones.

5.2 *The Dispersion of Future Cross-Industry Wage Growth*

I now turn to whether risk-neutral moments anticipate the dispersion of wage growth across industries. The rationale is that inflationary pressures generally raise labor compensation (Blanchard 1986 and Mehra 1991), but industries where workers have low bargaining

Table 8. Option-Implied Moments and Future Break-Even Moments, by Labor Slack

Horizon →	3 Months		6 Months		12 Months	
	Tight	Slack	Tight	Slack	Tight	Slack
vol_{t-1}^{opt}	0.352* (1.81)	0.387 (1.35)	0.400** (2.00)	0.109 (0.38)	0.595*** (3.78)	-0.399** (-2.54)
	<i>Dependent Variable: $vol_{t-1}^{br,k}$</i>					
$skew_{t-1}^{opt}$	0.095 (0.51)	0.080 (0.73)	0.682** (2.29)	0.221** (2.13)	0.665* (1.81)	0.081 (1.13)
	<i>Dependent Variable: $skew_{t-1}^{br,k}$</i>					
$kurt_{t-1}^{opt}$	0.126 (0.67)	-0.042 (-0.37)	0.528* (1.99)	-0.129*** (-2.98)	0.472 (1.09)	-0.141*** (-3.79)
	<i>Dependent Variable: $kurt_{t-1}^{br,k}$</i>					

Note: The coefficients reported in the table are from the following regressions using monthly data: $mom_{t-1}^{br,k} = \alpha + \beta \cdot mom_{t-1}^{opt} + \gamma \cdot mom_{t-1}^{br,k} + \delta \cdot \Delta part_{t-1} + \epsilon_t$, where mom_{t-1}^{opt} is either option-implied log-volatility, skewness, or kurtosis, and $\Delta part_{t-1}$ is the change in the labor force participation rate over the previous 12 months. Tight/slack labor market is defined as $\Delta part_{t-1}$ being one standard deviation above/below the mean. The coefficients and t -statistics are based on Newey and West (1987) with lags equal to double the horizon. All variables are standardized. The sample covers 2010 to 2019.

power are less likely to see wage growth (Stansbury and Summers 2020). Coupled with downward nominal rigidity in wages, this observation is likely to generate high cross-industry dispersion in wage growth when inflationary pressures are strong.

Dispersion is the log-difference of the highest and lowest wage-growth rates across industries⁶ in a given time period, divided by average growth:

$$disp_t = \ln \frac{\max(w_j) - \min(w_j)}{n^{-1} \cdot \sum_{j=1}^n w_j}, \quad (13)$$

where w_j is the relative change in wages between months t and $t+h$, where $h = 3$ or $h = 6$, depending on the horizon.

To measure worker bargaining power in a given industry, I use the fall in industry employment between 2001 and 2009 (see the discussion of how unemployment affects bargaining power in Summers 1988).⁷ As Pierce and Schott (2016) highlight, employment changes over that period were heavily influenced by a 2000 change in U.S. trade policy that eliminated the risk of higher tariffs on imports from China. Industries most exposed to competition from Chinese imports saw sharp declines in employment.⁸

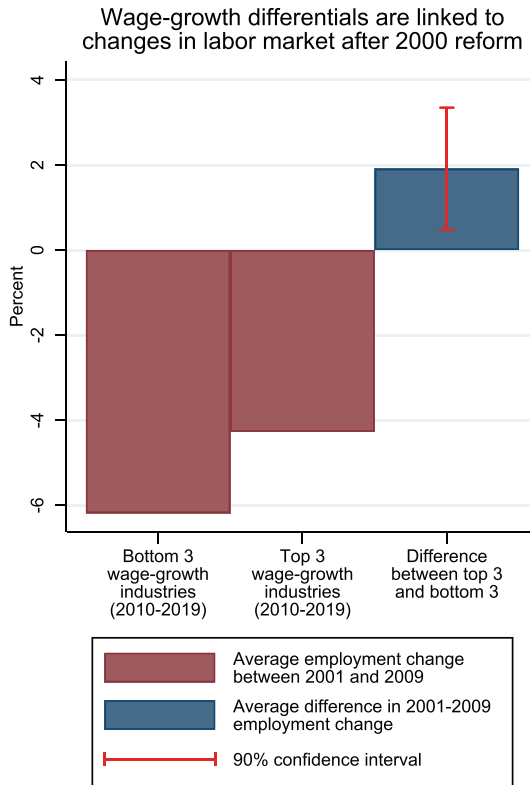
Figure 2 shows that firms with larger employment declines between 2001 and 2009 experienced lower wage growth between 2010 and 2019, supporting the conjecture that cross-industry dispersion in wage growth depends on labor bargaining power. This finding,

⁶I consider the following industries based on availability (data codes for the St. Louis Fed's FRED data set are shown in parentheses): construction (CES2000000008), education (CES6500000008), financials (CES5500000008), information (CES5000000008), leisure and hospitality (CES7000000008), manufacturing of durable goods (CEU3100000008), manufacturing of nondurable goods (CES3200000008), mining and logging (CES1000000008), professional and business services (CES6000000008), retail trade (CES4200000008), transportation and warehousing (CES4300000008), utilities (CES4422000008), and wholesale trade (CES4142000008).

⁷While union membership is an intuitive measure of bargaining power, union participation in the United States fell from 20 percent in 1983 to 10 percent in 2022 (Bureau of Labor Statistics 2023).

⁸A broad literature finds that import competition normally has adverse effects on wage stability (Bertrand 2004) and distribution (Borjas and Ramey 1995), in line with a negative effect on bargaining power.

Figure 2. Wage Inflation Dispersion and Labor Outside Options



Note: In a given month between 2010 and 2019, industries are sorted into two groups based on wage growth over the following three months. These two groups include, respectively, the three industries with the lowest future wage growth and the industries with the highest future wage growth. As a result, such sorting emphasizes realized cross-industry wage dispersion within time periods. For each group, the bars show the average decline in industry employment between 2001 and 2009, after China was granted permanent normal trade relations by the U.S. Congress in October 2000 (see Pierce and Schott 2016). A smaller decline in employment signals better industry-specific labor outside options during the 2010s.

in turn, suggests that inflationary pressures can affect wage-growth dispersion, since differences in worker bargaining power across industries are reflected in the pass-through from inflationary pressures to wages.

To the extent that implied inflation moments are informative about future inflation risk, they should be positively associated with future wage-growth dispersion, especially if—like high skewness—they express asymmetric risk of high inflation. I gauge the link between risk-neutral inflation moments and future wage-growth dispersion with the following monthly regressions:

$$\begin{aligned} disp_t = & \alpha + \beta \cdot mom_{t-1} + \gamma \cdot disp_{t-1} + \delta \cdot \Delta part_{t-1} \\ & + \lambda \cdot mom_{t-1} \cdot \Delta part_{t-1} + \epsilon_t, \end{aligned} \quad (14)$$

where mom_{t-1} is either log-volatility, skewness, or kurtosis, and standard errors are based on Newey and West (1987) with lags equal to the lead horizon in months plus 12 (the length of the moving window over which $\Delta part$ is calculated). All variables are standardized, so the coefficients can be interpreted as the effect of one-standard-deviation increases in the independent variables on the standard deviation of the dependent variable.

Without conditioning on the labor market, higher volatility and skewness anticipate a wider wage-growth range over the next three months (Table 9). In contrast, kurtosis signals a narrower dispersion. This finding is consistent with the result in Tables 7 and 8 that higher risk-neutral kurtosis, when the coefficient is statistically significant, often prefigures lower realized kurtosis, that is a lower incidence of tail inflation realizations. At the six-month horizon, only the coefficient on skewness remains statistically significant, with a roughly unchanged magnitude. Taking the state of the job market into account (Table 10), the results indicate, once more, that option-implied moments are more informative in periods of labor tightness. The effect is particularly strong for skewness, which, as discussed in the previous paragraph, can be expected to have a stronger effect on wage-growth dispersion because it expresses asymmetric risk of high inflation.

6. Conclusions

While the measured Phillips curve has flattened over time, option-implied inflation distributions indicate that perceived inflation risk has remained sensitive to labor market dynamics. In particular,

Table 9. Inflation Moments and the Dispersion of Industry Wage Growth

Dep. Var. →	<i>disp_t</i>			<i>disp_t</i>		
Horizon →	3 Months			6 Months		
<i>vol_{t-1}^{opt}</i>	0.264** (2.18)			0.060 (0.40)		
<i>skew_{t-1}^{opt}</i>		1.712* (1.75)			1.707* (1.93)	
<i>kurt_{t-1}^{opt}</i>			-0.945** (-2.55)			-0.198 (-0.47)
<i>disp_{t-1}</i>	0.525*** (7.75)	0.554*** (7.88)	0.559*** (8.34)	0.667*** (13.24)	0.637*** (11.12)	0.676*** (13.17)
Obs.	118	118	118	118	118	118
R ²	0.574	0.555	0.564	0.591	0.605	0.590

Note: The dependent variable is the dispersion of wage growth across industries, defined as $disp_t = \ln \frac{\max(w_j) - \min(w_j)}{n-1 \cdot \sum_{j=1}^n w_j}$, where w_j is the relative change in wages between months t and $t + 3$ or $t + 6$, depending on the horizon indicated in the panels above. The variable $disp_{t-1}$ is defined in a similar way, but with the relative change in wages being computed between months $t - 3$ or $t - 6$ and t , depending on the horizon. All variables are standardized and t -statistics are computed using standard errors based on Newey and West (1987) with lags equal to twice the lead/lag horizon. The monthly sample covers 2010–19.

Table 10. Inflation Moments and Wage-Growth Dispersion, by Labor Slack

Horizon →	Marginal Effect of Option-Implied Moments			
	3 Months		6 Months	
Labor Market →	Tight	Slack	Tight	Slack
<i>vol_{t-1}^{opt}</i>	0.303* (1.88)	0.089 (0.47)	0.061 (0.64)	-0.013 (-0.05)
<i>skew_{t-1}^{opt}</i>	0.494*** (4.98)	0.062 (1.29)	0.228** (2.21)	0.118** (2.05)
<i>kurt_{t-1}^{opt}</i>	-0.306** (-2.20)	-0.151** (-2.11)	0.067 (0.57)	-0.087 (-1.17)

Note: This table reports the coefficients of regressions (monthly frequency) linking the future dispersion of industry wage growth to lagged option-implied inflation moments. The specification is $disp_t = \alpha + \beta disp_{t-1} + \gamma x_{t-1} + \delta \cdot \Delta part_{t-1} + \lambda \cdot x_{t-1} \cdot \Delta part_{t-1} + \epsilon_t$. The variable x_{t-1} represents one of the different option-implied moments, while $disp_t$ and $disp_{t-1}$ are defined as detailed in Table 9. All variables are standardized and t -statistics are computed using standard errors based on Newey and West (1987) with lags equal to the lead horizon plus 12 ($\Delta part$ is computed over 12 months). The sample covers 2010–19.

upside risk increases when the unemployment gap shrinks, especially in an already tight labor market. Among the various inflation moments, implied skewness is particularly reactive to the unemployment gap. Importantly, implied moments convey useful information, in that they anticipate future patterns in market-based inflation expectations and in wage growth. Overall, the results presented in this paper point to complex dynamics for (risk-neutral) inflation risk in the background of an apparent detachment of headline inflation from the labor market.

The use of options to compute inflation moments has two important implications. The first is that the moments incorporate risk premia, which generally create a wedge relative to estimates based on surveys or econometric methods. These premia, however, incorporate useful information on outcomes that matter the most to investors and that affect their decision-making. The second consequence is that the reliability of the implied moments depends on the quality of option prices. While these instruments were illiquid in the second half of the sample and prices largely reflected dealer quotes, dealers have strong incentives to provide quotes close to fair value. The main reason is that their clients reportedly use the data to mark-to-market legacy positions in inflation options.

Appendix

A.1 Effects of Including Data from the Pandemic

This section provides more details on the behavior of inflation moments during the pandemic and on the effect of including the pandemic in the sample on the main results. While data are available to cover the pandemic and its immediate aftermath, the paper focuses on the pre-pandemic period for two main reasons.

The first reason is that the dislocations generated by the pandemic and the resulting data outliers can distort inference about economic relations that hold during normal periods. There has been considerable effort in the literature to contain these distortions. See, for instance, Davis and Ng (2023) and Carriero et al. (2024). The second reason is that, as noted in the main text, institutional features of the market for inflation options mean that the informativeness of these options was expected to decline through the early 2020s.

Table A.1. Marginal Effects of Unemployment Gap

Labor Market	Marginal Effects		
	Vol.	Skew	Kurtosis
Slack	0.170 (0.97)	-0.547* (-1.75)	0.091 (0.30)
Tight	0.376*** (2.88)	0.936*** (2.76)	-0.615** (-2.43)

Indeed, data for several strikes were discontinued starting in August 2021.

The remainder of this section provides selected details on how including data from the pandemic (up to August 2021) affects the analysis. It will then provide details on the liquidity of inflation options in the latter part of the sample.

Table A.1 shows the marginal effects of the unemployment gap on the various implied moments when the labor market is slack or tight, when using quarterly data that extends to the end of the sample in the second quarter of 2021. The table corresponds to the bottom left panel of Table 5 in the manuscript. The results are quite similar to those shown in Table 5.

While changes in data availability in August 2021 do not affect the analysis discussed in the paper, which focuses on the pre-pandemic sample, a pertinent question is whether the quality of the data started to decline before the quotes for some strikes became unavailable. I address this point in the first part of the next section.

A.2 Evidence on Options Data Informativeness

A.2.1 The Effect of Discarding Stale Prices

Even if no volume is available for inflation options, it is possible to gauge the quality of the data by studying instances when prices do not change from one day to the other (“stale” prices). Prices that remain unchanged are not necessarily a sign of poor data quality. Especially for out-of-the-money (OTM) options, which by construction have low prices, a stale quoted price can simply mean that the

intrinsic value of the option has not changed more than the minimum tick used by an exchange or by a desk that disseminates quotes.

Before proceeding further, it is useful to consider the incidence of prices that do not change from one day to the next in the market for options on the S&P 500 index (ticker SPX), which are some of the most liquid options available. The following statistics refer to data for the month of August 2023, obtained from Optionmetrics via Wharton Research Data Services.

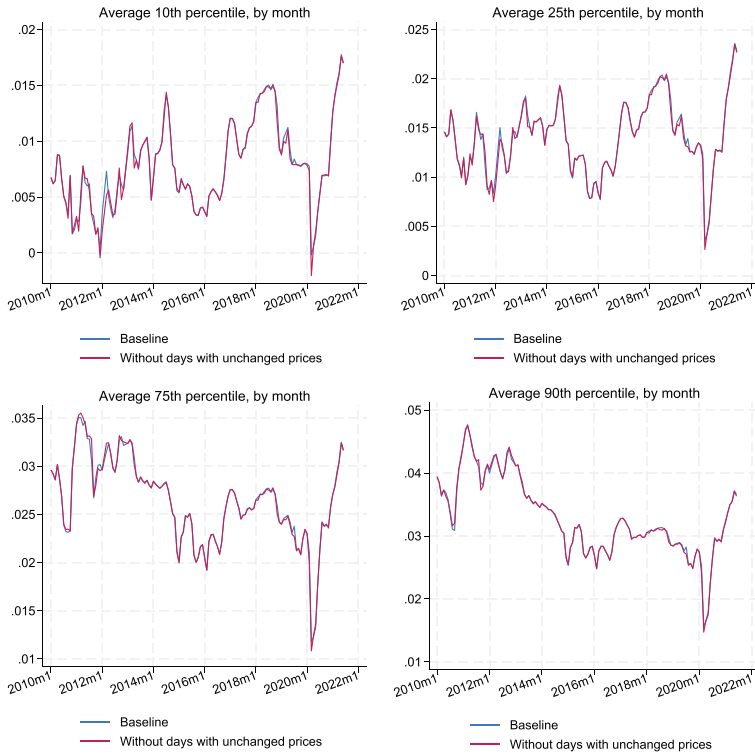
- There are 400,958 observations in the August 2023 file.
- Of these, 29,211 observations (7 percent) have either the bid price or ask price that did not change compared to the previous trading day.
- Of these, 28,289 observations (97 percent) are OTM options (with the absolute value of the option delta below 0.1). The high incidence of OTM options is expected, because low delta options have low prices and the “true price” may move less than the minimum tick.
- Of these 28,289 observations, 7,204 (25 percent) have non-zero trading volume, and 4,325 (15 percent) have trading volume greater than 10 contracts

Going back to the question of whether the quality of the inflation-option data started to decline before the quotes for some strikes became unavailable, a conservative approach to gauging the issue is to discard days in which at least one of the options has a price that does not change relative to the previous day. Figure A.1 shows option-implied inflation percentiles computed this way (red lines) along with the percentiles based on the data used in the manuscript (blue lines). Besides a discrepancy in the 10th percentile at the beginning of 2012, the baseline moments are virtually identical to their counterparts that drop days when at least one option price is unchanged. This is also the case before and during the pandemic.

A.2.2 Evidence from Option-Implied Volatility

The implied volatility of inflation saw large movements around the pandemic (see Figure 1 in the main text). While this behavior is

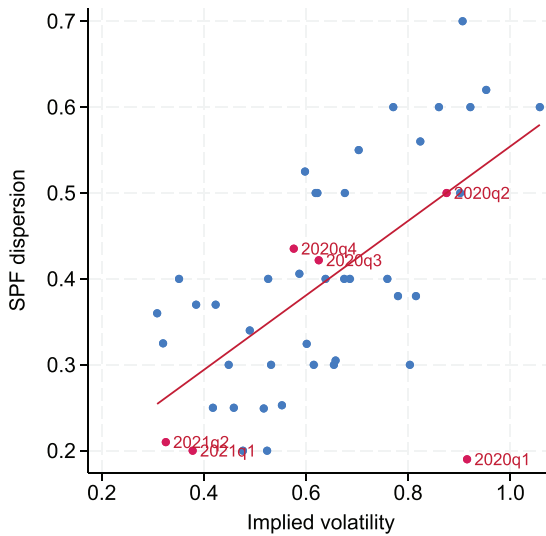
Figure A.1. Implied Inflation Percentiles after Removing Stale Prices



not unexpected given the impact of the pandemic, it is important to ensure that these movements are not the consequence of issues with the data or methodology. Even if the pandemic is not included in the sample and cannot drive the results, assessing the dynamics of implied moments around the pandemic is useful to confirm that the data and methodology are sound.

Figure A.2 shows a scatterplot of implied inflation volatility (x-axis) against a measure of expected-inflation dispersion obtained from the Survey of Professional Forecasters (SPF), provided by the Federal Reserve Bank of Philadelphia (y-axis). The measure of dispersion is the interquartile range of forecasts for inflation over the next five years. The SPF data are quarterly, and implied inflation

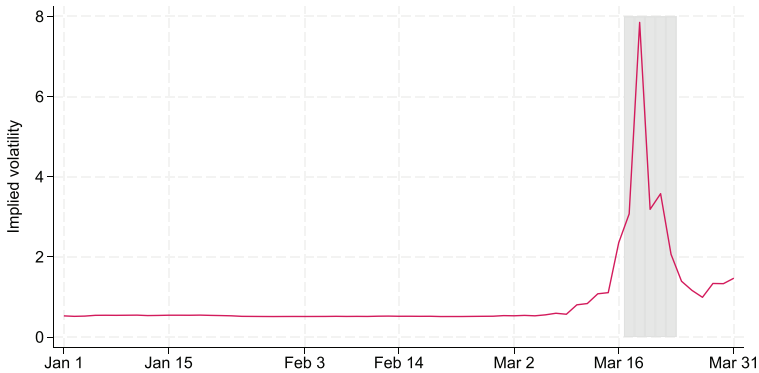
Figure A.2. Inflation Survey Dispersion and Implied Inflation Volatility



volatility is averaged within a quarter. The comovement is relatively strong between 2010 and 2019 (the main sample) and the correlation is 68 percent. Including data through the second quarter of 2021, the correlation drops to 63 percent, but the comovement is still quite strong. The one exception is the first quarter of 2021, when option-implied volatility is much higher than the survey-based measure.

Figure A.3 depicts the time series of daily implied inflation volatility during the first quarter of 2020, when asset prices were extremely volatile due to the initial impact of the pandemic. Early in the quarter, implied volatility was in line with end-2019 values, but rose to very high levels in mid-March 2020 and declined only after the Federal Reserve set up several liquidity facilities in support of credit intermediation. This spike is the reason why the average value of inflation implied volatility in the first quarter of 2020 is unusually high. Other measures of financial market risk jumped to historic highs around that time. For instance, the VIX index closed at 208 percent on March 16, 2020, about 15 times the average closing value in the fourth quarter of 2019 (14 percent).

Figure A.3. Option-Implied Volatility during the First Quarter of 2020



Note: The shaded area covers March 17 to March 23, 2020. During this period, the Federal Reserve announced several liquidity facilities to support credit intermediation.

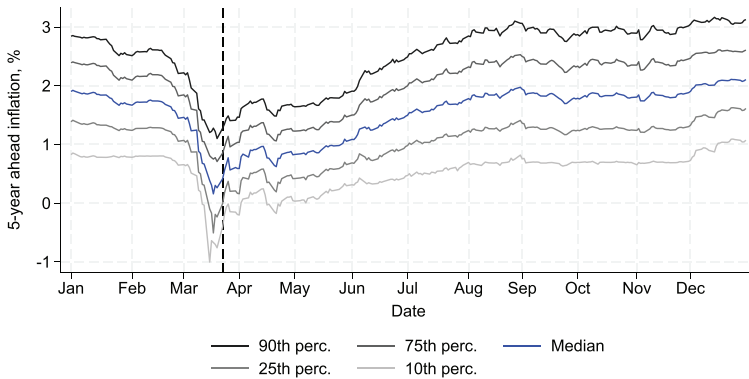
A.2.3 Implied Distribution Dynamics in Early 2020

Reviewing inflation densities during the pandemic can help to better understand whether information embedded in option prices reflects rapid shifts in economic conditions during a challenging period. Figure A.4 shows the time series of percentiles of implied densities, which make it easier to understand changes in the distributions over time.

The chart includes selected percentiles ranging from the 10th to the 90th, spanning 2020. The chart also shows March 23, 2020, when the Federal Reserve set up several liquidity facilities that supported credit markets. Starting in mid-February, implied distributions start shifting rapidly to the left as the impact of the pandemic had large negative effects on current and expected economic growth. The shift to the left was precipitous in March and started to revert as policymakers deployed significant resources to contain the economic fallout of the pandemic. By late summer, the distributions returned to pre-pandemic shapes.

Figure A.5 shows the overall change in percentiles between January 2 and March 23 (corresponding to the vertical line shown in the time series in Figure A.4). The bar chart represents the shift in the shape of the implied distribution. While the whole distribution

Figure A.4. Selected Percentiles of Option-Implied Inflation Distributions in 2020



Note: The vertical line shows March 23, 2020, when the Federal Reserve established liquidity facilities in support of corporate credit intermediation.

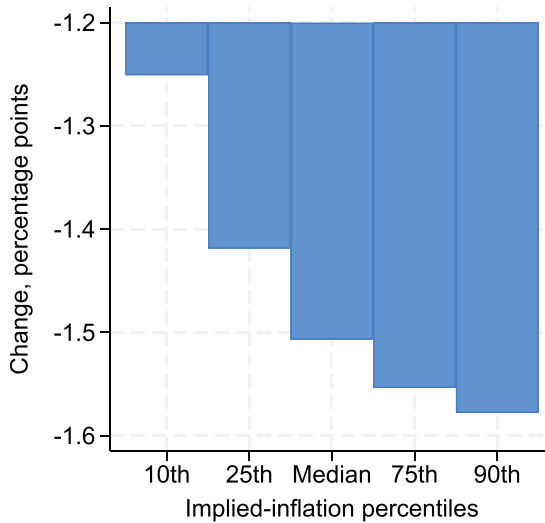
shifted left, as indicated by the drop in the median, the right tail compressed even further, as shown by the large decline in the 90th percentile.

A.2.4 Implied Moments after Key Monetary Policy Announcements

This section provides evidence on how implied inflation moments react to important announcements that shifted the monetary policy stance. Specifically, I compute the average change in implied volatility, skewness, and kurtosis following certain announcements that changed the Federal Reserve's balance sheet policy.⁹ I then compare these averages to average changes over the rest of the sample. As shown in Figure A.6, average month-on-month changes in implied moments after these events (blue dots) are outside of the 90

⁹The events are QE2 hinted (August 2010), Operation Twist announced (September 2011), Operation Twist extended (June 2012), QE3 expanded to include more Treasuries (December 2012), QE3 tapering begins (December 2013), QE3 ends (October 2014), Federal Reserve announces balance sheet normalization (June 2017), and Federal Reserve Chair emphasizes balance sheet flexibility if needed (January 2019).

Figure A.5. Change in Implied Percentiles, from January 2 to March 23, 2020



Note: On March 23, 2020, the Federal Reserve established liquidity facilities in support of corporate credit intermediation.

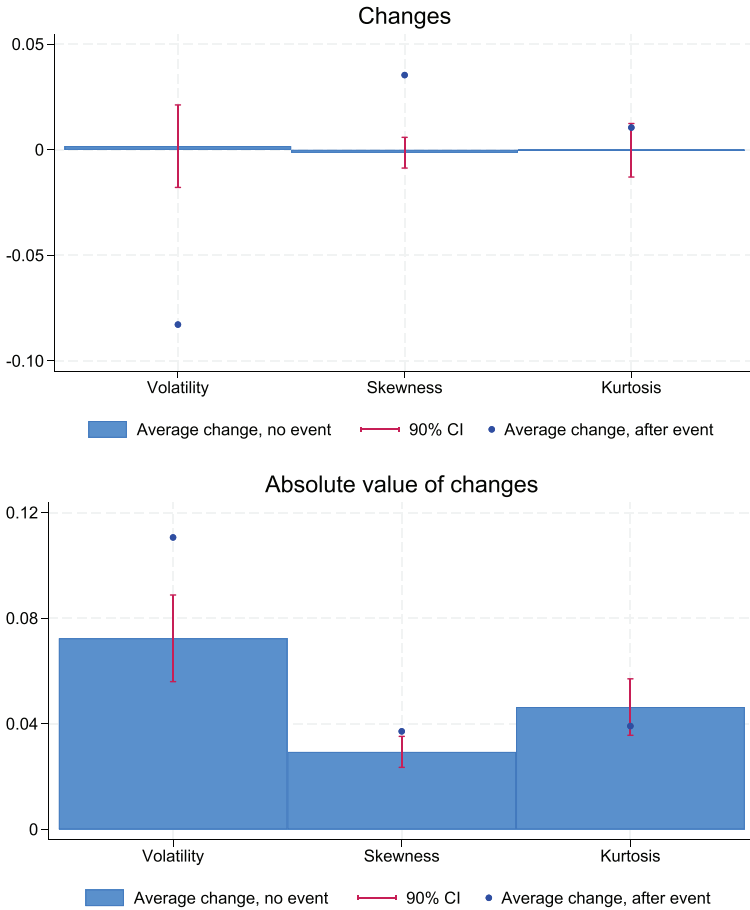
percent confidence intervals for average changes in the rest of the sample, except for kurtosis (top chart). While average changes over the full sample can be expected to be close to zero (the moments should be stationary), the same conclusions apply when considering the absolute values of changes (bottom chart).

On average, volatility decreases and skewness increases, meaning that—following significant monetary policy announcements—investors become less uncertain about the future path of inflation, and (due to the increase in skewness) the risk of low inflation subsides.

A.2.5 Implied Distributions after Selected QE Announcements

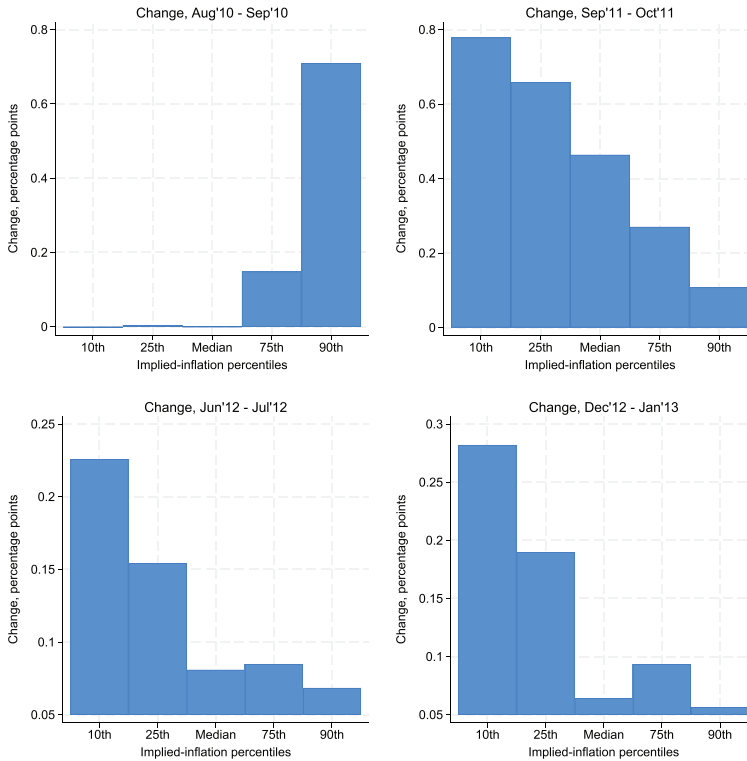
To illustrate the effect that significant announcements related to the monetary policy stance have on the implied distribution of inflation, the four charts in Figure A.7 show changes in selected percentiles

Figure A.6. Changes in Implied Moments after Key Monetary Policy Announcements



from the month in which an announcement was made to the following month. The charts refer to the following announcements: QE2 hinted (August 2010); Operation Twist announced (September 2011); Operation Twist extended (June 2012); and QE3 expanded to include more Treasuries (December 2012). In the first case, higher percentiles increased markedly, while the rest remained unchanged. As such, the distribution saw a thickening of the right tail. In contrast, each of the three other announcements saw an increase in the

Figure A.7. Changes in Implied Distribution Percentiles after QE Announcements



lower percentiles, indicating a shift in the left-tail probability mass toward the median and a declining risk of low inflation.

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