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Wage-Price Spirals: A Risk-Based Approach

Michal Franta and Jan Vlček*

Abstract

The discussion about wage-price spirals has revived recently due to the wave of elevated inflation. We propose a framework based on quantile regression to assess the risk of simultaneous rapid growth in wages and prices. We show that for the UK and US, the risk of such growth in wages and prices coincides with the risk of their heightened persistence or even acceleration. The materialization of the risk then defines the occurrence of a wage-price spiral. The proposed framework allows us to identify forthcoming episodes of elevated wage-price spiral risk and episodes of its materialization. Moreover, we show that the risk of a wage-price spiral varies with the usual business cycle factors and monetary policy. Based on the outcomes, we suggest general lessons for policymakers. Finally, the framework is also applied to the Czech Republic to show its usefulness and properties in the case of short time series.

Abstrakt

V důsledku vlny zvýšené inflace došlo v nedávné době k oživení diskuse o mzdově-cenových spirálách. Pro vyhodnocení rizika souběžného rychlého nárůstu mezd a cen navrhujeme rámec založený na kvantilové regresi. Dokládáme, že v případě Spojeného království a Spojených států riziko takového nárůstu mezd a cen splývá s rizikem jejich zvýšené perzistence či dokonce akcelerace. Materializace tohoto rizika pak definuje výskyt mzdově-cenové spirály. Navrhovaný rámec nám umožňuje identifikovat blížící se období zvýšeného rizika mzdově-cenové spirály a období jeho materializace. Dále ukazujeme, že riziko mzdově-cenové spirály je proměnlivé v závislosti na obvyklých faktorech hospodářského cyklu a měnové politice. Na základě těchto výsledků navrhujeme obecná poučení pro tvůrce měnové politiky. Nakonec aplikujeme tento rámec také na Českou republiku, abychom ukázali jeho užitečnost a vlastnosti i v případě krátkých časových řad.

JEL Codes: C32, E24, E31.

Keywords: Inflation, inflation and wage growth at risk, quantile regression, wage-price spiral.

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1. Introduction

After a decade of low inflation following the global financial crisis, a mix of supply and demand shocks pushed inflation well above inflation targets in the early 2020s. Concerns appeared once again that wages and prices could start feeding off each other, creating a wage-price spiral, as observed in some economies during the 1970s. As a consequence, the risk of a wage-price spiral affected policymakers' decisions.[1] Some have even declared its presence.[2,3]

We put forward an empirical framework able to assess the risk of a wage-price spiral, signalize its materialization, and analyze the economic circumstances accompanying it. The framework is based on the joint distribution of nominal wage and price growth conditional on macroeconomic variables. We start with the 'north-east' tail of the distribution, which represents simultaneous and fast growth in wages and prices diverting from the economic fundamentals. Simultaneous growth in wages and prices is a natural characterization of the wage-price nexus when feedback effects typical of spirals materialize. Furthermore, as the distribution is conditional on macroeconomic variables, realizations in the tail represent simultaneous growth in wages and prices above and beyond what is consistent with the business cycle position of the economy and the usual (often linear) relationships.

The empirical findings presented in this paper show that for the UK and US, the 'north-east' tail also represents the risk of highly persistent wages and prices and their potential acceleration. Therefore, a wage-price spiral is defined as the realization of the tail, i.e. a tail event, and the tail itself represents the risk of a wage-price spiral (wage growth and price growth at risk). Such a risk-based approach to wage-price spirals contrasts with the literature, which does not consider the probabilistic aspect of observed wages and prices.

More precisely, we apply a risk-based approach to wage-price spirals for the US and the UK since the 1970s and for the Czech Republic since 2000. In the case of the Czech Republic, we discuss the economic and econometric issues related to a short time series. In the first step, an index of wage and price inflation is set up, which is a projection of observations from the wage growth-price growth space to a single dimension. Instead of examining the 'north-east' tail of the conditional joint distribution of two variables, we deal with the upper tail of the conditional distribution of the index. Based on simulations of a standard structural model, we demonstrate that such projection indeed imprints the 'north-east' tail of joint distribution onto the upper tail of the index distribution

[1] The Monetary Policy Committee of the Central Bank of Iceland in its statement from May 24, 2023 asserts: "*In light of this* [observed economic activity, inflation and long-run inflation expectations]*, it is necessary to tighten the monetary stance still further. It is especially important to prevent a wage-price spiral, particularly in view of the strong demand pressures in the economy and how soon the next round of wage negotiations will begin.*"

[2] Bank of England governor Andrew Bailey pointed out the effects underlying the wage-price spiral in his speech on May 17, 2023, stating that "*Some of the strength in core inflation reflects the indirect effects of higher energy prices. But it also reflects second-round effects as the external shocks we have seen interact with the state of the domestic economy.*"

[3] The minutes of the Czech National Bank's Board meeting on May 3, 2023 states: " *… The threat of inflation expectations becoming unanchored and the related risk of a wage-price spiral also remained significant risks in the same [inflationary] direction. … Karina Kubelková expressed concern about the risk of a wage-price spiral, the partial materialisation of which was already being signalled by the available analyses. Tomáš Holub agreed, adding that, despite the significant real decline in wages, the nominal wage growth of around 10% represented a further increase in firms' costs, one which could feed through to prices and thus exacerbate the price spiral. …"*

i.e. the high-index periods almost always correspond to periods of high wage growth *and* high inflation.

The upper tail of the distribution of the wage-price index is then predicted as a function of current nominal and real economic conditions and examined using quantile regression. The distribution is also conditional on the nominal interest rate to gauge the role of systematic monetary policy. Finally, we assess the role of exogenous factors (exchange rate and PPI). The list of determinants extends the wage and price versions of the Phillips curve as the tails can be affected by variables other than those entering the usual business cycle relationship. The estimation results show that real economic slack and interest rates predict the risk of a wage-price spiral. In addition, exogenous factors play an important role in the predictive power of the upper tail of the index for open economies such as the UK and the Czech Republic.

The estimated upper quantile of the index distribution suggests the evolution of the risk of a wage-price spiral over time. In addition, a comparison of the predictive upper quantiles and the ex-post observed values of the wage-price index point to periods of risk materialization, i.e. periods exhibiting wage-price spirals. For the UK and US, the results indicate two main periods of wage-price spiral materialization: the 1970s, which is often regarded as a period with characteristics of a wage-price spiral, and the recent period related to the outbreak of Covid-19 and the war in Ukraine. The detailed discussion of the two episodes presented in this paper serve as in-sample validation of the approach.

In general, it turns out that the evolution of nominal wages and prices exhibits nonlinear behavior which can take the form of a regime change, giving rise to periods of highly persistent inflation and wage growth. However, economic policies can address the issue. The risk-based approach presented here provides a framework, which helps to set an appropriate policy response. Note that the framework can be useful not only in the case of wage-price spirals, i.e. where the upper tail relates to the risk of more persistent nominal variables. Policymakers pursuing price stability, who also act as risk managers, seek to mitigate the risk of high growth of nominal variables, which in and of itself prevents the materialization of a spiral.

The paper ties together the literature on wage-price spirals and the Macro-at-Risk literature. In addition, it is motivated by recent empirical studies on regime changes and the behavior of inflation and wages in a high-inflation environment.

The literature on wage-price spirals is scarce and there is no consensus on the definition of a wage-price spiral. While simultaneous growth in wages and prices is common to all available definitions, other aspects differ significantly. Empirical definitions consider specific dynamics of wage and price growth over time or their specific iterations. Boissay et al. (2022) consider the situation of nominal wage growth exceeding inflation, while Alvarez et al. (2022) define the spiral as periods in which wages and prices accelerate for at least three out of four consecutive periods. Theoretical definitions consider a wage-price spiral to be a consequence of a structural shock and thus the behavior of wages and prices is an integral part of the underlying model’s dynamics (Blanchard, 1986, Lorenzoni and Werning, 2023).

In this paper, the definition of a wage-price spiral is closer to empirical definitions in that it does not uncover any causal relationships constituting feedback/mutually reinforcing effects between wages and prices. It focuses on reduced-form evidence. Furthermore, our definition is not based on the conditional mean relationships between wages and prices. This contrasts our approach with theoretical definitions, which impose linear dynamics, a single regime and Gaussianity through variants of New Keynesian-type models.

The empirical evidence provided in the literature on wage-price spirals, despite different definitions, shows that periods of sustained acceleration of wages and prices are rare (Alvarez et al., 2022). Even the current period of elevated inflation does not relate to any clear and broadly observed rise in wages (Boissay et al., 2022).[4] We add a probabilistic perspective on the results found in the literature. Therefore, in the recent period, for example, we have witnessed an increase in the risk of a wage-price spiral in all the countries examined, regardless of the moderate and narrow-based rise in wages.

Our risk-based approach to the wage-price spiral is inspired by the Macro-at-Risk literature. This stream of literature extends the usual conditional mean analyses to whole conditional distributions and can thus shed some light on the risks related to macroeconomic variables. If a distribution tail is of importance to a policymaker, the approach can provide important policy insights. The flagship of this stream of literature is the Growth-at-Risk concept introduced in Adrian et al. (2019). Policymakers dealing with the real-economy consequences of financial crises use it to exploit the estimates of Growth-at-Risk, i.e. the lower tail of output growth distribution, to assess financial stability. In this paper, the tail capturing the fast growth of nominal wages and prices is what ultimately interests policymakers as this situation represents very serious circumstances as demonstrated by the experience in the 1970s.

Another subject in the Macro-at-Risk literature, which is tightly connected to the topic of this paper, is Inflation-at-Risk. Banerjee et al. (2020) – for the panel of advanced and emerging market economies – and López-Salido and Loria (2022) – for the US and the euro area – found how important changes in the tails of the conditional distribution of one-year-ahead inflation can be hidden behind the observed evolution of prices.

In this paper, another dimension consisting of nominal wages is added to inflation in order to understand ‘wage growth and inflation’ at risk. Adding a dimension contrasts with the Macro-at-Risk literature, which is limited to single-dimensional distributions. The wage-price spiral is inherently a two-dimensional phenomenon and an approach dealing with a multi-dimensional set up is needed. Franta (2023) surveys various approaches based on multiple-output quantile regression. In this paper, a directional approach based on projections from a multi-dimensional data cloud to a single-dimensional space is employed.

Finally, our approach adds to the recent literature on changes in the dynamics of nominal macroeconomic variables in a high-inflation environment. López-Salido and Loria (2022) demonstrate how the different inflation regimes identified by the Markov-switching regression model of US inflation correspond to quantile regression results. The upper tail of the conditional distribution of inflation corresponds to a 'high inflation' regime. Borio at al. (2023) discusses stylized facts related to a high inflation regime such as the tight link between wages and prices. We add to this stream of evidence by providing some evidence on the way in which wage-price spirals represented by the materialization of wage-price spiral risks can be viewed as a regime change.

[4] Similar conclusions for the Netherlands can be found in Bolt et al. (2022).

The structure of the paper is as follows. Section 2 introduces the wage-price index. The theoretical framework behind our empirical analysis is presented in Section 3. The aim of the section is to justify the use of a wage-price index and to suggest a possible interpretation of the empirical results. The next section presents the data and empirical approach. The results are discussed in Section 5. Section 6 concludes, and additional results and robustness checks can be found in the appendices.

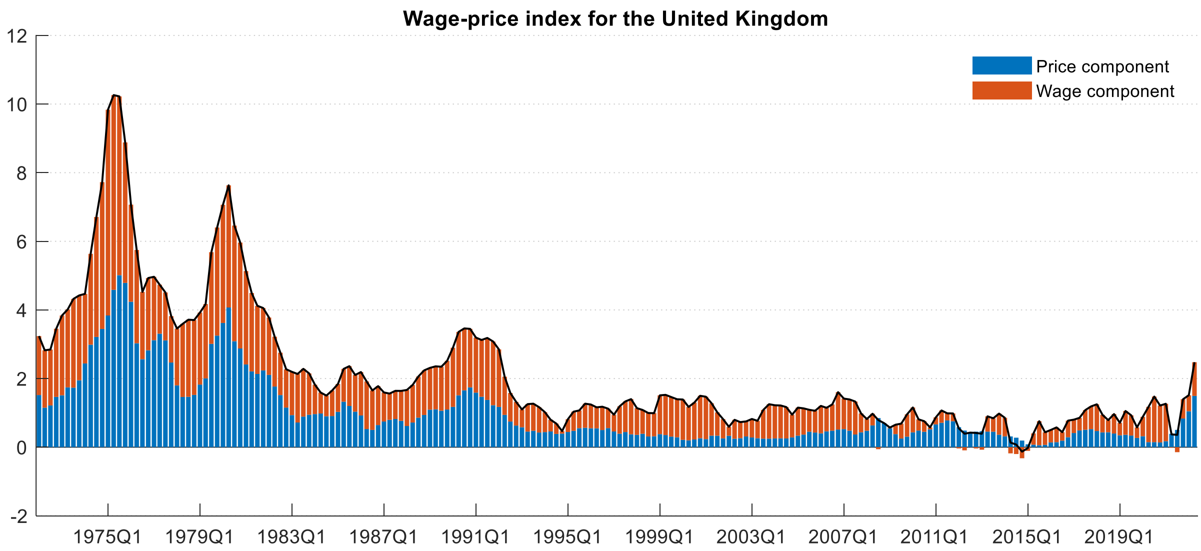
2. Wage-Price Index

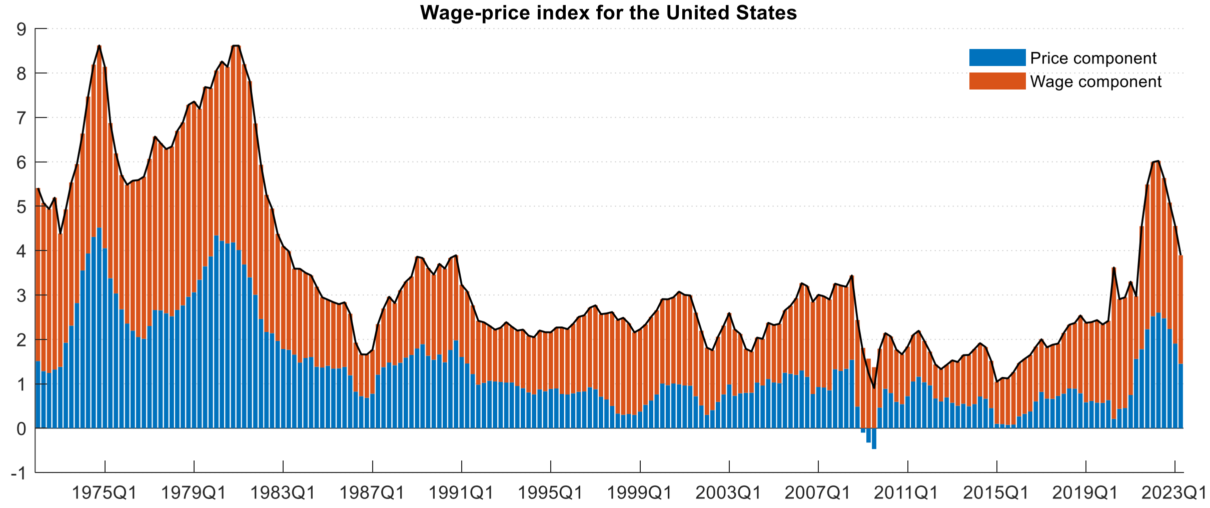
We construct an index to capture the 'north-east' tail of the conditional joint distribution of wage growth and price growth by a single quantity. The wage-price index is defined as the weighted sum of wage growth and price growth. The growth is defined as year-on-year change and quarter-on-quarter change respectively and the weights are reciprocals of the respective growth standard deviations:

$$index_t^h = 100\left[\frac{1}{std(\Delta_h p_t)}\Delta_h p_t + \frac{1}{std(\Delta_h w_t)}\Delta_h w_t\right], \quad h = 1.4 \tag{1}$$

where p_t and w_t are the logs of prices and wages, and Δ_h stands for the difference over h periods.

Figure 1: The Wage-Price Index for the United Kingdom (upper panel) and the United States (lower panel) and Its Components





Note: The index and its components are based on year-on-year growth rates.

The two components of the index are strongly correlated.[5] Such an observation links the actual data with the structural model in Section 3, which implies a positive cross correlation of wage and price growth. In addition, the positive correlation implies that high (low) values of the index can be reached only if both prices and wages are growing fast (slowly). This is apparent in Figure 1, which shows the wage-price index for the UK and US. Nevertheless, we are interested in high values in terms of realizations from conditional distributions. That is why an empirical model is set up in subsection 4.2 to control for drivers of inflation and wage growth.

The highest values of the index can be observed for both countries in the 1970s, when both components also separately achieve historical highs. This period witnessed oil price shocks, which affected the nominal side of economies significantly. Expectations played an important role as well. The recent periods, including the Covid-19 shock and the invasion of Ukraine, result in similarly high values, especially for the US.

3. Theoretical Framework

This section discusses the link between the tails of the joint distribution of wages and prices and the tail of the wage-price index distribution. We assume a closed economy model with sticky prices and wages as in Erceg et al. (2000) and Galí (2008). The model consists of households and firms, both monopolistically competitive, and a central bank. The log-linearized first order conditions of optimization problems can be reduced to four behavioral equations.

The first is aggregate demand, equation (2). This is in fact the Euler equation for the output gap, which corresponds to the consumption gap, $\hat{c}$ if a closed economy without investment is assumed:

$$\hat{c}_t = \frac{h}{1+h}\hat{c}_{t-1} + \frac{1}{1+h}E_t\hat{c}_{t+1} - \frac{1}{\sigma}\frac{1-h}{1+h}\,(i_t - E_t\pi_{t+1}) + \varepsilon_t^{\hat{c}}, \tag{2}$$

[5] The correlation coefficient for the UK equals 0.68 for quarterly growth in wages and prices and 0.87 for inflation and wage growth in terms of year-on-year changes. For the US, the correlation coefficient equals 0.63 and 0.81 respectively. In contrast, the correlation coefficient is lower for the Czech Republic, with values of 0.20 and 0.24.

where i is the nominal interest rate, π is headline inflation, and $\varepsilon^{\hat{c}}$ is a demand shock. Parameter h is a habit persistence parameter and ρ is a risk aversion parameter determining the elasticity of intertemporal substitution. The Euler equation captures intertemporal substitution and it can be derived from household maximization of lifetime utility function, equation (3). Each *i-th* household consumes a basket of goods, $C(i)$, buys financial securities, $B(i)$, and is an imperfectly competitive supplier of a differentiated labor service, $L(i)$. Households maximize the present value of the lifetime utility with internal habit persistence:

$$E_t \sum_{k=0}^{\infty} \beta^k [\frac{(C_{t+k}(i) - hC_{t-1+k}(i))^{1-\sigma}}{1-\sigma} + (1 - L_{t+k}(i))] \quad (3)$$

subject to the budget constraint holding at each point of time

$$(1 + i_t)B_{t-1}(i) + W_t(i)L_t(i) + \Gamma_t(i) = P_t C_t(i) + B_t(i), \quad (4)$$

where $W(i)$ is nominal wage related to specific labor $L(i)$, $\Gamma(i)$ are profits distributed from firms, and β is the deterministic discount factor.

On the labor market, households act as wage setters facing a constant probability $(1 - \omega^w)$ of re-optimizing wage contracts. Those labor suppliers who cannot re-optimize use a full backward indexation on past aggregate wage growth. This staggered wage setting leads to deviations of real wages from the marginal rate of substitution between consumption and leisure. The log-linearized first-order conditions corresponds to the second equation of the model for wage inflation, π^w:

$$\pi_t^w = \frac{1}{1+\beta} \pi_{t-1}^w + \frac{\beta}{1+\beta} E_t \pi_{t+1}^w + \frac{(1-\omega^w)(1-\omega^w\beta)}{\omega^w(1+\beta)} \left(-\widehat{wr}_t + \left(\sigma + \frac{1}{1-\alpha} \right) \hat{c}_t \right) + \varepsilon_t^{\pi^w}, \quad (5)$$

where $\widehat{wr}$ is a real wage gap and ε^{π^w} is a wage cost push shock.

The third model equation is the price Phillips curve, equation (8). The model assumes monopolistically competitive firms producing differentiated goods consumed by households. Firms use a labor bundle, N, to produce goods. The *J*-th firm sets the price and demands labor to maximize profits:

$$\max\left(P_t(j)Y_t(j) - W_t N_t(j)\right) \quad (6)$$

given the production function

$$Y_t(j) = N(j)^{1-\alpha}. \quad (7)$$

However, when setting prices, firms face a probability of re-optimizing prices $(1 - \omega^p)$. Assuming full backward indexation leads to the standard Phillips curve:

$$\pi_t = \frac{1}{1+\beta} \pi_{t-1} + \frac{\beta}{1+\beta} E_t \pi_{t+1} + \frac{(1-\omega^p)(1-\omega^p\beta)}{\omega^p(1+\beta)} \left(\widehat{wr}_t + \frac{\alpha}{1-\alpha} \hat{c}_t \right) + \varepsilon_t^{\pi^p}, \quad (8)$$

where ε^{π^p} is a price cost push shock.

Fourth, a monetary policy rule closes the model, i.e. it anchors inflation expectations.

$$i_t = \rho_i i_{t-1} + (1 - \rho^i)\left(\gamma^\pi \pi_t^4 + \gamma^{\hat{c}} \hat{c}\right), \quad (9)$$

where π^4 is year-on-year inflation, ρ^i is an interest rate smoothing parameter, γ^π is the weight on inflation in the policy rule, and $\gamma^{\hat{c}}$ is the weight on the output gap.

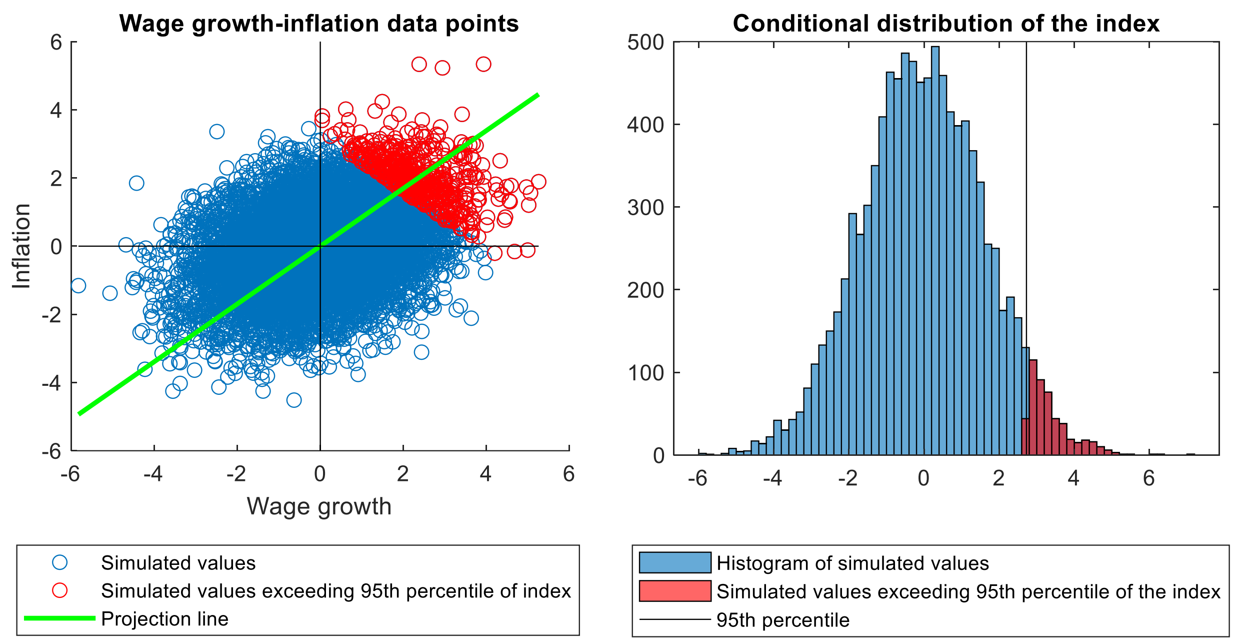
The model is calibrated. See Table 1 for the values of the parameters.

Table 1: Calibration of Model Parameters

Parameter	Meaning	Calibration
h	Habit persistence	0.75
β	Deterministic discount factor	0.99
σ	(1/σ) is elasticity of intertemporal substitution	2
α	Output elasticity with respect to labor	0.6
ω^p	$(1-\omega^p)$ probability to re-optimize price contracts	0.7
ω^w	$(1-\omega^w)$ probability to re-optimize wage contracts	0.8
ρ_i	Policy rule smoothing	0.75
γ^π	Weight on inflation in the policy rule	1.5
$\gamma^{\hat{c}}$	Weight on the output gap in the policy rule	0.25

The structural model is employed to illustrate the relationship between the conditional joint distribution of wage and price growth and the conditional distribution of their weighted average.

Figure 2: Scatter Plot of Simulated Wage Growth and Inflation (left panel) and the Corresponding Conditional Distribution of the Wage-Price Index (right panel)



The upper tail of the conditional distribution of the simulated index corresponds to the 'north-east' tail of the conditional joint distribution of wage growth and inflation. We simulate inflation, wage growth and the index one period ahead using 10,000 draws of all structural shocks.[6] The left panel of Figure 2 shows a scatter plot of simulated values of wage growth and inflation. If the data points

[6] We assume unit shock variances along with the normal distribution of shocks. We fix the values of the variables in the previous periods that enter the model equations at their respective steady state values. The results are robust with respect to the variance of shocks as all the shocks in the model imply the co-movement of prices and wages.

constituted by the two variables are projected on the line with the direction given by their standard deviations (the green line), the resulting index has the conditional distribution presented on the right panel. The upper tail of the index (the 95th percentile indicated by the vertical line on the right panel) corresponds to the 'north-east' tail of the conditional joint distribution of wage growth and price growth (indicated by red dots on the left panel). Therefore, the upper tail of the index distribution can be examined in order to shed some light on the simultanous and rapid growth of wages and prices.

The correspondence between the 'north-east' tail and the upper tail of the distribution of the index follows directly from the fact that the calibrated structural model implies a positive correlation between wage growth and inflation and the relationship between the two is linear. More importantly, the correspondence remains even if the linear assumption is dropped. The positive instantaneous cross-correlation is a natural outcome as both prices and wages are nominal variables.[7]

Two ways of departing from the linearity assumption are considered – wage indexation and regime switching. These are often mentioned in the literature as possible sources of changes in the dynamics of inflation (Borio et al., 2023). Both situations are modeled in a very simplistic manner.

Wage indexation is modeled so that when the observed rise in prices exceeds 1.5 times the standard deviation of inflation, wage growth is set to be equal to the observed inflation. The regime change is modeled such that we assume that there are two regimes given by different steady states of nominal variables (inflation and nominal wage growth). The transition matrix between the two regimes is defined as follows:

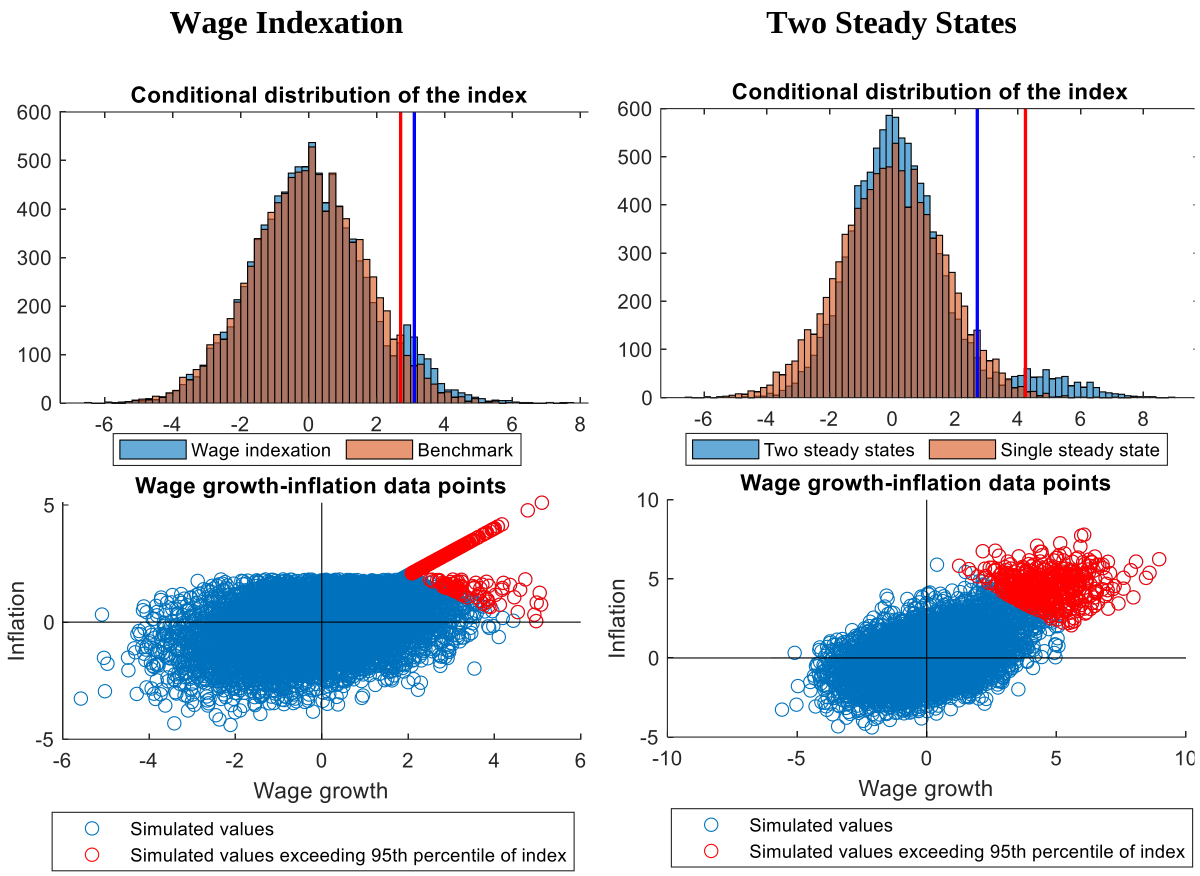
$$T = \begin{bmatrix} 0.95 & 0.05 \\ 0.60 & 0.40 \end{bmatrix}. \tag{10}$$

The 'normal' regime with steady-state inflation and nominal wage growth equal to zero is very persistent. There is only a 0.05 probability of a switch from the 'normal' regime to a 'high inflation' regime. The 'high inflation' regime corresponds to the 'normal' regime but steady-state inflation and nominal wage growth equal to four.[8] In the 'high inflation' regime, there is a 0.40 chance of staying at the regime and a 0.60 probability of returning to the 'normal' regime.

[7] Even if the model was extended by a productivity shock, the cross correlation would be non-negative.

[8] If the simulated draws from the conditional distribution of inflation and the conditional distribution of nominal wage growth are from the 'high inflation' regime, they are simply increased by four.

Figure 3: Simulated Conditional Distributions of the Index in a Model with Wage Indexation and with Two Steady States



Note: The vertical lines denote the 95th percentile.

Figure 3 demonstrates that the 'north-east' tail of the wage growth-price growth conditional distribution corresponds to the upper tail of the conditional distribution of the index for both wage indexation and regime change. Moreover, it demonstrates two additional aspects. First, wage indexation and regime change represent an example of how non-normal conditional distributions can arise. Consequently, this is when quantile regression suggests nontrivial effects of explanatory variables on the quantiles of the index distribution.

Second, regime change can explain why tail events might be observed in the actual data in several consecutive quarters. Assuming the shocks are independently and identically distributed according to the normal distribution (as in the case of a single regime), the probability of observing the index in the upper tail of its conditional distribution for two quarters is $(0.05)^2 = 0.0025$, which means 2.5 occurrences in 1,000 quarters. However, in our empirical application (~230 observations for the US), we observe the periods of several quarters in the upper tail more often – we observe three occurrences for the US (Table 5, second column). Our example with two steady states provides a possible reason. The probability of observing two consecutive simulated values in the upper tail equals 0.013, which roughly corresponds to the number of observed wage-price episodes for the US.

4. Data and Empirical Model

4.1 Data

Aside from inflation and wage growth, the data employed in the analysis include a real economic indicator (output gap), a labor market conditions measure (unemployment gap), a monetary conditions indicator (interest rate), and an indicator of supply shocks (PPI). The exchange rate (real exchange rate) is also included for the United Kingdom and the Czech Republic. The data definitions and sources are listed in Table A1 in Appendix A. The data sets cover the period 1965 Q1–2023 Q2 for the United States, 1971 Q1–2022 Q4 for the United Kingdom, and 2000 Q1–2023 Q1 for the Czech Republic. All data, except for interest rates, are seasonally adjusted and log transformed. All gaps are computed using the HP filter except the Czech output gap which is the Czech National Bank's estimate. The real exchange rates are the effective exchange rates for the Czech Republic and the UK. The real exchange rate is specified in gap form for the Czech Republic because the Czech economy has been going through the process of economic convergence, which implies an appreciation trend.

All variables (except interest rates) enter the estimations in growth rates (or gaps of variables in growth rates). In this paper, we work with two definitions of growth rates – quarter-on-quarter change and year-on-year change. The annual growth rate is chosen as it corresponds to the horizon usually considered in the related literature. Policymakers are interested in the one-year horizon as it encompasses the horizon they can often affect the most using the available policy instruments. The quarterly growth rates are employed because the evolution of the variable can be directly attached to the shock, which occurred in a particular quarter. Such distinction helps us to discuss whether a regime change or a series of shocks occurred when observing tail events for several quarters in a row in our empirical analysis.

4.2 Empirical Model

The relationship between the predictive distribution tail of the wage-price index and the macroeconomic variables is estimated using quantile regression. Quantile regression relates the future conditional quantile of the distribution of the index to macroeconomic variables and a constant within a linear relationship:

$$\hat{Q}_\tau\left(index_{t+h}^h | x_t\right) = x_t \hat{\beta}_\tau \qquad h = 1.4 \tag{11}$$

where $\tau = 0.95$ is the quantile characterizing the tail of the distribution and $\hat{\beta}_\tau$ is a $kx1$ $-$dimensional vector of the estimated quantile-specific parameters.

The vector of parameters $\hat{\beta}_\tau$ is obtained in the following optimization problem (Koenker and Bassett, 1978):

$$\hat{\beta}_\tau = \underset{\beta_\tau \in \mathbb{R}^k}{\arg\min} \sum_{t=1}^{T-h}\left[\rho_\tau\left(index_{t+h}^h - x_t\hat{\beta}_\tau\right)\right], \quad h = 1.4 \tag{12}$$

where $\rho_\tau(\cdot)$ is a check function defined as follows:

$$\rho_\tau(u) = u\left(\tau - \mathbf{1}_{\{u<0\}}\right), \tag{13}$$

with $\mathbf{1}_{\{u<0\}}$ denoting the indicator function.

Two sets of specifications of the right-hand side of the model, x_t, are estimated for each country. First, we estimate a simple specification containing only a constant, a current index and a specific macroeconomic variable. This simple version of the model is used to analyze the tail behavior of the wage-price index in response to key macroeconomic variables.

The second, a full specification of the model, uses a potentially larger set of macroeconomic determinants to predict the index's tail. The choice of variables employs a forward iterative procedure. More precisely, the simple specifications are considered as a starting point. The specification with the lowest quantile Bayesian information criterion (qBIC) is kept.[9] Each covariate is then added in turn and again the specification with the lowest qBIC is kept. The procedure is repeated until no decrease in qBIC is recorded during the addition of covariates. The resulting specification of the model is used to predict the upper tail of the index. The materialization of the risk is then identified by comparing the upper tail and the index realization.[10]

The motivation behind the simple specifications draws on the theory of extremal quantile regression i.e. quantile regression applied to the tails of the conditional distribution. To predict the tails accurately, the usual estimator of Koenker and Bassett (1978) need not be sufficient. Chernozhukov (2005) discusses an extension based on extreme value theory and Chernozhukov and Fernández-Val (2011) suggest a rule of thumb when the usual quantile regression and the extended version are more accurate. They demonstrate that if the sample size relevant for the inference and adjusted for the number of covariates in the model (11), $\frac{(1-\tau)T}{k-1}$, exceeds 15, then the standard quantile regression estimator is sufficient.

It is difficult to meet the above criteria with the available data sample for upper tails. For the US, the criterion equals to $\frac{0.05*230}{2} = 5.75$, which is below the suggested threshold. However, according to Chernozhukov and Fernández-Val (2011), the 85th percentile provides accurate quantile regression as the estimates are: $\frac{0.15*200}{2} = 15$ for the UK and $\frac{0.15*230}{2} = 17.25$ for the US. To address the issue of a low number of observations in the extreme tails, we follow the approach of Bondell et al. (2010) and impose that the fitted $0.05th, 0.10th, \dots, 0.90th, 0.95th$ quantiles do not cross each other over the whole sample. This is a way of employing information far from the tail for the estimation of the tail. By imposing that the fitted 85th percentile does not cross the 95th percentile (or the 90th either), some accuracy of the estimation of the tail is guaranteed. In what follows, we impose a 'no-quantile-crossing' property during the estimation procedure.[11]

Furthermore, note that the accompanied uncertainty related to the parameter estimates is obtained using the moving block bootstrap as in Fitzenberger (1997), who shows that the bootstrap procedure provides heteroscedasticity and autocorrelation consistent standard errors. The no-quantile-crossing condition is imposed when the model is re-estimated on bootstrapped samples. Finally, the goodness of fit (the quantile R^2 of Koenker and Machado, 1999) is presented with the estimation results. It

[9] The quantile BIC is defined based on loss in (12), i.e. $qBIC = k \log T + n \log(1/T) \sum \rho_\tau$, where T denotes the number of observations and k represents the number of predictors. The qBIC penalizes the number of model parameters more than quantile Akaike information criterion, which is the reason for the choice of this criterion.

[10] The observed data are realizations from the distribution conditional on all the relevant macroeconomic variables. We therefore employ a full model specification to relate the fitted upper tail to the observed data.

[11] The 'no-quantile-crossing' condition can be viewed as an alternative to the usual approach of smoothing the conditional distribution. In the Macro-at-Risk literature, skewed-t distribution is usually employed to fit estimated quantiles.

expresses the loss improvement of conditional regression quantiles over the historical unconditional quantiles.

5. Empirical Results

The estimation results for the UK and US are presented in the first subsection. This is followed by an analysis of the Czech data, which involves a short time series. Finally, the last subsection presents how a risk-based approach to wage-price spirals can guide policymakers.

5.1 United Kingdom and United States

In this subsection, we describe the results related to the upper tail of the conditional distribution of the wage-price index. These results are the outcomes of simple specification models. We then discuss the results drawing on the relationship between the ex-post observed index and the upper tail of its predictive distribution. In this case the assessment relies on the full model specification.

Table 2 and Table 3 report the estimation results for the simple specifications of the quantile regression model (11). The results for both the upper tail represented by the 95^{th} percentile and the median (the 50^{th} percentile) are presented. The median is reported for comparison in order to shed some light on the differences in the dynamics of the tail and the median.

The main finding, which is robust over all simple specifications in both countries, is that the conditional distribution of the index encompasses the qualitatively different dynamics of nominal variables. While the successive realizations from the center of the conditional distribution exhibit stationary behavior, explosive dynamics of the index cannot be ruled out for the tail. The possibility of nonstationary successive realizations from the upper tail corresponds to the nature of the wage-price spiral. The term ‘spiral’ evokes interactions between wages and prices in a self-reinforcing process resulting in an explosive path of the two variables. Therefore, the realization of the index from the upper tail is denoted as a wage-price spiral.

More precisely, for both the UK and US and all simple specifications, the hypothesis that the coefficient of the current index exceeds one can be rejected for the median of the conditional distribution but cannot be rejected for the 95^{th} percentile of the conditional distribution. An estimated coefficient of below one implies stationary behavior of the realizations from the median of the predictive distribution. On the other hand, a coefficient equal to or exceeding one means that two successive realizations from the tail imply, ceteris paribus, at least constant change of the index i.e. the acceleration of wages and prices.

Furthermore, the successive realizations from the upper tail exhibit higher persistence than those from the center of the distribution. The amount of evidence for the hypothesis of different coefficients of the current index for the upper tail and median is close to conventional levels and statistically significant in some cases for the UK. We do not point out a specific economic reason for the different behavior of the tail and center of the conditional distribution. Nevertheless, the literature suggests changes in the inflation expectation formation, the market power of firms and wage indexation to prices as prominent reasons (see e.g. Bolt et al., 2022). The simulations in Section 3 suggests how wage indexation, for example, results in different dynamics of realizations from the upper tail and center of the distribution of the index.

Table 2: Quantile Regression Estimation for Index of Quarter-on-Quarter Change of Wages and Prices, United Kingdom

	95 perc	50 perc	95 perc	50 perc	95 perc	50 perc	95 perc	50 perc	95 perc	50 perc
Constant	1.40	0.46	1.44	0.37	1.46	0.36	1.42	0.30	-2.81	-0.47
	(1.10,1.87)	(0.20,0.58)	(1.15,1.85)	(0.11,0.21)	(1.08,2.01)	(0.11,0.54)	(1.13,1.92)	(0.08,0.52)	(-5.97,-0.28)	(-1.47,1.27)
Index	1.15	0.74	1.20	0.74	1.16	0.67	1.06	0.76	1.00	0.74
	(0.82,1.28)	(0.63,0.92)	(0.84,1.27)	(0.66,0.92)	(0.67,1.21)	(0.52,0.84)	(0.85,1.28)	(0.67,0.94)	(0.84,1.23)	(0.64,0.94)
	[0.86,1.22]	[0.65,0.89]	**[0.88,1.23]**	**[0.68,0.88]**	[0.74,1.18]	[0.55,0.81]	**[0.90,1.26]**	**[0.68,0.90]**	[0.88,1.20]	[0.67,0.90]
Unemployment gap	**-0.61**	**-0.28**								
	[-1.02,-0.03]	[-0.41,-0.10]								
Output gap			0.14	0.11						
			[-0.12,0.20]	[-0.02,0.13]						
PPI growth					0.08	0.11				
					[-0.02,0.38]	[-0.03,0.30]				
Interest rate gap							**-0.30**	**-0.14**		
							[-0.38,-0.10]	[-0.20,-0.06]		
Real exchange rate									**3.60**	0.73
									[1.89,5.34]	**[-0.44,1.29]**
No. of observations	205	205	205	205	205	205	205	205	205	205
Quantile R2	0.57	0.41	0.56	0.41	0.56	0.41	0.58	0.42	0.58	0.41

Notes: Central 90% confidence bands based on 1,000 bootstrapped samples are reported in parenthesis. Central 80% confidence bands based on 1,000 bootstrapped samples are reported in brackets. The 90% confidence band is used to illustrate the amount of evidence for two-tailed hypotheses, the 80% confidence band is used to illustrate the amount of evidence for one-tailed hypotheses. The estimates in bold indicate that the amount of evidence for a positive/negative coefficient corresponds to 10% level of significance. Bolded intervals indicate that the amount of evidence for different coefficients corresponds to a 10% level of significance. 'No crossing' of the fitted quantiles imposed during the estimation and inference.

Table 3: Quantile Regression Estimation for Index of Quarter-on-Quarter Change of Wages and Prices, United States

	95 perc	50 perc	95 perc	50 perc	95 perc	50 perc	95 perc	50 perc
Constant	1.79	0.66	1.97	0.60	1.85	0.52	1.82	0.64
	(1.10,2.27)	(0.36,1.02)	(1.01,2.30)	(0.25,0.94)	(1.04,2.72)	(0.14,0.93)	(1.10,2.67)	(0.17,0.86)
Index	0.93	0.81	0.93	0.80	0.92	0.86	0.93	0.85
	(0.85,1.10)	(0.66,0.92)	(0.88,1.14)	(0.67,0.95)	(0.73,1.18)	(0.68,1.00)	(0.79,1.11)	(0.70,0.97)
	[0.88,1.05]	[0.70,0.89]	[0.89,1.09]	[0.71,0.93]	[0.78,1.14]	[0.72,0.97]	[0.84,1.05]	[0.73,0.95]
Unemployment gap	0.07	**-0.10**						
	[-0.04,0.25]	[-0.15,-0.05]						
Output gap			0.18	0.18				
			[-0.23,0.32]	[-0.11,0.32]				
PPI growth					0.00	-0.07		
					[-0.12,0.13]	[-0.14,0.07]		
Interest rate gap							-0.04	**-0.10**
							[-0.24,0.03]	[-0.17,-0.04]
No. of observations	235	235	235	235	235	235	235	235
Quantile R2	0.50	0.45	0.51	0.44	0.50	0.44	0.50	0.45

Notes: Central 90% confidence bands based on 1,000 bootstrapped samples are reported in parenthesis. Central 80% confidence bands based on 1,000 bootstrapped samples are reported in brackets. The 90% confidence band is used to illustrate the amount of evidence for two-tailed hypotheses, the 80% confidence band is used to illustrate the amount of evidence for one-tailed hypotheses. The estimates in bold indicate that the amount of evidence for a positive/negative coefficient corresponds to 10% level of significance. 'No crossing' of the fitted quantiles imposed during the estimation and inference.

Regarding other covariates, the real effective exchange rate predicts positively related changes in the upper tail of the conditional distribution of the index for the UK (Table 2). Thus, the upper tail seems to follow an open economy Phillips curve relationship and real exchange rate appreciation reduces the size of extreme rises in wages and prices. Furthermore, the nominal policy interest rate in the UK predicts changes in the conditional upper tail. Systematic monetary policy predicts the changes in the upper tail – policy tightening predicts a fall in the tail and policy loosening predicts a rise in the tail. Systematic monetary policy thus plays the role of automatic stabilizer of the upper tail of the index in addition to its mean impact on the nominal variables.

There is also some evidence on the effects of real economic activity. Specifically, a tighter labor market implying a lower unemployment gap predicts a fall in the upper tail of the conditional distribution of the index. The output gap as a proxy for the business cycle exhibits positive effects on the prediction of the upper tail. Despite having an intuitive effect on the upper tail, the output gap is not statistically significant. Similar holds for the PPI.

For the US, the evidence on the effects of other covariates on the conditional distribution of the index is less convincing providing only some weak evidence on the negative relationship of the interest rate gap with the upper tail (Table 3).

Table 4: Quantile Regression Estimation for Index of Wage and Price Growth, Full Specification

	United Kingdom				United States			
Wage and price changes:	quarter on quarter		year on year		quarter on quarter		year on year	
	95 perc	50 perc	95 perc	50 perc	95 perc	50 perc	95 perc	50 perc
Constant	-2.62	0.11	-2.12	-1.77	1.96	0.58	1.16	0.49
	(-4.76,1.16)	(-1.02,1.42)	(-5.11,0.07)	(-4.12,0.09)	(1.06,2.32)	(0.25,0.91)	(0.41,1.89)	(-0.01,0.94)
Index	1.01	0.77	**1.57**	**0.70**	0.93	0.80	1.16	0.87
	(0.85,1.24)	(0.66,0.95)	(0.95,1.90)	(0.55,0.98)	(0.86,1.13)	(0.68,0.95)	(0.92,1.40)	(0.65,1.07)
	[0.89,1.22]	[0.68,0.92]	**[1.10,1.77]**	**[0.58,0.88]**	[0.89,1.08]	[0.71,0.92]	[0.95,1.31]	[0.71,1.03]
Unemployment gap			**-0.38**	**-0.38**				
			[-0.67,-0.28]	[-0.62,-0.24]				
Output gap			**0.07**	**0.07**	0.15	0.17		
			[0.02,0.12]	[0.02,0.13]	[-0.22,0.32]	[-0.12,0.33]		
PPI growth							0.11	0.03
							[-0.02,0.22]	[-0.01,0.09]
Interest rate gap	**-0.12**	**-0.12**						
	[-0.34,-0.06]	[-0.20,-0.05]						
Real exchange rate	**3.46**	0.16	**2.35**	**1.83**				
	[0.68,4.31]	[-0.71,0.88]	[0.78,4.07]	[0.56,3.08]				
No. of observations	205	205	199	199	235	235	229	229
Quantile R2	0.59	0.42	0.59	0.45	0.51	0.44	0.53	0.48

Notes: Central 90% confidence bands based on 1,000 bootstrapped samples are reported in parenthesis. Central 80% confidence bands based on 1,000 bootstrapped samples are reported in brackets. The 90% confidence band is used to illustrate the amount of evidence for two-tailed hypotheses, the 80% confidence band is used to illustrate the amount of evidence for one-tailed hypotheses. Bolded estimates indicate that the amount of evidence for a positive/negative coefficient corresponds to a 10% level of significance. Bolded intervals indicate that the amount of evidence for different coefficients corresponds to 10% level of significance. Bolded estimates of a coefficient of the current index indicate accepting the hypothesis of the coefficient being lower/higher than one. 'No crossing' of the fitted quantiles imposed during the estimation and inference.

The full specification estimates confirm the findings from the simple specifications (for the US the full specifications coincide with simple specifications) – see Table 4. Importantly, the full specification for the UK based on the year-on-year growth rates provides evidence of exploding dynamics in the tail of the index distribution. The hypothesis that the coefficient of the current index is greater than or equal to one is accepted. Consecutive realizations of the index from the tail of its distribution follow an explosive path.

The full specifications are used to identify the wage-price spiral episodes as several covariates drive the upper tail of the conditional distribution. This is done by comparing the observed data with the estimated upper tail of the predictive distributions. If the observed index exceeds the 95th percentile of the estimated predictive distribution, materialization of the risk, i.e. a wage-price spiral, is present.

Table 5: Wage-Price Spiral Episodes

Index based on quarter-on-quarter changes in wages and prices		Index based on year-on-year changes in wages and prices	
United Kingdom	United States	United Kingdom	United States
1972Q4	1972Q1*	1975Q1-1975Q3*	1968Q4
1974Q3*	1974Q2-1974Q3*	1980Q2	1974Q2-1975Q1*
1975Q1	1978Q2*	2022Q2-2022Q4*	2021Q4-2022Q3*
1979Q3*	1990Q1		
1991Q2	2009Q2-2009Q3		
1998Q3	2020Q2*		
2006Q4	2021Q1-2021Q3*		
2016Q2*			
2020Q2			
2021Q4*			

Note: Episodes denoted by an asterisk indicate that 90% of bootstrapped values of the 95th percentile reside below the observed index at least for one quarter

Table 5 lists the wage-price spiral episodes identified for the UK and US. The list of wage-price spiral episodes based on quarterly changes in wages and prices suggests the different character of the episodes in the UK and US economy respectively. While the UK episodes are all one-off events, some US episodes cover several consecutive quarters. Based on the simulations of the structural model in Section 3 and the discussion thereof, the UK episodes are rather consequences of extreme shocks and never became a full-blown wage-price spiral with explosive dynamics of nominal variables. On the other hand, for the US wage-price spiral episodes identified over several quarters, changes in the dynamics of key macroeconomic variables might be experienced.

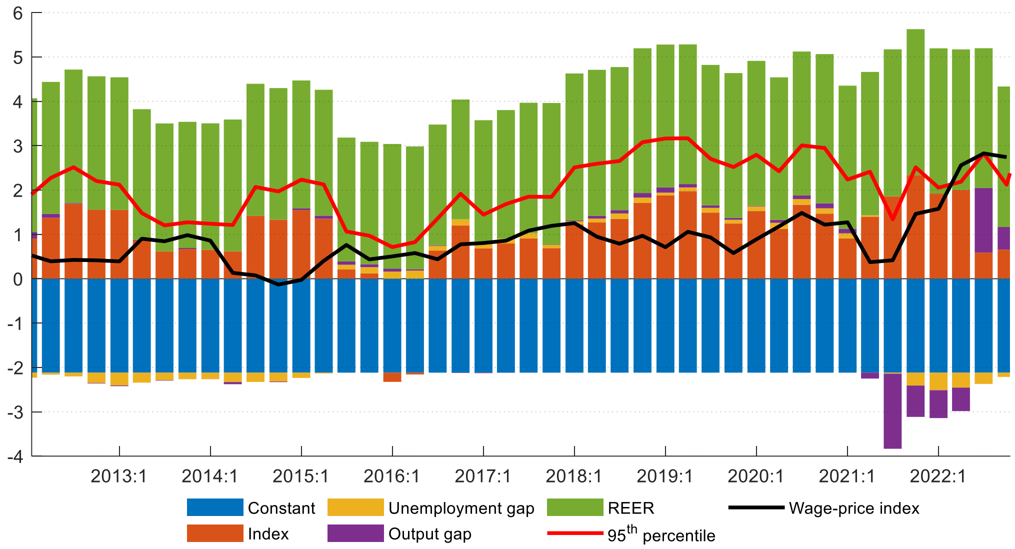
For the UK, for example, the wage-price spiral episode in 1974 Q3 related to the first oil price shock, when the price of crude oil increased four-fold during 1974. The episode was a consequence of an extreme shock, not a manifestation of regime change. Similarly, the US episode in 1972 Q1 was probably a consequence of the end of Nixon’s 90-day wage and price freezes in August 1971. The annualized quarter-on-quarter change in wages was almost 12% in 1972 Q1 representing an extreme wage shock given inflation of around 4%. On the other hand, the 1974 Q2–1974 Q3 episode in the US exhibited a boom in both wages and prices over several quarters exceeding values related to macroeconomic fundamentals. It was the period when the first oil price shock hit the US economy and inflation expectations persistently changed (Reis, 2022).[12]

[12] Our suggestion here that longer wage-price spiral episodes represent a regime change can be supported by the literature on regimes in the US economy. For example, Bianchi (2013) estimate regime changes from the Hawk regime (a regime characterized by a strong monetary policy response to inflation and a negligible reaction to output) to the Dove regime (a weak reaction of monetary policy to inflation and a strong response to output). This regime change is estimated within a structural model in about 1973.

When focusing on wage-price spiral episodes based on specifications with annual changes in wages and prices, evidence of wage-price spiral episodes is found for the 1970s and post-2019. The episode in the 1970s relates to the oil price shocks and is the only period, where some consensus exists on the appearance of a wage-price spiral in the US and the UK (see Alvarez et al., 2022). The post-Covid-19 period and the war in Ukraine witnessed the revival of the discussion on wage-price spirals (see IMF, 2022).

Starting with the post-2019 period and focusing, for instance, on the case of the UK described in Figure 4, risks of a wage-price spiral remained roughly constant at the end of 2021 and during 2022 (red line), while the wage-price index increased rapidly (black line). During that period, the effects of the continuing depreciation of sterling in real terms after Brexit and rising actual wages and prices were offset by increasing unemployment and a slowdown of the real economy, keeping the upper tail roughly constant. However, the wage-price spiral index exceeded the upper tail. The rising index was driven by both price and wage growth, which was above the UK economy's fundamentals.[13] Brexit coincided with slower real economic growth and some labor market issues. Despite that, wages continued to grow fast even in real terms after Brexit. Once energy started to spike, inflation also sped up, taking its toll in a real wage decline. In this situation, companies and workers started to pass price rises on to each other.[14] This is in line with the assessment of the Bank of England which warned in early 2023 about the risk of a wage-price spiral – see the introductory quote in footnote 2.

Figure 4: Wage-Price Spiral Index and the 95th Percentile Decomposition, United Kingdom

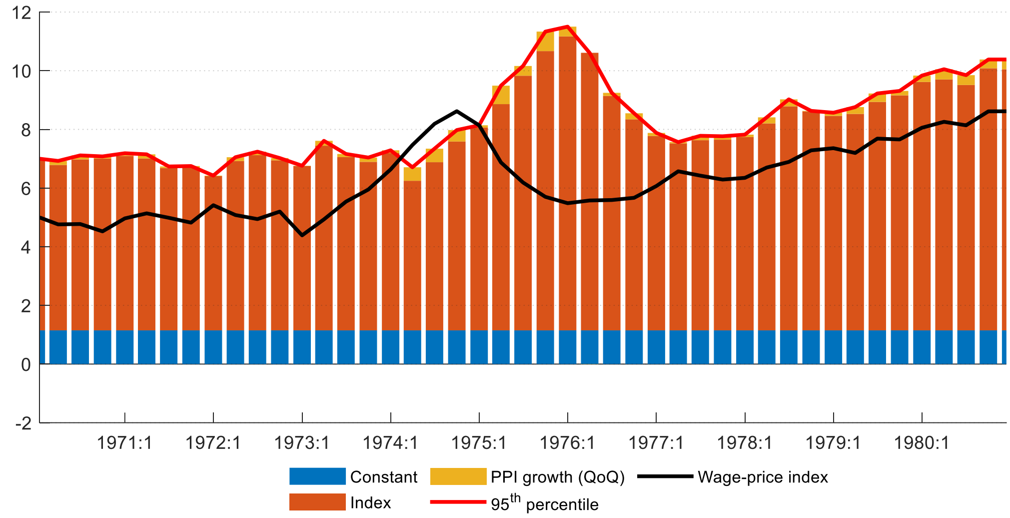


Note: The index is based on year-on-year changes in wages and prices. The full model specification is employed.

[13] By mid-2022, inflation had risen to almost 8 percent and wage growth had exceeded 6 percent.

[14] Hew Pill (chief economist at the Bank of England) said: "*Understandably, firms and households will seek to resist the impact of higher energy prices on their spending power by seeking to pass those costs onto their customers or employers and by raising their own prices and wages. But at the aggregate level, attempts to shift the unavoidable cost to someone else are self-defeating. All they achieve is to create additional nominal demand pressures on resources that ultimately will create inflation and endanger the achievement of the inflation target.*" https://www.bankofengland.co.uk/speech/2023/april/huw-pill-speech-at-the-international-centre-for-monetary-and-banking-studies-public-lecture.

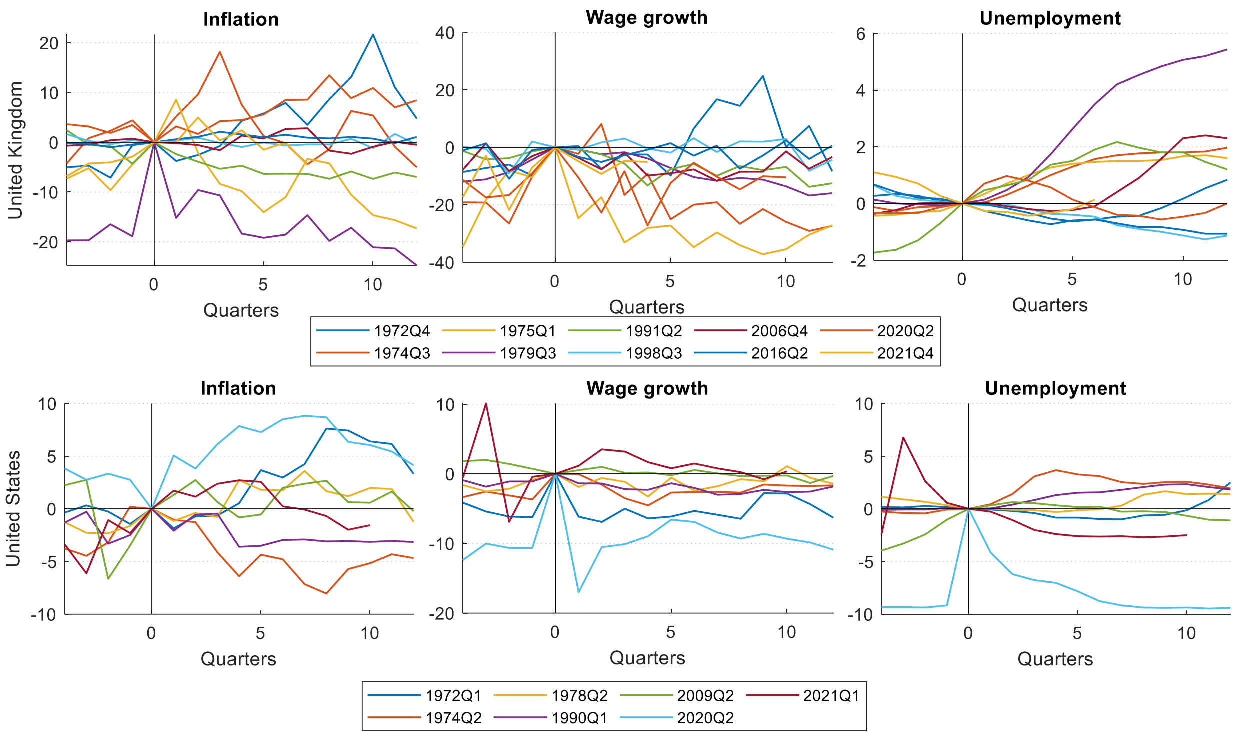
Figure 5: Wage-Price Spiral Index and the 95th Percentile Decomposition, United States



Note: The index is based on year-on-year changes in wages and prices. The full model specification is employed.

The second robust period of the appearance of a wage-price spiral is estimated for the 1970s. The wage-price spiral episode is related to the first oil price shock and subsequent changes in the economy. The period 1974 Q2–1975 Q1 for the US is examined in Figure 5. During 1972–1973, the wage-price spiral risk (red line) was roughly constant. Later, the risk materialized as the index increased above the upper tail of the distribution due to the first oil price shock and Nixon's policy response. The materialization results in an additional increase in the future risk of a wage-price spiral. In addition, PPI growth (supply shocks) predicted a heightened wage-price spiral risk. The risk of a wage-price spiral continued to increase after a drop in 1976. However, the risk of a wage-price spiral did not materialize after 1975. The important effect of the index on the upper tail of the future index can capture the role of inflation expectation formation or union power.

Figure 6: The Evolution of Macroeconomic Variables after Wage-Price Spiral Episodes in the United Kingdom and the United States



Notes: The thick lines show the median of observed macroeconomic variables shortly before and after the start of a wage-price spiral episode. The macroeconomic variables are normalized to zero in the starting quarter of the wage-price spiral episode. An index based on quarterly changes in wages and prices is employed.

To summarize the evolution of macroeconomic variables, Figure 6 presents the evolution of prices, wages and unemployment shortly before and after the wage-price spiral episodes. All variables are normalized according to the values the variables attain in the (first quarter of the) wage-price spiral episode.

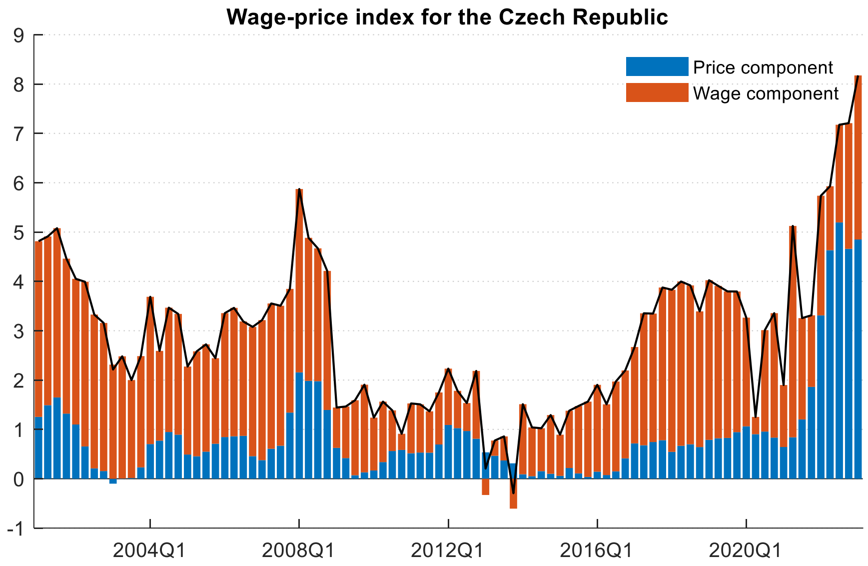
Various profiles can be observed. Some wage-price spiral episodes are clearly one-off events. Inflation and wage growth return to their pre-episode levels within a few quarters (for instance, the 1975 Q1 episode in the UK and the 1978 Q2 episode in the US). Other episodes clearly exhibit signs of very persistent inflation and wage growth along with rising unemployment in the medium run. They suggests that the materialization of the wage-price spiral risk can leave scars on both the nominal and real sides of the economy. These are, for example, the episodes starting in 1979 Q3 in the UK and the episode starting with the Covid-19 shock in 2020 Q2 in the US.

The observed paths of macroeconomic variables presented in Figure 6 suggest that the situation in the 1970s could be a driving force behind our findings. In Appendix B, we discuss the estimates based on post-1980 data. It turns out that the upper tail of the index still represents the risk of a higher persistence of nominal variables although the extreme case of persistence in the form of nonstationarity cannot be concluded robustly. Next, the restricted data sample confirms the important role of the unemployment gap and the interest rate gap for the evolution of the upper tail of the distribution of the index.

5.2 Short Time-Series: The Czech Republic

Although we have less than 100 observations for the Czech Republic, the risk-based approach to wage-price spirals remains useful. The short sample implies that quantile regression is a less reliable tool from both the econometric and economic point of view. The econometric reasons concern the relevance of normal approximations of tails – see the discussion in subsection 4.2. In addition, the precision of estimates is lower as reflected by wider confidence bands in comparison to the case of the US and UK. As above, we address this issue to some extent by imposing a no-quantile-crossing condition. From an economic perspective, there might be fewer episodes resembling a wage-price spiral in such a short sample (see Figure 7).

Figure 7: Wage-Price Index for the Czech Republic



Note: The index and its components are based on year-on-year growth rates.

The empirical results for the simple and full specifications are presented in Tables 6 and 7. The role of the predictors of the upper tail of the index is similar to the cases of the UK and US – an increase in the output gap and PPI growth predicts an increase in the upper tail (Table 6). In addition, the interest rate gap varies with the upper tail in the opposite direction (Table 7). Nevertheless, the conclusions about the dynamic properties of the index in the center and upper tail of its conditional distribution no longer hold. The nominal variables follow, ceteris paribus, the same dynamics regardless of whether the realization is from the center or the tail of the distribution. No regime changes or nonlinearities are detected in the setting of nominal wages and prices.

Table 6: Quantile Regression Estimation for Index of Quarterly Change in Wages and Prices, Czech Republic

	95 perc	50 perc	95 perc	50 perc	95 perc	50 perc	95 perc	50 perc
Constant	3.94	1.31	3.20	1.32	3.56	1.34	3.05	1.12
	(2.55,4.60)	(0.94,1.85)	(2.56,4.05)	(0.81,1.82)	(2.49,4.35)	(0.88,1.86)	(2.40,4.61)	(0.80,1.57)
Index	0.38	0.20	0.16	0.20	0.53	0.12	0.89	0.30
	(-0.09,0.46)	(-0.15,0.36)	(-0.06,0.51)	(-0.12,0.38)	(-0.06,0.65)	(-0.09,0.28)	(0.11,0.90)	(0.06,0.45)
	[-0.01,0.40]	[-0.12,0.27]	[-0.02,0.43]	[-0.06,0.32]	[-0.02,0.58]	[-0.04,0.24]	[0.15,0.84]	[0.09,0.37]
Output gap	**0.58**	**0.14**						
	[0.10,0.75]	[0.06,0.25]						
PPI growth			**0.38**	0.03				
			[0.08,0.44]	[-0.01,0.11]				
Interest rate gap					-0.63	**-0.62**		
					[-1.15,0.45]	[-1.00,-0.30]		
Real exchange rate							0.14	**0.08**
							[-0.00,0.39]	[0.04,0.11]
No of observations	90	90	90	90	90	90	90	90
Quantile R2	0.29	0.08	0.33	0.05	0.24	0.11	0.26	0.09

Notes: Central 90% confidence bands based on 1,000 bootstrapped samples are reported in parenthesis. Central 80% confidence bands based on 1,000 bootstrapped samples are reported in brackets. The 90% confidence band is used to illustrate the amount of evidence for two-tailed hypotheses, the 80% confidence band is used to illustrate the amount of evidence for one-tailed hypotheses. Bolded estimates indicate that the amount of evidence for a positive/negative coefficient corresponds to a 10% level of significance. 'No crossing' of the fitted quantiles imposed during the estimation and inference.

Table 7: Quantile Regression Estimation for Index of Wages and Price Growth, the Czech Republic, full specification

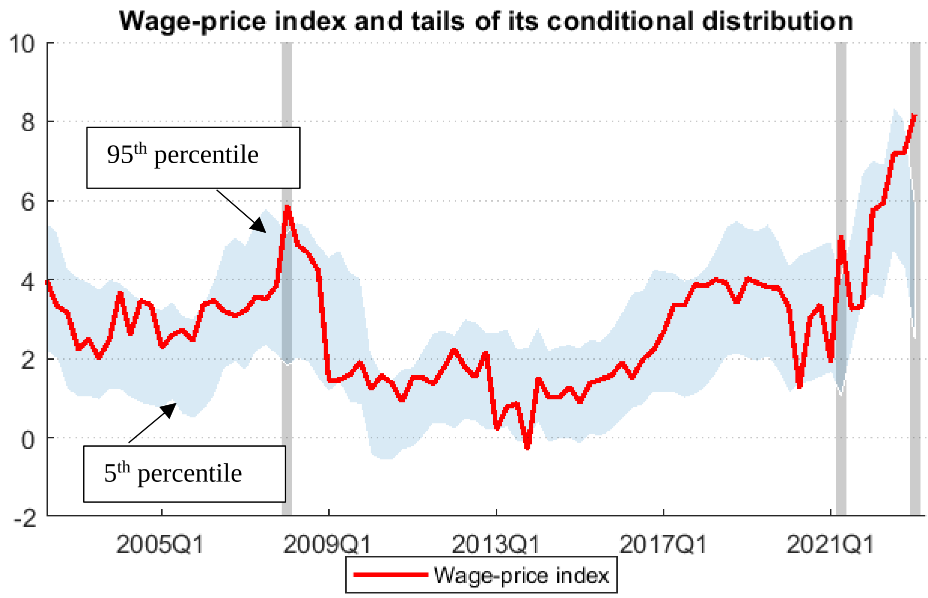
Wage and price changes:	quarter on quarter		year on year	
	95 perc	50 perc	95 perc	50 perc
Constant	3.63	1.41	3.30	1.81
	(2.62,4.41)	(1.05,1.89)	(2.19,3.96)	(1.44,2.44)
Index	0.03	0.03	0.26	0.30
	(-0.16,0.29)	(-0.21,0.23)	(0.05,0.71)	(0.12,0.45)
	[-0.12,0.21]	[-0.18,0.16]	[0.11,0.58]	[0.18,0.42]
Output gap	**0.36**	**0.17**	**0.54**	**0.39**
	[0.08,0.66]	[0.07,0.27]	[0.34,0.65]	[0.29,0.46]
PPI growth	**0.25**	**0.05**		
	[0.05,0.37]	[0.01,0.11]		
Interest rate gap			**-1.33**	**-1.46**
			[-1.57,-0.98]	[-1.59,-1.06]
Real exchange rate				
No of observations	90	90	84	84
Quantile R2	0.38	0.08	0.48	0.50

Notes: Central 90% confidence bands based on 1,000 bootstrapped samples are reported in parenthesis. Central 80% confidence bands based on 1,000 bootstrapped samples are reported in brackets. The 90% confidence band is used to illustrate the amount of evidence for two-tailed hypotheses, the 80% confidence band is used to illustrate the amount of evidence for one-tailed hypotheses. Bolded estimates indicate that the amount of evidence for a positive/negative coefficient corresponds to a 10% level of significance. 'No crossing' of the fitted quantiles imposed during the estimation and inference.

The same (and low) persistence of the index realizations, regardless of the part of the distribution they are from, implies that the realizations from the tail cannot be denoted as wage-price spiral episodes. However, quantifying the risk of the unusually high growth in wages and prices still represents important information for policymakers. A risk-management approach implies a reaction if the risk of very high growth in wages and prices is estimated – see the next section for details.

The full specification in year-on-year terms provides three statistically significant episodes of high growth in wages and prices not aligned with macroeconomic fundamentals: 2008 Q1, 2021 Q2, and 2023 Q1 – see Figure 8 for the episodes, index and tails of the conditional distribution of the index. The last episode coincides with the period when the Czech National Bank started to worry about the second-round effects of very high observed inflation – see footnote 3 for quotations.

Figure 8: The Wage-Price Index for the Czech Republic and the 5th and 95th Percentiles of Its Conditional Distribution (lower and upper bands of the blue area)



Note: The shaded vertical lines indicate wage-price episodes. The index and its components are based on year-on-year growth rates.

5.3 Guiding Policymakers

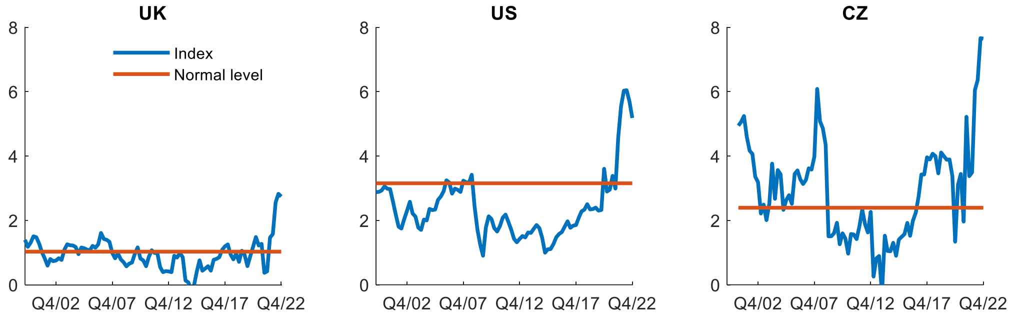
The wage-price spiral index and the 95th percentile of its predictive distribution can convey the following messages to policymakers.

First, following the logic of the inflation targeting framework, the high level of the wage-price spiral index and its forecast call for the tightening of monetary policy. This is because the index and its forecast are above the 'normal' level consistent with the fulfilment of the inflation target and the real growth of the economy's potential. Assuming, for example, a 2% inflation target and average nominal wage growth of around 5 percent would imply the "normal" level of the index to be around 3.5 percent.[15] Figure 9 shows the index compared to its normal level. Prior the global financial

[15] The "normal" level is computed by weighting the inflation target and the average nominal wage growth by their historical variance following the definition of the wage-price spiral index. Hence, for example, (1/2.3)*2+(1/1.9)*5 = 3.5, where 2.3 is the standard deviation of y-o-y inflation and 1.9 is the standard deviation of y-o-y wage growth.

crisis, the indexes in the countries under review exceeded the "normal" level consistent with the inflation target calling for tighter monetary policy. In the wake of the global financial crisis the indexes stayed below the "normal" level and many central banks resorted to unconventional policy measures. The indexes soar well above the "normal" level at the end of the sample, suggesting a need for tighter monetary policy.

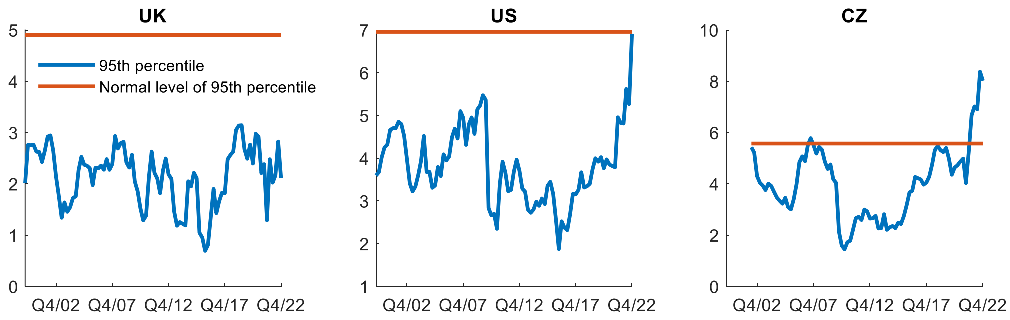
Figure 9: Wage-Price Index (y o y) and Its Normal Level



Note: We assume an inflation target of 2%, which is the official target for most of the plotted sample. Standard deviations are used for the whole estimation sample.

Second, a high or sharply increasing 95th percentile calls for more prudent monetary policy and thus a tightening over and above the extent suggested by the observed index. A sharply increasing 95th percentile means that the probability of high price and wage growth above the target is rising, posing a risk to price stability. This is the case in particular if the sharp increase in the percentile is above the "normal" level of the 95th percentile.[16] Such a situation can happen even when the observed index is constant as the increasing 95th percentile gives a chance for the realization of the index at levels not consistent with the target. Figure 10 presents the normal level of the 95th percentile. It shows a sharp increase in the 95th percentile in 2021–2022 in the US and the Czech Republic. While the percentile reached its normal level in the US, the percentile was well above the normal level in the Czech Republic.

Figure 10: Estimate of the 95th Percentile of the y-o-y Indexes and Its Normal Level



Note: The normal level of the 95th percentile is computed as the sum of the normal level of the index plus 2 standard deviations of the index.

[16] Assuming that two standard deviations of the index above its "normal" level constitute the "normal" 95th percentile.

Finally, the index realization exceeding the 95th percentile for more than one quarter indicates the materializing risk of a wage-price spiral and the risk of the underlying characteristics of the inflation process. This would again call for a more aggressive policy response. The risk of a high index level comes from the threat that inflation may become more widespread and indexed as highlighted in Boissay et al. (2022).

6. Conclusions

The paper introduces a novel empirical approach to quantify the risks of wage-price spirals. The approach is in essence probabilistic. It estimates the distribution of future growth in wages and prices and focuses on situations where the ex-post observed growth of both variables is extreme. For the UK and US, we demonstrate that such a situation represents a possible acceleration in wages and prices which is in line with the common intuition behind a wage-price spiral.

The probabilistic approach to a wage-price spiral is very intuitive. One is simply interested in the risk of simultaneous rapid growth in wages and prices. A wage-price spiral is then identified when the risk materializes. On the other hand, to be informative, the approach requires a relatively long data span, i.e. it is data intensive. However, using a short data span for the Czech Republic, we demonstrate that the approach can still be informative about the risk of simultaneous and high growth in wages and prices.

Several research avenues can be followed related to the research presented in this paper. First, the paper provides reduced-form evidence and as such cannot provide insights into the causal relationships between wages and prices to shed some light on the nature of the feedback loops between the two. Also, the effects of covariates take the form of predictive power, not causal link. The causality in the form of the effect of policy shocks on the tail of the wage and price growth distribution is a matter of future research. Second, some econometric issues related to the estimation of extreme conditional quantiles are present. For example, the no-quantile-crossing condition is a way of smoothing conditional distribution. Some assessment of the procedure with respect to other possibilities (parametric, semi-parametric) is a natural question, which needs to be resolved rigorously as the Macro-at-Risk literature becomes an unavoidable part of the applied research toolbox.

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Appendix A: Data

Table A1: Data

Variable	Description	Source
United States		
Price index	Personal Consumption Expenditures: Chain-type Price Index	FRED: PCEPI
Wage index	Average Hourly Earnings of Production and Nonsupervisory Employees, Total Private	FRED: AHETPI
Unemployment	Unemployment Rate	FRED: UNRATE
GDP	Real Gross Domestic Product, Billions of Chained 2012 Dollars	FRED: GDPC1
PPI	Producer Price Index by Commodity: All Commodities	FRED: PPIACO
Interest rate	Federal Funds Effective Rate	FRED: DFF
United Kingdom		
Price index	Consumer Price Index of All Items	FRED: GBRCPIALLMINMEI
Wage index	Average labor compensation per hour worked	Office of National Statistics
Unemployment	Prior to 1983: Unemployment Rate in the United Kingdom	FRED: AURUKM
	After 1983 Harmonized Unemployment Rate: Total: All Persons for the United Kingdom	FRED: LRHUTTTTGBM156S
GDP	Gross Domestic Product by Expenditure in Constant Prices	FRED: NAEXKP01GBQ652S
PPI	Domestic Producer Prices Index: Manufacturing for United Kingdom	FRED: GBRPPDMMINMEI
Interest rate	Bank of England rate	BoE
Exchange rate	US Dollar to Pound Sterling	FRED: DEXUSUK
	Since April 1999: US Dollar to Euro	FRED: DEXUSEU
	Prior to April 1999: Deutsche Mark to US Dollar	FRED: EXGEUS
Czechia		
Price index	Consumer price index: All items	Czech Statistical Office
Wage index	Average gross monthly wage	Czech Statistical Office
Unemployment	General unemployment rate	Czech Statistical Office
GDP	Real gross domestic product	Czech Statistical Office
PPI	PPI manufacturing	Eurostat
Interest rate	PRIBOR 3M	Czech National Bank
Exchange rate	CZK/EUR	Czech National Bank

Appendix B: Post-1980 Period

This appendix presents estimation results where the data sample is restricted to the post-1980 period. The motivation for such an exercise is to shed some light on the role of the 1970s for our results as the discussion of the results suggests that it plays an important role. We should avoid the pitfall of our results being driven by some one-off rare event which cannot occur ever again.

The difference between the 1970s and the recent experience is significant. Starting with more robust monetary policy frameworks with a stronger focus on maintaining anchored inflation expectations, less energy-intensive economies and more flexible labor markets, the risk of wage-price spirals unfolding is much more limited (OECD, 2022). On the one hand, the tail events we attempt to analyze are rare events and it should not come as a surprise that they occur on very limited occasions. Moreover, the reduced-form approach can structurally different periods view similarly and also the consequences for dynamics of macroeconomic variables can be similar.

The estimation results for the full specifications are presented in Table B1. The estimated parameters still suggest that the upper tail of the index represents the risk of persistent nominal variables. This finding is more profound for the US, but the confidence bands are wide due to the low number of observations. The extreme form of persistence – nonstationarity – cannot be ruled out for the US. The role of other covariates is still important, especially the unemployment gap and the interest rate gap.

Table B1: Quantile Regression Estimation for Index of Wage and Price Growth, Full Specification, Post-1980 Data

	United Kingdom				United States			
Wage and price changes:	quarter on quarter		year on year		quarter on quarter		year on year	
	95 perc	50 perc	95 perc	50 perc	95 perc	50 perc	95 perc	50 perc
Constant	2.11	0.75	-2.47	-0.36	2.54	1.20	1.28	1.29
	(1.90,2.95)	(0.53,1.06)	(-2.85,2.25)	(-2.15,1.92)	(1.49,2.84)	(0.80,1.51)	(0.91,3.41)	(0.89,1.82)
Index	0.77	0.61	0.66	0.66	0.81	0.60	1.03	0.57
	(0.38,0.77)	(0.44,0.70)	(0.56,0.97)	(0.51,0.78)	(0.52,1.02)	(0.49,0.71)	(0.45,1.13)	(0.42,0.73)
	[0.45,0.75]	[0.47,0.68]	[0.59,0.93]	[0.54,0.75]	[0.57,0.96]	[0.53,0.68]	[0.54,1.05]	[0.45,0.67]
Unemployment gap	**-0.67**	**-0.34**	**-0.94**	**-0.77**				
	[-0.78.-0.32]	[-0.59,-0.07]	[-1.22,-0.50]	[-1.11,-0.44]				
Output gap	0.19	0.16	0.06	0.05	0.27	0.25		
	[-0.18,0.36]	[-0.14,0.17]	[-0.08,0.07]	[-0.02,0.06]	[-0.33,0.41]	[-0.11,0.35]		
PPI growth								
Interest rate gap			**-0.25**	**-0.25**			-0.15	-0.05
			[-0.35,-0.16]	[-0.38,-0.14]			[-0.57,0.02]	[-0.15,0.07]
Real effective exchange rate			3.62	0.83				
			[-0.23,3.04]	[-0.66,1.83]				
No of observations	171	171	168	168	173	173	170	170
Quantile R2	0.500	0.311	0.575	0.425	0.495	0.316	0.520	0.334

1,000 bootstrapped samples are reported in brackets. The 90% confidence band is used to illustrate the amount of evidence for two-tailed hypotheses, the 80% confidence band is used to illustrate the amount of evidence for one-tailed hypotheses. Bolded estimates indicate that the amount of evidence for a positive/negative coefficient corresponds to a 10% level of significance. 'No crossing' of the fitted quantiles imposed during the estimation and inference.

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