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DISCUSSION PAPER

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Keywords: inflation, wages, monetary policy, Beveridge curve, inflation expectations

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1 Introduction

The UK entered the coronavirus pandemic in March 2020 with an annual CPI inflation rate of 1.5%. By March 2021, UK CPI inflation had fallen to 0.7%. The vaccination programme was proceeding at fast pace and a new EU trading relationship had been agreed, following the 2016 Brexit vote, but economy was still subject to pandemic restrictions with 18% of private sector workers furloughed, high infection rates, and mobility indices at low levels similar to the original outbreak.

In February 2021, the Bank of England forecasted CPI inflation to be 2.1% in 2023Q1; the average of other forecasters was 1.8%, with a range between 0.7% and 2.5% (Bank of England, 2021a). In the event, however, annual inflation started to build over 2021, reaching 5.4% in December 2021, 7.0% in March 2022, and peaked at 11.1% in October 2022, before falling to the Bank's 2% in May 2024.

This paper asks: what caused this inflation surge? Popular accounts are replete with conjecture. One answer has as its primary focus energy and goods price shocks. The Bank's February 2021 forecast was that gas and oil prices, at that time 46 pence per therm and 55 dollars per barrel would be the same in 2022 and 2023 (Bank of England, 2021a). This turned out to be a substantial underestimate: oil prices peaked at around $110 (around £100) per barrel in 2022 Q2, and UK gas prices at over 350 pence per therm in 2022 Q3. As for goods price shocks, international supply shortages emerged during the recovery from the pandemic following the vaccine rollout adding to the widely-discussed shortages due to the uncertainty around supply relations following Brexit.

A second class of explanations focuses on increased cost pressure from a tight labour market. At the time of the March 2020 lockdown, the UK government introduced a furlough scheme with the government paying 80% of wages for those unable to work due to lockdown restrictions. At its peak, in early May 2020, almost 9 million jobs were furloughed, equivalent to about a third of private sector workers. Just before the furlough scheme closed in September 2021 there were still 1 million jobs furloughed (around 5% of private sector workers) of which over 300,000 jobs had been furloughed continuously since March 2020 (when the scheme started). Vacancies grew strongly through early and mid-2021 so that, by September 2021, unemployment was around historical averages, but the vacancies-to-unemployment (V/U) ratio was 0.8, well above the pre-pandemic level of about 0.6 and more than double the historical average of below 0.4. Indeed, the V/U ratio kept rising over much of 2022 (see Figure 2). Such a tight labour market might have exacerbated second-round effects from the strong relative price shocks.

A third class has a focus on inflation expectations. In the November 2021 Monetary Policy Report (Bank of England, 2021b), the Bank of England surveyed short- and long-run inflation expectations by households, firms and markets, and found somewhat of an upward drift. Such an upward shift of expectations might in turn have been caused, it is argued, by the monetary policymakers not initially counteracting the rise in inflation.[1]

On the assumption that the answer is likely to be a combination of these various explanations, we implement the Bernanke and Blanchard (2023) (henceforth BB) model for the UK, as it offers an organised framework to combine them and quantify their relative importance. In the BB model, firms and workers settle on wages, whereupon firms set prices as a mark-up over those wages. Wage growth depends on (a) expected inflation, (b) labour market tightness and (c) the real wage workers aspire to. Thus, for example, a shock to prices potentially changes both expected prices and aspiration real wages and so changes settlements, feeding back into pressure on prices. Inflation expectations (short and long run) are modelled as functions of (past and present) actual inflation. Wage-price dynamics arise via assumed transmission lags in the system, including a possible adjustment of real aspiration wages to actual real (consumption) wages if, for example, workers attempt to "catch-up" their current real wage settlements to past real wage losses. These "catch-up" effects mirror the real wage resistance effects analysed by, for example, Bruno and Sachs (1985), Layard et al. (2005), and Newell and Symons (1987): see Bean (1994) for an excellent survey. Dynamics also arise as inflation expectations adjust to current inflation.

The BB model was originally applied to the US, with two main findings. First, estimates suggest that shocks to the system from, for example energy or food prices, dissipate quite quickly, restoring inflation to previous rates. This is because there is little catch-up effect; and inflation expectations, despite high inflation, remained quite well-anchored. Second, US inflation, after initially being due mostly to external shocks, was increasingly driven by a tight labour market.

This paper estimates a version of the BB model using UK data up to 2024 and analyses a number of extensions. Our major findings are, in many ways, quite similar to BB on US data. First, like BB, we find a limited role for catch-up in wage determination and that inflation expectations are remarkably well-anchored (considering the actual inflation shocks the UK has experienced). Second, we find that the initial rise in inflation in 2021 was mostly due to energy and supply chain pressure. Third, subsequent rises, however, were more due to food price shocks but also a tightening in the labour market. Finally, using illustrative conditional

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[1] Since our focus is on the labour market, we concentrate on the various ideas set out, but acknowledge there are others. One is that a combination of QE and loose monetary policy fuelled inflation by excessive money growth, allied with abnormally high household bank deposits that were accumulated during lockdown. We think of this, in our framework, as a combination of the possibility of an excessively tight labour market and/or drifting inflation expectations. Another explanation is so-called "greedflation", for which we find no evidence at a macro-scale (Haskel, 2023).

forecasts, inflation falls slowly back to target, suggesting a degree of 'stickiness' of inflation in the estimated model.

The rest of this paper proceeds as follows. Section 2 briefly discusses other studies on the pandemic-era inflation spike. Section 3 sets out the model in theory and in the empirical work. Section 4 describes our data and illustrates our key input variables. Section 5 presents the estimated equations and the implied impulse response functions of the exogenous variables on inflation. Section 6 presents decompositions of wage and price inflation into their model-implied drivers over the period since 2020. Section 7 shows illustrative conditional forecasts using the model. Section 8 concludes.

2 Literature

There is of course a vast literature on UK inflation. Classic papers include Laidler (1976) for a monetarist perspective and Hendry (1980) for a critique of econometric models: Bruno and Sachs (1985) and Grubb et al. (1982) study 1970s stagflation across countries. But although the pandemic-era surge in inflation has been widely discussed in the media there is, perhaps because it is so recent, relatively little formal academic literature.

Ball et al. (2022) decompose US headline inflation into core inflation (measured by weighted median inflation) and deviations from the core rate. They explain core inflation by long-run inflation expectations, labour market tightness and non-linear passthrough of headline shocks into core inflation. In turn, they explain the headline shocks using measures of energy prices and supply chain disruptions. They find that headline price shocks, passthrough of those shocks, and labour market tightness all contributed to the increase in US annual inflation between December 2020 and September 2022, with relatively little role for long-run inflation expectations.

Dao et al. (2023) use the same framework to account for annual inflation in the US and Euro area (EA) up to April 2023. They find that most recent EA inflation can be explained by the energy price shock and the passthrough of that shock, with very little role for labour market tightness; meanwhile for the US, labour market tightness is the key driver. The IMF World Economic Outlook in October 2023 (IMF, 2023) applies the same framework to account for the increase in inflation since the end of 2019 in the US, EA and UK, up to July 2023. Their findings for the US and EA mirror Dao et al. (2023), while for the UK they find larger headline shocks, less passthrough of those shocks, and a small role for labour market tightness (albeit much less than for the US).

Two recent studies adopt an accounting approach. Haskel (2023) uses the price and quantity relations implicit in National Accounts to decompose UK, US, and EA inflation into domestic factors (payments to labour and capital and net taxes from the income side of GDP) and non-domestic factors (import prices). On an accounting basis, UK inflation in 2022 was partly due to higher labour and capital income, and partly due to a terms of trade shock. Dhingra and Page (2023) use an input-output approach to account for UK inflation by the costs of production of domestic consumption goods. They find that energy and imports explain a large share of cumulative UK inflation between 2019 and 2022, with a more modest role for unit wage costs and capital income.

Some other papers consider one explanation or phenomenon in isolation. Harding et al. (2023) emphasise a nonlinear Philips curve using US data. Jordà and Nechio (2023) study the impact of pandemic payments on wage growth and inflation across countries. Castle et al. (2022) argue for a large role of energy prices in UK inflation based on historic evidence, predicting inflation in 2022 reasonably well.

With some disagreement of the causes of the recent increase in UK inflation, and relatively little structural empirical work for the UK, we proceed with the BB model.[2]

3 The Bernanke and Blanchard model

3.1 Outline

The Bernanke and Blanchard (2023) model is a semi-structural model of wages, prices and inflation expectations building on previous empirically-motivated work focussing on inflation and the labour market, see e.g. Bean (1994) for a survey. It combines theoretically-motivated exclusion and homogeneity restrictions with largely data-driven short-run dynamics.

3.2 The model in detail

Wage equation

The (log) nominal wage level depends on expected (log) prices, real aspiration wages (ω^A) and labour market tightness (x):

$$w_t = p_t^e + \omega_t^A + \beta x_t \qquad (1)$$

Real aspiration wages (ω^A) are a function of the last quarter's ω^A, last quarter's realised real wage and wage-push factors z_ω:

$$\omega_t^A = \alpha \omega_{t-1}^A + (1-\alpha)(w_{t-1} - p_{t-1}) + z_{\omega,t} \qquad (2)$$

[2] Following BB's work for the US, teams from the central banks of the UK, Canada, Japan, several EA countries, and the ECB, applied the BB model to their respective countries; Bernanke and Blanchard (2024) summarise the results of that work, and document the respective papers for each country. The UK's contribution to that work is an earlier version of the present paper.

Where trend productivity is added in the empirical work to capture the long-run trend of real wages. Substituting (2) into the wage equation (1) and rearranging gives:

$$w - w_{t-1} = (p_t^e - p_{t-1}) + \alpha(p_{t-1} - p_{t-1}^e) + \beta(\alpha x_t - (1-\alpha)\Delta x_{t-1}) + z_\omega \qquad (3)$$

As (3) shows, if α≠0, then wage inflation is expected price inflation plus a term in the gap between last period's price level and what it was expected to be. This is a "catch-up" term reflecting real wage rigidity, i.e. that workers expect to be compensated for past unexpected inflation. The final term suggests that wage inflation depends on both the level and change in labour market tightness, again depending on the extent of catch-up. This is important, since, on most measures, the pandemic period has seen rising then falling labour market tightness (*x*), which would potentially add and then subtract to wage inflation.[3]

Price equation

Prices depend on the wage level plus a non-wage price-push term z_P

$$p = w + z_P \qquad (4)$$

Where in the empirical work, z_P will include commodity price (energy and food) changes and a variable to capture supply chain pressure.

Inflation expectations

Short-run inflation expectations are a weighted average of long-run expectations (π^*) and last period's actual inflation:

$$p_t^e - p_{t-1} = \delta\pi^* + (1-\delta)\left(p_{t-1} - p_{t-2}\right) \qquad (5)$$

Long-run expectations are an average of lagged long-run expectations, and last period's actual inflation:

[3] The empirical wage equation in this paper is very much in the spirit of other widely-used wage equations, including those in Yellen (2017) and Haldane (2018), both of which are used by the Bank of England in their Monetary Policy Reports. For instance, Yellen (2017) regresses the quarterly change in log wages on lagged changes in log wages, inflation expectations, slack (a measured by the unemployment gap: U-U*) and its change, and productivity growth. It perhaps forgotten that Phillips (1958) contains an extensive discussion of how wage growth is likely affected by both the level of unemployment *and* changes in unemployment (available computing power precluded multiple regression analysis, see his note 3).

$$\pi^{*} = \gamma\pi^{*}_{t-1} + (1-\gamma)\left(p_{t-1} - p_{t-2}\right) \quad (6)$$

If γ and δ are close to 1, expectations are less "backward-looking", in the sense that they depend less on past realisations of inflation, and so are more well-anchored.

3.3 The model at work

The model can be written instructively as follows. First, price inflation is wage inflation plus shocks:

$$\Delta p = \Delta w + \Delta z_{P} \quad (7)$$

Second, wage inflation is given by:

$$\Delta w = \underbrace{\Delta p_{t}^{e}}_{\text{Exp inf}} + \alpha\underbrace{(p_{t-1} - p_{t-1}^{e})}_{\text{Catch up}} + \beta\underbrace{(\alpha x + (1-\alpha)\Delta x)}_{\text{Lab tightness}} + z_{\omega} \quad (8)$$

so that wages rise with expected inflation, catch-up, labour market tightness (level and change), and the wage-push shock.

Third, expected inflation is given by:

$$\Delta p_{t}^{e} = \delta\gamma \underbrace{\pi^{*}}_{\substack{\text{Long run}\\ \text{inf expects}}} + (1-\delta\gamma)\underbrace{\Delta p_{t-1}}_{\text{Lagged inf}} \quad (9)$$

Such that it is a weighted average of long-run inflation expectations and last period's inflation.

From this we may note the following response to a one-period shock to prices, Δz_P. From equation 7, at given wages, inflation rises for one period only. Any second-round effects depend upon wages.

Suppose first that α=0. Then wages only rise to the extent to which expected inflation rises. The rise in expected inflation, see equation 9, depends in turn on the weight that agents put, on long-run inflation expectations and lagged realised inflation when forming expectations: if the weight on lagged inflation is very low, then expected inflation hardly rises, wages hardly rise and there are no second-round effects. In this case, inflation can be said to be transitory. If α>0, wage inflation and hence price inflation rises according to the strength of catch-up and any changes in labour market tightness.

3.4 The transition to empirical work

Sample period

In our main results, we estimate all four equations on quarterly data from 1990 Q1 to 2024 Q1, what we call the "full sample". In Appendix A we set out results when estimating using a pre-pandemic sample period.

This differs somewhat from Bernanke and Blanchard (2023), who estimate only the price equation on the full sample[4], in order to capture sufficient variation in their "shortages" variable, but the wage equation and two expectations equations on the pre-pandemic sample.[5]

The choice of estimation period depends rather upon the question at hand. For the moment, we use the full sample to speak to the question of our best account of inflation using the full information set available now. (In Appendix A we discuss the equations estimated on the pre-pandemic sample (up to 2019 Q4) which speaks to the question of what might have been forecasted then.)

Including the pandemic period does however raise the question of how to deal with the historically unique conditions of mid-2020, when a huge fraction of the workforce was on furlough. The interpretation of the wage, vacancy and unemployment data is almost impossible in this period, with no historic precedent. To avoid this period affecting the estimated coefficients, we add dummies for each of 2020 Q2 and 2020 Q3 (see also Cascaldi-Garcia, 2022). Whilst crude, the wage equation without these dummies creates very large errors which "carry over" for many periods in the dynamic forecast of the pandemic period given the lags in wage and price formation.

Estimated equations

In implementing these equations, we follow BB and allow for four lags of all variables to capture adjustment dynamics. Starting with the wage equation, we estimate the following:

$$gw_t = \sum_{k=1,2,3,4} \alpha_k^{gw} gw_{t-k} + \sum_{k=1,2,3,4} \alpha_k^{VU} (V/U)_{t-k} + \sum_{k=1,2,3,4} \alpha_k^{catchup} catchup_{t-k} + \sum_{k=1,2,3,4} \alpha_k^{iesr} iesr_{t-k} + u_t^{gw} \quad (10)$$

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[4] In BB, this is 1990 Q1 to 2023 Q1 as that was the last time period available at the time of their work.

[5] In more recent work in collaboration with the authors of this paper and economists at other central banks, Bernanke and Blanchard (2024) have adopted the use of the model estimated over the 'full sample'. Our approach in this paper therefore aids comparability of our results with those for other countries.

Where *gw* is the quarter-on-quarter annualised log change in wages, *vu* is the vacancy-to-unemployment ratio (our measure of labour market tightness), *catchup* is the difference between realised annual inflation and one-year ahead expected inflation a year ago, *iesr* is the one-year ahead inflation expectation, and the final term is an error. Note that, in this equation, all variables enter only with a lag such that the system is identified and the model can be simulated iteratively (see Section 6.1).

The price equation is:

$$\begin{aligned} gp = & \sum_{k=1,2,3,4} \beta_k^{gp} gp_{t-k} + \sum_{k=0,1,2,3,4} \beta_k^{w} gw_{t-k} + \sum_{k=0,1,2,3,4} \beta_k^{scp} scp_{t-k} \\ & + \sum_{k=0,1,2,3,4} \beta_k^{grpe} grpe_{t-k} + \sum_{k=0,1,2,3,4} \beta_k^{grpf} grpf_{t-k} + \sum_{k=1} \beta_k^{gpty} gpty_{t-k} + u_t^{gp} \end{aligned} \quad (11)$$

Where *gp* is the quarter-on-quarter annualised log change in CPI (i.e. price inflation), *gw* is wage growth as above, *scp* is a measure of global supply chain pressures, *grpe* is the quarter-on-quarter annualised log change in the relative price of energy to wages, *grpf* is the quarter-on-quarter annualised log change in the relative price of food to wages, *gpty* is the trend growth of productivity, and the final term is an error.

The supply chain, energy and food terms make up the price-push term z_P from equation 4. Energy and food inflation are expressed relative to wages to avoid inflation being on both sides of the equation. In robustness checks we add more general imported inflation but with little difference (see Appendix E). We might expect that a persistent rise of energy or food prices, relative to other prices/wages, would directly raise the long-run price level in proportion to the energy and food shares in the consumption basket. Thus, we would expect the long-run coefficients to be similar to those shares (which we test in Figure 6). If they are above those shares, that would suggest indirect effects of changes in such prices on other prices.

The equations for short- and long-run inflation expectations are:

$$iesr_t = \sum_{k=1,2,3,4} \phi_k^{iesr} iesr_{t-k} + \sum_{k=0,1,2,3,4} \phi_k^{ielr} ielr_{t-k} + \sum_{k=0,1,2,3,4} \phi_k^{gp} gp_{t-k} + u_t^{iesr} \quad (12)$$

and

$$ielr_t = \sum_{k=1,2,3,4} \theta_k^{cielr} ielr_{t-k} + \sum_{k=0,1,2,3,4} \theta_k^{gp} gp_{t-k} + u_t^{ielr} \quad (13)$$

Where *iesr* is short-run (one-year) inflation expectations, *ielr* is long-run (5-10 years) inflation expectations, and *gp* is price inflation as above.

Finally, in taking this framework to the data, we follow BB in imposing homogeneity restrictions such that the long-run Philips curve is vertical (so that in the long-run any change in inflation is matched by changes in short-run and long-run inflation expectations).[6] Our data does not reject these restrictions.

4 Data

4.1 Measures

The data are largely from the UK Office for National Statistics (ONS), combining multiple vintages of data in some cases. Growth data are all quarter-on-quarter annualised natural log changes. The series we use are outlined below, with additional description in the Data Appendix (Appendix C).

- Price inflation (*gp*) = growth in the 'all items' Consumer Price Index (CPI)[7] published by the ONS, which we seasonally adjust using X-13ARIMA-SEATS.
- Relative food price inflation (*grpf*) = growth in the ratio of the food and non-alcoholic beverages component of the CPI, which we seasonally adjust using X-13ARIMA-SEATS, relative to wage growth described below.
- Relative energy price inflation (*grpe*) = growth in the ratio of the energy component (covering electricity, natural gas, and vehicle fuels) of the CPI, which we seasonally adjust using X-13ARIMA-SEATS, relative to wage growth described below.
- Wage growth (*gw*) = growth in Average Weekly Earnings, private sector regular pay (i.e. excluding bonuses), seasonally adjusted by ONS, adjusted for the effects of furlough (during the pandemic) and compositional changes (at all times).
- Vacancy-to-unemployment ratio (*vu*) = ratio of vacancies (from the ONS Vacancies survey since 2000, spliced with a series reflecting job centre vacancies before 2000) to unemployment of people aged 16 and over.

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[6] This means imposing that the coefficients on the (lagged and contemporaneous) endogenous variables sum to one in each equation. In the wage equation: coefficients on lagged wage growth, and lagged one-year inflation expectations. In the price equation: coefficients on lagged and current wage growth, and lagged price inflation. In the one-year inflation expectations equation: coefficients on lagged one-year inflation expectations, lagged and current price inflation, and lagged and current long-run inflation expectations. In the long-run inflation expectations equation: coefficients on lagged long-run inflation expectations, and lagged and current price inflation.

[7] We use CPI, consistent with the Bank of England's inflation target of 2% CPI inflation. The ONS' preferred inflation measure, CPIH, also includes owner-occupied housing costs; CPI does not, but does include actual rental costs.

- Supply chain pressure (*scp*) = the Global Supply Chain Index (GSCPI), a composite index of shipping and supply chain conditions, published by the Federal Reserve Bank of New York.[8]
- One-year inflation expectations (*iesr*) = a composite series constructed by Thomas and Dimsdale (2017), covering expectations of households and professional forecasters, extended using household expectations.
- Long-run inflation expectations (*ielr*) = a composite series based on Thomas and Dimsdale (2017), covering expectations of households, professional forecasters, and financial markets, benchmarked to average inflation over the sample period.
- Catch-up (*catchup*) = a linear combination of two other endogenous variables: realised annual price inflation minus one-year inflation expectations a year prior.

4.2 The data illustrated

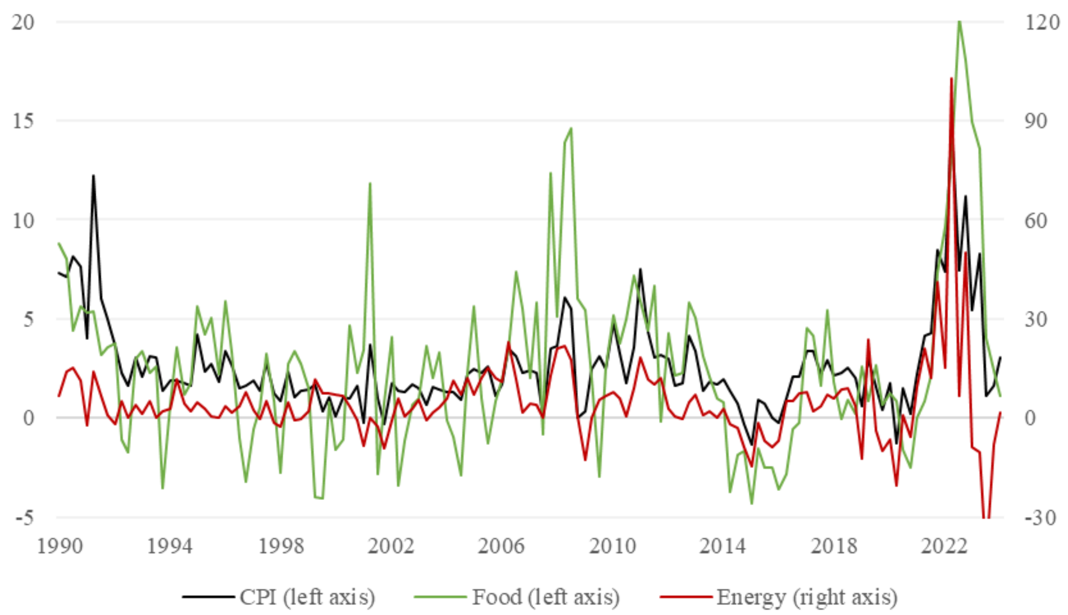
Starting with inflation, Figure 1 shows headline CPI, food, and energy inflation in the UK over the whole sample period. The rise in inflation over 2021-22 is historically large and our focus here. The following points are worth noting.

First, headline CPI and energy appear to co-move to a large degree. The responsiveness of UK inflation to energy price shocks will reflect the structure of UK energy markets: notably, the marginal source of supply in the UK is gas, so electricity prices are highly sensitive to gas prices, and household energy prices are regulated (Haskel, 2022).

Second, CPI inflation, as measured here in annualised quarter on quarter changes, started to rise in 2021 Q1 (in 2020 Q4 it was 0, then 2.7, 3.7, 4.7 and 8.1 over 2021). Notice that energy prices had already started to rise in 2021 Q2, well before Russia's invasion of Ukraine in February 2022. Food prices began to rise in 2021 Q4 and then increased strongly from 2022 Q2 and onwards.

Figure 1: Quarter-on-quarter annualised inflation, headline CPI, food, and energy, 1990 Q1 to 2024 Q1

[8] In a previous version of this paper, we used the Google trends result for "shortage" in the UK, as a proxy for supply chain problems (following BB). In this version we replace that with the GSCPI, since the Google measure seems to perform less well since 2023.



Source: ONS, authors' calculations.
Notes: Series are seasonally adjusted quarter-on-quarter natural log changes (annualised by multiplying by 400), so are more volatile than conventional annual inflation measures. Energy includes household gas and electricity bills, and fuels and lubricants used in personal transport equipment (i.e. petrol, diesel). Food includes non-alcoholic beverages. CPI and Food series shown against the left-hand side axis, energy shown against the right-hand side axis.

Figure 2 shows nominal wage growth as well as the V/U ratio, our preferred measure of labour market tightness.[9] These wage data are adjusted for labour force composition and for the effects of the pandemic furlough scheme (see Appendix C for details). The data show a strong rise in the V/U ratio in recent times alongside a strong rise in wage inflation, although V/U has receded since the end of 2022.

Turning to expectations, Figure 3 shows the series of short and long run expectations we use.[10] Both are composite series covering expectations of households, professional forecasters, and financial markets (see Appendix C for details). Both short and long run measures rose somewhat during the pandemic-era inflation spike, and then fallen again. However, it is notable that long-run expectations have varied very little.

Figure 2: Wage growth and labour market tightness (vacancies-to-unemployment ratio), 1990 Q1 to 2024 Q1

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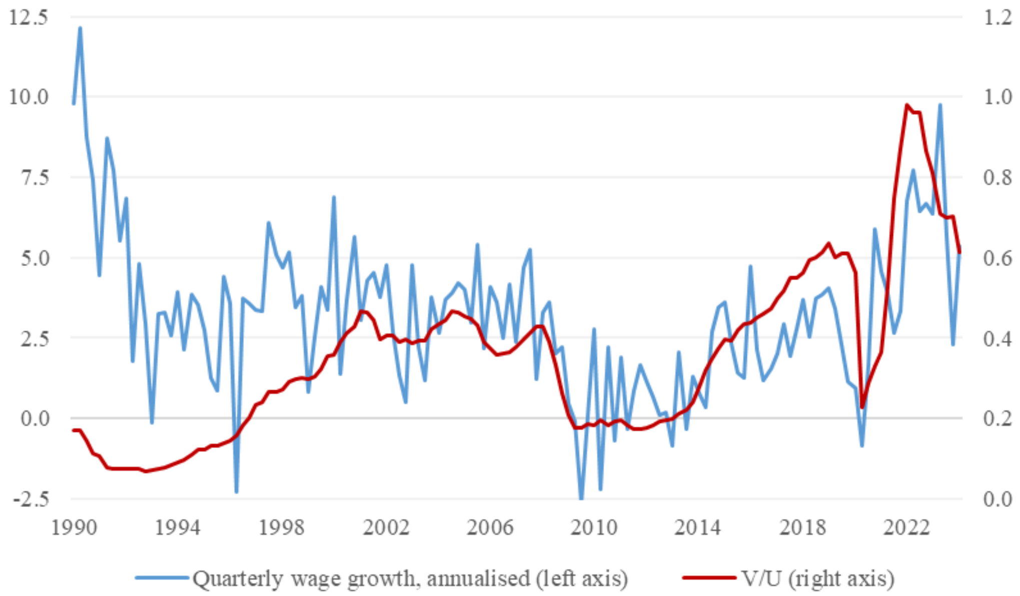
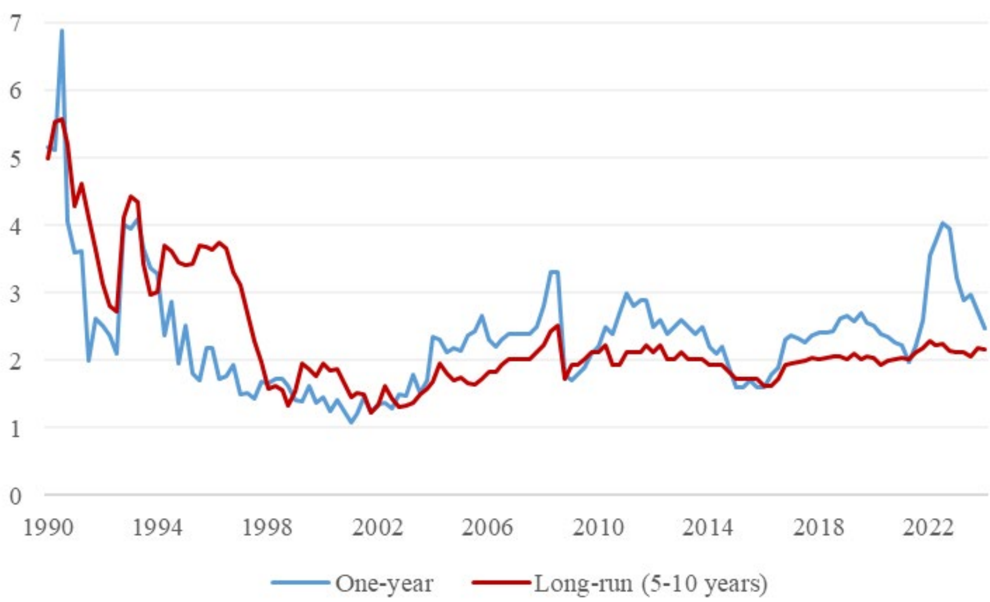
[9] It is interesting to note that the V/U ratio in the UK is much lower than the US, see Appendix B, Figure B5. One reason might be that a significantly higher share of new flows into employment in the US comes from transitions from inactivity rather than from unemployment relative to the UK/Europe. So, the US "requires" more vacancies relative to the unemployment stock to keep the unemployment stock constant.
[10] For description of data available on inflation expectations in the UK, see Mann (2022) and Tenreyro (2019).



Source: ONS, Bank of England, authors' calculations.
Notes: Wage growth is private sector regular pay (i.e. excluding bonuses etc.), from the Average Weekly Earnings, seasonally adjusted. It is adjusted for changes in composition of the workforce, and for the effect of furlough during the pandemic. Wage growth is quarter-on-quarter log changes, annualised by multiplying by four. The V/U ratio covers all vacancies and all unemployed (meeting standard definitions).

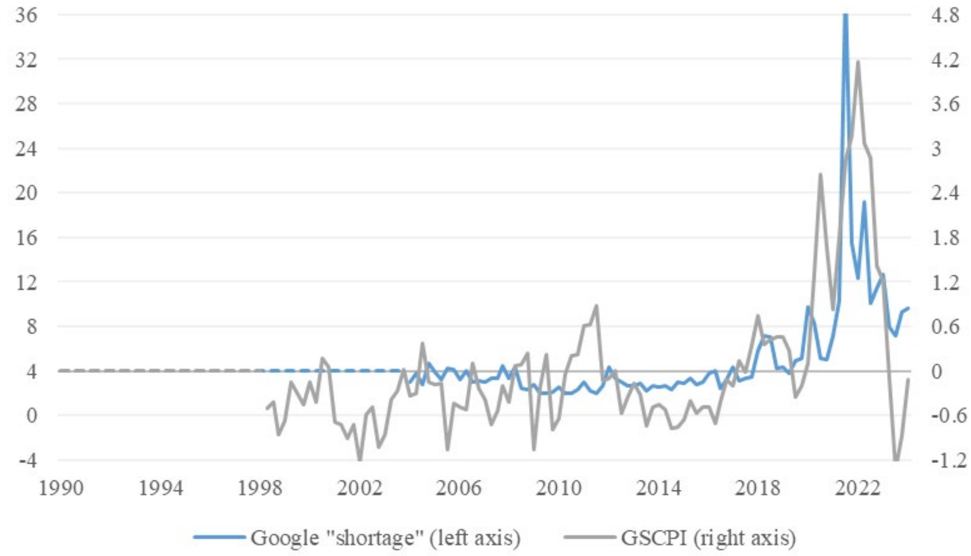
Figure 3: One-year and long-run inflation expectations, 1990 Q1 to 2024 Q1



Source: Bank of England, authors' calculations.
Note: One-year inflation expectations is a composite series covering expectations of households and professional forecasters. Long-run inflation expectations is a composite series covering expectations of households, professional forecasters and financial markets, benchmarked to average inflation over the sample period. See Appendix C for more details.

Figure 4 shows two indicators of supply chain disruption: the Global Supply Chain Pressure Index (GSCPI) produced by the Federal Reserve Bank of New York[11], which we use in the estimation, and an indicator derived from Google searches, used by BB.

Figure 4: Supply chain pressure measures, 1990 Q1 to 2024 Q1

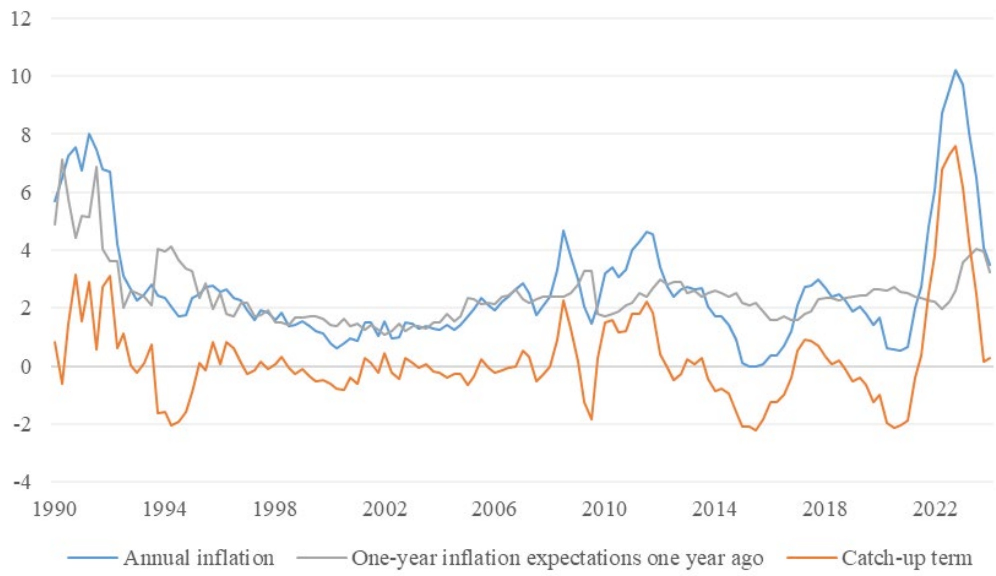


Source: Google, Federal Reserve Bank of New York, authors' calculations.
Notes: GSCPI = Global Supply Chain Pressure Index, published by the New York Fed. Dashed line represent assumed backseries prior to the start of the series – GSCPI set to 0 in the backseries, and Google "shortage" set to 4 in the backseries, both approximate averages over observed pre-pandemic data. BB use 5 as assumed backseries for Google "shortage". Series and axes aligned such that GSCPI=0 and Google=4 are aligned.

Turning to the catch-up term, Figure 5 shows, following BB, current annual inflation in period t, less what inflation in period t had been expected to be in t-4, i.e., four quarters ago. The large gap between realised and expected during the pandemic-era inflation spike is notable.

[11] https://www.newyorkfed.org/research/policy/gscpi#/overview

Figure 5: "Catch-up" term (realised inflation less one-year inflation expectations a year ago), 1990 Q1 to 2024 Q1



Source: ONS, Bank of England, authors' calculations.
Notes: Graph shows realised annual inflation, one-year inflation expectations lagged by a year, and catch-up term = realised annual inflation minus one-year inflation expectation a year ago.

5 Initial results

Following BB, we first report the estimated coefficients of the four equations[12] (Sections 5.1 to 5.3), before presenting the implied impulse respond functions (IRFs) of shocks to the exogenous variables (Section 5.4). Then Section 6 shows the decompositions of inflation and wage growth over the period from 2020 to 2024, and Section 7 shows conditional forecasts.

Each equation is estimated using up to four lags as reported in the sub-sections below (see Section 3.4 for the full equations). We report the sums of coefficients on the lags, to aid computation of short- and long-run elasticities, and joint tests of statistical significance. The full set of coefficients are in Appendix A, and charts of the fitted values against outturns for each equation are in Appendix B. We impose homogeneity on the equations as do BB; this restriction is not rejected in the data as point estimates are very similar without such homogeneity imposed.

5.1 Wage equation

Table 1 shows the wage equation and suggests the following. First, the effect of V/U is positive and statistically significant. The effect of a half-point (i.e. 0.5) rise in the V/U ratio (from, say,

[12] Although unlike BB we estimate these over the full sample (1990 Q1 to 2024 Q1) – see Section 3.4 for discussion.

1.0 to 1.5) is to raise wage growth in the long-run by 2.6pp.[13] This suggests that wage growth in the UK is more sensitive to the level of labour market tightness (as measured by the V/U ratio) than in the US.[14]

Table 1: Wage growth equation (dependent variable = *gw*)

Independent variable	*gw*	*vu*	*catchup*	*iesr*	*gpty*
Lags	-1 to -4	-1 to -4	-1 to -4	-1 to -4	-1
Sum of coefficients	0.596	2.102	0.004	0.404	0.201
p-stat (sum)	0.000	0.032	0.972	0.000	0.116
p-stat (joint)	0.000	0.017	0.151	0.001	-
R-squared	0.578				
No. observations	137				

Notes: Sample is 1990 Q1 to 2024 Q1. "p-value (sum)" is the p-value for the null hypothesis that the sum of coefficients is zero, "p-value (joint)" is the p-value for the joint hypothesis that each of the lag coefficients separately equals zero. R-squared is over the estimation period. Without the homogeneity constraint, the sum of coefficients on *gw* is 0.592 and on *iesr* is 0.462, and combined is 1.054.

Second, the sum of the coefficients on the lagged dependent variable is 0.60 (US: 0.46) and therefore on inflation expectations it is 0.40 (US: 0.54) (these are constrained to sum to unity by the homogeneity constraint). Thus, short-run inflation expectations feed into wage inflation slightly more slowly than in the US. Third, catch-up is statistically insignificant in the long run, as found in the US work; however, it can have dynamic effects, which we explore in Section 5.3.

Figure B1 in Appendix B shows fitted values[15] for wage growth from the wage equation for the pandemic and post-pandemic period. In UK data, quarter-on-quarter wage growth is volatile, especially so during the pandemic, and so difficult to predict precisely. However, the model does reasonably well to match the approximate level of wage growth after 2020 Q3. Annual wage growth in the year to 2024 Q1 is 5.8%, against 5.5% in the fitted values.[16] Indeed, in annual growth terms (not shown), the fitted values match the data remarkably closely from 2022 Q3 onwards.

[13] This is the change in the V/U ratio, multiplied by the sum of coefficients on V/U, divided by one minus the sum of coefficients on the lagged dependent variable: 0.5 x 2.102 / (1 - 0.596) = 2.6pp. This is the long-run effect at given inflation expectations; allowing for expectations to also increase, the effect increases over time.

[14] The comparison with the US is obscured because this is a semi-elasticity. The average level of the V/U ratio is substantially lower in the UK than the US (with or without including the pandemic period), so a 0.5-point increase in the V/U ratio implies a larger proportional increase in tightness in the UK than the US. The short-run elasticity of wage growth to a percentage increase in the V/U ratio (at the sample mean of V/U) is 0.73 in the UK and 0.40 in the US, while the long-run elasticity is 1.80 in the UK and 0.75 in the US.

[15] Since there are no contemporaneous regressors in the wage equation, these fitted values are akin to one-period ahead forecasts, replacing exogenous and endogenous variables by their realised values in each period and all previous periods.

[16] This is on the basis of averaging the four quarter-on-quarter annualised natural log changes, which is exactly equivalent to a quarter-on-same-quarter-a-year-ago natural log change, but not the same as the equivalent percentage change, which is more widely quoted. In percentage changes the comparison is 6.0% in the data, against 5.7% in the fitted values.

5.2 Price equation

Table 2 summarises the estimated price inflation equation, with the full specification in Appendix A.

Table 2: Price inflation regression (dependent variable = *gp*)

Independent variable	*gp*	*gw*	*grpe*	*grpf*	*scp*	*gpty*
Lags	-1 to -4	0 to -4	0 to -4	0 to -4	0 to -4	-1
Sum of coefficients	0.680	0.320	0.025	0.108	0.123	-0.218
p-stat (sum)	0.000	0.000	0.226	0.051	0.416	0.004
p-stat (joint)	0.000	0.000	0.000	0.000	0.781	-
R-squared	0.869					
No. observations	137					

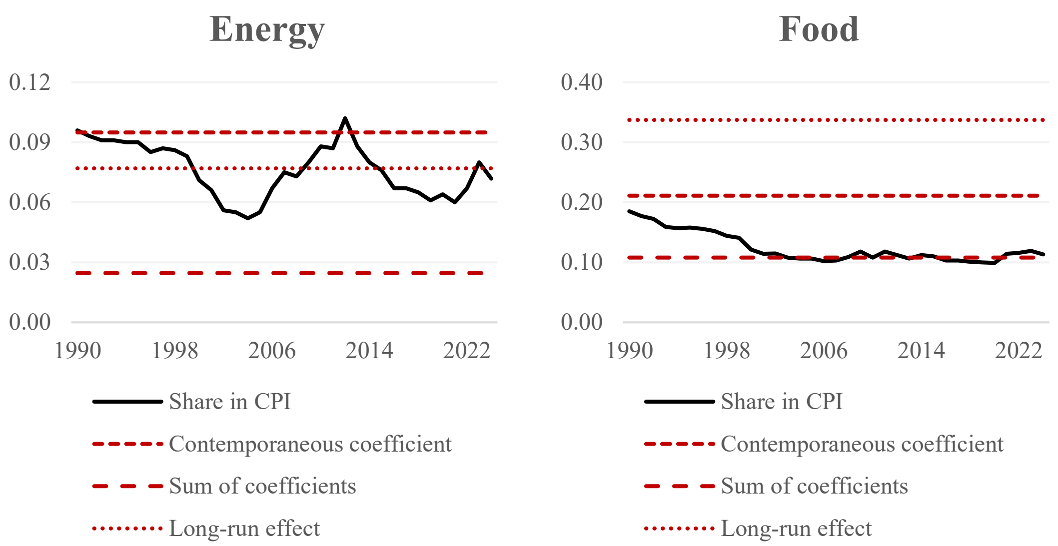
Notes: Sample is 1990 Q1 to 2024 Q1. "p-value (sum)" is the p-value for the null hypothesis that the sum of coefficients is zero, "p-value (joint)" is the p-value for the joint hypothesis that each of the lag coefficients separately equals zero. R-squared is over the estimation period. Without the homogeneity constraint, the sum of coefficients on *gp* is 0.608 and on *gw* is 0.306, and combined is 0.914.

We find the following. First, the sum of coefficients on lagged wage growth is 0.32, which is smaller than that for the US (0.67). The corollary to this is that the sum of coefficients on price inflation is 0.68, which is larger than that for the US (0.34). Recall that these are constrained to sum to unity by the homogeneity constraint (without this imposed they are 0.31 and 0.61).

Second, energy and food relative price changes are both relevant for inflation. Figure 6 illustrates and puts into context the coefficients on energy and food. It shows the coefficient on contemporaneous energy and food prices (0.09 and 0.21 respectively, see Appendix A, Table A2), the sum of coefficients (see Table 2), the long run effects of each (0.08 and 0.34 respectively)[17], and the shares of energy and food in the CPI basket in the UK over time. The contemporaneous coefficients are close to the average shares of each in the CPI basket over the estimation period, which is reassuring. The long-run effect of energy is similar to that found for the US (0.08 vs 0.10), but that for food is somewhat larger than found for the US (0.34 vs 0.19). We discuss the size of these effects further in Section 5.4, but note for now the apparently large and persistent role for food price shocks in the UK.

[17] Calculated as the sum of coefficients on energy or food, divided by one minus the sum of coefficients on the lagged dependent variable. For energy this is: 0.025 / (1 - 0.680) = 0.077. For food this is: 0.108 / (1 - 0.680) = 0.337.

Figure 6: Coefficients on energy and food, and shares in the CPI basket, 1990-2024



Notes: Energy includes natural gas, electricity, and vehicle fuels. Food includes food and non-alcoholic beverages. Sum of coefficients includes the contemporaneous coefficient. Long-run effects calculated as the sum of coefficients on energy or food, divided by one minus the sum of coefficients on the lagged dependent variable (see footnote 16).

Third, the supply chain pressure variable predicts higher inflation. The GSCPI measure has a mean average of zero by construction, so zero reflects 'average' supply chain conditions, with tighter-than-average conditions taking a positive value and looser-than-average conditions a negative value. Thus, a positive sum of coefficients on supply chain pressure indicates that supply chain frictions lead to higher inflation. Though note, the mean average of the GSCPI includes the extreme supply chain issues experienced during the pandemic (see Figure 4), so a zero value implicitly includes some frictions, and the pre-pandemic average is less than zero.[18]

As Figure B2 in Appendix B shows, the equation fits realised inflation over the pandemic period well. This is partly due to the important effects of energy and food in UK inflation over this period which enter the price equation contemporaneously. The equation fits quarterly inflation less well starting in mid-2023, with the fitted values exceeding actual inflation by around 1.5pp in 2023 Q4 and2024 Q1. This follows two smaller errors in the preceding two quarters, such that the fitted value for annual inflation in the year to 2024 Q1 is only 0.4pp higher than actual inflation (3.7% vs 3.3%).

[18] Note that we use a different measure of supply chain pressure (or shortages in their language) to BB for the US, who use the Google trends measure. This takes a value between 0 and 100 and has a mean of around 5. As such, the interpretation of the coefficients differs, though the sign and size of their contribution to inflation over the pandemic-era are similar.

5.3 Inflation expectations equations

Table 3 shows the short-run inflation expectations equation. It suggests that short-run inflation expectations are strongly dependent on their own lags (sum of coefficients = 0.85), weakly on long-term expectations (0.13) and also weakly on realised inflation (0.02). This is a little different to the results for the US in BB, who find larger roles for long-term inflation expectations (0.51) and current inflation (0.12), and a smaller role for the lagged dependent variable (0.37), relative to our results for the UK. With a larger role for the lagged dependent variable in the UK results, we note that one-year inflation expectations are more 'sticky' in the UK and are less adaptive to current inflation. That said, they appear relatively less anchored to long-run inflation expectations than in the US.

Table 3: One-year inflation expectations (dependent variable = *iesr*)

Independent variable	*iesr*	*ielr*	*gp*
Lags	-1 to -4	0 to -4	0 to -4
Sum of coefficients	0.847	0.134	0.020
p-stat (sum)	0.000	0.016	0.390
p-stat (joint)	0.000	0.000	0.053
R-squared	0.829		
No. observations	137		

Notes: Sample is 1990 Q1 to 2024 Q1. "p-value (sum)" is the p-value for the null hypothesis that the sum of coefficients is zero, "p-value (joint)" is the p-value for the joint hypothesis that each of the lag coefficients separately equals zero. R-squared is over the estimation period. Without the homogeneity constraint, the sum of coefficients on *iesr* is 0.837, on *ielr* is 0.123, and on *gp* is 0.026, and combined is 0.986.

Figure B3 in Appendix B shows that the fitted values for one-year inflation expectations over the pandemic are similar to the outturn data, albeit somewhat more volatile. This mechanically follows from the volatility in realised (quarter-on-quarter, annualised) inflation over this period. While the sum of coefficients is only 0.02 (Table 3), the coefficient on contemporaneous inflation is larger at 0.05 (Appendix A, Table A3). The variation in quarterly inflation thus generates variation in one-year inflation expectations.

Table 4 summarises the estimated long-run inflation expectations equation, estimated on the pre-pandemic sample, which is similar to the findings for the US. Long-run expectations depend strongly on their own lags (sum of coefficients: 0.99, US: 0.975) and weakly on current price changes (0.01, US: 0.025). As in the US, therefore, high realised inflation raises long-run expectations in the model only slightly, but the high autocorrelation in long-run expectations will keep them slightly elevated for time even after current inflation recedes. Figure B4 in Appendix B shows that long-run inflation expectations seem well-anchored. As for one-year inflation expectations, the fitted values of the long-run inflation expectations equation are more volatile than actual long-run expectations, co-moving with contemporaneous inflation.

Table 4: Long-run inflation expectations (dependent variable = *ielr*)

Independent variable	*ielr*	*gp*
Lags	-1 to -4	0 to -4
Sum of coefficients	0.993	0.007
p-stat (sum)	0.000	0.543
p-stat (joint)	0.000	0.000
R-squared	0.944	
No. observations	137	

Notes: Sample is 1990 Q1 to 2024 Q1. "p-value (sum)" is the p-value for the null hypothesis that the sum of coefficients is zero, "p-value (joint)" is the p-value for the joint hypothesis that each of the lag coefficients separately equals zero. R-squared is over the estimation period. Without the homogeneity constraint, the sum of coefficients on *ielr* is 0.975, and on *gp* is 0.011, and combined is 0.986.

5.4 Impulse response functions

We may use the model to study the predicted response of consumer prices to shocks to the exogenous variables, of which we have four: prices of energy and food (relative to wages), supply chain pressures, and the V/U ratio. To aid interpretation, we look at the effects of shocks on quarter-on-same-quarter-a-year-ago percentage changes. These units are thus more directly comparable with widely quoted annual inflation data than the quarter-on-quarter annualised log changes used in the regressions (see Figures B7 and B8 in Appendix B for charts on a quarter-on-quarter annualised basis).

We choose the shocks to be average pre-pandemic shocks, that is, to be one standard deviation of relative energy and food prices, and the supply chain variable, between 1990 Q1 and 2019 Q4.[19] These are one-period price level shocks which are not reversed, so that the level of prices rises and stays higher than before the shock but does not continue to rise faster than before. In contrast, we model supply chain pressures as a one-period supply chain disruption, which normalises in the following period.

Figure 7 shows the results of the first three shocks. First, the peak effect on annual inflation of a typical pre-pandemic shock to relative food prices is after four quarters, at which point it would add about 0.3pp to annual inflation. After this, the effect dissipates as the initial increase falls out of the annual calculation. However, it continues to push up on inflation for several years, adding around 0.02pp to annual inflation four years after the shock.

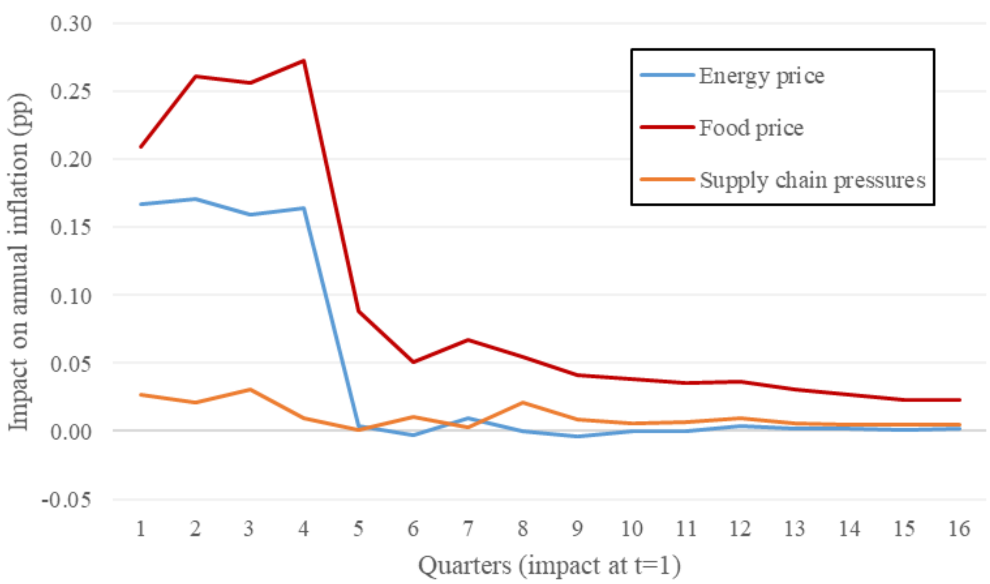
Second, the peak effect from supply chain pressures is after three quarters, which then unwinds towards zero, and settles at close to zero (though marginally positive) after about two years after the initial shock. Pre-pandemic supply chain shocks were relatively small, adding just 0.03pp to annual inflation at peak. However, the supply chain shocks during 2021 were much larger, adding as much as 0.8pp to annual inflation (see section 6.2).

[19] Notice these are not the same as BB, who (their Figure 10) use shocks equal to the standard deviation in the exogenous variables over the pandemic period 2020 Q1 to 2023 Q1, which are substantially larger. We show this in Appendix B (Figure B7) for comparison.

Third, as for energy prices, there is little impact on quarter-on-quarter inflation after the first quarter, such that the effect on annual inflation of a typical pre-pandemic shock to relative energy prices is little changed across the first four quarters at a little under 0.2pp. Then, the impact on inflation falls sharply to near zero, and is around zero thereafter. Energy price shocks seem to be the least persistent of the three exogenous shocks considered in the model.

We should note that Figure 7 uses *pre*-pandemic standard deviations in relative energy prices, relative food prices, and supply chain pressures, such that they reflect the impacts of typical pre-pandemic shocks implied by the model. The magnitude of these is 7.0, 4.0 and 0.4 respectively. To interpret the relative price changes, which are measured in quarter-on-quarter annualised log changes, this is a quarterly change in the price of energy or food, relative to the quarterly change in average wages, annualised (which is to say, the annual rate if the quarterly rate continued for four quarters). The shocks to these variables during the pandemic and post-pandemic period are *much* larger: the maximum quarterly shocks being 95 for relative energy prices in 2022 Q2 (that is, a roughly 25% quarterly rise relative to wages, which would have been roughly a doubling had it continued for four quarters), 14 for relative food prices in 2022 Q3, and 4.2 for supply chain pressure in 2021 Q4. These are 13.5, 3.5 and 9.7 times larger than typical pre-pandemic shocks respectively.[20]

Figure 7: Impulse response functions of annual price inflation to shocks to the relative price of energy, relative price of food, and supply chain pressures



Notes: Shows the full-model response of quarter-on-same-quarter-a-year-ago inflation (i.e. annual inflation) to a one-quarter (i.e. one-off) positive shock to relative energy prices, relative food prices, and supply chain pressure. Shocks equal to the standard deviation of the exogenous variable over 1990 to 2019 (a typical pre-pandemic shock).

[20] Put another way, the standard deviations of relative energy prices, relative food prices, and supply chain pressure over the period 2020 Q1 to 2023 Q1 are 29.9, 6.2 and 1.1 respectively, equal to 4.3, 1.6 and 2.6 times their pre-pandemic standard deviations.

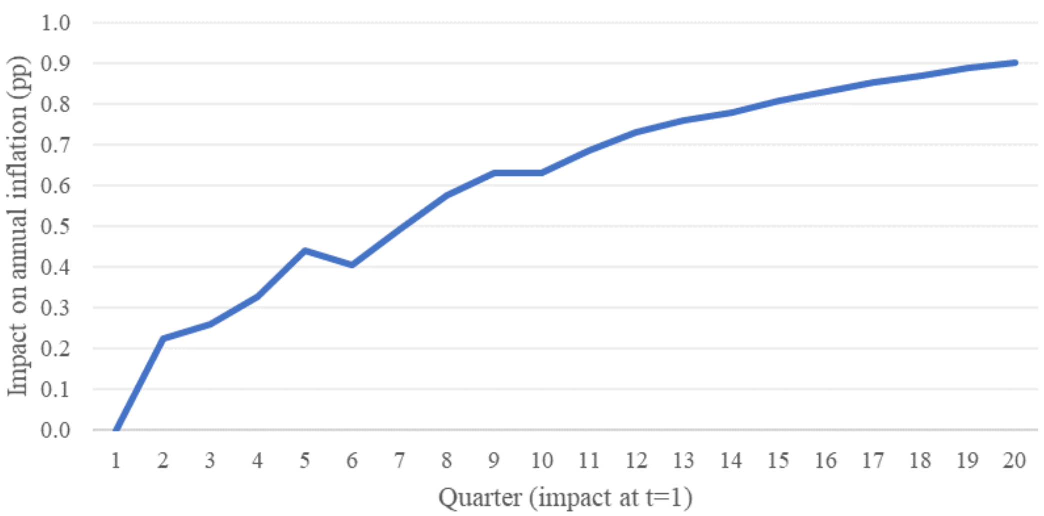
Turning to the fourth exogenous variable, namely labour market tightness, Figure 8 shows the response of annual inflation to a *permanent* increase in the V/U ratio. Recall that in the model, V/U enters only the wage equation, and then only with a lag, and then wage growth enters the inflation equation contemporaneously (and with a lag). Thus, there is no contemporaneous impact on inflation (or wage growth) from a shock to the V/U ratio. Unlike for the price shocks in Figure 7, a permanently higher level of V/U persistently raises wage growth and thus price growth, not just the wage (and price) level. That is, a world with a persistently tighter labour market produces persistently faster wage *growth* and thus *inflation*, whereas a world with persistently higher food prices produces *temporarily* faster inflation, and a persistently higher price *level*.

As for the price shocks above, we scale this increase by the standard deviation of the V/U ratio over the period 1990 Q1 to 2019 Q4. The shock is equal to 0.15-points in the UK.

In the long run, such a shock delivers permanently higher wage growth, and thus permanently higher inflation. Once wage growth increases after the initial rise in the V/U ratio, the pattern of quarterly coefficients and the rest of model (via catch-up and inflation expectations) keeps wage growth increasing. Thus, price inflation also continues to increase.

This result highlights a feature of the model, namely the lack of an explicitly modelled monetary policy response. This would constitute an extension to the model beyond the scope of this paper.

Figure 8: Impulse response function of annual price inflation to a permanent increase in labour market tightness



Notes: Shows the full-model response of annual inflation to a permanent one standard deviation rise in V/U. Standard deviation calculated over 1990 Q1 to 2019 Q4, such that is represents a typical pre-pandemic shock.

To compare with the US, BB use a shock to V/U in their IRF (their Figure 11) of 0.59-points, based on the standard deviation of V/U over the pandemic period (2020 Q1 to 2023 Q1), which results in inflation being about 1pp higher after four years. The equivalent numbers for the UK are a standard deviation of 0.27-points, and inflation approximately 1.5pp higher after four years. The relative size of these shocks is similar given that the V/U ratio in the US is, on average, about double what it was in the UK between 1990 and 2023 (see Appendix B, Figure B5). The difference in long-run effects is consistent with the difference in long-run elasticities discussed in Section 5.1 (see footnote 13 in particular).

6 Accounting for inflation over the pandemic

6.1 Method

We wish to use our model to predict inflation over the pandemic and post-pandemic periods, and then decompose it into economically interpretable contributions. We do this, following BB, by separating the effects of shocks that happened during and after the pandemic from the lingering effects of those before.

In seeking to account for inflation, we have (what we treat as) exogenous variables, endogenous variables and lags. Thus, we proceed as follows.

We choose a starting point for the model as 2020 Q1 with the actual data of all exogenous and endogenous variables up to 2019 Q4. For quarters thereafter, we condition on *actual* outturns of the exogenous variables but use the *predictions* of endogenous variables in each period as inputs to subsequent predictions. Since each equation depends on the lags of some endogenous variables (either lags of the dependent, or lags of another endogenous variable) the prediction is computed iteratively, with predictions for each period calculated and then used as an input into the prediction for the next period. Since we use the model predictions of the endogenous variables, rather than their actual outturns, any errors in predictions are effectively 'carried over' into subsequent predictions (we can additionally decompose each data outturn into the prediction and errors to the prediction itself and see the impact of these errors on subsequent predictions in the model).

We call the predictions the process generates as predictions of the "full dynamic model". But we wish to decompose the model prediction into the contribution each of the exogenous variables. To do this, we set, one-by-one, each of the exogenous variables to a counterfactual value (say, their pre-pandemic level, more on this below), and re-simulate the model. This then gives four alternative predictions for all the endogenous variables, that is, one alternative prediction with each of the four exogenous variables set at their pre-pandemic value. The difference between the full dynamic model prediction and these alternative predictions is the contribution of the particular exogenous variable to the endogenous variable's realisation. Notice this contribution covers both direct and indirect effects via other endogenous variables. For example, an energy price shock enters the price equation directly, but will also affect the catch-up variable, which enters the wage equation, and wages then enter the price equation. Hence holding energy prices constant and simulating the model tells us the simulated outcome on the endogenous variables, accounting for direct and indirect effects, had energy prices stayed constant. We return to this in Section 6.3.

We need then to decide the values of the exogenous variables consistent with the pre-pandemic conditions continuing. Following BB, we call "initial conditions" as the model predictions under the counterfactual where the pandemic did not occur.

What values of exogenous variables are consistent with this counterfactual of pre-pandemic conditions? We set the change in the relative price of energy and food to their respective 2012-2019 averages, which are -1.3% and -1.5% (quarter-on-quarter log changes, annualised) respectively. This implies that the prices of energy and food increase slower than nominal wages, which was the norm prior to the pandemic. These values differ slightly to those used by BB, who set these both to zero, i.e. the nominal energy and food prices move in line with nominal wages. This was not the norm in the UK before the pandemic, especially for food prices, so zero relative price changes would be a moderately inflationary assumption.

We similarly set the supply chain pressures variable at its pre-pandemic average value (roughly -0.2) representing 'normal' pre-pandemic conditions. Note that the GSCPI is constructed to have zero mean over its entire time series, and given the large disruption to supply chains during the pandemic (represented by large positive values), the pre-pandemic average is less than zero. We set trend productivity growth to 0.5% per year which is roughly the post-GFC average, and consistent with forecasts made shortly before the pandemic.

We follow BB in holding the V/U ratio at its 2019 Q4 level, in our data, about 0.6. Whilst this is consistent with the spirit of holding other exogenous variables at their levels at this time, it is worth noting that this V/U level is around twice its long-run pre-pandemic average. This means then that the V/U initial conditions embody a historically "tight" labour market. Indeed, relative to the estimation period average (roughly 0.35) the model interprets this as a persistent increase in the V/U ratio of roughly 0.25-points. Recall that the IRF for a persistent increase in labour market tightness (Figure 8) implies increased price *inflation* (and wage growth), in contrast to the IRFs for price shocks (Figure 7) for which a shock leads to a permanent increase in the price *level,* but a temporary increase in inflation.

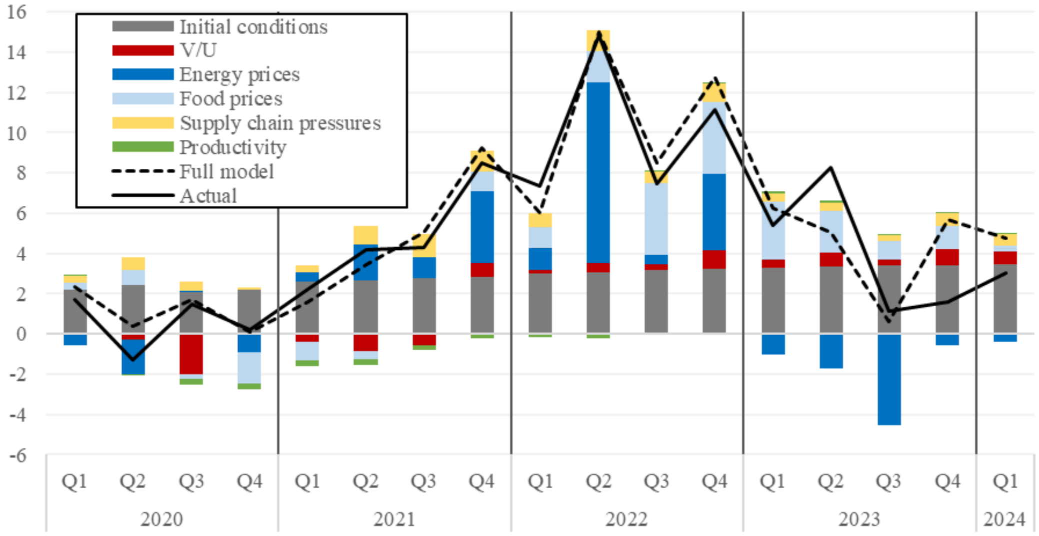
How do these choices affect our decomposition? Under the assumptions in the "initial conditions", quarter-on-quarter annualised inflation would have risen from 2.2% in 2020 Q1 to 3.4% in 2024 Q1. Thus, in our decompositions below, the contributions of the exogenous variables should be thought of as relative to this (underlying upward) path. We return to this point in Section 6.3, and it is worth emphasising that results are sensitive to the choices for the initial conditions. Appendix D describes a range of alternative assumptions for the initial conditions (especially on the V/U ratio), and how the contributions in the decomposition change accordingly.

6.2 Results

6.2.1 CPI inflation

Figure 9 shows the decomposition of quarter-on-quarter annualised CPI inflation between 2020 Q1 and 2024 Q1. We use the quarter-on-quarter data here since it relates more closely to the estimated model, but we note that whilst the CPI inflation measure here has the same broad pattern as the headline/target annual CPI inflation rate it is not of course exactly the same.

Figure 9: Decomposition of quarter-on-quarter annualised price inflation, 2020 Q1 to 2024 Q1



Notes: "Initial conditions" reflect the model prediction under counterfactual conditions where the V/U ratio remains at the level in 2019 Q4, relative food and energy price changes match their 2012-2019 averages, supply chain pressures are at 'normal' levels, and trend productivity growth is 0.5% per year; see text for interpretation of these conditions. Dynamic effects of two dummies in the wage equation are omitted.

The simulations suggest the following as regards inflation. First, the "initial conditions" line is trending up slowly. It was 2.2% in 2020 Q1 but has been drifting up slowly to 3.4% in 2024 Q1. This then implies that, as discussed above, had there been no price shocks, and had the V/U ratio remained at its level immediately before the pandemic, inflation would have risen. Thus the "initial conditions" bars embody a significant labour market tightness effect. We explore this further in Section 6.3.

Second, proceeding year by year, inflation in 2020 is difficult to decompose. National lockdowns in response to the spread of Covid-19 started in 2020 Q1 and continued to a varying extent through to 2022 Q1, though the lockdown stringency was much lower after 2021 Q1. We do not over-interpret 2020.

Third, inflation in 2021 is a little easier to interpret. Between 2021 Q1 and 2021 Q4, annualised quarter-on-quarter CPI inflation averaged 4.8% (2.8pp above the Bank of England's 2% target), to which energy contributed 1.7pp and supply chain disruptions 0.8pp. So the increase in inflation over that period was mostly due to energy and supply chain pressures.[21]

The contribution of labour market tightness over 2021 is predicted to have been negative until 2021 Q4 (relative to the assumptions for initial conditions). Recall that the furlough scheme ran until the end of September 2021, which may have eased labour market conditions; the V/U ratio rose sharply after it ended.

Fourth, as for inflation in 2022, energy was the key contributor in Q2, associated with another steep increase in the regulated energy price in April 2022. Food prices begin to play an important role from 2022 Q3 onwards. Labour market tightness was of growing importance throughout 2022 and into 2023. Similarly, the "initial conditions" bar is growing.

Fifth, inflation in 2023 starts to fall. The energy contribution to inflation turns negative, as energy prices declined from their post-Covid highs. Food prices continued to be important positive contributors to inflation in the first half of 2023, although that effect waned towards the end of the year and the start of 2024. Supply chain pressures continued to play a small role, which can be interpreted as past shocks continuing to work through the system. The tight labour market remained important. The model fails to predict the uptick in quarter-on-quarter annualised inflation in 2023 Q2, with an outturn of 8.3 against 5.0 predicted by the model. The model then over-predicts somewhat in 2023 Q4 and 2024 Q1. That said, the model explains annual inflation closely: see Figure B9 in Appendix B.

Equivalent charts for short- and long-run inflation expectations are included in Appendix B (Figures B11 and B12 respectively). The model explains the increase and then decrease in short-run inflation expectations well, with the deviations from initial conditions driven by the same shocks that affect price inflation. However, the model over-predicts the increase in long-run inflation expectations which in practice have remained remarkably well anchored through the recent inflationary period.

6.2.2 Wage inflation

Figure 10 shows the model decomposition of wage growth. The prediction of wage growth here fails to capture some of the quarterly variation, but does match the level of wage growth fairly well, especially after the end of the furlough scheme in 2021 Q3. The dummies in 2020 Q2 and 2020 Q3 are important to fit wage growth in those quarters given the sharp swing in the V/U

[21] Even though wholesale energy prices had been rising through 2021 in anticipation of Russia's eventual invasion of Ukraine, the pass through to CPI inflation was delayed by the regulatory arrangements for consumer prices. That meant that regulated energy prices increased notably in October 2021.

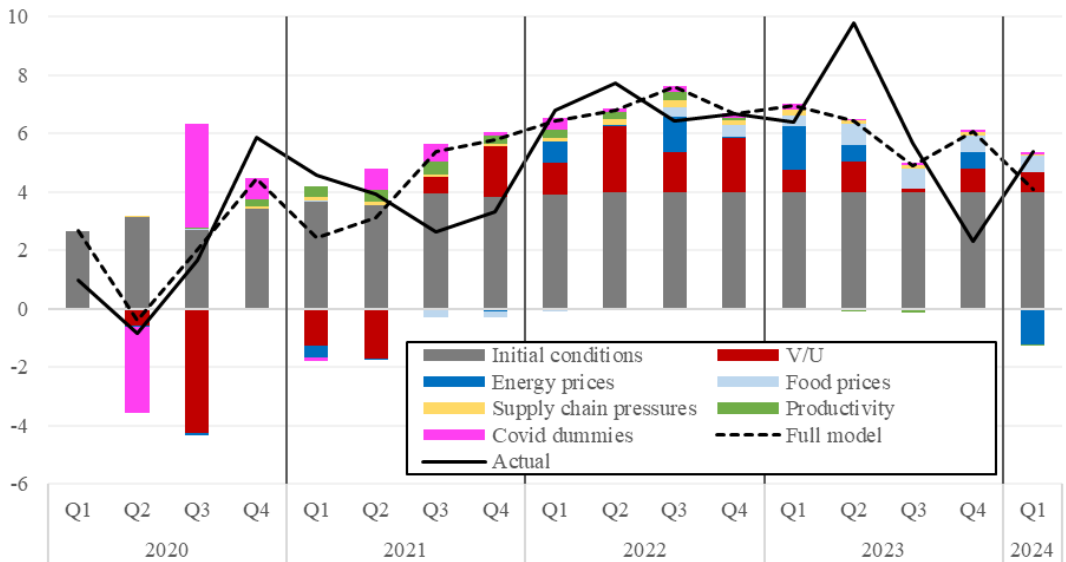
ratio, which by the dynamic nature of the model propagates. This can be interpreted as a wage stickiness effect: wage growth was higher in 2020 than it would otherwise have been given the drastic fall in labour market tightness, and that higher initial level of wage growth causes wage growth later to be a little higher than it would otherwise have been.

The "initial conditions" trend up over 2020 and 2021 in Figure 10, as in Figure 9 for price inflation, consistent with the V/U ratio being held at a 'tight' level, and thus leading to rising wage growth. They level off at about 4.0% from 2022 onwards.

Aside from the initial conditions, higher wage growth can be explained mostly by labour market tightness. This contributes 1.6pp to wage growth on average in 2022, 0.7pp on average in 2023, and 0.7pp in 2024 Q1. Energy prices, food prices and supply chain conditions, operating through inflation expectations and catch-up, also contribute to higher wage growth in 2022 and 2023 – around 1pp combined on average over this period, but turning negative in 2024 Q1 due to energy price falls.

Wage growth jumps to nearly 10% on a quarter-on-quarter annualised basis in 2023 Q2, before falling to just 2% in 2023 Q4 and returning to over 5% in 2024 Q1. The model cannot fit this volatility, which might reflect measurement error in the official wage data, and instead suggests a more gradual decline. However, the model matches the level of annual wage growth across 2023 and 2024 Q1 well, as shown in Figure B10 in Appendix B.

Figure 10: Decomposition of quarter-on-quarter annualised wage inflation, 2020 Q1 to 2024 Q1



Notes: "Initial conditions" reflect the model prediction under counterfactual conditions where the V/U ratio remains at the level in 2019 Q4, relative food and energy price changes match their 2019-2019 averages, supply chain pressures are at 'normal' levels, and trend productivity growth is 0.5% per year; see text for interpretation of these conditions. Dynamic effects of two dummies in the wage equation are omitted.

6.3 Inflation, labour market tightness and second-round/catch-up effects

This section uses the model to discuss the inflation/labour market nexus, labour market tightness and catch-up, given this is a focus of the model and of policymakers' interest (e.g. in preventing "second-round" effects).

As we have seen, labour market tightness (the V/U ratio) embodied in the initial conditions (0.61) was the highest level in the pre-pandemic sample (see Figure 2). While inflation was at or below target in 2019, wage growth was somewhat elevated relative to the prior period (see Figure 2), and the Bank of England's Monetary Policy Committee judged that the labour market was tight.[22] So it seems likely that the V/U ratio was above target-consistent levels in 2019 (the pre-pandemic sample average was 0.31).

Thus, the initial conditions embody a persistently tight labour market, while the contribution of the V/U ratio in the model (red bars in Figures 9 and 10) show the effect of tightness relative to that in the initial conditions (i.e. relative to V/U=0.61). If we selected an alternative (lower, i.e. looser) path for the V/U ratio in the initial conditions, then the apparent contribution of labour market tightness to wage growth and inflation in the model would be larger, since it would be relative to a lower counterfactual.

Appendix D sets out the effect of changing the counter-factual assumption on the V/U ratio underlying the initial conditions and we summarise it here.

The main result is that the contribution of labour market tightness to inflation during 2022 and 2023 could be larger than depicted in Figure 9. The contribution of labour market tightness to quarter-on-quarter annualized inflation over 2022 and 2023 averages 0.5pp in the baseline scenario shown in Figure 9. Assuming a lower counterfactual path for the V/U ratio (where it falls to its 2012-2019 average of 0.42 over 8 quarters and remains there) pushes the contribution of labour market tightness up to 1.3pp on average (initial conditions then rise more slowly, to 2.4% in 2024 Q1, and all other contributions are the same). A more extreme path for the V/U ratio in the counterfactual (where it falls to its 1990-2019 average of 0.31 over 8 quarters and remains there) gives an average contribution of labour market tightness to inflation of 1.8pp over 2022 and 2023, with the initial conditions finishing at 1.9% in 2024 Q1. Thus, a range of 0.5-1.8pp for the contribution of labour market tightness to inflation over 2022-2023 seems plausible. These and various other paths for V/U, and the associated contributions to inflation, are described in Appendix D.

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[22] See Bank of England Monetary Policy Reports from November 2019 and January 2020. For instance, "The labour market remains tight, and this has caused pay and domestic cost pressures to increase" (Bank of England, 2019, page 15) and "Survey measures of recruitment difficulties also remain elevated, consistent with a tight labour market" (Bank of England, 2020, page 30).

Turning to catch-up, its effect is not set out separately in Figures 9 and 10 since it is endogenously determined. Recall that catch-up is measured as actual annual inflation less what was expected a year ago: both of these are endogenous. Thus, to get some insight into catch-up, we proceed as follows. Recall that the effects on inflation of a price shock can be thought of as encompassing two broad channels: a "price-price" channel, captured by the coefficient on the contemporaneous and lagged exogenous variable, reflecting the impact on CPI directly (e.g. the impact of the cost of energy via the energy component of the CPI, and via energy used as an input in the production of other products), and a "wage-price" channel or second-round effects, captured by the response of the rest of the model to the first-round effects, reflecting a range of other channels including via real wage resistance (catch-up).

Therefore, to study the effect of catch-up on wage growth and inflation, we separate the effects of price shocks via the catch-up channel from effects via the other channels.

To do this we follow a similar method to that described in Section 6.1, namely running the dynamic model under different assumptions and comparing the results. Setting the catch-up variable equal to the values that would have occurred in the absence of exogenous shocks (i.e. the "initial conditions" scenario), but allowing the outturns of the exogenous price shocks to feed through to the rest of the model, reveals the effects of the price shocks via all channels other than catch-up, which can then be differenced with the behaviour of the full dynamic model to give the effect of the price shocks via catch-up alone.

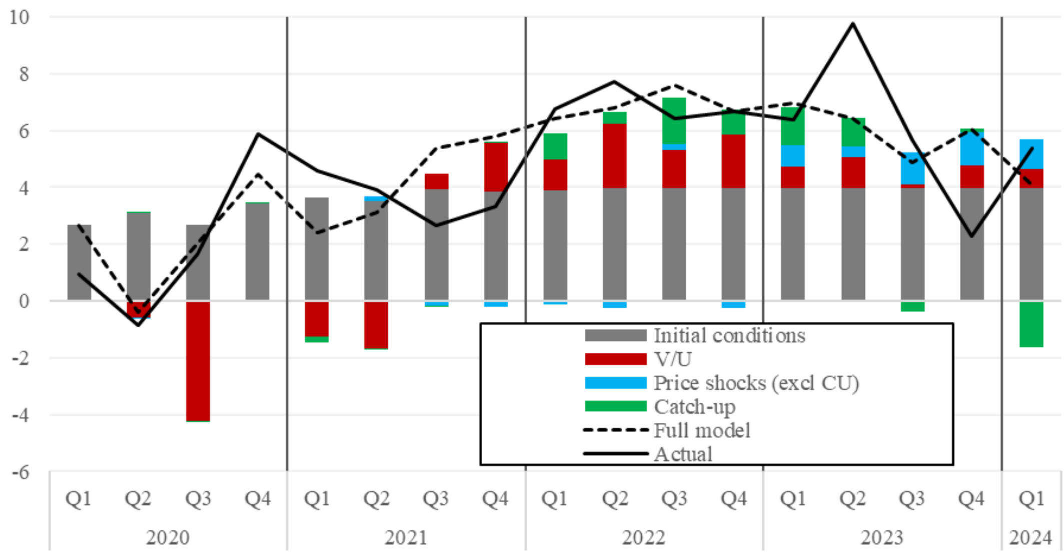
While the sum of coefficients on catch-up in the wage equation are close to zero (Table 1), catch-up still has an impact in the short run. During 2022 and 2023 the UK experienced a series of large shocks causing inflation and thereby an unexpected loss of purchasing power (Figure 5). And while the estimated models suggests that each of these shocks will have little effect on wage growth in the long run, they induce important dynamics in the short run. Thus, the cumulative effect of such shocks on wage levels can still be large.

Figure 11 (wage growth) and Figure 12 (price inflation) are equivalent to Figure 10 and Figure 9 respectively, but now the effects of the exogenous price shocks via the catch-up channel are separated into the green "Catch-up" bars. The contributions of the exogenous variables of energy prices, food prices, supply chain disruptions, and productivity, excluding through the catch-up channel, are grouped in the light blue "Price shocks (excl CU)" bars. The sum of the bars is the same as before, and the full dynamic model prediction is the same – these Figures simply show a re-arrangement of the contributions of Figures 9 and 10.

The catch-up channel (of the price shocks) pushes up on wage growth starting in 2022 Q1, contributing on average 1.0pp to quarter-on-quarter annualised wage growth between then and 2023 Q2. This passes through to price inflation (via wage growth), with the catch-up channel adding on average 0.4pp to quarter-on-quarter annualised inflation between 2022 Q1 and 2023 Q4.

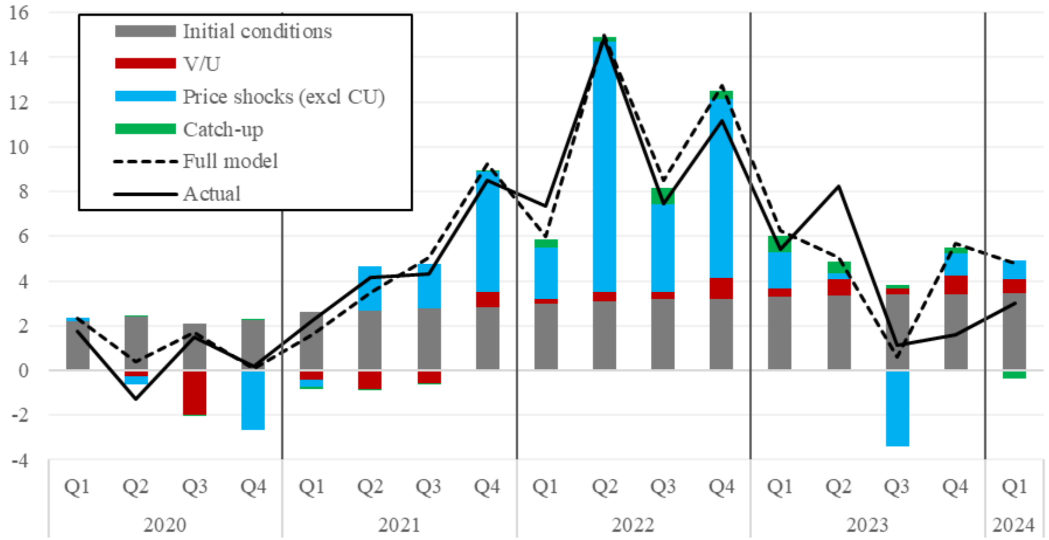
However, the effect of catch-up on quarterly wage growth is near zero in the second half of 2023, and negative in 2024. This reflects two factors. First, the positive catch-up shocks over 2022-2023 initially exert upward pressure on wages, but after a time this becomes negative due to the pattern of quarterly lag coefficients. Note that the sum of coefficients on catch-up in the wage equation is near zero, so the long-run effect of catch-up shocks is near zero, with positive initial effects offset by later negative effects. This could be interpreted as temporary real wage resistance, which is bargained away over time. Second, the large positive catch-up shocks of 2022-2023 are replaced in 2023 Q4 and 2024 Q1 by near zero catch-up shocks – that is, one-year inflation expectations one year prior were very close to outturn inflation. As such, there is no further upward pressure on wages from further catch-up shocks. The waning of these catch-up effects on wage growth passes through to price inflation, with the net effect of catch-up on quarterly price inflation turning negative in 2024 Q1.

Figure 11: Decomposition of wage inflation, separating the effects via the catch-up channel, 2020 Q1 to 2024 Q1



Notes: "Initial conditions" reflect the model prediction under counterfactual conditions where the V/U ratio remains at the level in 2019 Q4, relative food and energy price changes match their 2019-2019 averages, supply chain pressures are at 'normal' levels, and trend productivity growth is 0.5% per year; see text for interpretation of these conditions. Dynamic effects of two dummies in the wage equation are omitted. "Price shocks (excl CU)" reflect the effects of energy prices, food prices, and supply chain pressure excluding via the catch-up channel, which is shown separately. Re-arrangement of contributions in Figure 10.

Figure 12: Decomposition of quarter-on-quarter annualised price inflation, separating the effects via the catch-up channel, 2020 Q1 to 2024 Q1



Notes: "Initial conditions" reflect the model prediction under counterfactual conditions where the V/U ratio remains at the level in 2019 Q4, relative food and energy price changes match their 2019-2019 averages, supply chain pressures are at 'normal' levels, and trend productivity growth is 0.5% per year; see text for interpretation of these conditions. Dynamic effects of two dummies in the wage equation are omitted. "Price shocks (excl CU)" reflect the effects of energy prices, food prices, and supply chain pressure excluding via the catch-up channel, which is shown separately. Re-arrangement of contributions in Figure 9.

7 Projections

We use the model to provide some illustrative conditional forecasts for inflation. Our aim here is not to make accurate forecasts for inflation, but rather to illustrate the dynamics of the model, in the context of the post-pandemic inflation.

Nevertheless, to make a projection for inflation with this model, we must choose the paths for the exogenous variables starting in 2024 Q2. To progress, we set the growth in the relative prices of energy and food to their pre-pandemic 2012-2019 period averages of -1.3 and -1.5 (quarter-on-quarter log changes, annualised). Notice that shocks up to and including 2024 Q1 will still be in the dynamic simulation of the model. Similarly, we set the supply chain indicator to zero, consistent with its estimation period average, and trend productivity growth to 0.5% per year, roughly consistent with the post-GFC average and the assumption we used in Section 6.

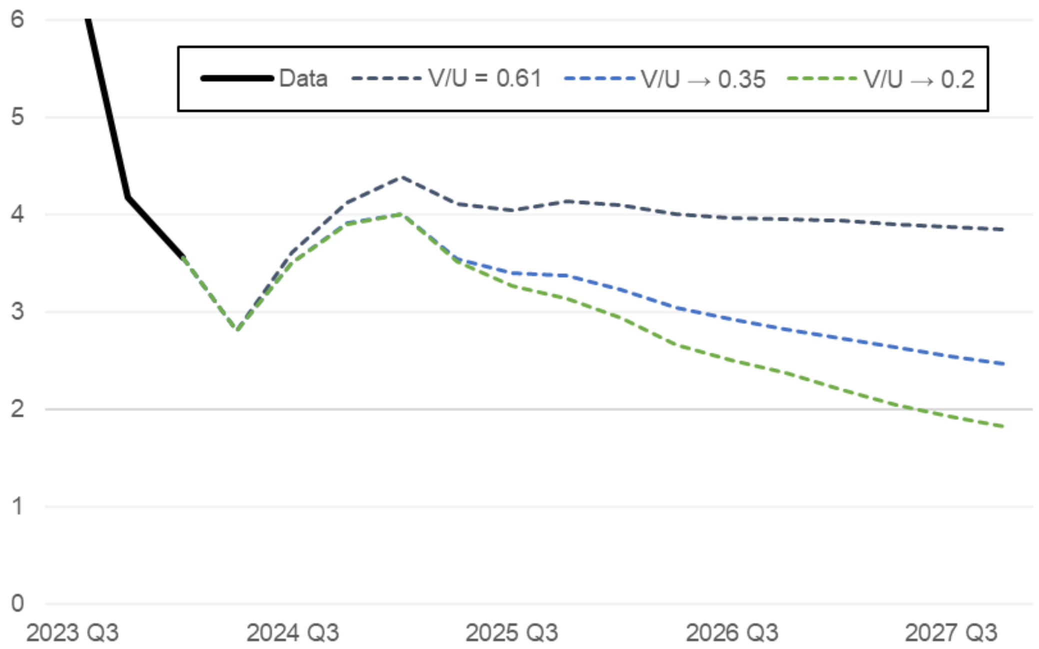
To illustrate the sensitivity of inflation to labour market tightness, we then choose different paths for the V/U ratio. Following BB, we take a simple approach and set three terminal values for V/U with linear adjustment towards them. These three paths are (a) staying at the 2024 Q1 level of 0.61 (note this is approximately the same as the 2019 Q4 level used in the initial conditions in Section 6, and a little less than twice the estimation period average), (b) decline towards the estimation period average of 0.35 over 4 quarters, and (c) decline towards

0.2, roughly the level seen after the 2008/09 recession and thus consistent with the loosest labour market in recent times (see Figure 2), over 6 quarters. The latter two paths reflect a similar decline in V/U of around 0.07 points per quarter, with path (c) declining further than path (b). This is roughly consistent with the average pace of decline in the V/U ratio between its peak in mid-2022 and 2024 Q1.

The results of this exercise are set out in Figure 13, where inflation is shown transformed into annual percentage changes at quarterly frequency. The black line on the far left of the chart shows outturn data from 2023 Q3 to 2024 Q1. The coloured dashed lines then show the model projections of inflation from 2024 Q2 onwards on the basis of the different paths for the V/U ratio described above, holding constant the path for the other exogenous variables as described above.

Of course, *actual* inflation will not look like this forecast, since actual energy and food prices will have differed from what we have assumed (at time of writing, actual energy prices have fallen substantially, for example). But our purpose here is to show that the main message of Figure 13 is the sensitivity of inflation to the degree of labour market tightness.

Figure 13: Model projections of inflation with different V/U ratios



Notes: Annual inflation (i.e. quarter on same quarter a year ago percentage changes). Assumptions as described in text. Three scenarios for the V/U ratio: 1) stays at its 2024 Q1 level of 0.61; 2) falls to its estimation period average of 0.35 over 4 quarters; 3) falls to 0.2 (roughly the level seen after the 2008/09 recession and thus consistent with the loosest labour market in recent times, over 6 quarters.

The three dashed lines, reflecting markedly different paths for the V/U ratio, are similar to begin with. This is because labour market tightness affects wage growth only with a lag in the model, and in turn wage growth affects inflation contemporaneously and with a lag. Thus, changes in labour market tightness take time to work through the wage-price system, and only materially affect inflation after a few quarters. If the main effect of monetary policy tightening were to reduce the V/U ratio by cooling excess demand in the economy, then this lagged effect in the model is consistent with the typically long lags associated with the impact of monetary policy.

With the V/U ratio held at its 2024 Q1 level (which is also its 2019 level), inflation settles at close to 4% (relative to the Bank of England's inflation target of 2%). In the simulation with the V/U ratio falling to its estimation period average of around 0.35, inflation returns slowly towards 2% (and would eventually reach it). When the V/U ratio falls further to 0.2 (a roughly recession-level degree of labour market tightness) and stays there, inflation falls more rapidly and undershoots the 2% target further out.

The differences between the lines follow logically from the degree of labour market tightness, but in all cases inflation adjusts slowly. This reflects significant 'stickiness' of inflation in the model, which follows from the sum of coefficients on the lagged dependent variable being relatively large in the price equation (see Table 2). It is notable that inflation expectations do not un-anchor in the scenarios where the V/U ratio declines, with both short-run and long-run expectations remaining at or below their estimation period averages in all cases.[23] Thus, the model predicts a slow return of inflation to target even with well-anchored inflation expectations.

8 Conclusion

To cast light on the UK's inflation experience over the pandemic and post-pandemic period, we have estimated the model of inflation, wages and inflation expectations proposed by Bernanke and Blanchard (2023) on UK data, 1990-2024.

Our findings are largely similar to those of BB for the US. First, relative price level shocks dissipate quickly (Figure 7), and thus tend to be transitory. However, the model explicitly allows for second-round effects via inflation expectations and real wage catch-up. In our estimated UK model, these are relatively small in the medium-run, since the sum of coefficients on current inflation in the two inflation expectations equations are small (Table 3 and Table 4), and the sum of coefficients on catch-up in the wage equation are close to zero (Table 1). However, they can have short-run dynamic effects (for instance, see Figures 11 and 12). We find that food price shocks are more persistent than energy price shocks (Figure 7), and more persistent in the UK than in the US.

[23] In the scenario where V/U remains high (at its 2024 Q1 value of 0.61), short-run and long-run expectations rise slowly but continuously, consistent with de-anchoring.

Second, the level of wage growth and pattern of inflation over the pandemic and post-pandemic period is fairly well explained by the model (Figures 9 and 10), consistent with findings by Bernanke and Blanchard (2023) for the US and for a range of other countries as documented in Bernanke and Blanchard (2024). That suggests that inflation is behaving broadly as expected in the face of large relative price shocks and a tight labour market.

Third, the major causes of recent high inflation in the UK were initially large shocks to energy prices and supply chains, and later shocks to food prices (Figure 9). As of early 2024, these price shocks are wearing away – indeed, changes in energy prices are now dragging on inflation.

Fourth, the role of post-Covid labour market tightness is smaller (at least in our baseline model) but has grown somewhat over time. As of early 2024, labour market tightness (relative to 2019 levels) is contributing about 0.7pp to wage growth and 0.6pp to price inflation. However, the role of tightness depends crucially on the assumptions underlying the “initial conditions” in the model (see Section 6.3). In our baseline model, following BB, we lock into the “initial conditions” the level of the V/U ratio immediately before the pandemic, which was already tight. Relative to this initial level of labour market tightness, additional tightness during 2022 and 2023 has contributed somewhat to inflation; but relative to a lower counterfactual for the V/U ratio, tightness would have been estimated to contribute more (Appendix D).

Finally, we use the model to make some illustrative conditional forecasts of inflation (Section 7), on the basis of some assumed paths for the exogenous variables and three scenarios for labour market tightness. A sharper fall in V/U to a lower level reduces inflation more quickly, albeit still relatively slowly, suggesting that the model embodies fairly sticky wage growth and price inflation (Figure 13).

We believe this model provides insights into recent UK inflation experience. Its simplicity makes for easy interpretation and considering how volatile the period is, the simple model fits well. Future work on, for example, the determinants of the V/U ratio and the role of policy, would of course extend our understanding further.

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