Recent UK inflation: an application of the Bernanke-Blanchard model

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Abstract

We apply the Bernanke and Blanchard (2023) model of inflation to UK quarterly data from 1990 to 2023. The model explains wage growth, price inflation, and inflation expectations (short- and long-run) as functions of labour market tightness, shocks to energy and food prices, shortages, and productivity. Labour market tightness is measured by the vacancies-to-unemployment (V/U) ratio. The estimated equations are similar to those for the US, although the UK appears to have stickier wage and price inflation, and more persistent effects of food price shocks. UK inflation in 2021 is explained by shortages and energy price shocks, and in 2022 and 2023 also by food price shocks and labour market tightness. Inflation expectations have been more well-anchored than predicted by the model. Conditional projections suggest UK inflation will fall sharply in 2023 from disinflationary energy and food price effects, but the decline will slow markedly thereafter.

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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[1], UK CPI inflation had fallen to 0.7%. The 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 (March 2020). The coronavirus vaccination program was proceeding at significant pace, with the vaccines having been first approved and rolled out in December 2020. By summer 2021, lockdowns had been largely removed. Following the Brexit vote to leave the EU in 2016, a trading relation with the EU, effective 1st January 2021, had been agreed. Goods were tariff-free, subject however to rules of origin, with some customs checks introduced: some services (legal, financial) were subject to new restrictions and UK workers could not work permanently in the EU.

In March 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%.[2] 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 4.6% in October 2023 (the latest data).

This paper asks: what caused this surge of inflation? 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.[3] 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.[4] As for goods price shocks, international supply shortages emerged during the recovery from the pandemic following the vaccine rollout[5] 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, equivalent to about a third

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[1] All data in this paragraph are from (Bank of England, Monetary policy report, February 2021) and ONS https://www.ons.gov.uk/economy/inflationandpriceindices/bulletins/consumerpriceinflation/september2023.

[2] (Bank of England, Monetary policy report, February 2021, Table 1A) and (Chart B, other forecasters expectations, MPR Chart slides and data, https://www.bankofengland.co.uk/-/media/boe/files/monetary-policy-report/2021/february/mpr-february-2021-chart-slides-and-data.zip).

[3] (Table 1, conditioning assumptions, MPR Chart slides and data, https://www.bankofengland.co.uk/-/media/boe/files/monetary-policy-report/2021/february/mpr-february-2021-chart-slides-and-data.zip).

[4] Alternatively, in 2022 Q4, oil prices averaged \$89 per barrel, and gas prices averaged 201 pence per therm (November 2023 MPR, table 1).

[5] Supply was restricted due to pandemic restrictions in goods-exporting countries, and demand was rising unusually quickly.

of private sector workers, were furloughed. Over 2021, lockdown restrictions were lifted with periodic short re-impositions, and the furlough scheme closed in September 2021. At that time, there were still 1 million jobs furloughed (around 5% of private sector workers) with over 300k jobs that 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 3). 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 (Box C, Table 1, p.35), 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 rise in inflation not initially being counteracted by monetary policy.[6]

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, for 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.[7] Dynamics also arise as inflation expectations adjust to current inflation.

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[6] 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). Regarding forecast errors, it must be noted that, besides the furlough scheme, the main UK fiscal measures over the pandemic was the energy price guarantee which capped retail (and some commercial) energy prices and paid a compensation fee to energy companies. This directly capped consumer energy prices and so mechanically affected inflation. However, it was an announced temporary programme of fixed length (which was, in practice, renewed). BoE conventions are to base forecasts on announced policy, which meant that BoE forecasts reflected the fixed length and then assumed energy prices would sharply increase at the end of the price cap (which never occurred). Hence the forecasts were wrong due to incorrect conditioning assumptions.

[7] These "catch-up" effects mirror the real wage resistance effects analysed by, for example, Bruno and Sachs (1985), Jackman, Layard and Nickel (2005), and Newell and Symons (1987): see Bean (1994) for an excellent survey.

BB have two main findings on US quarterly data. 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 rising inflation, have remained quite well-anchored. Second, US inflation, after initially being due mostly to external shocks, is increasingly driven by a tight labour market.

This paper replicates the BB model on UK data 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 shortage shocks. Third, subsequent rises, however, were more due to food price shocks but also a tightening in the labour market.

Although the recent surge in inflation has been widely discussed, there is relatively little literature as yet that seeks to account for how it came about in a structured way, especially for the UK.

Ball, Leigh and Mishra (2022) decompose US headline inflation into core inflation (measured by the weighted median inflation) and deviations from core. In turn, they explain core inflation by labour market tightness and passthrough of headline shocks into core, with non-linear patterns, and explain the headline shocks using measures of energy prices and supply chain issues. In explaining the increase in US annual inflation between December 2020 and September 2022, they find roles for headline price shocks, passthrough of those shocks, and labour market tightness, with relatively little role for inflation expectations (see their Figure 12).

Dao et al. (2023) use the same framework to account for annual inflation in the US and Euro Area up to April 2023. They find that most of the Euro Area 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 (see their Chart 14). The IMF World Economic Outlook in October 2023 (IMF, 2023) applies the same framework to account for the increase in three-month inflation since the end of 2019 in the US, Euro Area, and UK, up to July 2023 (their Figure 1.9). Their findings for the US and Euro Area mirror Dao et al. (2023), and 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).

Haskel (2023) employs a framework based on national income accounting to decompose UK, US and Euro Area inflation into domestic and non-domestic factors. Domestic factors are the income components of value added – namely payments to labour, payments to capital, and net taxes on production – less total-factor productivity growth. Non-domestic factors are principally import prices, and the extent to which the domestic sector produces output other than that for household consumption. They find that UK inflation in 2022 was due partly to higher labour and capital income, and partly to a terms of trade shock. Consistent with IMF (2023), labour costs play a relatively larger role in the US, and the terms of trade shock a larger role in the Euro Area.

Dhingra and Page (2023) use an input-output approach to explain UK CPI inflation by the costs of production of domestic consumption goods. They find that energy and imports (both direct imports of consumption goods, and imports used as intermediate inputs for domestic production) explain a large share of cumulative UK inflation between 2019 Q4 and 2022 Q4, 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 support (direct transfers) 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. Others provide suggestions without an empirical application. Reis (2022) considers four hypotheses, but does not test them empirically.

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

The rest of this paper proceeds as follows. In the next section, we set out the model in theory and in the empirical work. Section 3 describes our data and illustrates our key input variables. Section 4 presents the estimated equations and compares the fitted values against the outturn data. Section 5 presents decompositions of wage and price inflation into their model-implied drivers over the period since 2020. Section 6 describes a number of robustness checks, with more detail in Appendix A. Section 7 shows conditional forecasts using the model. Section 8 concludes.

2 The Bernanke and Blanchard model

2.1 Outline

The Bernanke and Blanchard (2023) (henceforth BB) model is one of wages, prices and inflation expectations. To see briefly its workings, consider an unanticipated rise in inflation due to, for example, an unanticipated external price level shock to food or energy. Suppose as well that the higher price level is persistent (but the inflation rise is temporary). Such a rise affects the wage/price system as follows.

First, at given wages, such a rise lowers employee real wages. That will lead to increased wage pressure to the extent that employees attempt to regain previous real consumption wage levels. That increased wage pressure raises firms' marginal costs and final output prices.

Second, a rise in actual inflation potentially affects short- and long-run inflation expectations. That rise might raise inflation expectations persistently in at least two ways: (a) if long-run inflation expectations rise (become "unanchored") and (b) if short-run inflation expectations rise and take a long time to return to prior levels (are quite "backward-looking"). In turn, the expectation of inflation raises wage pressure and hence price pressure as above.

2.2 The model in detail

2.2.1 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

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

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 $\alpha \neq 0$, 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. workers expect to be compensated for past unexpected inflation.[8] The final term suggests that wage inflation depends on both the level and change in

[8] The Bank of England's November 2023 Monetary Policy Report (https://www.bankofengland.co.uk/monetary-policy-report/2023/november-2023, Chart 1.3) shows a swathe of wage models, including wage equations based on Yellen (2017) and Haldane (2018), and an error-correction model. These are very much in the spirit of the empirical application in this paper. For instance, Yellen (2017) regresses the quarterly change in log wages on lagged changes

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.

2.2.2 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 shortages.

2.2.3 Inflation expectations

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

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

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

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

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.

2.3 The model at work

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

$$\Delta p = \Delta w + \Delta z_p \qquad (7)$$

Second, wage changes are given by:

in log wages, inflation expectations, slack (a measured by the unemployment gap: U-U*) and its change, and productivity growth. Chart 2.14 from the November 2023 Monetary Policy Report shows the contributions to recent wage growth using the Yellen (2017) model, transformed into annual growth space.

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

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:

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

being a weighted average of long-run inflation expectations and last year's inflation.

From this we may note the following response to a one period shock to prices, Δz_P. From (1), 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 (3), depends in turn on the weight that agents put, when forming expectations, on long-run inflation expectations and lagged realised inflation: 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 then rises to the extent of catch-up and any changes in labour market tightness.

2.4 The transition to empirical work

2.4.1 Homogeneity and sample period

In taking this framework to the data we do the following. First, following BB we impose 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).[9] Our data does not reject these restrictions.

[9] 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.

Second, on the choice of sample period: in our main results, we estimate all four equations on the "full sample", which is quarterly data from 1990 Q1 to 2023 Q2 (given four lags on several variables in the estimated equations, the dataset in fact starts in 1989 Q1). In Appendix A we set out results for an alternative sample period.

This differs somewhat from BB, who estimate only the price equation on the full sample, in order to capture sufficient variation in the shortages variable, but the wage equation and two expectations equations on the pre-pandemic sample.[10] 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. 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.

Finally, we note that in more recent work in collaboration with the authors of this paper and economists at other central banks, BB have adopted the use of the model estimated over the full sample. This approach therefore aids comparability of our results with those forthcoming for other countries.

2.4.2 Estimated equations

In implementing these equations, we follow BB and allow four lags of all variables to allow for dynamics and lag the V/U ratio in the wage equation. Starting with the wage equation, we estimate

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

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

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

between realised annual inflation and one-year ahead expected inflation one year ago, *iesr* is the one-year ahead inflation expectation, and the final term is an error.

The price equation is:

$$gp = \sum_{k=1,2,3,4} \beta_k^{gp} gp_{t-k} + \sum_{k=0,1,2,3,4} \beta_k^{w} gw_{t-k} + \sum_{k=0,1,2,3,4} \beta_k^{shortage} shortage_{t-k} + \sum_{k=0,1,2,3,4} \beta_k^{grpe} grpe_{t-k} + \sum_{k=0,1,2,3,4} \beta_k^{grpf} grpf_{t-k} + \sum_{k=1} \beta_k^{gpty} gpty_{t-k} + u_t^{gp} \tag{11}$$

where *gp* is the quarter-on-quarter annualised log change in CPI (i.e. price inflation), *gw* is wage growth as above, *shortage* is an index of shortages (see section 3.1), *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 shortage, 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 section 6). We might expect that a long run 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 mirror those shares. If they are above those shares, that would suggest indirect effects of changes in such prices on other prices.

The short-and long-run expectations equations are:

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

and

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

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.

3 Data

3.1 Measures

The data are largely sourced 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)[11] published by the ONS, which we seasonally adjust.
- Relative food price inflation (*grpf*) = growth in the ratio of the food and non-alcoholic beverages component of the CPI, which we seasonally adjust, 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 relative to wage growth described below.
- Wage growth (*gw*) = growth in Average Weekly Earnings, private sector regular pay (i.e. excluding bonuses), 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.
- Shortages (*shortage*) = Google trends result for "shortage" in the UK, as a proxy for supply chain problems (following BB).
- One-year inflation expectations (*iesr*) = a composite series covering expectations of households and professional forecasters.
- Long-run inflation expectations (*ielr*) = a composite series 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 variables: actual annual price inflation minus one-year inflation expectations one year prior.

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

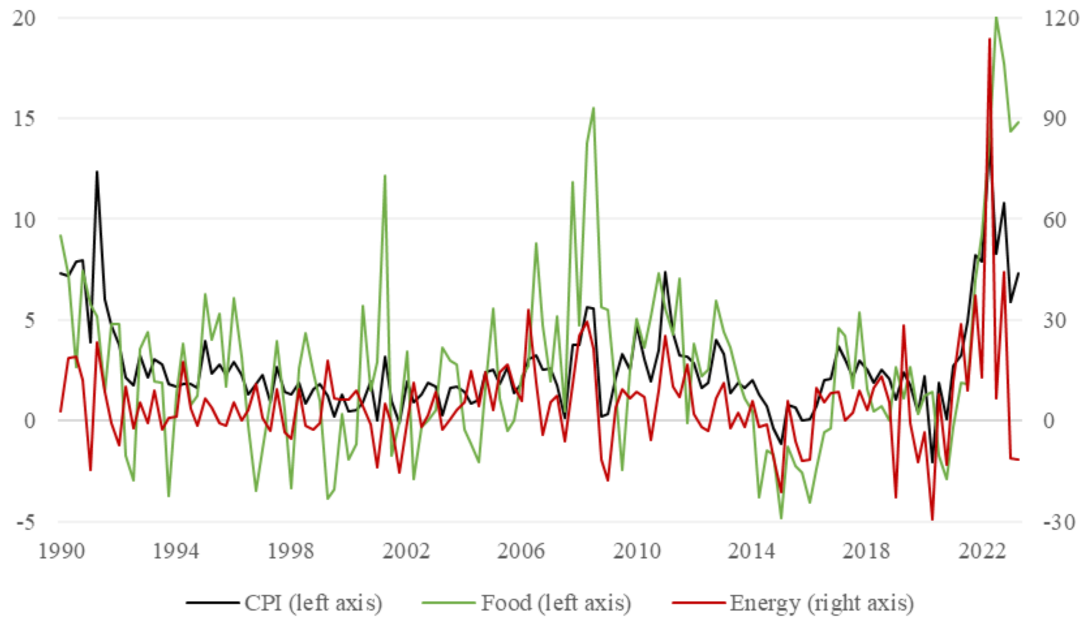
3.2 The data illustrated

Starting with inflation, Figure 1 shows CPI, food and energy inflation in the UK over the whole sample period (notice, as in BB, the series are noisier that usual annual averages since they are natural log changes between successive quarters, multiplied by 400). The rise in inflation in recent quarters is notable and shown in a bit more detail in Figure 2. The following points are worth noting.

First, the responsiveness of UK inflation to energy price shocks is both larger and has different lags due to, respectively, the structure of UK energy markets (the marginal source of supply is gas) and energy price regulation (Haskel, 2022).

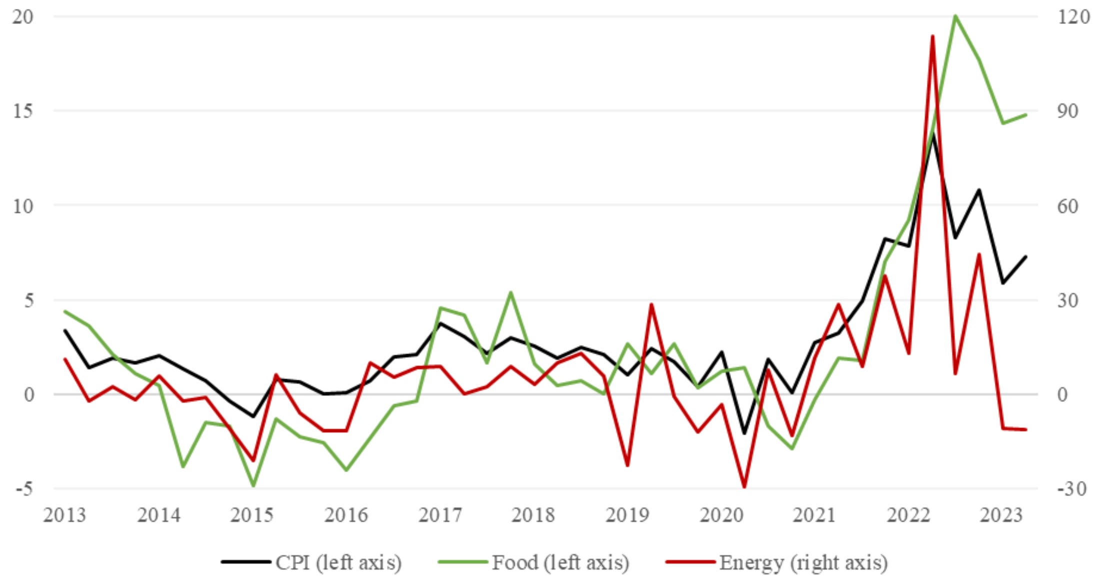
Second, CPI inflation, (as measured here in annualised quarter on quarter), started to rise in 2021 Q1 (in 2020 Q4 it was 0, then 2.7, 3.7, 4.7 and 8.1 over 2021). Notice that energy prices started to rise in 2021 Q2, well before the outbreak of the Ukraine war in 2022 Q1. Food prices began to rise in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

Figure 1: Quarter-on-quarter annualised inflation, CPI, food and energy, 1990 Q1 to 2023 Q2



Source: ONS, Bank of England, authors' calculations.
Notes: Series are 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 are seasonally adjusted and shown against the left-hand side axis. Energy shown against the right-hand side axis.

Figure 2: Quarter-on-quarter annualised inflation, CPI, food and energy, 2013 Q1 to 2023 Q2



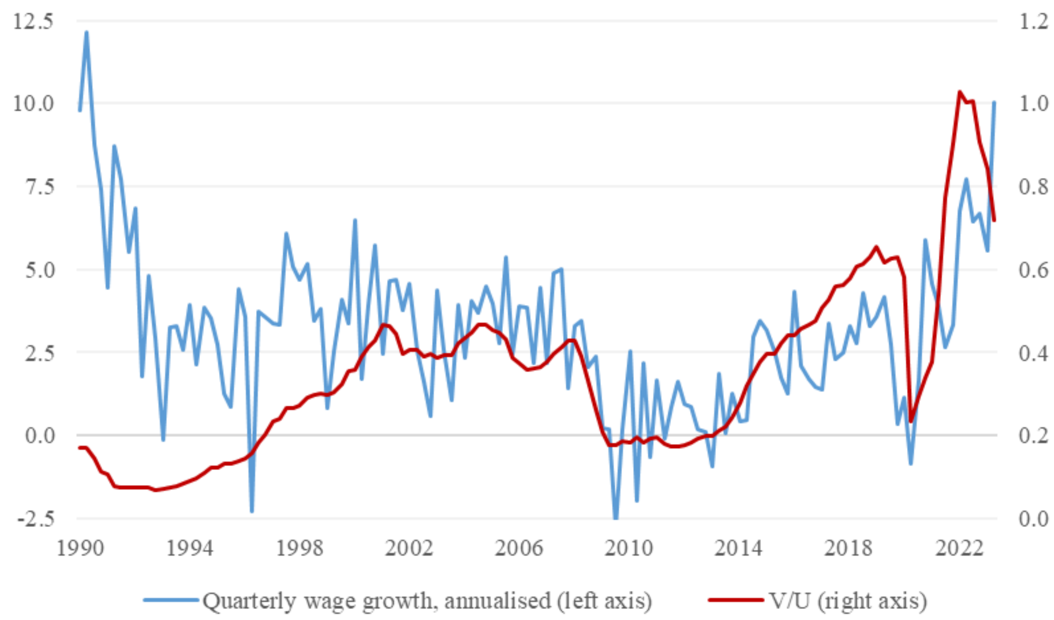
Source: ONS, Bank of England, authors' calculations.
Notes: Series are quarter-on-quarter natural log changes (annualised by multiplying by 400), so are more volatile than conventional annual inflation measures. Energy includes household gas and electricity bills, and fuels and lubricants used in personal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

Turning to the labour market, Figure 3 shows nominal wage growth and a labour market tightness measure, namely the V/U ratio.[12] These wage data are adjusted for labour force composition and for furlough, a scheme during the pandemic described below. The data show a strong rise in the V/U ratio in recent times along with a strong rise in wage inflation, although V/U has receded somewhat in the first half of 2023.

Turning to expectations, Figure 4 shows the series of short and long run expectations we use.[13] Both are amalgams of financial, professional forecaster and household expectation survey data in a way that is as historically comparable as possible, and that avoid recent distortions in financial measures owing to a forthcoming change in the way one UK inflation index (the RPI), widely used in index-linking, is computed. Both short and long run measures have risen somewhat in recent quarters and then fallen again.

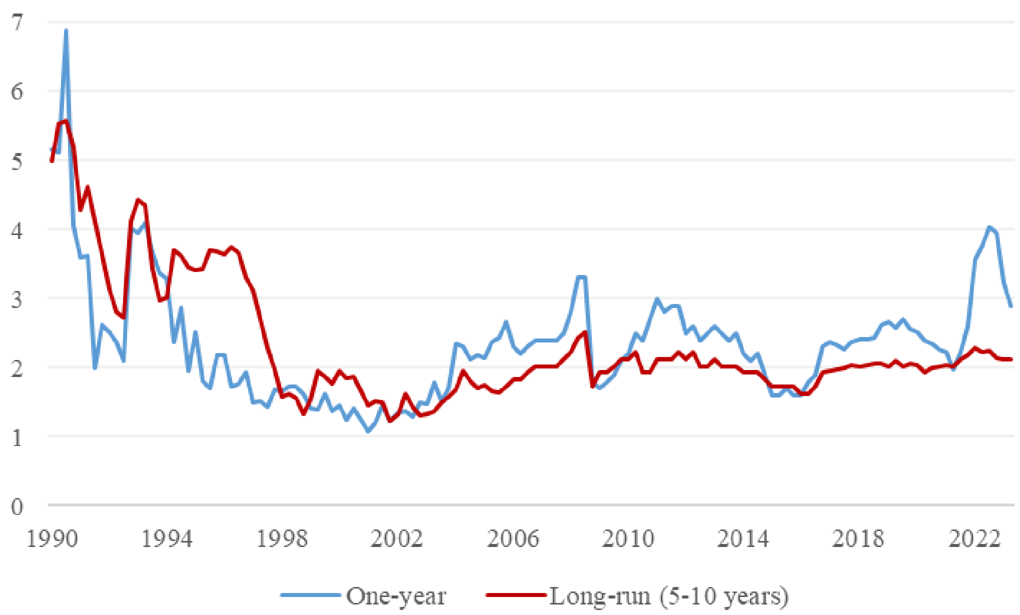
[12] It is interesting to note that the V/U ratio in the UK is much lower than the US, see Appendix B, Figure B1. One reason might be that a significantly higher share of new flows into employment in the US comes from transitions from inactivity rather than from unemployment relative to the UK/Europe. So, the US "requires" more vacancies relative to the unemployment stock to keep the unemployment stock constant.
[13] For more on UK inflation expectations measures, see Mann (2022) and Tenreyro (2019).

Figure 3: Wage growth and labour market tightness (vacancies-to-unemployment ratio), 1990 Q1 to 2023 Q2



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).

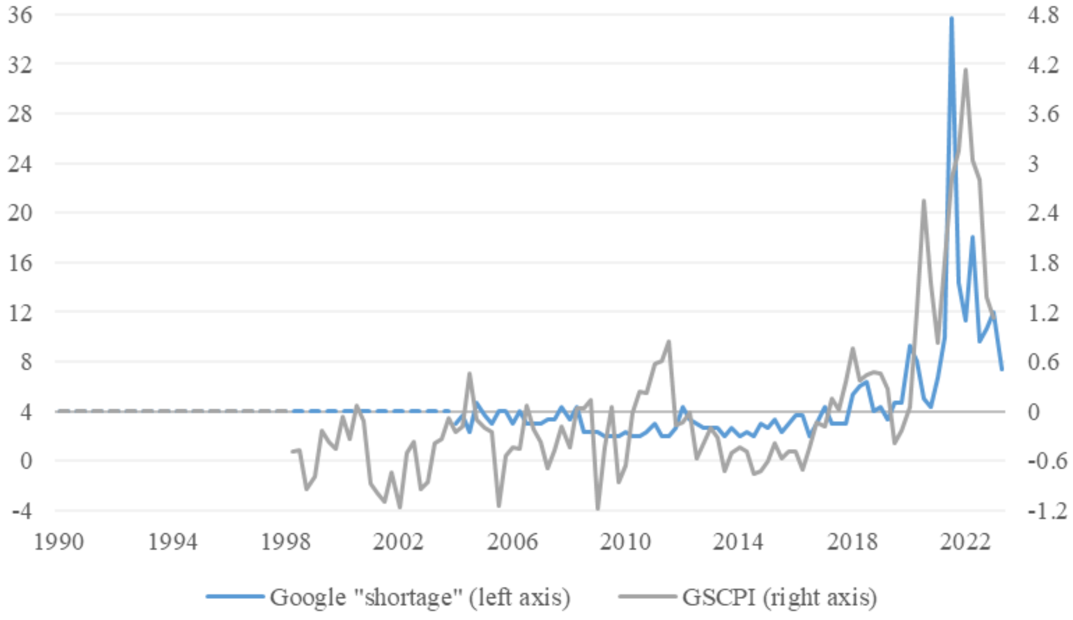
Figure 4: One-year and long-run inflation expectations, 1990 Q1 to 2023 Q2



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 text for more details.

Figure 5 shows two shortage measures: one derived from Google searches, and the other the Global Supply Chain Pressure Index (GSCPI) produced by the Federal Reserve Bank of New York[14]. Note, the GSCPI is not a UK-specific measure. The Google search data starts in 2004, and the GSCPI in 1998. They behave similarly over the pandemic, rising strongly in 2021 Q1, just when UK inflation starts rising and strongly again in the last quarters of 2021 and into 2022 before easing back.

Figure 5: Shortage measures, 1990 Q1 to 2023 Q2

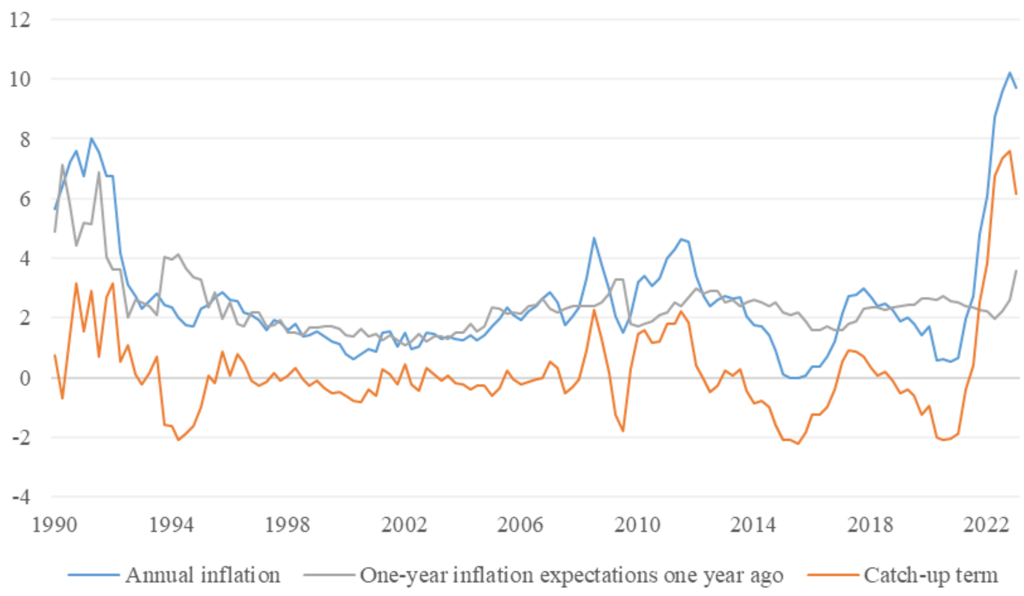


Source: Google, Federal Reserve Bank of New York, authors' calculations.
Notes: GSCPI = Global Supply Chain Pressure Index, published by the New York Fed. Dashed line represent assumed backseries prior to the start of the series – GSCPI set to 0 in the backseries, and Google "shortage" set to 4 in the 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 6 shows, following BB, current inflation in period t, less what inflation in period t had been expected to be in t-4, i.e. 4 quarters ago. The large gap between actual and expected in recent quarters is notable.

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

Figure 6: "Catch-up" term (actualised inflation less one-year inflation expectations one year ago), 1990 Q1 to 2023 Q2



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

4 Initial results

Following BB, we first report the estimated coefficients of the four equations[15] (sections 4.1 to 4.3), before presenting the implied impulse respond functions (IRFs) of shocks to the exogenous variables (section 4.4). Then section 5 shows the decompositions of inflation and wage growth over the period since 2020, and section 7 shows conditional forecasts.

Each equation is estimated using up to four lags as reported in the sub-sections below (see section 2.4.2 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. 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.

4.1 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

[15] Although unlike BB we estimate these over the full sample (1990 Q1 to 2023 Q2) – see section 2.4.1 for discussion.

(from, say, 1.0 to 1.5) is to raise wage growth in the long-run by 3.0pp.[16] 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.[17]

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	0.602	2.364	0.088	0.398	0.210
p-stat (sum)	0.000	0.016	0.510	0.000	0.093
p-stat (joint)	0.000	0.007	0.260	0.001	-
R-squared	0.597				
No. observations	134				

Notes: Sample is 1990 Q1 to 2023 Q2. "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. Parallels Table 2 in BB. R-squared is over the estimation period. Without the homogeneity constraint, the sum of coefficients on *gw* is 0.600 and on *iesr* is 0.420, and combined is 1.021.

Second, the sum of the coefficients on the lagged dependent is 0.60 (US = 0.46) and therefore on inflation expectations 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 7 shows fitted values[18] for wage growth from the wage equation for the pandemic and post-pandemic period. Note that, due to the inclusion of dummies for 2020 Q2 and 2020 Q3, the fitted values exactly match the data in these periods. We can conclude the following. First, quarter-on-quarter wage growth is somewhat 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 2020Q3. Annual wage growth in the year to 2023 Q2 is 7.2%, against 6.9% in the fitted values.[19]

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[16] 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 2.364 / (1 - 0.602) = 3.0pp.

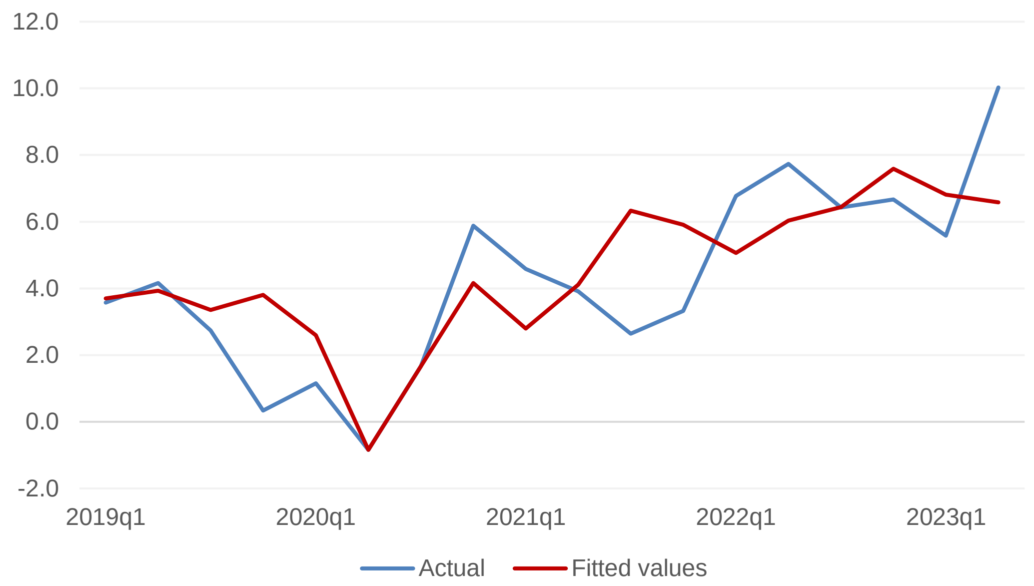
[17] The comparison with the US is obscured because this is a semi-elasticity. The average level of V/U is substantially lower in the UK than the US (with or without including the pandemic period), so a 0.5-point increase in the V/U ratio implies a larger proportional increase in tightness in the UK 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 0.81 in the UK and 0.40 in the US, while the long-run elasticity is 2.04 in the UK and 0.75 in the US.

[18] 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.

[19] This is on the basis of average the 4 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 are more widely quoted. In percentage changes the comparison is 7.4% in the data, against 7.1% in the fitted values.

Second, the fitted value for the latest period (2023 Q2) is a substantial under-prediction, as outturn quarter-on-quarter annualised wage growth increases to 10%, and the fitted value falls below 7%, given the declining value of V/U. The 2023 Q2 data point is unusually strong and may reflect variance in the data at higher frequency.

Figure 7: Wage growth, outturns and fitted values, 2020 Q1 to 2023 Q2



Notes: Fitted values (red) are point estimates from the price equation using all other outturn data available up to that period; the information set is updated with outturn data each quarter. Actual (blue) are quarter-on-quarter annualised growth in Average Weekly Earnings private sector regular pay, with adjustments for furlough and composition effects by Bank of England staff. Parallels Figure 3 in BB (they refer to "Simulated", since they estimate over the pre-pandemic period, so theirs are out-of-sample simulations).

4.2 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*)

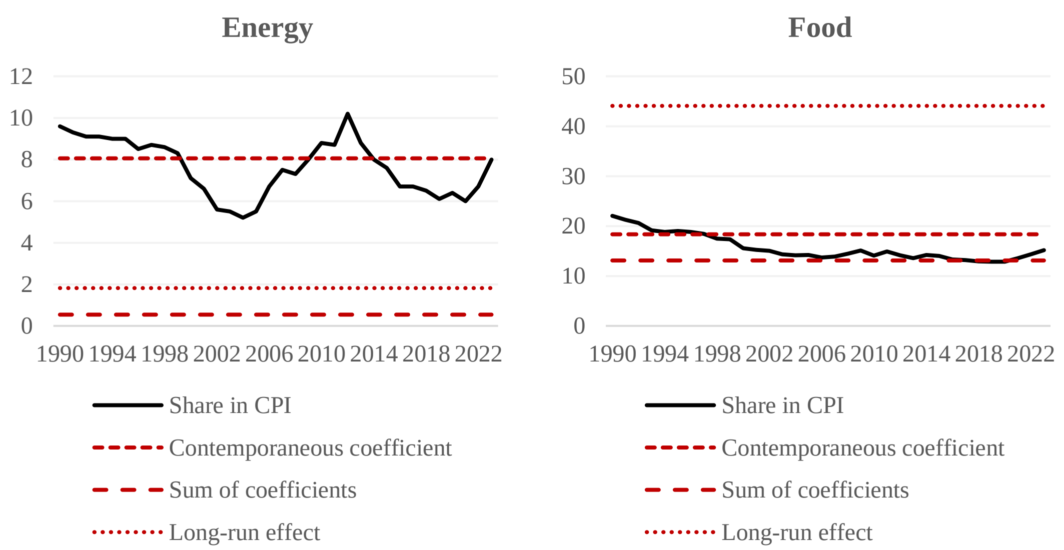
Independent variable	*gp*	*gw*	*grpe*	*grpf*	*shortage*	*gpty*
Lags	-1 to -4	0 to -4	0 to -4	0 to -4	0 to -4	-1
Constrained sum of coefficients	0.703	0.297	0.005	0.131	0.036	-0.221
p-stat (sum)	0.000	0.000	0.768	0.013	0.375	0.002
p-stat (joint)	0.000	0.000	0.000	0.000	0.030	-
R-squared	0.888					
No. observations	134					

Notes: Sample is 1990 Q1 to 2023 Q2. "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. Parallels Table 3 in BB. R-squared is over the estimation period. Without the homogeneity constraint, the sum of coefficients on *gp* is 0.683 and on *gw* is 0.291, and combined is 0.974.

We find the following. First, the sum of coefficients on lagged wage growth is approximately 0.30, which is smaller than that for the US (0.67). The corollary to this is that the sum of coefficients on price inflation is 0.70, 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 0.29 and 0.68).

Second, energy and food relative price changes are both relevant for inflation, although the size of the energy coefficients are surprisingly small. Figure 8 illustrates and puts into context the coefficients on energy and food. It shows the coefficient on contemporaneous energy and food prices (0.08 and 0.18 respectively, see Appendix A, Table A2), the sum of coefficients (see Table 2), the long run effects of each (0.02 and 0.44 respectively)[20], 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 smaller than found for the US (0.02 vs 0.09), but that for food is larger than found for the US (0.44 vs 0.19). We discuss the size of these effects further in section 4.4, but note for now the apparently large and persistent role for food price shocks in the UK.

Figure 8: Coefficients on energy and food, and shares in the CPI basket 1990-2022



Notes: Energy includes natural gas, electricity, and vehicle fuels. Food includes food and non-alcoholic beverages; food share in CPI also includes 30% of weight on catering, consistent with the share of food products in total output of the food services industry, which is assumed to pass on food prices near instantaneously. 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 20).

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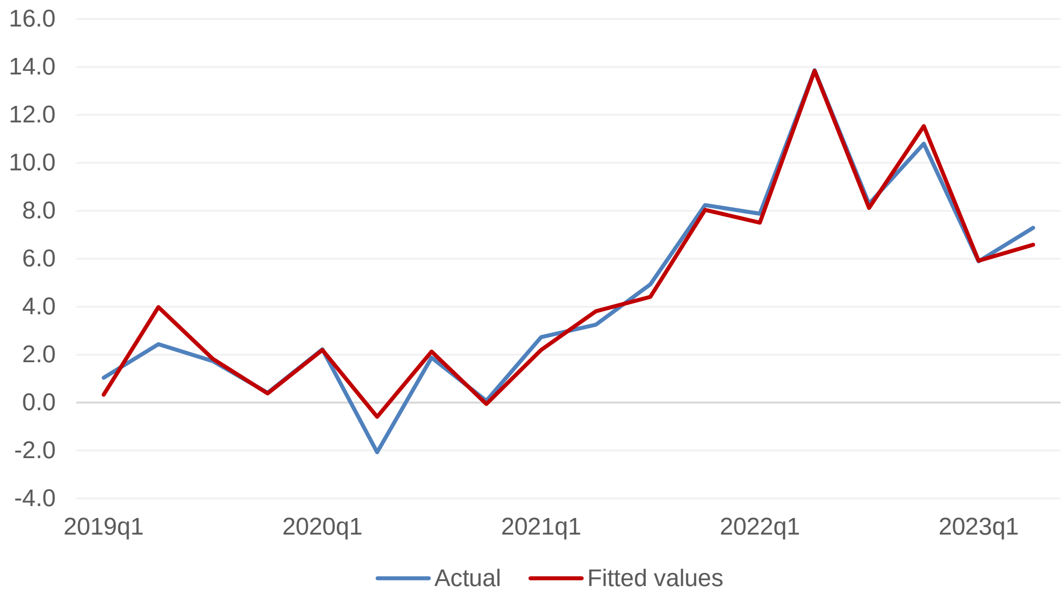
[20] Calculated as the sum of coefficients on energy or food, divided by one minus the sum of coefficients on the lagged dependent variable. For energy this is: 0.005 / (1 - 0.703) = 0.018. For food this is: 0.131 / (1 - 0.703) = 0.441.

Third, the shortage variable predicts higher inflation: the sum of coefficients on shortages is 0.04, similar to that found for the US (0.03). While these appear small, given the variation of the shortages measure (see Figure 5), this can still have material effects on predicted inflation (as we will see in section 5.2.1).

As Figure 9 shows, the equation fits realised inflation over the pandemic period well. This is likely due to the important effects of energy and food in UK inflation in recent quarters which enter the price equation contemporaneously.

Figure 9: Price inflation, outturns and fitted values, 2020 Q1 to 2023 Q2



Notes: Fitted values (red) are point estimates from the price equation using all other outturn data available up to that period; the information set is updated with outturn data each quarter. Actual (blue) are quarter-on-quarter annualised growth in seasonally-adjusted CPI. Parallels Figure 7 in BB.

4.3 Inflation expectations equations

Table 3 shows the short-run inflation expectations equation. It suggests that short-run inflation expectations are strongly dependent on themselves lagged (sum of coefficients = 0.84), weakly on long-term expectations (0.14) and also weakly on current 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 (sum of coefficients = 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, it could be said 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.

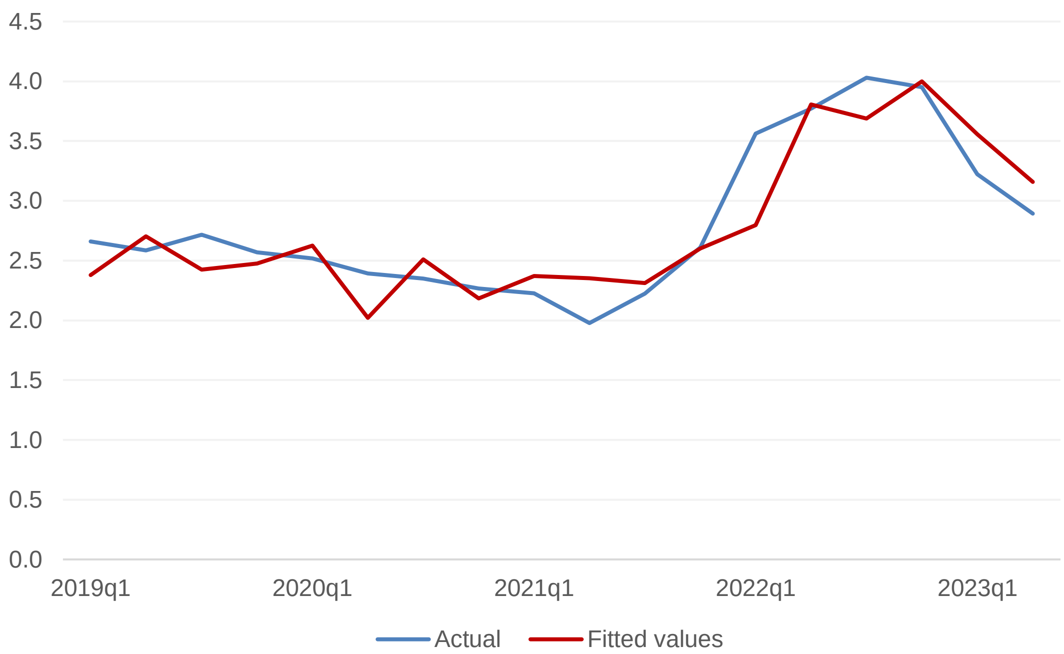
Table 3: One-year inflation expectations (dependent variable = *iesr*)

Independent variable	*iesr*	*ielr*	*gp*
Lags	-1 to -4	0 to -4	0 to -4
Constrained sum of coefficients	0.841	0.143	0.015
p-stat (sum)	0.000	0.012	0.519
p-stat (joint)	0.000	0.000	0.027
R-squared	0.831		
No. observations	134		

Notes: Sample is 1990 Q1 to 2023 Q2. "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. Parallels Table 4 in BB. R-squared is over the estimation period. Without the homogeneity constraint, the sum of coefficients on *iesr* is 0.831, on *ielr* is 0.134, and on *gp* is 0.021, and combined is 0.986.

Figure 10 shows that the fitted values for one-year inflation expectations over the pandemic are similar to the outturn data, albeit more noisy. This likely follows from the variation in current (quarter-on-quarter, annualised) inflation over this period. While the sum of coefficients is less than 0.02 (Table 3), the coefficient on contemporaneous inflation is larger at 0.07 (Appendix A, Table A3). The variation in quarterly inflation (see Figure 9) thus generates variation in one-year inflation expectations. It seems unlikely that inflation expectations, even expectations of short-run inflation, vary so much from quarter to quarter.

Figure 10: One-year inflation expectations, outturns and fitted values, 2020 Q1 to 2023 Q2



Notes: Fitted values (red) are point estimates from the price equation using all other outturn data available up to that period; the information set is updated with outturn data each quarter. Actual (blue) are a composite of one-year inflation expectations measures as described in text. Parallels Figure 8 in BB.

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 themselves lagged (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 current inflation raises long-run expectations in the model only slightly, but the high autocorrelation in long-run expectations keeps them elevated even after current inflation recedes (note that falling current inflation due to, say base effects, will reduce long-run inflation expectations).

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

Independent variable	*ielr*	*gp*
Lags	-1 to -4	0 to -4
Constrained sum of coefficients	0.994	0.006
p-stat (sum)	0.000	0.640
p-stat (joint)	0.000	0.000
R-squared	0.944	
No. observations	134	

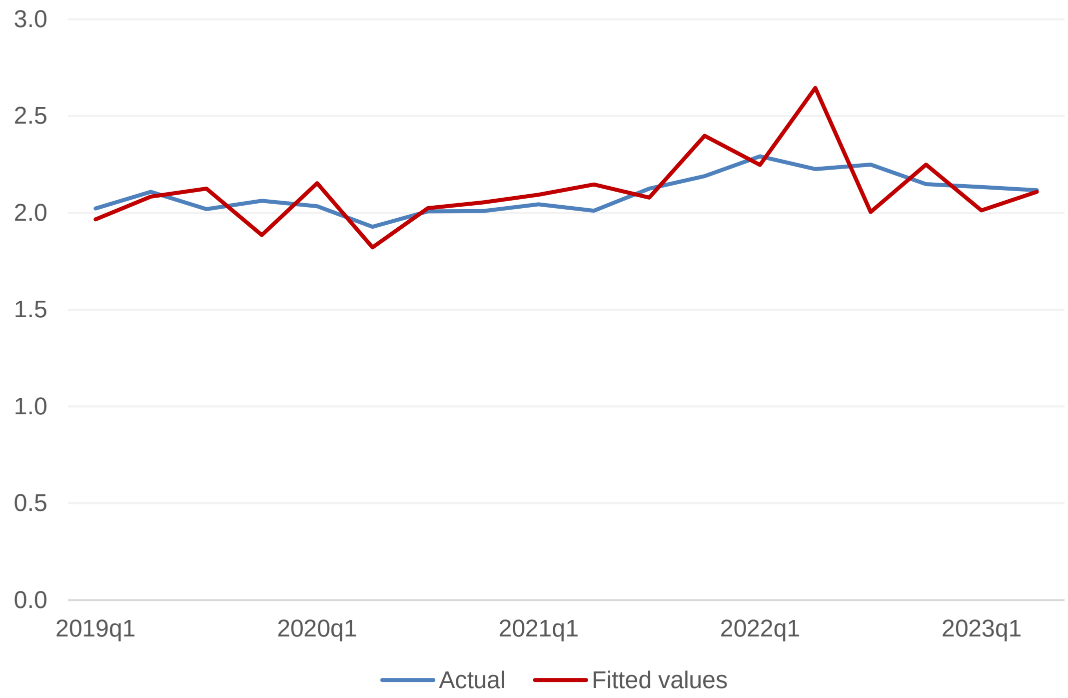
Notes: Sample is 1990 Q1 to 2023 Q2. "p-value (sum)" is the p-value for the null hypothesis that the sum of coefficients is zero, "p-value (joint)" is the p-value for the joint hypothesis that each of the lag coefficients separately equals zero. Parallels Table 5 in BB. R-squared is over the estimation period. Without the homogeneity constraint, the sum of coefficients on *ielr* is 0.977, and on *gp* is 0.009, and combined is 0.986.

Figure 11 shows that long-run inflation expectations seem well-anchored. Like for one-year inflation expectations in Figure 10, the fitted values of the long-run inflation expectations equation are arguably too variable, co-moving too strongly with inflation in the current quarter. For instance, the spike in predicted long-run inflation expectations in 2022 Q2 is due to the spike in current inflation in that quarter, associated with the increase in the regulated price of household energy bills in April 2022 (Ofgem price cap). The fitted value for the subsequent quarter is much lower however, given the true outturn of long-run inflation expectations from the quarter remained relatively low.

4.4 Impulse response functions

We may use the model to study the predicted response of consumer prices to shocks to the exogenous variables, which in this case are the prices energy and food (relative to wages), shortages, 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 the Bank of England's 2% inflation target than the quarter-on-quarter annualised log changes used in the regressions.

Figure 11: Long-run inflation expectations, outturns and fitted values, 2020 Q1 to 2023 Q2



Notes: Fitted values (red) are point estimates from the price equation using all other outturn data available up to that period; the information set is updated with outturn data each quarter. Actual (blue) are a composite of long-run inflation expectations measures as described in text. Parallels Figure 9 in BB.

We choose the shocks to be average pre-pandemic shocks, that is a one standard deviation of relative energy and food prices, and the shortages variable, between 1990 Q1 and 2019 Q4.[21] These are one-period price shocks which are not reversed, so that the level of prices and shortage rises and stays higher than before the shock, but do not continue to rise.

Figure 12 shows the results. 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 close to 0.05pp to annual inflation four years after the shock.

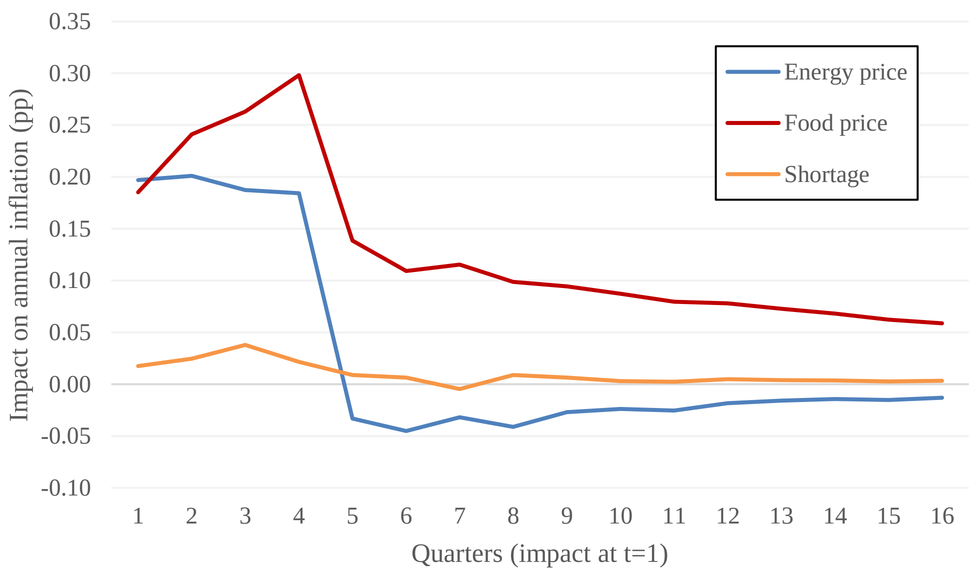
The peak effect from shortages is after three quarters, which then unwinds towards zero more quickly than for food prices, and settles at close to zero (though marginally positive) from around two years (eight quarters) onwards. Pre-pandemic shortages shocks in the UK were relatively small, adding just 0.04pp to annual inflation at peak. However, the shortages shocks during 2021 were much larger.

[21] 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 B3) for comparison.

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 about 0.2pp. Then, by base effects, this effect reverses, and actually drags on annual inflation by a small amount thereafter. This may capture the autoregressive nature of UK energy prices, where increases are often followed by decreases. It might also capture changes in weights in the CPI.[22]

We should note that Figure 12 uses *pre*-pandemic standard deviations in relative energy prices, relative food prices, and shortages, such that they reflect the impacts of typical pre-pandemic shocks implied by the model. The magnitude of these is 9.8, 4.0 and 1.0 respectively (all measured in quarter-on-quarter annualised log changes). The shocks to these variables during the pandemic and post-pandemic period are *much* larger: the maximum quarterly shocks being 106 for relative energy prices in 2022 Q2, 14 for relative food prices in 2022 Q3, and 36 for shortages in 2021 Q3. These are 10.8, 3.4 and 36.1 times larger than typical pre-pandemic shocks respectively.[23]

Figure 12: Impulse response functions of annual inflation to shocks to the relative price of energy, relative price of food, and shortages



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 shortages. Shocks equal to the standard deviation of the exogenous variable over 1990 to 2019 (a typical pre-pandemic shock).

[22] Since demand for energy is likely very inelastic, an increase in price likely increases the expenditure share of energy which in turn increases energy's weight in the CPI. Thus, when energy prices fall, the fall carries a greater impact on CPI than the increase did.

[23] Put another way, the standard deviations of relative energy prices, relative food prices, and shortages over the period 2020 Q2 to 2023 Q2 are 32.9, 6.0 and 7.5 respectively, equal to 3.4, 1.5 and 7.6 times their pre-pandemic standard deviations.

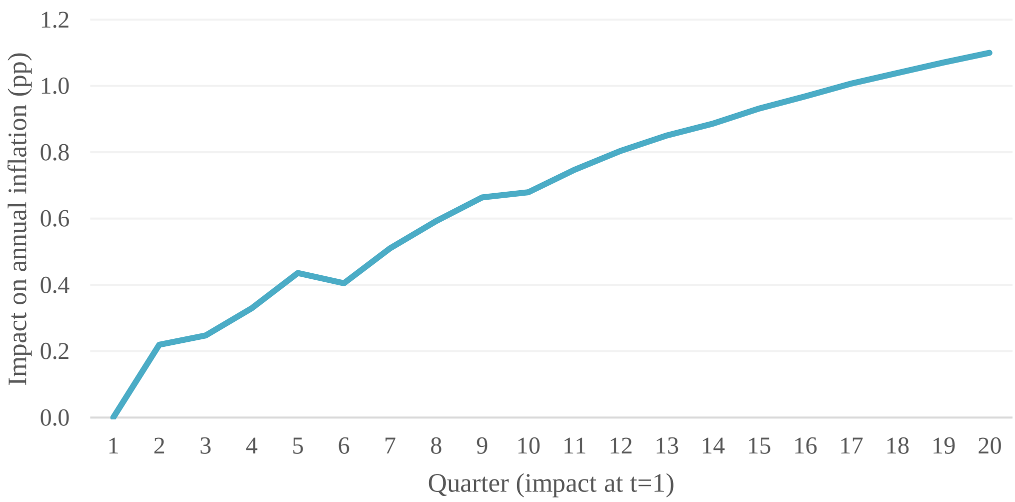
Turning to the effects of V/U, Figure 13 shows the response of annual inflation to a permanent increase in the V/U ratio. Recall that in the model, V/U enters only the wage equation, and then only with a lag, and then wage growth enters the inflation equation. Thus, there is no contemporaneous impact on inflation (or wage growth) from a V/U shock. Unlike for the price shocks in Figure 12, 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 products *temporarily* faster inflation, and a persistently higher price *level*.

As for the price shocks above, we scale this increase by the standard deviation of V/U over the period 1990 Q1 to 2019 Q4. The shock is equal to 0.16-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 V/U, 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. It is likely that a permanent increase in labour market tightness which raises wage growth and thus raises inflation above target would be met with contractionary monetary policy, which would in turn reduce tightness.

Figure 13: Impulse response function of annual inflation to a permanent increase in V/U



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 1.7pp higher after four years. The relative size of these shocks is actually quite similar given that V/U in the US is, on average, about double what it was in the UK between 1990 and 2023 (see Appendix B, Figure B1). The difference in long-run effects is consistent with the difference in long-run elasticities discussed in section 4.1 (see footnote 17 in particular).

Immediately before the pandemic (in 2019 Q4), the V/U ratio in the UK was equal to about 0.63. It fell sharply in 2020 in response to the national lockdown, before accelerating rapidly during the re-opening and recovery, peaking at just over one in 2022 Q1. The increase from 0.63 (pre-pandemic) to 1.03 (at peak) is about 0.4, equal to 2.5 times the pre-pandemic standard deviation of 0.16. From trough (0.23 in 2022 Q2) to peak, the increase in V/U was about 0.8, or around five times the pre-pandemic standard deviation. The effects on wage growth and inflation of such shocks will be commensurately larger than those in Figure 13 (which is calibrated on a typical pre-pandemic shock).

5 Accounting for inflation over the pandemic

5.1 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 shocks that happened during and after the pandemic from those before.

What we call the prediction of the "full dynamic model" starts the model from 2020 Q1 with the actual data of all exogenous and endogenous variables up to 2019 Q4. Thereafter, we give the model the 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 prediction 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 and see the impact of these errors on subsequent predictions in the model).

The prediction of the full dynamic model uses the outturn data of all the exogenous variables, essentially treating these as observed shocks. We are then interested in decomposing the model prediction into the role of each of the exogenous variables. To do this, we set one of the exogenous variables to a counterfactual value (more on this below), and re-simulate the model, giving alternative predictions for all the endogenous variables. The difference between the full dynamic model prediction and this partial model outcome is the contribution of the particular exogenous variable to the endogenous variable outcome. This contribution covers both direct and indirect effects via other endogenous variables. For instance, 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. We return to this in section 5.3.

Following BB, we refer to as "initial conditions" the model predictions under the counterfactual where the pandemic did not occur, and the economy continued as it was immediately before. This can be thought of as the predictions of the model when the effect of all exogenous variables from 2020 onwards is removed.

What values of exogenous variables are consistent with this counterfactual of pre-pandemic conditions? We follow BB in setting the change in the relative price of energy and food both to 0 (i.e. food and energy prices move in line with wages), V/U is held at its 2019 Q4 level, the shortage variable at its pre-pandemic average (which is 4 in our data), and productivity growth to roughly 0.4% (the post-GFC average). Thus, the "initial conditions" can be thought of as a prediction of what inflation would have been under these circumstances.

These values can be interpreted as follows. The change in relative energy prices was negative in 2019, i.e. energy prices were falling relative to wages. To keep *grpe* at this negative value would imply a counterfactual of continued sharp relative deflation of energy, which seems unlikely. Thus, setting it to 0 seems relatively neutral – that is, the counterfactual assumes energy prices would have moved in line with wages through the subsequent 3.5 years. The same goes for relative food prices (*grpf*), which were mildly negative before the pandemic, and then set to 0; and productivity growth, which was a little stronger than average in 2019, but we assume would have returned to its pre-pandemic post-2008 trend. For shortages, the measure was at roughly its pre-pandemic average in 2019, so holding it at this level implies continued 'normal' supply chain conditions.

For V/U, the intuition is easier, but implications more challenging. In 2019 Q4, V/U was 0.63 – around twice its long-run pre-pandemic average. Following BB, we hold V/U at this level in the "initial conditions" – that is, we assume the labour market stays at this 2019 Q4 level of tightness. This means, however, that the initial conditions embody a persistently tight labour market. Indeed, relative to the estimation period average (roughly 0.35) the model interprets this as a persistent increase in V/U of roughly 0.28-points. Recall that the IRF for a persistent increase in V/U (Figure 13) leads to increased price *inflation* (and wage growth), in contrast to the IRFs for price shocks (Figure 12) 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 2.8% in 2020 Q1 to 4.6% in 2023 Q2. 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 5.3.

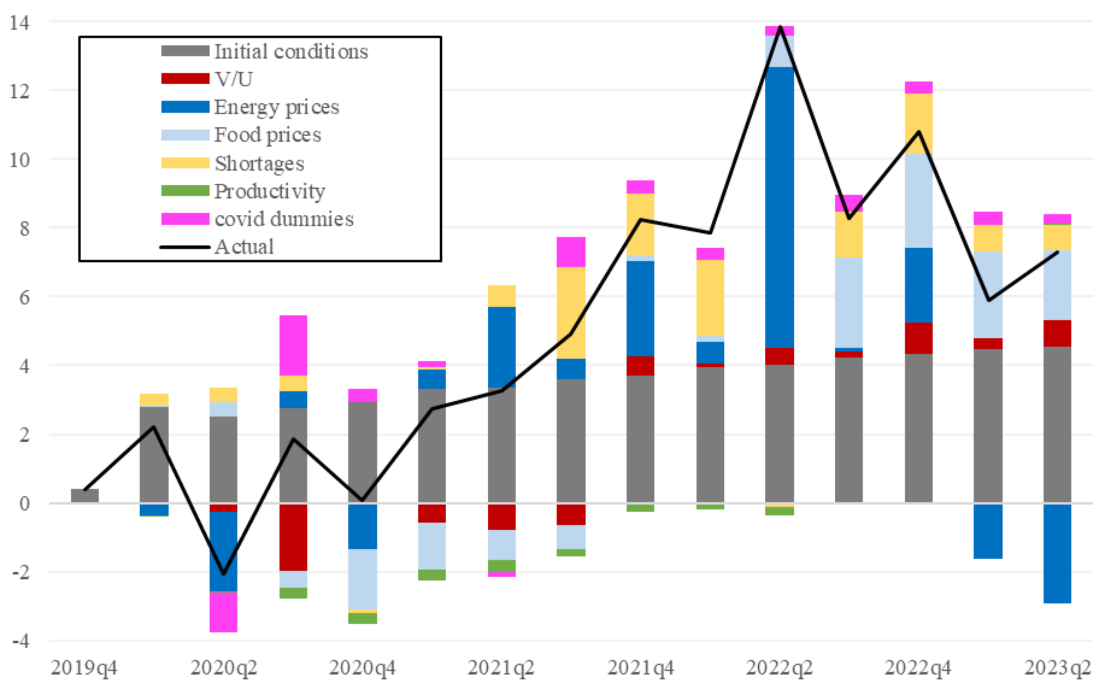
It is worth noting that these choices are not neutral assumptions. Clearly the true counterfactual outcomes for the exogenous variables in the absence of the pandemic are unknowable. However, assuming that they are as we have done has implications for the model decomposition and interpretation of the results. Different assumptions for the initial conditions do not alter the overall model predictions, but do change the decomposition of those predictions into the contribution of the exogenous shocks and the "initial conditions". Appendix D describes a range of alternative assumptions for the initial conditions (especially V/U), and how the contributions in the model change accordingly.

5.2 Results

5.2.1 CPI inflation

Figure 14 shows the decomposition of quarter-on-quarter annualised CPI inflation between 2019 Q4 and 2023 Q2.

Figure 14: Decomposition of price inflation, 2019 Q4 to 2023 Q2



Notes: "Initial conditions" reflect the model response under hypothetical conditions where V/U remains at the level in 2019 Q4, relative food and energy price changes are 0, shortages remain at roughly their historic average, and productivity matches its 2012-2019 average; see text for interpretation of these conditions. Parallels Figure 12 in BB.

The simulations suggest the following as regards inflation. First, the "initial conditions" line is trending up slowly. It was 2.8% in 2020 Q1 but has been drifting up slowly to 4.6% in 2023 Q2. This then says that, had there been no price shocks, and had V/U remained at its level immediately before the pandemic, inflation would, by now, be well above target. As suggested in the discussion above, this suggests that the immediate pre-pandemic V/U ratio is above its target-consistent level. Thus the "initial conditions" bar embodies a significant V/U effect: we explore this further in section 5.3.

Second, proceeding year by year, inflation in 2020 is hard to decompose, with national lockdowns in response to the spread of covid-19 from the end of 2020 Q1 through to 2021 Q2, a slight respite in 2021 Q3 and subsequent tightening in 2021 Q4. We do not over-interpret this period.

Third, inflation in 2021 follows a similar story to that in the US found by BB. Between 2021 Q1 and 2021 Q4, annualised quarter-on-quarter CPI inflation averaged 4.8%, of which energy contributed 1.6pp (33%) and shortages 1.3pp (27%) on average across the year. The contribution of labour market tightness was negative until 2021 Q4 (under these assumptions for the initial conditions). Recall that the furlough scheme ended at the end of September 2021; V/U rose in its importance after then. Recall further that the Ofgem price cap meant that regulated energy prices increased notably in October 2021.

Fourth, inflation in 2022: energy was the key contributor in 2022 Q2, associated with the increase in the regulated energy price (Ofgem price cap) in April 2022 – this causes the contribution of energy to be lumpy. Food prices begin to play an important role from 2022 Q3. Labour market tightness and demand conditions more broadly (represented by the V/U ratio) was of growing importance throughout 2022 and into 2023. Similarly, the "initial conditions" bar is growing (although the size of these bars depends crucially on the assumptions for the initial conditions, discussed in section 5.1 and further in 5.3).

Fifth, regarding inflation in the first half of 2023, the energy contribution turns negative, as energy prices decline from their recent highs and now begin to drag on inflation. Food prices continue to be important large contributors, and shortages continue to play a small role. The tight labour market remains important (and would be more so if we changed the "initial conditions" to correspond to a lower V/U ratio, see more below). However, the model fails to predict the uptick in quarter-on-quarter annualised inflation in 2023 Q2, with the outturn being 7.3%, against 5.5% predicted by the model.

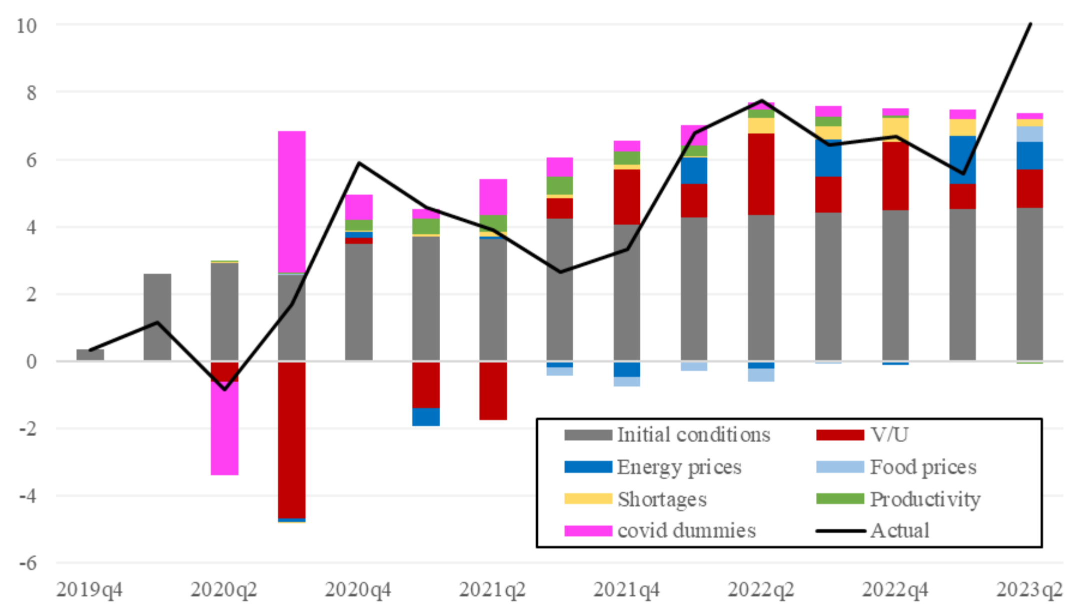
5.2.2 Wage inflation

Figure 15 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 V/U, and by the dynamic nature of the model this effect perpetuates. 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" are trending up in Figure 15, as in Figure 14 for price inflation, consistent with V/U being held at a 'tight' level, and thus leading to above-target-consistent levels of wage growth. They reach 4.6% in 2023 Q2.

Aside from the initial conditions, higher wage growth can be explained mostly by labour market tightness (V/U). This contributes 1.6pp to wage growth on average in 2022, and 0.9pp on average in the first half of 2023. Energy prices and shortages, 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.

Figure 15: Decomposition of wage inflation, 2019 Q4 to 2023 Q2



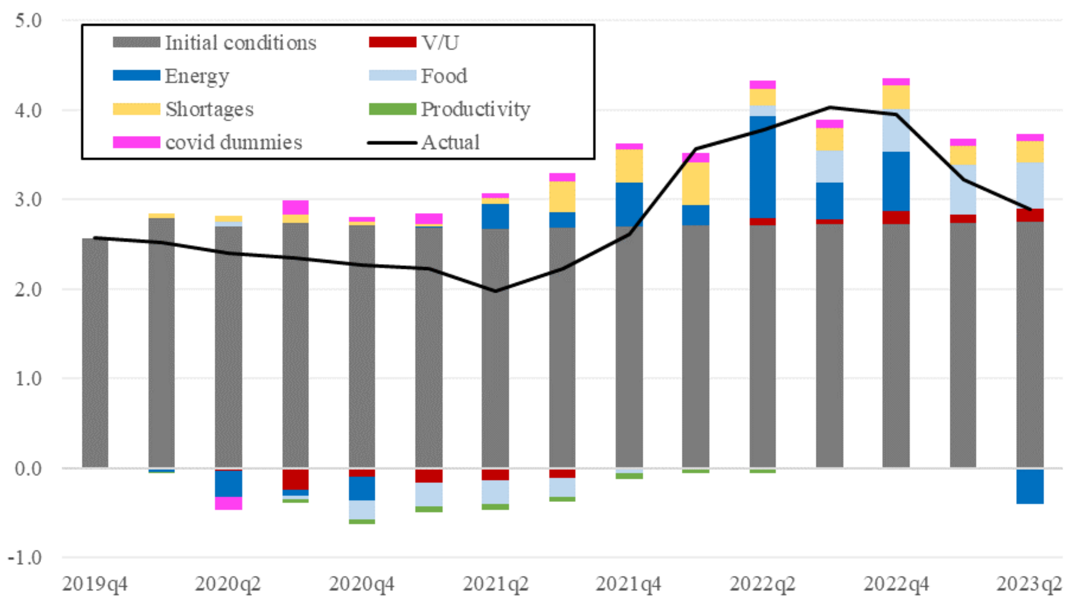
Notes: "Initial conditions" reflect the model response under hypothetical conditions where V/U remains at the level in 2019 Q4, relative food and energy price changes are 0, shortages remain at roughly their historic average, and productivity matches its 2012-2019 average; see text for interpretation of these conditions. Parallels Figure 13 in BB.

5.2.3 Expectations

Just as for wage growth and inflation, the model also allows a decomposition of one-year inflation expectations and long-run inflation expectations, following the same method as described in section 5.1.

Figure 16 shows this decomposition for one-year inflation expectations. The model predicts these fairly well, although it tends to over-predict them slightly from mid-2021 onwards. This relates in part to the slight over-prediction of inflation in the model over much of this period. The increase in one-year inflation expectations during 2022 is driven by the same factors that drive the increase in current inflation (Figure 14).

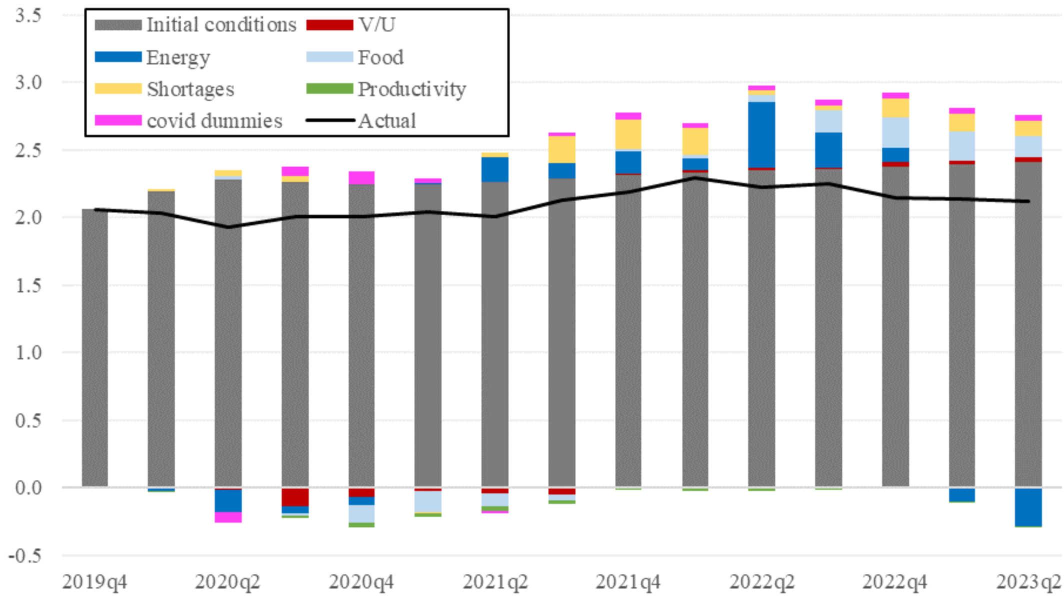
Figure 16: Decomposition of one-year inflation expectations, 2019 Q4 to 2023 Q2



Notes: "Initial conditions" reflect the model response under hypothetical conditions where V/U remains at the level in 2019 Q4, relative food and energy price changes are 0, shortages remain at roughly their historic average, and productivity matches its 2012-2019 average; see text for interpretation of these conditions.

Figure 17 shows the decomposition of long-run inflation expectations. Here, the model rather markedly over-predicts from mid-2021 onwards. The model expects high current inflation through 2022 and 2023 to push up on long-run inflation expectations – as discussed in section 4.3, even small coefficients can have large impacts on predicted inflation expectations given the high and variable levels of quarterly inflation during 2022 and 2023. In reality, however, long-run inflation expectations have remained remarkably well anchored, peaking at just 2.3% (on this measure) in 2022 Q1, before slowly falling back to 2.1% in the first half of 2023. Had long-run inflation expectations followed the model predictions, they would have peaked at 3.0% in 2022 Q2 – a level not seen in the UK since the late-1990s (Figure 4).

Figure 17: Decomposition of long-run inflation expectations, 2019 Q4 to 2023 Q2



Notes: "Initial conditions" reflect the model response under hypothetical conditions where V/U remains at the level in 2019 Q4, relative food and energy price changes are 0, shortages remain at roughly their historic average, and productivity matches its 2012-2019 average; see text for interpretation of these conditions.

5.3 Inflation, labour market tightness and catch-up

Given our interest in the labour market we focus on the V/U effect and catch-up. As Figure 14 shows, the "initial conditions" contribution grows over the period to 4.6% by 2023 Q2. We have also seen that the V/U ratio embodied in the initial conditions (0.63) was the highest level in the pre-pandemic sample (see

Turning to the labour market, Figure 3 shows nominal wage growth and a labour market tightness measure, namely the V/U ratio. These wage data are adjusted for labour force composition and for furlough, a scheme during the pandemic described below. The data show a strong rise in the V/U ratio in recent times along with a strong rise in wage inflation, although V/U has receded somewhat in the first half of 2023.

Turning to expectations, Figure 4 shows the series of short and long run expectations we use. Both are amalgams of financial, professional forecaster and household expectation survey data in a way that is as historically comparable as possible, and that avoid recent distortions in financial measures owing to a forthcoming change in the way one UK inflation index (the RPI), widely used in index-linking, is computed. Both short and long run measures have risen somewhat in recent quarters and then fallen again.

Figure 3). While inflation was at or below target in 2019, wage growth was somewhat elevated relative to the recent past (see Figure 3), and the MPC judged that the labour market was tight.[24] So it seems likely that V/U 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 V/U in the model (red bars in Figure 14 and Figure 15) show the effect of tightness relative to V/U in the initial conditions (i.e. relative to V/U=0.63). If we selected an alternative (lower, i.e. looser) path for V/U in the initial conditions, then the contribution of V/U would be larger, since it would be relative to a lower counterfactual.

Appendix D summarises the effect of changing the assumption on V/U underlying the initial conditions, and thus changing the contribution of V/U to inflation (which is offset by the initial conditions contribution). This is now better thought of capturing a range of counterfactuals, rather than "initial conditions" as described by BB, since we are varying V/U from its initial (2019 Q4) conditions.

These show that the contribution of V/U to inflation during 2022 and 2023 could be larger than depicted in Figure 14. The contribution of V/U to quarter-on-quarter annualized inflation over 2022 and the first half of 2023 averages 0.5pp in the baseline scenario shown in Figure 14. Assuming a lower counterfactual path for V/U (where V/U falls to its 2012-2019 average of 0.42 over 8 quarters and remains there) pushes that up to 1.3pp (initial conditions then rise more slowly, to 3.5% in 2023 Q2, and all other contributions are the same). A more extreme path for V/U (where it falls to its 1990-2019 average of 0.31 over 8 quarters and remains there) gives V/U an average contribution to inflation of 1.8pp over 2022 Q1 to 2023 Q2, with the initial conditions finishing at 3.0% in 2023 Q2. Thus, a range for the V/U contribution from 0.5-1.8pp seems plausible. These and various other paths for V/U, and the associated contributions to inflation, are described in Appendix D.

Turning to catch-up, its effect is not set out separately in Figures 14-17 since it is endogenously determined. Recall that catch-up is measured as actual annual inflation less what was expected a year ago. 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-

[24] 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" (Nov 2019 MPR, page 15) and "Survey measures of recruitment difficulties also remain elevated, consistent with a tight labour market" (Jan 2020 MPR, page 30).

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 "wage-price" 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).

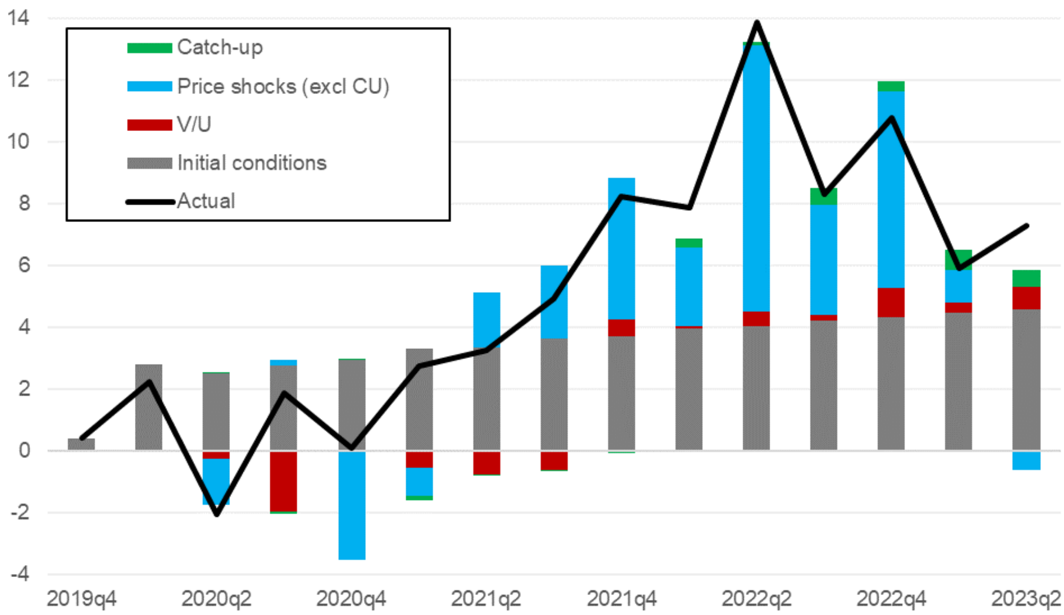
Therefore, to study the effect of catch-up on wage growth and inflation, we separate the effects of price shocks via the catch-up channel from effects via the other channels.

To do this we follow a similar method to that described in section 5.1, namely running the dynamic model under different information sets 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 positive catch-up shocks (Figure 6) – each of these shocks have little effect on wage growth in the long-run, but can have effects in the short-run. The cumulative effect of such shocks turns out to have quite a large effect.

Figure 18 (price inflation) and Figure 19 (wage growth) are equivalent to Figure 14 and Figure 15 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, and shortages, 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 show simply a re-arrangement of the contributions of Figures 14 and 15. The exceptions are that we have omitted showing the covid dummies (and their dynamic effects) and productivity for brevity.

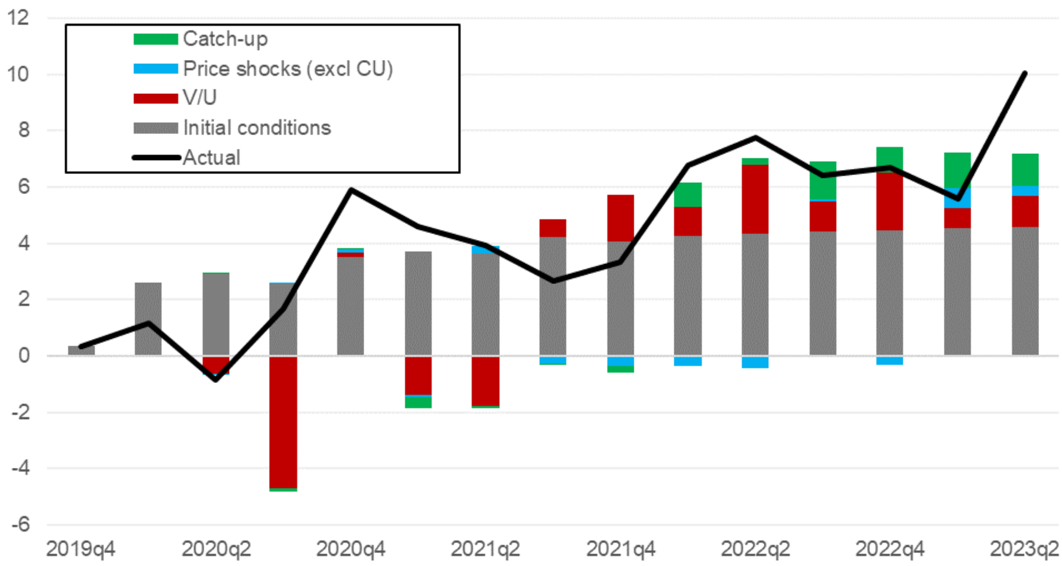
Figure 18: Decomposition of price inflation, separating the effects via the catch-up channel, 2019 Q4 to 2023 Q2



Notes: "Initial conditions" reflect the model response under hypothetical conditions where V/U remains at the level in 2019 Q4, relative food and energy price changes are 0, shortages remain at roughly their historic average, and productivity matches its 2012-2019 average; see text for interpretation of these conditions. "Price shocks (excl CU)" reflect the effects of energy prices, food prices, and shortages excluding via the catch-up channel, which is shown separately. Dynamic contributions of covid dummies and productivity excluded for brevity. Re-arrangement of contributions in Figure 14.

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 inflation (via wage growth), and with the catch-up channel adding on average 0.4pp to quarter-on-quarter annualised inflation between 2022 Q1 and 2023 Q2.

Figure 19: Decomposition of wage inflation, separating the effects via the catch-up channel, 2019 Q4 to 2023 Q2



Notes: "Initial conditions" reflect the model response under hypothetical conditions where V/U remains at the level in 2019 Q4, relative food and energy price changes are 0, shortages remain at roughly their historic average, and productivity matches its 2012-2019 average; see text for interpretation of these conditions. "Price shocks (excl CU)" reflect the effects of energy prices, food prices, and shortages excluding via the catch-up channel, which is shown separately. Dynamic contribution of covid dummies and productivity excluded for brevity. Re-arrangement of contributions in Figure 15.

6 Robustness checks

The model is robust to a range of robustness checks. Appendix A details how the estimated equations differ according to the sample period over which they are estimated, and some other variations. In this section, we describe briefly some additional robustness check.

6.1 Food and energy prices

Previous research (e.g. Cavallo et al., 2017; D'Acunto et al., 2019) suggests that household inflation expectations are particularly sensitive to inflation in salient items, including most notably food and energy. These are products which consumers interact with regularly, and jointly account for a relatively large portion of the budget of many households. Inflation in these products could thus be thought to influence the perception of inflation of many households more strongly, and thus impact inflation expectations.

To test this, we trialled including the relative energy and food price terms (contemporaneous and with four lags, as for headline inflation) in the one-year inflation expectations equation. The sum of coefficients on both the energy and food terms was negative, close to zero and jointly insignificant in both cases. The same goes for the contemporaneous coefficients. The overall fit of the equation was also reduced. As such, we reject the hypothesis of a direct inflation salience effect on expectations in this model.

We also looked for longer lags in the transmission of energy and food prices through the supply chain by including up to 8 lags (2 years) of each in the price equation. In the case of energy, the sum of coefficients on the additional four lags is negative, close to zero and jointly insignificant. The sum of coefficients on all energy terms (contemporaneous and with all lags) turns from slightly positive with four lags to slightly negative with eight lags, although the contemporaneous coefficient is little changed. As such, we reject additional lags on energy prices.

In the case of food prices, we find tentative evidence for additional passthrough at 6 to 7 lags (i.e. 6 to 7 quarters after the price shock). The coefficient on the sixth lag is insignificant, while on the seventh lag it is significant at the 10% level. While this may be spurious, they continued to return positive and broadly consistent coefficients when including up to 12 lags (3 years) of food prices. The sum of the coefficients on the fifth to eighth lag is 0.07 which, while jointly insignificant, is quantitatively large. The sum of all food terms (contemporaneous and with all lags) increases from 0.13 with four lags, to 0.22 with eight lags. However, given that the additional four lags are jointly insignificant, and that the sum of coefficients on food prices in the baseline model is already large relative to its share of the CPI basket, we do not include these in the baseline model. That said, together with the results of the baseline model (see Figure 12 in particular), this supports an important and persistent role for food prices in UK inflation dynamics.

6.2 Import prices

In a relatively small open economy, one might imagine that import prices are important for inflation. While we include energy and food prices in the inflation equation, and both contain substantial imported content for the UK, prices of non-energy-non-food imports might also be important.

We trialled including measures of import prices, consumer-producer price wedges (the CPI-GVA price and CPI-GDP price wedges), and the Sterling exchange rate in the inflation equation. All improved the fit of the price equation slightly, albeit at the cost of adding five additional variables to a model with already 25 regressors fitted on only 133 observations. Most reduced the sum of coefficients on food and energy prices slightly, consistent with the additional variable sharing some information content with these variables (either directly in the case of the import price measure, or indirectly in the case of the wedge effects). In all cases the contemporaneous coefficient was statistically significant, but the sum of coefficients was insignificant.

All imported products share the effects of the exchange rate, and so energy, food and import prices share some information. Further, since each are expressed relative to wages (to capture relative price effects), they share additional information. Empirically, relative non-energy-non-food import prices co-move with relative food prices to a large extent. Thus, we cannot disentangle their effects sufficiently precisely.

6.3 Signals from wages

One response to the wage data, particularly during the pandemic lockdowns and furlough period, is that the measured wage is so far from that faced by the marginal firm that is it not allocative. If that is so, then the impact on prices will not be allocative either, suggesting a negative correlation between residuals in the wage and price equation. As it turned out, the residuals of the equations are weakly positively correlated over 2020 Q1 to 2023 Q2, but are weakly negatively correlated if restricting to the furlough period (2020 Q1 to 2021 Q3). Of course, this latter period is just seven quarters, two of which have dummies in the wage equation, such that they have zero residuals – excluding these weakens the negative correlation.

In summary, any effects of "un-allocative" wages are small and do not invalidate the model.

7 Projections

We use the model to provide some illustrative conditional forecasts for inflation.

To project inflation, we must make a number of assumptions regarding the paths for the exogenous variables. We start by filling in some available data for 2023 Q3 using the latest official data, including relative energy and food prices (*grpe* and *grpf*). Consumer energy prices fell sharply in 2023 Q3 as a result of the Ofgem price cap dropping in July 2023 relative to the previous quarter. Coupled with strong wage growth, this implies a sharp relative price deflation. Quarterly food price inflation was low in 2023 Q3, with annual food price inflation slowing accordingly: this gives mildly negative *grpf* in 2023 Q3.

To construct *grpe* and *grpf* for 2023 Q4 we use the near-term forecasts for the energy and food components of the CPI, and wage growth, from the Bank of England's November 2023 Monetary Policy Report. The Ofgem price cap for 2023 Q4 is already announced, which makes the forecast for consumer energy prices in that period very certain. The short-term inflation forecast of food price inflation is historically very reliable.

For shortages, we have monthly Google trends data up to November, so can extend the series for 2023 Q3, and make a nowcast for Q4 on the basis of the available (partial) data.[25] For productivity, given that it already aims to capture a trend, we do not think there is much value

[25] These turn out to be 6.4 in 2023 Q3 and 9.0 in 2023 Q4. These relate to a pre-pandemic (2004-2019, given that the series starts only in 2004) average of 3.2 and an estimation period (1990-2023) average of 4.4, and an average over 2020 Q1 – 2023 Q2 of 11.6.

in incorporating the latest quarterly datapoint (which may of course be revised in future), and thus assume a trend of 0.5% (quarter-on-quarter, annualised) from 2023 Q3 onwards.

That gives reliable estimates for 2023 Q3 and Q4 for the price shocks. Thereafter we make some assumptions, broadly in line with BB: we set *grpe* and *grpf* to 0, shortages to 4 (roughly the long-run average), and maintain trend productivity growth at 0.5%. It should be noted that *grpe* and *grpf* averaged below zero before the pandemic and might be expected to do so again in coming years, especially as recent inflation in both energy and food prices fade, while wage growth remains relatively more sticky. However, this is clearly uncertain, so we do not account for this possible future here.

We have, as well, to choose the path of the V/U ratio. Following BB we take a simple approach, and set three arbitrary terminal values for V/U, with linear adjustment towards them. These three paths are (a) staying at the 2023 Q2 level = 0.72 (note this is just over 2 times the estimation period average), (b) decline towards the 2012-2019 average = 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 3), over 8 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 V/U since it peaked in 2022 Q3.

The results of this exercise are set out in Figure 20, where inflation is shown transformed into annual percentage changes on quarterly frequency.[26] The black line on the far left of the chart shows outturn data for the first two quarters of 2023. The coloured lines then show the model projections of inflation from 2023 Q3 onwards on the basis of the different V/U paths described above, each using the same set of other exogenous variables as described above.

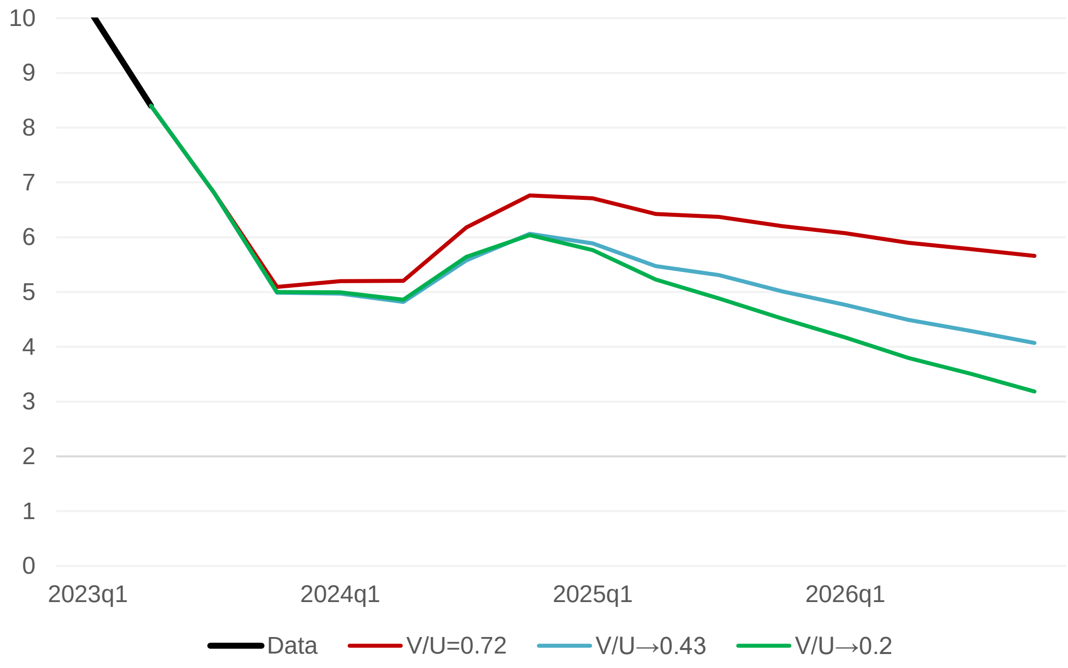
The disinflationary effects of the decline in relative energy and food prices in the near term reduce inflation sharply in all three scenarios, consistent with most forecasts (and with the latest inflation data). The decline moderates in all three scenarios during 2024 as the disinflationary price shocks end. We do not over-interpret the 'hump-shape', whereby inflation temporarily increases a little in 2024 – this is driven principally by the coefficients on lagged energy prices, which are somewhat dubious.

Looking through this, the decline in inflation moderates for a time, then continues more slowly. The red line, with V/U held at its 2023 Q2 level of 0.72, remains high and barely falls, suggesting that this level of V/U is not target-consistent. Reducing V/U in both of the other two lines (green and blue) brings inflation down more quickly, albeit still relatively slowly in this

[26] The outturns in 2023 Q1 and 2023 Q2 thus differ from those in Figure 14 which are quarter-on-quarter annualised inflation.

model. In the scenario with the lowest V/U level, inflation reaches 3.2% in by the end of 2026. It is important to note that the average inflation over the estimation period (1990 Q1 to 2023 Q2) is about 2.7%, so the model will only produce at-target (i.e. 2%) inflation with looser than 'average' conditions (on aggregate across all exogenous variables).

Figure 20: 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. For reference, approximate values of V/U are different times are: 2019 Q4 = 0.63, 2023 Q2 = 0.72, 2012-2019 average = c. 0.43, 1990-2019 average = c. 0.31, 1990-2023 average = c. 0.35, average 2009-2012 = c. 0.2.

All of these scenarios show an initially quick decline in inflation given disinflationary effects of energy and food, and then a slower decline driven by falling V/U. This latter slower decline in inflation reflects the high degree of wage and inflation 'stickiness' in the model, with the sum of coefficients on the lagged dependent being relatively large in both the wage and price equations (see Tables 1 and 2). It is notable that inflation expectations do not de-anchor in the scenarios where V/U declines, with both short-run and long-run expectations being at or below their estimation period averages in all cases.[27] Thus, the model predicts a slow return of inflation to target even with inflation expectations remaining anchored.

[27] In the scenario where V/U remains high (at its 2023 Q2 value of 0.72), long-run expectations rise slowly but continuously, while short-run expectations are about flat but above their typical levels, consistent with de-anchoring.

8 Conclusion

We have implemented the model of inflation, wages and inflation expectations proposed by Bernanke and Blanchard (2023) on UK data, to cast light on the UK's inflation experience over the pandemic and post-pandemic period. To do so we have used quarterly data covering over 30 years (1990 Q1 to 2023 Q2), largely from publicly available data sources.

Our findings are largely similar to those of BB for the US. First, price shocks dissipate quickly (Figure 12), and thus tend to be transitory. However, the model makes clear that they can have second-round effects via inflation expectations and real wage catch-up. These effects are relatively small in the medium-run in our estimated UK model, 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, these can have short-run dynamic effects (for instance, see Figure 18 and Figure 19). Food price shocks appear to be more persistent than energy price shocks (Figure 12), and more persistent than in the US.

Second, the level of wage growth and pattern of inflation over the pandemic and post-pandemic period can be explained by the model fairly well (Figure 14 and Figure 15). That suggests that inflation is behaving broadly as expected in the face of large relative price shocks and a tight labour market. If that were not the case, then our model would not be able to explain the current level of inflation and wage growth – in fact, inflation and wage growth have been a little lower than predicted by the model.

Third, the major causes of recent high inflation in the UK were initially large shocks to energy prices and shortages, and later shocks to food prices (Figure 14). The energy and shortages shocks are wearing away – indeed, energy prices are now dragging on inflation – while the food price shock is still an important contributor to current inflation.

Fourth, the role of labour market tightness is smaller (at least in our baseline model) but has grown somewhat over time. However, the role of tightness depends crucially on the assumptions underlying the "initial conditions" in the model (see section 5.3). In our baseline model, following BB, we lock into the "initial conditions" the level of V/U immediately before the pandemic, which was already tight. Relative to this initial level of V/U, additional tightness during the 2022 and 2023 has contributed somewhat to inflation; but relative to a lower counterfactual for V/U, tightness would have been estimated to contribute more (Appendix D).

Finally, we use the model to make some conditional forecasts of inflation (section 7). Disinflationary effects of energy and food prices cause an initially sharp decline in inflation until the end of 2023, but inflation thereafter is stickier and declines slowly (Figure 20). 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.

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Appendix A – Full model estimation and sensitivities to other specifications

Table A1: Wage equation: dependent variable = gw

	Baseline: full sample, with dummies, using V/U	Variant: full sample, without dummies, using V/U	Variant: pre-pandemic sample, using V/U	Variant: pre-pandemic sample, using ln(V/U)	
gw (-1)	0.27*** (0.09)	0.23** (0.09)	0.13 (0.09)	gw (-1)	0.13 (0.10)
gw (-2)	0.20** (0.09)	0.22** (0.09)	0.26*** (0.09)	gw (-2)	0.26*** (0.09)
gw (-3)	0.14 (0.09)	0.15 (0.09)	0.25*** (0.09)	gw (-3)	0.26*** (0.09)
gw (-4)	-0.01 (0.09)	-0.01 (0.09)	0.01 (0.09)	gw (-4)	0.03 (0.09)
iesr (-1)	-0.16 (0.33)	-0.11 (0.34)	-0.22 (0.31)	iesr (-1)	-0.29 (0.32)
iesr (-2)	-0.56 (0.42)	-0.69 (0.42)	-0.60 (0.39)	iesr (-2)	-0.62 (0.40)
iesr (-3)	1.05*** (0.37)	1.03*** (0.38)	1.01*** (0.34)	iesr (-3)	0.96*** (0.35)
iesr (-4)	0.06 (0.32)	0.19 (0.32)	0.15 (0.30)	iesr (-4)	0.27 (0.30)
magpty (-1)	0.21* (0.12)	0.25* (0.13)	0.16 (0.12)	magpty (-1)	0.18 (0.12)
vu (-1)	13.31*** (5.00)	3.04** (1.37)	22.62** (9.35)	lnvu (-1)	8.01** (2.69)
vu (-2)	-16.01** (7.15)	-3.54* (2.11)	-6.04 (16.29)	lnvu (-2)	-5.78 (4.73)
vu (-3)	5.19 (5.69)	1.54 (2.13)	-21.50 (16.82)	lnvu (-3)	-3.11 (4.93)
vu (-4)	-0.13 (3.79)	-0.31 (1.38)	6.45 (10.17)	lnvu (-4)	1.52 (2.80)
catch-up (-1)	0.30 (0.21)	0.33 (0.21)	0.37* (0.21)	catch-up (-1)	0.45** (0.22)
catch-up (-2)	-0.39 (0.27)	-0.29 (0.28)	-0.33 (0.27)	catch-up (-2)	-0.33 (0.27)
catch-up (-3)	0.44 (0.28)	0.30 (0.28)	0.31 (0.27)	catch-up (-3)	0.32 (0.27)
catch-up (-4)	-0.25 (0.22)	-0.23 (0.22)	-0.37* (0.21)	catch-up (-4)	-0.32* (0.21)
constant	-0.94** (0.42)	0.77** (0.37)	-0.74* (0.43)	constant	-2.36** (0.39)
D 2020Q2	-2.79 (1.76)				
D 2020Q3	5.00* (2.52)				
R-squared	0.597	0.574	0.627		0.627
Observations	134	134	120		120
Estimation period	1990 Q1 – 2023 Q2	1990 Q1 – 2023 Q2	1990 Q1 – 2019 Q4		1990 Q1 – 2019 Q4

Note: Clustered standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. R-squared calculated over estimation period. See text for definition of variables.

Table A2: Price equation: dependent variable = gp

	Baseline: full sample, using Google trends "shortage"	Variant: pre-pandemic sample, using Google trends "shortage"	Variant: full sample, using GSCPI	
gp (-1)	0.25*** (0.09)	0.25*** (0.09)	gp (-1)	0.24*** (0.09)
gp (-2)	0.10 (0.09)	0.07 (0.10)	gp (-2)	0.09 (0.09)
gp (-3)	0.12 (0.09)	0.14 (0.09)	gp (-3)	0.10 (0.09)
gp (-4)	0.23*** (0.08)	0.19** (0.09)	gp (-4)	0.24*** (0.08)
gw	0.42*** (0.06)	0.40*** (0.06)	gw	0.42*** (0.06)
gw (-1)	-0.09 (0.06)	-0.08 (0.07)	gw (-1)	-0.11 (0.07)
gw (-2)	-0.05 (0.06)	-0.02 (0.07)	gw (-2)	-0.05 (0.07)
gw (-3)	-0.07 (0.06)	-0.07 (0.07)	gw (-3)	-0.03 (0.07)
gw (-4)	0.09 (0.06)	0.12* (0.07)	gw (-4)	0.10 (0.06)
magpty	-0.22*** (0.07)	-0.17** (0.08)	magpty	-0.24*** (0.07)
grpe	0.08*** (0.01)	0.08*** (0.01)	grpe	0.07*** (0.01)
grpe (-1)	-0.02** (0.01)	-0.02* (0.01)	grpe (-1)	-0.02* (0.01)
grpe (-2)	-0.01 (0.01)	-0.01 (0.01)	grpe (-2)	-0.01 (0.01)
grpe (-3)	-0.02* (0.01)	-0.02 (0.01)	grpe (-3)	-0.02* (0.01)
grpe (-4)	-0.03*** (0.01)	-0.03** (0.01)	grpe (-4)	-0.03*** (0.01)
grpf	0.18*** (0.03)	0.18*** (0.03)	grpf	0.19*** (0.03)
grpf (-1)	0.01 (0.03)	0.01 (0.04)	grpf (-1)	-0.00 (0.03)
grpf (-2)	-0.01 (0.03)	0.00 (0.04)	grpf (-2)	-0.01 (0.03)
grpf (-3)	-0.01 (0.03)	-0.02 (0.03)	grpf (-3)	-0.01 (0.03)
grpf (-4)	-0.04 (0.03)	-0.03 (0.03)	grpf (-4)	-0.04 (0.03)
shortage	0.07*** (0.03)	-0.07 (0.16)	GSCPI	0.28 (0.21)
shortage (-1)	0.01 (0.03)	0.02 (0.17)	GSCPI (-1)	0.05 (0.29)
shortage (-2)	0.04 (0.03)	-0.05 (0.17)	GSCPI (-2)	-0.27 (0.29)
shortage (-3)	-0.10** (0.04)	-0.03 (0.18)	GSCPI (-3)	0.24 (0.30)
shortage (-4)	0.01 (0.04)	-0.14 (0.17)	GSCPI (-4)	-0.07 (0.25)
constant	0.15 (0.20)	1.10* (0.56)		0.32** (0.13)
R-squared	0.888	0.749		0.881
Observations	134	120		134

Estimation period	1990 Q1 – 2023 Q2	1990 Q1 – 2019 Q4		1990 Q1 – 2019 Q4

Note: Clustered standard errors in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01. R-squared calculated over estimation period. See text for definition of variables.

Table A3: One-year inflation expectations equation: dependent variable = iesr

	Baseline: full sample	Variant: pre-pandemic sample
iesr (-1)	0.57*** (0.08)	0.56*** (0.09)
iesr (-2)	0.43*** (0.10)	0.45*** (0.11)
iesr (-3)	-0.14 (0.10)	-0.16 (0.10)
iesr (-4)	-0.03 (0.08)	0.01 (0.09)
ielr	0.82*** (0.16)	0.75*** (0.17)
ielr (-1)	-0.48* (0.25)	-0.31 (0.27)
ielr (-2)	-0.28 (0.25)	-0.45 (0.28)
ielr (-3)	0.04 (0.25)	0.15 (0.28)
ielr (-4)	0.03 (0.16)	-0.02 (0.17)
gp	0.07*** (0.02)	0.08** (0.03)
gp (-1)	-0.03 (0.03)	-0.07** (0.03)
gp (-2)	0.01 (0.03)	0.03 (0.03)
gp (-3)	0.00 (0.03)	0.00 (0.03)
gp (-4)	-0.03 (0.02)	-0.03 (0.03)
R-squared	0.831	0.828
Observations	134	120
Estimation period	1990 Q1 – 2023 Q2	1990 Q1 – 2019 Q4

Note: Clustered standard errors in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01. R-squared calculated over estimation period. See text for definition of variables.

Table A4: Long-run inflation expectations equation: dependent variable = ielr

	Baseline: full sample	Variant: pre-pandemic sample
ielr (-1)	1.23*** (0.09)	1.28*** (0.09)
ielr (-2)	-0.29** (0.14)	-0.41*** (0.15)
ielr (-3)	-0.22 (0.14)	-0.12 (0.15)
ielr (-4)	0.27*** (0.08)	0.24*** (0.09)
gp	0.06*** (0.01)	0.09*** (0.02)
gp (-1)	-0.04*** (0.01)	-0.06*** (0.02)
gp (-2)	-0.03* (0.02)	-0.01 (0.02)
gp (-3)	0.02 (0.01)	0.01 (0.02)
gp (-4)	0.00 (0.01)	-0.01 (0.02)
R-squared	0.944	0.948
Observations	134	120
Estimation period	1990 Q1 – 2023 Q2	1990 Q1 – 2019 Q4

Note: Clustered standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. R-squared calculated over estimation period. See text for definition of variables.

Comparing the equations estimated with the pre-pandemic sample

Table A5 summarises the differences between the equations estimated on the pre-pandemic sample, and the full sample. In each case, the sum of coefficients for the equations estimated on the full sample are as presented in Tables 1-4. The full set of coefficients in both cases are shown in the tables above in this Appendix.

In most cases, the differences are small. The price equation is relatively unaffected by the choice of sample period, with the exception of the shortage variable. Recall that BB estimate their equations on the pre-pandemic sample, but estimate their price equation on the full sample in order to capture sufficient variation in the shortage variable. Similarly, Table X shows that the sum of coefficients on the shortage variable is incorrectly signed when estimated on the pre-pandemic sample. Aside from this, price inflation is estimated to be slightly more ‘sticky’ (higher sum of coefficients on lagged price inflation) when estimated on the full sample than on the pre-pandemic sample.

The two inflation expectations equations change relatively little if estimated over the pre-pandemic or full sample. Long-run expectations exhibit slightly greater anchoring (greater weight on the lagged dependent) when estimated on the full sample than on the pre-pandemic sample, consistent with the observed anchoring of long-run expectations in the UK over the post-pandemic period. By contrast, the one-year expectations equation is slightly more responsive to current inflation when estimated on the full sample, although the coefficients on long-run expectations also increase which somewhat mitigates this. Overall, these are not very different.

The wage equation is rather more affected, consistent with the unusual and unpredictable behaviour of wage growth and its predictors (notably V/U) over the pandemic and post-pandemic period. It is important to note, firstly, that we have included two dummies when estimating the wage equation over the full sample: one in 2020 Q2, and one in 2020 Q3. The former is to deal with the sharp decline in wage growth in this quarter, which the wage equation cannot foresee, given that it uses only lagged information – notably, V/U fell sharply in 2020 Q2, but not in 2020 Q1, and the model sees only values up to and including 2020 Q1 when making a prediction for wage growth in 2020 Q2. The second dummy deals with the corollary to this issue: V/U falls sharply in 2020 Q2, which the model sees when making its prediction for 2020 Q3, by when wage growth had rebounded. Thus, these dummies principally deal with timing issues, given very rapid changes in economic conditions during the pandemic.[28]

Wage growth is estimated to be a little less 'sticky' when estimated on the full sample (lower weight on lagged dependent), and thus more responsive to one-year inflation expectations (by the homogeneity constraint). This might be consistent with a "rational inattention" behaviour (see Maćkowiak et al (2023) for a review), whereby households pay more attention to inflation when inflation is high (as in the post-pandemic period) than when it is not, and thus inflation expectations could play a greater role in wage-setting when inflation is high.

The sum of coefficients on V/U is higher when estimated on the full sample, suggesting that wage growth is more responsive to the level of labour market tightness than previously thought. Indeed, during the post-pandemic period wage growth was at its highest level in 30 years, and V/U was simultaneously at its highest ever level. More importantly for the predictions, however, is the profile and magnitude of the quarterly coefficients (shown in the Table A1 in this Appendix). While still relatively large and erratic, they are smaller in absolute value and less variable than in the model estimated on the pre-pandemic sample.[29] Changes in V/U thus impart a less extreme response of wage growth in the full-sample model, than the pre-pandemic-sample model; while the level of V/U is more important in the full-sample model than the pre-pandemic model.

[28] Dummy on 2020 Q2 = -2.786. Dummy on 2020 Q3 = 4.997.

[29] Average absolute coefficients on lags of V/U: pre-pandemic sample = 14.2, full sample = 8.7. Standard deviation of coefficients on lags of V/U: pre-pandemic sample = 16.2, full sample = 10.7.

Table A5: Comparing coefficients between equations estimated on pre-pandemic sample and full sample (sums of coefficients)

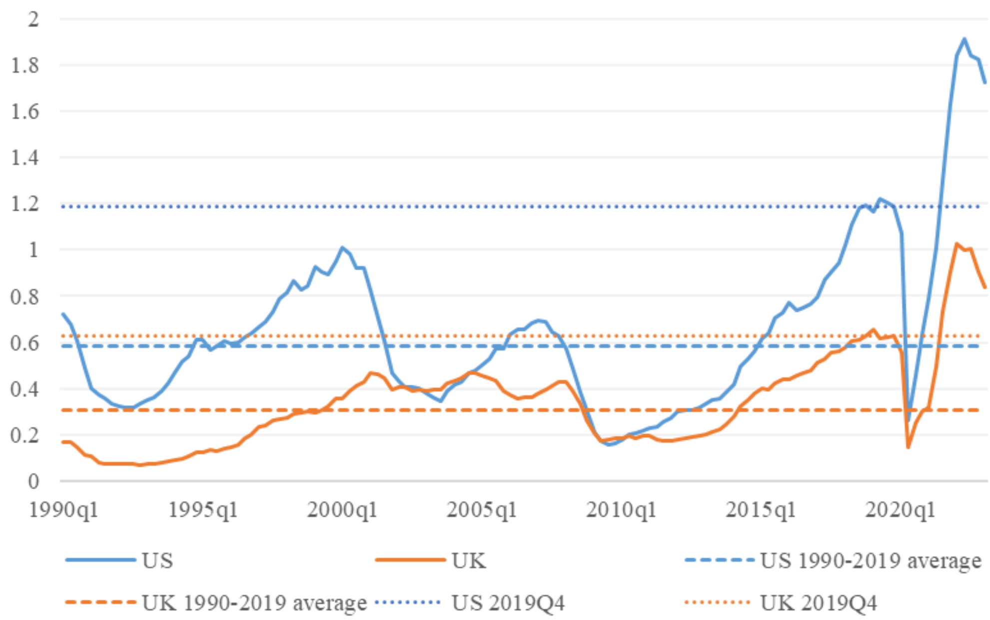
	Estimated on pre-pandemic sample	**Estimated on full sample**
Wage growth		
gw	0.658	0.602
v/u	1.522	2.364
catch-up	-0.012	0.088
iesr	0.342	0.398
gpty	0.157	0.210
Price inflation		
gp	0.649	0.703
gw	0.351	0.297
grpe	0.005	0.005
grpf	0.135	0.131
shortage	-0.265	0.036
gpty	-0.169	-0.221
One-year inflation expectations		
iesr	0.873	0.841
ielr	0.120	0.143
gp	0.007	0.015
Long-run inflation expectations		
ielr	0.989	0.994
gp	0.011	0.006

Notes: Table shows sum of coefficients on variables given in rows, estimated on either the pre-pandemic sample (first column) or full sample (second column). Coefficients in full sample column are equivalent to those in Table 1 (wage growth), Table 2 (price inflation), Table 3 (one-year inflation expectations), and Table 4 (long-run inflation expectations). Full set of coefficients and associated details are shown in Table A1 in this Appendix.

Appendix B – Additional results

VU ratio in UK and US compared

Figure B1: Vacancies to unemployment ratio, UK and US, 1990 Q1 to 2023 Q1



Additional IRF results

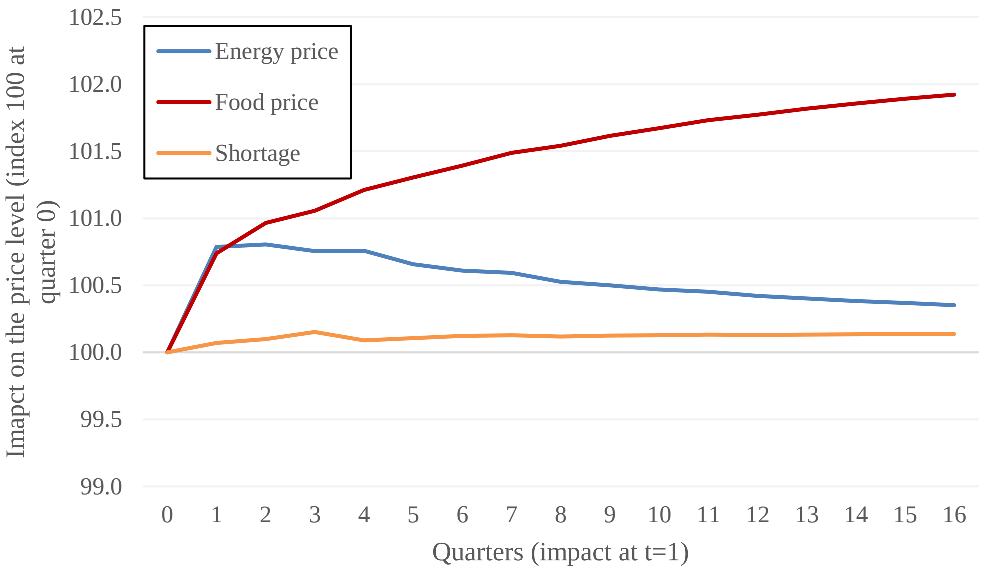
Exogenous price shocks – price level impact

Figure B2 shows the IRFs for the same exogenous price shocks as in Figures 12 and 13 in text, transformed into price levels. The price level is set to 100 in period 0, and then the exogenous price shock hits in period 1. Recall that the shock is a one-period shock, which is not reversed.

After 4 years, the price level is still higher than before the price shock for all three exogenous variables. However, for energy prices, the price level is declining back towards the level before the price shock, consistent with the sum of coefficients being close to 0 (Table 2).

For food prices and shortages, the price level is still increasing after 4 years, although more slowly, consistent with the declining impact on inflation in Figure 12. The difference between energy and food is striking, and suggests that food price shocks are much more persistent than energy price shocks. Why that should be the case is unclear.

Figure B2: Impulse response functions of the price level to shocks to the relative price of energy, relative price of food, and shortages



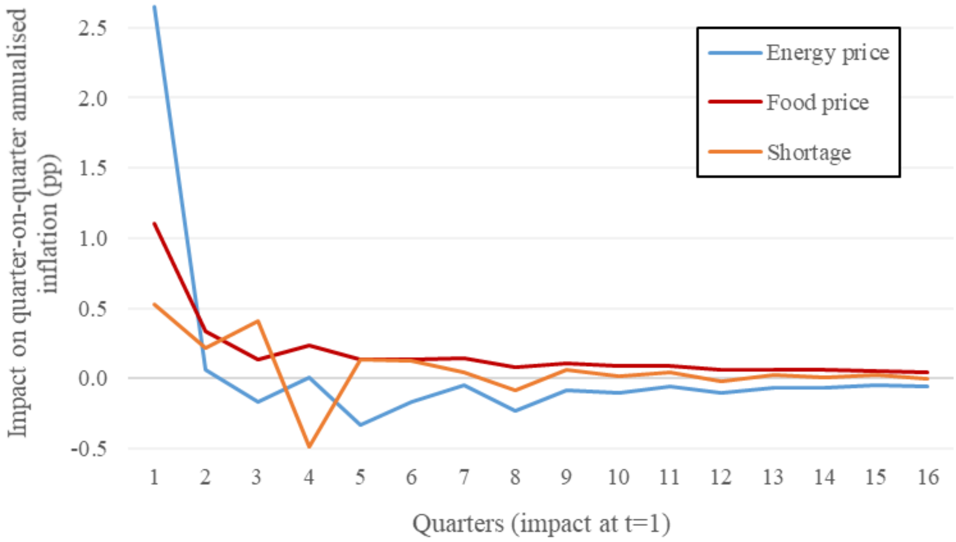
Notes: Shows the full-model response of the price level to a one-quarter (i.e. one-off) positive shock to relative energy prices, relative food prices, and shortages. Shocks equal to the standard deviation of the exogenous variable over 1990 to 2019 (a typical pre-pandemic shock). Represents a transformation of the series in Figure 12.

Exogenous price shocks – scaled by pandemic-era standard deviations

For comparison with BB, Figure B3 shows IRFs of the impact on quarter-on-quarter price inflation annualised for the exogenous price shocks, scaled by their pandemic-era standard deviations. These follow the same patterns as the quarter-on-quarter equivalent of Figure 12, but are scaled differently to mirror the approach in BB.

Since the standard deviation of energy shocks is much larger over the pandemic-era than the pre-pandemic-era, Figure B3 shows a much larger effect of energy price shocks on impact than Figure 12. The magnitude is very similar to that in BB (their Figure 10). The on-impact effects of food price shocks (1.1pp) and shortage shocks (0.5pp) are much smaller than for energy prices when scaled this way, consistent with BB, although the ordering of food and shortages is different to BB (0.4pp for food prices, 1.1pp for shortages).

Figure B3: Impulse response functions of quarterly inflation to shocks to the relative price of energy, relative price of food, and shortages, scaled by their pandemic-era standard deviations



Notes: Shows the full-model response of quarter-on-quarter annualised inflation to a one-quarter (i.e. one-off) positive shock to relative energy prices, relative food prices, and shortages. Shocks equal to the standard deviation of the exogenous variable over 2020 Q1 to 2023 Q2 (a typical pandemic-era shock). Parallels Figure 10 in BB.

Appendix C – Data Appendix

Price inflation (*gp*)

Quarter-on-quarter annualised natural log change (log change multiplied by 400) in the 'All Items' Consumer Price Index (CPI). Consistent with CPI published on 15 November 2023. We use the published CPI to three decimal places for increased precision in quarterly changes – this is consistent with the official index at one decimal place. The three decimal places series is labelled as "for analytical purposes" by ONS. It can be found in Table 57 of the Consumer price inflation tables dataset published by ONS.

CPI data tables (consistent with data published on 15 November 2023) – https://www.ons.gov.uk/economy/inflationandpriceindices/datasets/consumerpriceinflation

We use a series which is seasonally adjusted by Bank of England staff using ARIMA SEATS X-13 before log changes calculated.

Note: The UK CPI does not include "owner-occupier housing costs", i.e. the implicit costs of living in a house that you own rather than renting it. BB use the US CPI which does include owner-occupier housing costs, and thus has a larger weight on 'shelter' than the UK CPI that we use.

CPI technical manual – https://www.ons.gov.uk/economy/inflationandpriceindices/bulletins/consumerpriceinflation/october2023

Growth in relative price of energy (*grpe*)

Quarter-on-quarter annualised natural log change in relative price of energy (relative to wage). Calculated as in BB: Quarter-on-quarter annualised natural log change of energy price, minus contemporaneous change in *gw*. (Equivalently, quarter-on-quarter annualised natural log change in ratio of energy price to wage index consistent with *gw*.)

Our measure of energy prices covers household energy bills (natural gas and electricity) and vehicle fuels (petrol, diesel), from the UK CPI. This combined "energy" price series is published by ONS. As for *gp*, we use the series available to three decimal places for increased precision. See entry on *gp* for link and details.

Growth in relative price of food (*grpf*)

Quarter-on-quarter annualised natural log change in relative price of food (relative to wage). Calculated as in BB: Quarter-on-quarter annualised natural log change of food price, minus contemporaneous change in *gw*. (Equivalently, quarter-on-quarter annualised natural log change in ratio of energy price to wage index consistent with *gw*.)

Our measure of energy prices covers food and non-alcoholic beverages, i.e. all of COICOP category 1), from the UK CPI. Published by ONS. Seasonally adjusted using ARIMA SEATS X-13. As for *gp*, we use the series available to three decimal places for increased precision. See entry on *gp* for link and details.

Wage growth (*gw*)

Quarter-on-quarter annualised natural log change (log change multiplied by 400) in the Average Weekly Earnings, private sector, regular pay index. Consistent with AWE data published on 14 November 2023. Regular pay measure excludes bonus pay and arrears. It is a pay per employee measure, covering public and private sectors, and excludes the self-employment. No adjustment for working hours. Published data series is seasonally adjusted.

AWE data (consistent with data published on 14 November 2023) – https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/datasets/averageweeklyearningsearn01

Information about ONS AWE measures – https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/methodologies/averageweeklyearningsqmi

Note: Our wage series is more volatile than BB's (the Employment Cost Index), which we think makes fitting the equation more difficult. Other wage measures are even worse.

Adjusted for compositional effects throughout the time series using the trend in "labour composition" from ONS growth accounting suite (adjustment based on age, sex and industry, and relative pay of each group), consistent with the multifactor productivity (MFP) dataset published on 7 July 2022.

Labour composition data (consistent with data published on 7 July 2022) – https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/datasets/growthaccountingquarterlyuk

Information about ONS labour composition measures – https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/methodologies/qualityadjustedlabourinputqaliqmi

Underlying wage growth over the pandemic period is very hard to measure due to the effects of furlough. We use a Bank of England series for pay growth that has been adjusted for the furlough scheme (see Abel et al., 2016, for details on the Bank's approach to composition adjustment in normal times, which was adapted for the pandemic). Furlough likely has two related effects. First, average wage levels were reduced since furloughed workers were paid 80% of their base salary. On its own, this would tend to reduce average pay by 20% multiplied by the fraction of workers furloughed in a given period. Second, as lockdowns were reduced and the economy began to re-open, average wage levels rose, since those remaining on furlough were lower-paid than average (in low wage industries that remained closed, such as restaurants). See Chart 2.20 in the Bank of England's May 2022 Monetary Policy Report for an illustration of the offsetting effects of furlough directly (reducing average wages) and the resultant compositional effect (increasing average wages); although note that by base effects, these effects have opposite signs on annual growth rates after a year.

Abel et al. (2016) – https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2759723

Bank of England's May 2022 Monetary Policy Report – https://www.bankofengland.co.uk/monetary-policy-report/2022/may-2022

V/U ratio (*vu*)

Ratio of vacancies level to unemployment level. Vacancies from ONS Vacancy Survey (2000-2023), and backcast using JobCentre vacancies with official linking factor (1989-2000) sourced from "A millennium of macroeconomic data" dataset (Thomas and Dimsdale, 2017). Unemployment for people aged 16+, from official ONS labour market statistics (derived from Labour Force Survey). ONS Vacancy Survey is a survey of businesses. LFS is a survey of households. No adjustment for furlough (e.g. treating x% of furloughed workers as unemployed).

ONS Vacancy Survey data (2000-2023) (consistent with data published on 12 November 2023) – https://www.ons.gov.uk/employmentandlabourmarket/peoplenotinwork/unemployment/datasets/vacanciesandunemploymentvacs01

Information on ONS Vacancy Survey – https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/methodologies/vacancysurveyqmi

Information on ONS Labour Force Survey – https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/methodologies/labourforcesurveylfsqmi

"A millennium of macroeconomic data" dataset (Thomas and Dimsdale, 2017) available from – https://www.bankofengland.co.uk/statistics/research-datasets

Productivity (*gpty*)

Moving 8-quarter average of quarter-on-quarter market sector productivity growth (natural log changes), annualised. This approach follows BB. Note: Productivity index smoothed before growth rates taken, given volatility especially during covid period. Smoothing helps the fit.

Productivity measure is a combined series of broadly comparable data to achieve sufficient sample length. The series used are market sector GVA per hour worked (1997-2023), extended historically with market sector GVA per worker (1992-1997), and alternative market sector GVA per hour worked on annual basis (1988-1992). Market sector defined as the whole economy less the General Government and Non-Profit Institutions Serving Households (NPISH) institutional sectors.

Market sector GVA per hour worked (1997-2023) (consistent with data published on 7 July 2023) – https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/datasets/outputperhourworkeduk

Market sector GVA per worker (1992-1997) (historic dataset) – https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/datasets/labourproductivitytables110andr1

Alternative market sector GVA per hour worked on annual basis (1988-1992) (consistent with data published on 7 July 2022) – https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/datasets/growthaccountingannualuk

Shortages (*shortage*)

Google trends results for "shortage" in UK. Average of months to create quarterly series. Pre-2004, series set to = 4, approx. equal to average 2004-2007.

Extracted from https://trends.google.com/trends/ (search word "shortages" in United Kingdom)

In Appendix A we also report the estimated price equation using the Global Supply Chain Pressure Index (GSCPI) produced by the Federal Reserve Bank of New York. This data is also shown in Figure 5. The GSCPI is arguably a more sophisticated measure of supply chain disruption but is not a UK-specific measure. We use the Google measure, following BB, in our central results.

GSCPI – https://www.newyorkfed.org/research/policy/gscpi#/overview

Short-run (one-year) inflation expectations (*iesr*)

Expectation of annual inflation one year ahead. Level based on a Bank of England summary measure across households, business and professional forecasters, available 2006-2016. See Anderson and Maule (2014) for details. Their series (2006-2014) extended to 2016 using information in Bank of England Inflation Reports by Thomas and Dimsdale (2017), as published in the "A millennium of macroeconomic data" dataset. This adjusts for the persistent wedge between the level of inflation expectations and CPI outturns where necessary by benchmarking to average inflation over their period. By extending from their level, we are implicitly maintaining this benchmarking throughout the time series.

Thomas and Dimsdale (2017) extend this historically (pre-2006) using multiple sources from professional forecasters. We extend forward (post-2016) using a household expectations measure: the median one-year ahead inflation expectation from the Bank of England's Inflation Attitudes Survey (IAS). Note: Various other inflation expectations measures exist for various periods, which are broadly consistent with our composite measure.

Anderson and Maule (2014) – https://www.bankofengland.co.uk/-/media/boe/files/quarterly-bulletin/2014/assessing-the-risk-to-inflation-from-inflation-expectations.pdf

"A millennium of macroeconomic data" dataset (Thomas and Dimsdale, 2017) available from – https://www.bankofengland.co.uk/statistics/research-datasets

Bank of England's Inflation Attitudes Survey (IAS) data available from – https://www.bankofengland.co.uk/statistics/research-datasets

Long-run (c. 5-10 years) inflation expectations (*ielr*)

Expectation of annual inflation in the long-run (c. 5-10 years ahead). Level based on summary measure across households, professionals and markets, available 2006-2016 (Anderson and Maule, 2014; BoE Inflation Reports; and Thomas and Dimsdale, 2017). Extended historically (1989-2006) by Thomas and Dimsdale (2017) using financial markets implied measure. See one-year inflation expectations entry for more information on this source, and links.

We extend forward (2016-2023) using an average of various household measures, financial markets implied measures, and professional forecasters measure. Note: All of the individual series show a similar pattern over time. Various other inflation expectations measures also exist for various periods, which are broadly consistent with our composite measure.

Catch-up (*catchup*)

Calculated as in BB as annual inflation minus one-year inflation expectations one year ago.

Catchup = annual inflation in quarter *q* (average of current and past three *gp*) minus *iesr* from *q-4*.

Appendix D – Sensitivities to assumptions regarding initial conditions

We are interested in exploring how the assumptions underlying the "initial conditions" affects the contributions of the exogenous variables in the decomposition of inflation. Figure x in the main text showed the contributions on the basis of a set of initial conditions assumptions (described in section x of the main text), but different assumptions regarding the initial conditions would change those contributions.

Table D1 shows how these contributions change under different assumptions for the initial conditions. Note that changing the assumptions underlying the initial conditions does not change the "full dynamic model" prediction – that is, the contributions (and the initial conditions) sum to the same values. To be clear, we are not decomposing the initial conditions – rather, the Table mirrors Figure x in showing the contributions to inflation of the various exogenous drivers and the "initial conditions". Changing the assumptions underlying the initial conditions changes only the size of the different contributions – rearranging contributions into or out of the exogenous drivers, offset by changes in the initial conditions.

The table should be read as follows.

Rows show contribution of given exogenous variable, "initial conditions", and covid dummies ("covid") to quarter-on-quarter annualised inflation in the full dynamic model, under the stated assumptions about "initial conditions". Details of the assumptions used in the initial conditions are given in the shaded row above each panel.

In all cases, the full dynamic model prediction is the same, as detailed in the second row, labelled "Full model". As such, in all cases the sum of the contributions of the exogenous variables adds to the same amount, i.e. the "Full model". Only contributions that are different to the Baseline model are shown in each panel; thus, any omitted variables in each panel are the same as under the Baseline model (omitted for brevity).

All references to declines over given numbers of quarters (indicated by →) use linear changes from the level of the variable in 2019 Q4 to the given terminal value over the given number of quarters. Else, variables are set to their terminal value in 2020 Q1 and held there. For instance, in the bottom panel labelled "All at 1990-2019 averages", V/U declines from its 2019 Q4 value to its 1990-2019 average level in a linear pattern over 4 quarters, such that in 2020 Q4 it reaches its terminal level (the value given in the shaded row at the top of the panel); while all other exogenous variables are set at their 1990-2019 average levels from 2020 Q1 onwards.

Assumptions used in charts in main text correspond to top panel: "Baseline model (BB specification)".

Table D1: Contributions to quarter-on-quarter annualised price inflation, various assumptions regarding initial conditions, 2020 Q1 2023 Q2

	2020 Q1	**2020 Q2**	**2020 Q3**	**2020 Q4**	**2021 Q1**	**2021 Q2**	**2021 Q3**	**2021 Q4**	**2022 Q1**	**2022 Q2**	**2022 Q3**	**2022 Q4**	**2023 Q1**	**2023 Q2**
Actual	2.8	-0.4	2.6	-0.2	1.9	4.2	6.2	9.1	7.2	13.5	9.0	12.2	6.9	5.5
Full model	2.2	-2.1	1.9	0.1	2.7	3.3	4.9	8.2	7.9	13.9	8.3	10.8	5.9	7.3
Baseline model (BB specification): Energy = 0, food = 0, V/U = 0.63 (2019 Q4 level), shortage = 4, productivity = 0.4% (2012-2019 average)														
Initial conditions	2.8	2.5	2.8	2.9	3.3	3.3	3.6	3.7	3.9	4.0	4.2	4.3	4.5	4.6
V/U	0.0	-0.3	-2.0	0.0	-0.6	-0.8	-0.6	0.5	0.1	0.5	0.2	0.9	0.3	0.7
Energy	-0.4	-2.3	0.5	-1.4	0.6	2.4	0.6	2.8	0.6	8.2	0.1	2.2	-1.6	-2.9
Food	0.0	0.4	-0.5	-1.7	-1.4	-0.9	-0.7	0.2	0.2	0.9	2.6	2.7	2.5	2.1
Shortages	0.4	0.4	0.5	-0.1	0.1	0.6	2.7	1.8	2.2	-0.1	1.3	1.8	0.8	0.7
Prod'ty	0.0	0.0	-0.3	-0.3	-0.3	-0.4	-0.2	-0.3	-0.2	-0.3	0.0	0.0	0.0	0.1
Covid	0.0	-1.2	1.7	0.4	0.2	-0.1	0.9	0.4	0.4	0.3	0.5	0.3	0.4	0.3
Quick normalisation of V/U: Energy = 0, food = 0, V/U → declines to 0.42 (2012-2019 average) over 4 quarters, shortage = 4, productivity = 0.4% (2012-2019 average)														
Initial conditions	2.8	2.2	2.4	2.5	2.7	2.8	2. 9	2.9	3.1	3.1	3.3	3.3	3.4	3.4
V/U	0.0	0.0	-1.7	0.4	0.0	-0.3	0.0	1.3	1.0	1.4	1.1	2.0	1.4	1.9
Slow normalisation of V/U: Energy = 0, food = 0, V/U → declines to 0.42 (2012-2019 average) over 8 quarters, shortage = 4, productivity = 0.4% (2012-2019 average)														
Initial conditions	2.8	2.4	2.6	2.7	3.0	2.9	3.1	3.1	3.2	3.3	3.4	3.4	3.5	3.5
V/U	0.0	-0.1	-1.8	0.2	-0.3	-0.4	-0.2	1.1	0.8	1.2	1.0	1.8	1.3	1.8
Slow normalisation of V/U to low level: Energy = 0, food = 0, V/U → declines to 0.31 (1990-2019 average) over 8 quarters, shortage = 4, productivity = 0.4% (2012-2019 average)														
Initial conditions	2.8	2.3	2.5	2.6	2.9	2.7	2.8	2.8	2.8	2.9	2.9	2.9	2.9	3.0
V/U	0.0	0.0	-1.7	0.3	-0.1	-0.1	0.1	1.5	1.2	1.6	1.5	2.4	1.9	2.3
All at 2012-2019 averages: Energy = -1.4, food = -1.5, V/U → declines to 0.42 over 4 quarters, shortage = 3.4, productivity = 0.4%														
Initial conditions	2.4	1.7	1.9	1.9	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5
V/U	0.0	0.0	-1.7	0.4	0.0	-0.3	0.0	1.3	1.0	1.4	1.1	2.0	1.4	1.9
Energy	-0.3	-2.2	0.6	-1.3	0.7	2.4	0.7	2.9	0.7	8.2	0.2	2.2	-1.5	-2.9
Food	0.3	0.8	-0.1	-1.3	-0.9	-0.4	-0.1	0.7	0.8	1.5	3.3	3.4	3.2	2.8
Shortages	0.4	0.5	0.6	0.0	0.2	0.7	2.8	1.9	2.3	0.0	1.4	1.8	0.9	0.8
Prod'ty	0.0	0.0	-0.3	-0.3	-0.3	-0.4	-0.2	-0.3	-0.2	-0.3	0.0	0.0	0.0	0.1
All at 1990-2023 averages: Energy = 1.7, food = -0.8, V/U → declines to 0.35 over 4 quarters, shortage = 4.4, productivity = 1.5%														
Initial conditions	2.6	1.9	2.1	2.0	2.1	2.2	2.2	2.1	2.2	2.2	2.3	2.3	2.3	2.3
V/U	0.0	0.1	-1.5	0.6	0.2	-0.1	0.3	1.6	1.3	1.7	1.5	2.4	1.8	2.3
Energy	-0.5	-2.4	0.3	-1.5	0.5	2.2	0.5	2.7	0.5	8.1	0.0	2.1	-1.7	-3.0
Food	0.2	0.6	-0.3	-1.5	-1.1	-0.6	-0.4	0.5	0.5	1.3	3.0	3.1	2.9	2.5
Shortages	0.3	0.4	0.4	-0.1	0.0	0.6	2.6	1.7	2.2	-0.2	1.3	1.7	0.7	0.7
Prod'ty	0.2	0.2	-0.1	-0.1	0.0	0.0	0.1	0.1	0.2	0.1	0.4	0.4	0.4	0.4
All at 1990-2019 averages: Energy = 0.7, food = -1.2, V/U → declines to 0.31 over 4 quarters, shortage = 3.6, productivity = 1.6%														
Initial conditions	2.3	1.5	1.7	1.6	1.7	1.7	1.7	1.6	1.7	1.7	1.7	1.7	1.7	1.7
V/U	0.0	0.2	-1.5	0.7	0.3	0.0	0.4	1.7	1.5	1.9	1.7	2.6	2.1	2.6
Energy	-0.4	-2.4	0.4	-1.4	0.5	2.3	0.5	2.7	0.6	8.1	0.1	2.1	-1.7	-3.0
Food	0.2	0.7	-0.2	-1.4	-1.0	-0.5	-0.2	0.6	0.7	1.4	3.2	3.3	3.1	2.7
Shortages	0.4	0.5	0.5	0.0	0.1	0.7	2.7	1.8	2.3	-0.1	1.4	1.8	0.8	0.8
Prod'ty	0.2	0.2	-0.1	-0.1	0.0	0.0	0.1	0.1	0.2	0.1	0.4	0.4	0.4	0.5