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Abstract

Using the Bank of England Inflation Attitudes Survey we find that households with preferences for higher inflation and higher interest rates have lower expected inflation. The wedge is mildly correlated with existing measures of uncertainty and increases after major economic events such as the failure of Lehman Brothers or the Brexit referendum. We interpret the wedge as due to Knightian uncertainty about future monetary policy and the underlying economic environment. If households had treated uncertainty as measurable risk, consumption and output would have been around 1 percent higher both during the Great Recession and in recent years.

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1 Introduction

There is substantial debate about how households form the beliefs that drive their decisions. In this paper we investigate whether the preferences of households and their beliefs are related. Under rational expectations, there is no reason why they should be, since preferences and beliefs are both primitives. Yet the rational expectations hypothesis might not hold. For example, Knight (1921) distinguishes risk, which can be represented by well-specified predetermined probability distributions, from uncertainty, which cannot. Under uncertainty, an agent chooses her subjective probability distribution and maximizes expected utility based on beliefs which are negatively distorted by her preferences leading to a negative correlation between beliefs and preferences (Gilboa and Schmeidler 1989, Epstein and Schneider 2003, Hansen and Sargent 2001, Strzalecki 2011, and Maccheroni, Marinacci, and Rustichini 2006). Here we use household-level survey data to test whether preferences and beliefs are indeed negatively correlated and interpret the strength of the observed relation as measuring the amount of Knightian uncertainty faced by households.

Our data come from the Bank of England Inflation Attitudes Survey (BEIAS) that ask UK households for their expected inflation as well for their preferences about future inflation and nominal interest rates over the period 2003-2019. Preferences on inflation are elicited by asking the following question: "If a choice had to be made either to raise interest rates to try to keep inflation down, or keep interest rates down and allow prices in the shops to rise faster, which would you prefer?" We say that the household *likes inflation* if the household prefers an increase in inflation to one in interest rates. Preferences about interest rates are elicited asking the following question: "Which would be best for you personally, for interest rates to go up over the next few months, or to go down?". The household *likes interest rates*, if she prefers interest rates to go up. We document three key findings. First, wealthier households are more likely to dislike inflation and to like an increase in nominal interest rates. Secondly, households' expected inflation is negatively distorted by their preferences for inflation and interest rates: on average, households who like inflation, have an expected inflation at 1 year ahead time horizon which is 15 basis points lower than the expected inflation of households who dislike inflation. This difference falls by around 5 basis points when looking at expected inflation at 2 or 5 years ahead time horizon. A similar effect arises for household who like an increase in interest rates as opposed to households who dislike it. Thirdly, the effect of preferences on expected inflation varies over time: they are virtually zero in the early 2000's and peak to around 40 basis points in 2012. The results hold true, after controlling for several variables that might affect the information set of households as proxied for example by their geographical location, educational level, age, understanding of monetary policy and economics literacy.

There are some concerns with the previous evidence. One is that households might not report the beliefs on the basis of which they act.[1] In particular, households preferences could affect households' self-reported beliefs, but the component of beliefs due to preferences could have no or little effects on households' choices—i.e. be just a form of "cheap talking." In practice we find that changes in inflation expectations due to preferences change the saving, consumption, and financial portfolio behavior of households in a way that is quantitatively similar to the component of expected inflation which is not due to preferences.

Another concern is that differences in preferences might be correlated with differences in the information set available to households, so that our reduced form coefficients might just reflect an omitted variable bias. To address this concern we argue that preferences about inflation and interest rates are (at least partly) caused by differences in the financial position of the household, which can be used to instrument household preferences. To help guaranteeing that the instrument satisfies the exclusion restriction, we control for differences in education, several demographic variables, and even for household's self-reported beliefs about whether the UK economy (rather than the household) would benefit from experiencing higher inflation.[2] After instrumenting households' preferences with their financial position, we find that the distortion in beliefs due to preferences even increases. In the paper we also address the concern that households self-select into reporting their preferences or beliefs about expected inflation: to deal with possible selection biases, we use information on household's understanding of the questions in the survey to instrument their likelihood to report preferences and beliefs. Finally, we checked that a similar negative effect of preferences on beliefs arises when households are asked to predict the future evolution of nominal interest rates, rather than inflation.

To interpret our estimates and quantify their implications, we consider an economy where households differ in their financial asset position. The labor market is competitive and there are price rigidities. Households agree that nominal interest rates are set according to a simple Taylor rule and inflation is determined by a traditional Phillips curve. Household think that there are monetary and technology shocks which have similar effects on output but opposite effects on inflation: expansionary monetary shocks increase inflation; expansionary technology shocks reduce it. Technology shocks stand in for any deflationary shocks which causes a contraction in economic activity. Shocks could be either a source of risk, which households would evaluate using expected utility under rational expectations, or a source of Knightian uncertainty, which households would process using the multiple priors utility model of Gilboa and Schmeidler (1989) and Epstein and Schneider (2003) leading

[1]See Hurd (2009), Kézdi and Willis (2011), Armantier, de Bruin Wändi, Topa, van der Klaauw, and Zafar (2015), Gennaioli, Ma, and Shleifer (2016), and Coibion, Gorodnichenko, and Ropele (2020) for empirical evidence suggesting that agents act on the basis of their self-reported beliefs and expectations.

[2]Notice that the exclusion restriction would still hold in rational inattention models: under rational inattention, wealth matters for beliefs because it changes households incentive to acquire information to predict inflation accurately. Under rational inattention wealth would matter for the variance of the forecast error not for expected inflation.

to maximin preferences—an analytically convenient characterization for households' ambiguity aversion resulting from Knightian uncertainty. Under uncertainty, households choose their subjective probability distribution about the future realization of shocks and base their decisions on beliefs that are tilted towards the worst case scenario for the household. The model matches the previously discussed three facts in BEIAS: (i) wealthier households are more likely to dislike inflation and a reduction in nominal interest rates; (ii) households' beliefs about future inflation are negatively distorted by households preferences for higher inflation and nominal rates; and (iii) the bias varies over time, reflecting the amount of Knightian uncertainty about monetary policy and technology.

We take the effects of preferences on expected inflation from BEIAS as estimation targets and use indirect inference to recover the amount of Knightian uncertainty faced by UK households. Uncertainty varies over time: it increases after major economic events such as the failure of Lehman Brothers or the Brexit referendum. Uncertainty about monetary policy dominates the period 2010-2013, while uncertainty about technology is predominant at the beginning of the Great Recession and in the most recent years. Knightian uncertainty is only mildly correlated with other existing measures of uncertainty based on stock market volatility, counting words in official reports by the IMF (Ahir, Bloom, and Furceri 2018) or counting words in the social media (Baker, Bloom, and Davis 2016).

After measuring Knightian uncertainty, we aggregate the consumption choices of all households in the economy and calculate by how much aggregate output would have changed if households had processed uncertainty in the form of measurable risk. At the beginning of the Great Recession and over the period 2018-2019 output would have increased by approximately 1 percentage point. Monetary policy uncertainty has little effects on output while uncertainty due to technology is highly contractionary. This happens because there is a large proportion of UK households who dislike inflation. So, monetary policy uncertainty makes households act based on subjective beliefs that tend to overpredict future inflation, which is expansionary on aggregate demand and stimulates the economy.

Related literature In the absence of common knowledge, there are other reasons why preferences and beliefs could be correlated. In rational inattention models (Sims, 2003, 2010), agents choose how much to invest to improve their information set: here preferences affect beliefs because agents who care more about certain aspects of reality invest more to predict them more accurately, leading to a correlation between *intensity* of preferences and *precision* of beliefs, see Maćkowiak, Matějka, and Wiederholt (2018) and Gabaix (2019) for a review of the rational-inattention literature. In models which feature some initial differences in information sets (Angeletos and Pavan 2007, Simsek 2013, Angeletos and Lian 2018, Straub and Ulbricht 2018, Andrade, Gaballo, Mengus, and Mojon 2019), a correlation between preferences and beliefs could arise because of reverse causality. Ambiguity aversion models with Knightian uncertainty are unique in implying that agents behave according to the Murphy's law: "Anything that can go wrong will go wrong", which systematically generates a negative correlation between preferences and beliefs. This is the insight we follow in this paper leaving to further research whether these other models could be made consistent with our findings.

Ellsberg (1961) first provided experimental evidence consistent with the idea that, under uncertainty, agents choose their subjective probability distribution over-weighting their worst case scenario. Yet so far, there is little direct household-level evidence that Knightian uncertainty shapes households decisions and that the amount of uncertainty varies over time. Ilut and Schneider (2014), Bianchi, Ilut, and Schneider (2018), and Bhandari, Borovička, and Ho (2016) have first estimated the amount of Knightian uncertainty faced by households in the economy using (aggregate) time series evidence. These papers rely on the existence of a representative household which prevents them from explicitly modelling heterogeneity in household preferences and the associated disagreement in beliefs. Here we exploit panel data and a unique feature of BEIAS, that contains self-reported preferences about future inflation and interest rates. We show that household preferences are aligned with the theoretical predictions of the model and use the effect of preferences on beliefs as a novel margin to measure different sources of uncertainty. Our measures are available in real time and policy makers can use them to convert uncertainty into risk—conveying more accurate information about the probability distribution of future states of the economy. This would be highly expansionary when uncertainty is due to the economic environment (technology), rather than to monetary policy.

Several papers have shown the relevance of ambiguity aversion and Knightian uncertainty for business cycle analysis. Ilut and Schneider (2014) show that shocks to the degree of ambiguity can drive the business cycle, Backus, Ferriere, and Zin (2015), Ilut (2012), and Bianchi, Ilut, and Schneider (2018) examine asset pricing, Ilut and Saijo (2016) focus on firm dynamics, Ilut, Valchev, and Vincent (2016) study firm pricing decisions, Monti and Masolo (2020) and Michelacci and Paciello (2020) analyze monetary policy, while Ilut, Krivenko, and Schneider (2018) devise methods suitable for stochastic economies where ambiguity-averse agents differ in their perception of exogenous shocks, and study the implications for precautionary savings and asset premiums. Here we emphasize that households' heterogeneity in preferences about inflation and interest rates provide a novel approach to measure the amount of uncertainty in the economy.

Section 2 considers a simple model of ambiguity aversion. Section 3 discusses the data. Section 4 presents the evidence on the effects of preferences on beliefs. Section 5 focuses on time series variation. Section 6 uses indirect inference to quantify Knightian uncertainty. Section 7 concludes. The Appendix contains further details on model and data.

2 The model

We use a simple model to show that, under Knightian uncertainty, the beliefs that drive a household's decisions are affected by her preferences through wealth. Then we derive some testable predictions of the theory and propose a simple metric to measure uncertainty.

2.1 Assumptions

We compare two economies: one is subject to measurable risk about the future realization of (monetary and technology) shocks; the other is subject to uncertainty.

Households There is a unit mass of households, $i \in [0,1]$, who differ in wealth, a_{it}, invested in one-period bonds. Household i is infinitely-lived, with subjective discount factor β, and per-period preferences over consumption $u(c_{it}) = (c_{it}^{1-\sigma} - 1)/(1-\sigma)$, with $\sigma > 1$. At t, household i supplies inelastically one unit of labor and chooses the pair $\{c_{it}, a_{it+1}\}$ subject to the budget constraint

$$c_{it} + a_{it+1} = (1-\tau_w)w_t + r_t\, a_{it} + \tau_{it}, \tag{1}$$

where τ_w is the labor income tax rate, w_t is labor income, $(r_t - 1)\, a_{it}$ is capital income, and τ_{it} is a government transfer (possibly) targeted to household i (see below). Household i has Maximin preferences as in the multiple priors utility model of Gilboa and Schmeidler (1989), whose axiomatic foundations are provided by Epstein and Schneider (2003). Maximin preferences are convenient to provide an analytically tractable characterization of household behavior under Knightian uncertainty, having rational expectations under measurable risk as a particular case.[3] Let $\mathbf{C_t} = \{c_s(h^s)\}_{s=t}^{\infty}$ be the future stream of consumption with h^t denoting history up to time t. Preferences at t are defined recursively as follows:

$$V_t(\mathbf{C_t}) = u(c_t(h^t)) + \beta \min_{\Omega \subseteq \mathscr{S}_t, F \in \mathscr{P}_t(\Omega)} \int_{\Omega} V_{t+1}(\mathbf{C_{t+1}})\, F(d\omega), \tag{2}$$

where Ω is the support of the probability distributions F that household i ascribes to the possible realizations of history at $t+1$, indexed by ω. Household i chooses consumption plans $c_t(h^t)$ and savings $a_{t+1}(h^t)$ to maximize (2) subject to (1). Under Knightian uncertainty, the household chooses the support Ω from the set $\mathscr{S}_t$ and the associated probability distribution F from the set $\mathscr{P}_t(\Omega)$, so as to minimize the continuation utility V_{t+1}. Under measurable risk, the household maximizes expected utility taking as given Ω and the

[3] Similar results would arise under alternative modeling assumptions for ambiguity aversion, for example using multiplier preferences, as in Hansen and Sargent (2001). Multiplier preferences include maximin preferences as a special limit case and, as shown by Strzalecki (2011), are a special case of the variational preferences proposed by Maccheroni, Marinacci, and Rustichini (2006).

associated probability distribution F: the sets $\mathscr{S}_t$ and $\mathscr{P}_t$ are singletons.

Firms There is a unit mass of firms $[0,1]$ that produce differentiated varieties. Firm j is the unique producer of variety j. Final output is produced under perfect competition and is equal to $Y_t = (\int_0^1 y_{jt}^{1-1/\theta} dj)^{\frac{\theta}{\theta-1}}$, where y_{jt} is the amount of variety $j \in [0,1]$ used in production and $\theta > 1$. The optimal demand for y_{jt} is $y_{jt} = Y_t \left(p_{jt}/p_t\right)^{-\theta}$, where $p_t = \left(\int p_{jt}^{1-\theta} dj\right)^{\frac{1}{1-\theta}}$ is the aggregate nominal price. The variety j is produced combining labor ℓ_{jt} and final output x_{jt} so that $y_{jt} = x_{jt}^{1-\alpha}(e^{z_t}\,\ell_{jt})^{\alpha}$, where z_t is exogenous productivity. Firm j chooses the nominal price for its variety p_{jt}, labour ℓ_{jt} and final output x_{jt} to maximize the present value of profits net of taxes, $(1-\tau_d)\,d_{jt}$, where τ_d is the corporate tax rate and

$$d_{jt} = y_{jt}\,\frac{p_{jt}}{p_t} - w_t \ell_{jt} - x_{jt} - \kappa\left(\pi_{jt}, Y_t\right) - f \tag{3}$$

are gross profits where $f \geq 0$ is a fixed cost of production, and $\kappa\left(\pi_{jt}, Y_t\right) = \frac{\kappa_0}{2}\left(\pi_{jt}\right)^2 Y_t$ is an adjustment cost with $\pi_{jt} = (p_{jt} - p_{jt-1})/p_{jt-1}$ and $\kappa_0 > 0$, as in Rotemberg (1982).

Monetary policy The (gross) interest rate paid in period t is given by $r_t = R_{t-1}/\Pi_t$, where $\Pi_t = p_t/p_{t-1}$ is gross inflation and R_t is the (gross) nominal interest rate set by the monetary authority at period t (and paid at $t+1$) according to the Taylor rule

$$\ln R_t - \ln \bar{R} = \phi\,\left(\ln \Pi_t - m_t\right), \tag{4}$$

where $\bar{R} = 1/\beta$, $\phi > 1$, and m_t is a monetary policy shock.

Fiscal policy We assume that the transfers received by household i are equal to

$$\ln \tau_{it} = \ln \overline{\tau} + \overline{\tau}_{im}\, m_t + \overline{\tau}_{iz}\, z_t, \tag{5}$$

where $\overline{\tau}_{im}$ and $\overline{\tau}_{iz}$ are (exogenous) parameters used to match the cross-sectional variation in household preferences (after controlling for wealth). The government adjusts the supply of government bonds B_{t+1} to satisfy the budget constraint

$$B_{t+1} = r_t B_t + \int_0^1 \tau_{it}\, di + G - \tau_w\, w_t - \tau_d \int_0^1 d_{jt} dj, \tag{6}$$

which implies that changes in transfers τ_{it}'s are financed through government debt.

Financial market There is a competitive mutual fund that owns all firms in the economy, holds all government bonds and supply one-period bonds $A_{t+1} = \int_0^1 a_{it+1} di$. At t, after collecting the interest rate payments from the government $r_t B_t$ and the dividends from firms, the fund pays $r_t A_t$ to households and buys all government bonds B_{t+1}. The aggregate supply of one-period bonds at t satisfies

$$A_{t+1} = r_t A_t + B_{t+1} - r_t B_t - (1-\tau_d) \int_0^1 d_{jt} dj. \tag{7}$$

Product and labor market clearing In equilibrium, aggregate production Y_t is equal to aggregate consumption $C_t \equiv \int_0^1 c_{it}\, di$ plus government expenditure G and the demand for intermediate inputs $X_t \equiv \int_0^1 x_{it}\, di$:

$$Y_t = C_t + X_t + G + \kappa(\Pi_t, Y_t) + f.$$

Clearing of the labor market implies that labor demand is equal to labor supply, $\int_0^1 \ell_{it} di = 1$.

Risk vs uncertainty At t_0 the economy, initially in a steady state with zero inflation, experiences an unforeseen increase in risk or uncertainty, which is fully resolved at $t_0 + 1$, when (monetary and technology) shocks are realized; thereafter the economy converges deterministically back to the steady state. For simplicity prices are set before the shock at t_0. The risk/uncertainty shock is modelled as follows. At t_0 households learn that productivity at $t_0 + 1$ can be either low or high: $z_{t_0+1} \in \{z_l, z_h\} \equiv \{-\bar{\epsilon}, \bar{\epsilon}\}$. Then, $\forall t > t_0$, z_t follows an AR(1) process with persistence $\varrho_z \in [0, 1)$: $z_t = \varrho_z\, z_{t-1}$. Both $\varrho_z \in [0, 1)$ and $\bar{\epsilon} > 0$ are known at t_0. If the probability distribution of z_{t_0+1} is also known, $\bar{\epsilon}$ measures the amount of risk about the technology shock; if it is unknown, $\bar{\epsilon}$ measures the amount of uncertainty. Monetary shocks are modelled analogously. At t_0 households learn that $m_{t_0+1} \in \{m_l, m_h\} \equiv \{-\bar{v}, \bar{v}\}$, and $m_t = \varrho_\pi\, m_{t-1}$ $\forall t > t_0$. Both $\varrho_\pi \in [0, 1)$ and $\bar{v} > 0$ are known at t_0 and $\bar{v}$ measures the amount of risk or uncertainty about monetary policy. Under measurable risk, we assume that the shocks are orthogonal and have zero mean, which means that the possible combination of z_{t_0+1} and m_{t_0+1} have a uniform distribution (probability of one-fourth). Under uncertainty, we assume that the household thinks that the realizations of $z_{t_0+1} \in \{z_l, z_h\}$ and $m_{t_0+1} \in \{m_l, m_h\}$ could have any distribution with probabilities at a corner—which we assume just to more easily map the model to the data.

2.2 Results

Here we discuss some properties of the model, fully solved in Appendix B. A monetary shock reduces the nominal interest rate, increases output and inflation which further reduces the real interest rate. A technology shock is deflationary and thereby reduces both the nominal and the real interest rate through the Taylor rule in (4). As a result, both shocks reduce capital income, which is more harmful for wealthier households. For given non-capital income, there is a threshold level of wealth above which the household dislikes the monetary shock and another one above which the same household dislikes the technology shock.[4] As a result we have that:

Result 1. For given transfer function in (5), wealthier households are more likely to dislike an expansionary monetary shock and an expansionary technology shock.

Next we characterize household-i's expectations at t_0 for inflation at $t \geq t_0 + n$, $\forall n \geq 1$. We calculate expectations under measurable risk or Knightian uncertainty. Under measurable risk, expected inflation is equal for everyone

$$E^{\sigma}_{t_0}(\Pi_{t_0+n}) = \Pi^e_{t_0}$$

where $E^{\sigma}_{t_0}$ denotes expectations under measurable risk. This implies that:

Result 2. Under risk, households' expected inflation is independent of their preferences.

Let γ_{uv} denote the probability that the household ascribes at t_0 to a realization at t_0+1 of a technology shock z_u and a monetary shock m_v, $\forall u, v \in \{l, h\}$. The γ_{uv}'s satisfy

$$\sum_{u,v \in \{l,h\}} \gamma_{uv} = 1 \quad \text{with} \quad \gamma_{uv} \in \{0, 1\}\,, \; \forall u, v \in \{l, h\}. \tag{8}$$

Let $\overline{V}_i\left(a; z_{t_0+1}, m_{t_0+1}\right)$ denote the continuation utility of household i at t_0+1 given wealth a. Under uncertainty, household i solves the following problem:

$$\max_{a'} \left[\frac{\left(w_{i0} + \bar{R}\, a_{i0} + \tau_{i0} - a'\right)^{1-\sigma}}{1-\sigma} + \beta \min_{\gamma_{uv}; u,v \in \{l,h\}} \sum_{u,v \in \{l,h\}} \gamma_{uv}\, \bar{V}_i(a'; z_u, m_v) \right], \tag{9}$$

subject to the constraint in (8). At the optimal saving decision a', the minimization problem in (9) determines the worst-case beliefs of household i, in brief her *beliefs*. Beliefs assign all probability mass to the pair $s^*_i = (z^*_{it_0+1}, m^*_{it_0+1})$. Let $E^k_{it_0}(\Pi_{t_0+n})$ denote the household-i beliefs at t_0 of inflation at t_0+n, $n \geq 1$. Up to a first order approximation, we have that

$$E^k_{it_0}(\Pi_{t_0+n}) \approx 1 + \overline{\pi}_{mn}\, m^*_{it_0+1} + \overline{\pi}_{zn}\, z^*_{it_0+1}, \; \forall n \geq 1 \tag{10}$$

where $\overline{\pi}_{mn}$ and $\overline{\pi}_{zn}$ are the impulse response coefficients of inflation, $n-1$ periods after the monetary and technology shock, respectively. The coefficients are derived in Appendix B: an expansionary monetary shock is inflationary $\overline{\pi}_{mn} > 0$; an expansionary technology shock is deflationary $\overline{\pi}_{zn} < 0$. In general we have that:

[4] The thresholds are computed numerically in Section 6.1.

Result 3. Under uncertainty, household preferences for monetary and technology shocks affect her beliefs about future inflation.

Given the (worst-case) beliefs of household i, we can also define her *best-case* beliefs as equal to $s_i^{**} = -s_i^*$. We construct a dummy for whether household-i prefers a monetary expansion to a monetary tightening: $d_{im} = 1$ if $m^*_{it_0+1} < 0$ and $d_{im} = 0$ otherwise. Similarly, we construct another dummy for whether household-i prefers a technology regress to a technology improvement: $d_{iz} = 1$ if $z^*_{it_0+1} > 0$ and $d_{iz} = 0$ otherwise. Using these dummies in (10), we obtain that

$$E^k_{it_0}(\Pi_{t_0+n}) \approx 1 - \overline{\pi}_{mn}\,\overline{v}\,d_{im} + \overline{\pi}_{zn}\,\overline{\epsilon}\,d_{iz}. \tag{11}$$

Since $\overline{\pi}_{mn} > 0$ and $\overline{\pi}_{zn} < 0$, household-i beliefs about future inflation are negatively distorted by her preferences for a monetary expansion and a technology regress. Moreover:

Result 4. The effects of the household's preference dummies on her beliefs about future inflation reflect the underlying uncertainty about monetary and technology shocks, equal to $\overline{v}$ and $\overline{\epsilon}$, respectively.

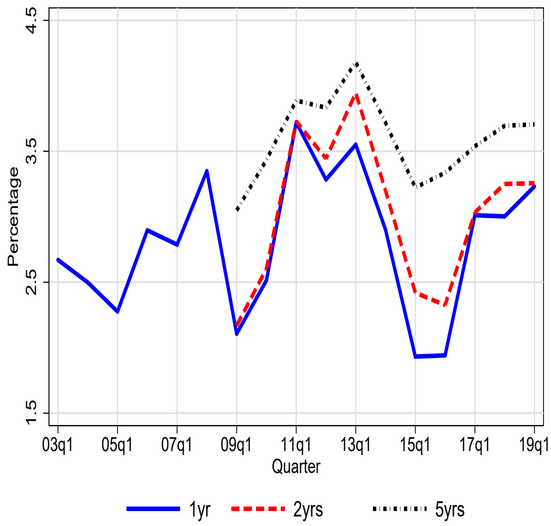
3 Descriptive evidence

First we discuss the data, then analyze the relation between wealth and preferences.

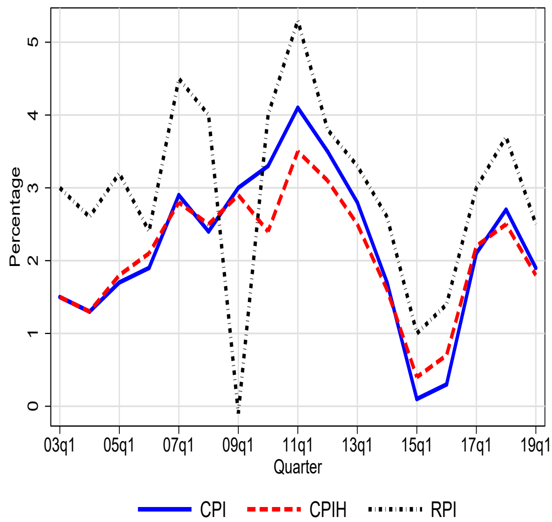
3.1 Data

Our main source of data is the Bank of England Inflation Attitudes Survey (BEIAS). BEIAS is a quarterly survey, conducted on behalf of the Bank of England to assess public attitudes towards inflation and monetary policy. People aged 16 and over are interviewed throughout the United Kingdom. The survey is not a panel as the pool of subjects changes from one quarter to another. Once weighted, the raw data are fully representative of the UK population. The survey is ran quarterly since 2001, but some questions are asked just in the first quarter of the year and other questions are started to be asked only since 2003. Overall, our sample period is 2003:I-2019:I. BEIAS asks households both about their expectations and about their preferences for inflation and interest rates. In particular, expected inflation at a 1 year time horizon is obtained by asking the following question: "How much would you expect prices in the shops generally to change over the next twelve months?". Starting from the first quarter of 2009, an analogous question is asked at a time horizon of 2 and 5 years. The time profile of expected inflation is plotted in panel (a) of Figure 1. Panel (b) of Figure 1 shows the evolution of three measures of realized inflation: the blue solid line corresponds to CPI inflation; the red dashed line includes owner occupiers' housing costs (CPIH); the

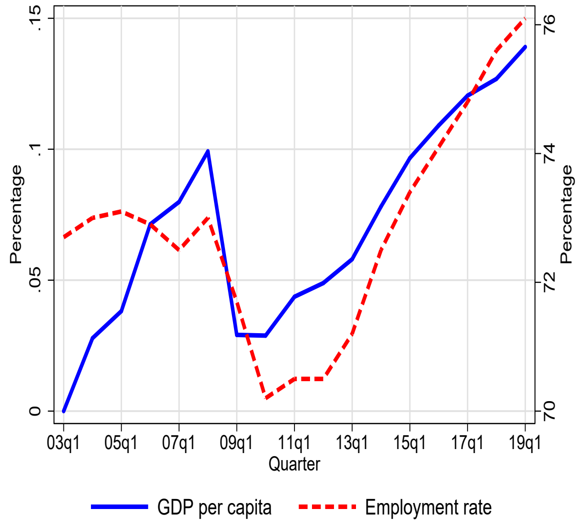
Figure 1: The UK economy



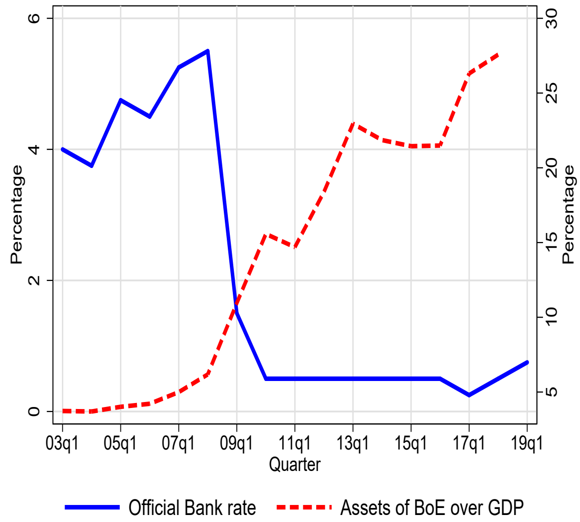
(a) Expected inflation



(b) Inflation



(c) GDP and employment



(d) Monetary policy

Panel (a) plots average expected inflation in BEIAS at 1, 2 and 5 years horizon. Panel (b) plots three measures of consumer price inflation. Panel (c) plots GDP per capita and the employment rate. Panel (d) plots the official central bank short term interest rate and a measure of the size of the Bank of England assets.

black dotted line measures inflation using the Retail Price Index (RPI), which used to be the principal official measure of inflation in the UK until very recent years. We notice that RPI inflation is always higher than CPI inflation, with the exception of 2009. On average, expected inflation in BEIAS tends to slightly overpredict future realized inflation, but the wedge is small and reverts sign when looking at RPI inflation (see Table 1). Panel (c) of Figure 1 shows logged GDP per capita, normalized to zero at the beginning of the sample period, (left scale of the y-axis) and employment rate as a dashed red line (right scale of the y-axis). The Great Recession materializes in 2008 and GDP and employment comoves closely. Between 2008:I and 2009:I, GDP falls by more than 7 percentage points, while the fall for the employment rate is by more than 2 percentage points. Panel (d) of Figure 1 characterizes monetary policy by the Bank of England in terms of prices and quantities over: the blue solid line on the left y-axis is the official rate set by the Bank of England, the red dashed line on the right y-axis is the level of assets held by the Bank. Quantitative easing started in March 2009.[5]

BEIAS elicits households' preferences about the standard monetary policy trade-off between setting higher interest rates and allowing higher inflation by asking the following question: "If a choice had to be made either to raise interest rates to try to keep inflation down, or keep interest rates down and allow prices in the shops to rise faster, which would you prefer—interest rates to rise or prices to rise faster?" Possible answers are: (i) Interest rates to rise; (ii) Prices to rise faster; or (iii) No idea. A negative monetary shock $m_t < 0$ in the Taylor rule (4) induces a higher interest rate and lower inflation, reproducing the monetary policy trade-off discussed in the question.[6] We interpret a household choosing option (i) as one that prefers m_t negative (monetary tightening) to m_t positive (monetary loosing). In the former case, we say that the household *dislikes inflation*, in the latter (option (ii)) that she *likes inflation*.

BEIAS elicits households' preferences about future changes in interest rates by asking the following question: "Which would be best for you personally, for interest rates to go up over the next few months, or to go down, or to stay where they are now, or would it make no difference either way?" Possible answers are: (i) Go up; (ii) Go down; (iii) Stay where they are; (iv) Make no difference; (v) No idea. Preferences for changes in interest rates are asked in absolute terms (not relative to changes in inflation as in the previous question). Given the interest rate rule (4), a household may report to prefer interest rate to go up either because she likes a monetary tightening (a fall in m_t) and/or because she likes a contractionary technology shock (a fall in z_t) which increases inflation Π_t and through (4) increases interest rates. The answers to the previous question on the monetary policy trade-off allows us to control for households' preferences for m_t, so the answers to this question should be interpreted as providing information about households' preferences for

[5]The official bank rate (also called the Bank of England base rate or BOEBR) is the interest rate that the Bank of England charges banks for secured overnight lending. It is the UK key interest rate for enacting monetary policy. The security for the lending can be any of a list of eligible securities (commonly Gilts) and are transacted as overnight repurchase agreements. Changes to BOEBR are recommended by the Monetary Policy Committee and enacted by the Governor of the Bank of England.

[6]The BEIAS also asks households if they agree with the existence of such trade-off. We will use the answers to this question later.

changes in nominal interest rates due to other real (technology) shocks. This is the logic we pursue further in Section 6.

Table 1 provides descriptive statistics for the key variables in our analysis. Descriptive statistics for other variables used in the analysis are in the Appendix. The majority of households dislike inflation, while the shares of households reporting a preference for higher or lower interest rates are similar. Average perceived inflation by households has been 3.08% in the sample, not statistically different from all measures of realized inflation, with the

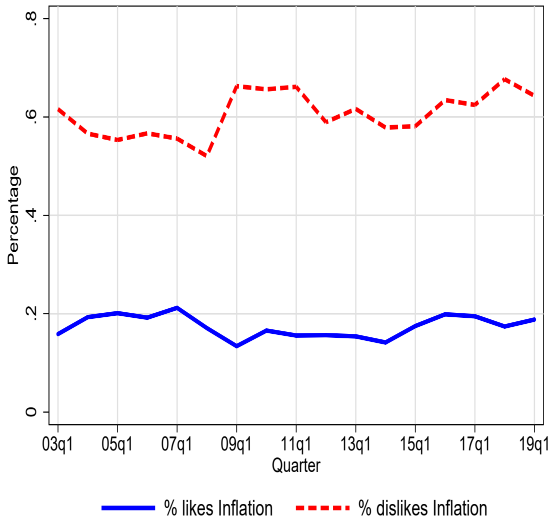
Table 1: Descriptive statistics

VARIABLES	(1) mean	(2) sd	(3) N	(4) min	(5) max
Year	2,011.12	4.94	68,425.00	2,003.00	2,019.00
Expect. Π over next 12 months	2.82	1.86	47,273.00	-1.00	5.50
2-years ahead Π^e (extended)	3.09	2.65	31,774.00	-5.50	10.50
5-years ahead Π^e (extended)	3.64	2.93	28,172.00	-5.50	10.50
Reported Π over last 12 months	3.08	1.93	58,862.00	-1.00	5.50
1-year ahead realized Π, % (CPI)	2.23	1.06	64,093.00	0.10	4.10
1-year ahead realized Π, % (CPIH)	2.13	0.81	64,093.00	0.40	3.50
1-year ahead realized Π, % (RPI)	2.95	1.32	64,093.00	-0.10	5.30
HH does not know Π^e	0.15	0.36	68,425.00	0.00	1.00
HH does not know past Π	0.14	0.35	68,425.00	0.00	1.00
i affects Π in 1-2 months	0.34	0.47	68,425.00	0.00	1.00
i affects Π in 1-2 yrs	0.38	0.49	68,425.00	0.00	1.00
HH dislikes Π	0.61	0.49	68,425.00	0.00	1.00
HH prefers high Π	0.17	0.37	68,425.00	0.00	1.00
HH doesn't know preference for Π	0.23	0.42	68,425.00	0.00	1.00
HH expects 1yr i up	0.47	0.50	68,425.00	0.00	1.00
HH expects 1yr i down	0.07	0.25	68,425.00	0.00	1.00
HH expects 1yr i unchanged	0.27	0.44	68,425.00	0.00	1.00
HH doesn't know expected 1yr i	0.19	0.39	68,425.00	0.00	1.00
HH prefers i up	0.23	0.42	68,425.00	0.00	1.00
HH prefers i down	0.27	0.45	68,425.00	0.00	1.00
HH prefers i unchanged	0.21	0.41	68,425.00	0.00	1.00
HH is indifferent on i	0.18	0.39	68,425.00	0.00	1.00
HH doesn't know preference for i	0.10	0.30	68,425.00	0.00	1.00
Income above 25000 pounds	0.51	0.50	68,425.00	0.00	1.00
Household with mortgage	0.29	0.46	68,425.00	0.00	1.00
Top Wealthy HH	0.19	0.39	68,425.00	0.00	1.00
Upper Middle Wealthy HH	0.27	0.44	68,425.00	0.00	1.00
Lower Middle Wealthy HH	0.20	0.40	68,425.00	0.00	1.00
Poor HH	0.34	0.47	68,425.00	0.00	1.00

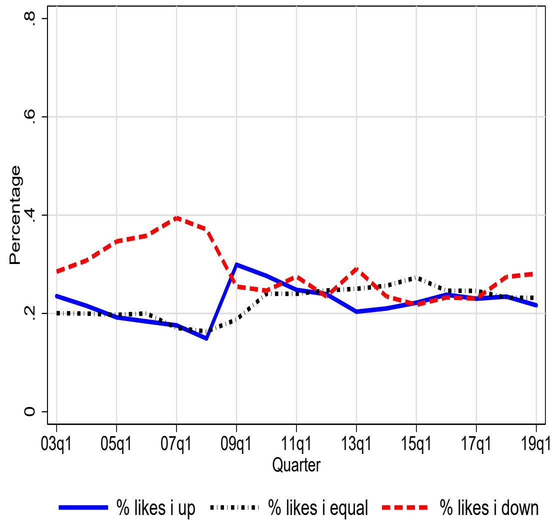
point estimate closer to RPI inflation. BEIAS also asks households if they agree with the statement that “a rise in interest rates makes prices in the high street rise more slowly in the short term (say a month or two)”; and if they agree with the statement that “a rise in interest rates makes prices rise more slowly in the medium term (say a year or two)”. We construct two dummies for whether the households report to agree or strongly agree with each of the two statements: the dummies measure households understanding of the monetary policy trade-off between interest rates and inflation. As we we will show below, households reporting to agree with the statements are more likely to report their preferences and expected inflation. BEIAS contains information on whether the household has a mortgage and assigns the household to one of 4 economic class variables constructed using the National Readership Survey (NRS) social grade classification. The social ranking roughly corresponds to the quartile of the UK wealth distribution. We refer to households in the 4 social groups as “Top Wealthy”, “Upper Middle Wealthy”, “Lower Middle Wealthy”, and “Poor”, respectively. We take these 4 dummy variables together with the dummy for whether the household has a mortgage as characterizing household’s wealth and her portfolio position in BEIAS. Table 1 provides descriptive statistics about these dummies. Finally, we construct a dummy for whether annual income is above 25,000 pounds per year, which roughly corresponds to the median income in the UK population.

Panel (a) of Figure 2 plots the fractions of households who like inflation (solid blue line) and who dislike it (dashed red line). The fraction of households who dislike inflation oscillates around 60 percent, whereas the fraction of households who dislike it oscillates around 20 percent. The fractions have remained relatively stable over the sample period. Panel (b) plots the fraction of households who prefers interest rate to go up (solid blue line), down (dashed red line) or are indifferent (dotted black line). Panel (c) plots the difference in 1-year ahead expected inflation between households who like inflation and households who dislike it, with the grey area representing 95 percent confidence intervals. There is a statistically significant difference in expected inflation: households who like inflation have lower expected inflation than households who dislike it. The difference peaks to around 40 basis in 2012:I, while it is not statistically different from zero in 2004:I and 2016:I. Panel (d) reports the difference in the (average) one-year expected inflation of households who prefers interest rates to go up and the expected inflation of households who prefer interest rates to go down. Again there is a statistically significant difference in expected inflation. The difference peaks to more than 40 basis in 2015 and is high also in 2006, 2007, and 2016.

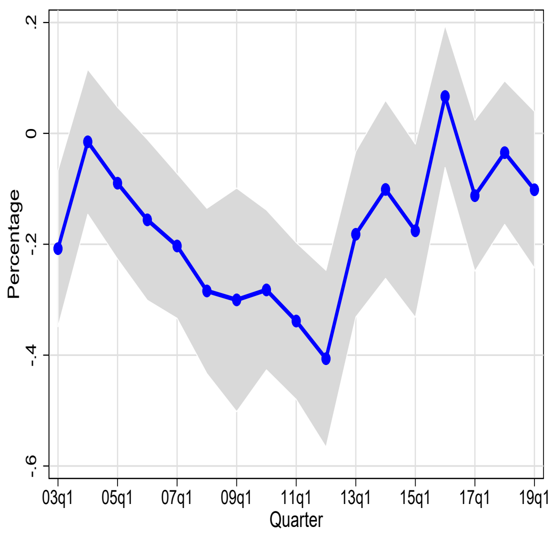
Figure 2: Expected inflation and preferences for inflation



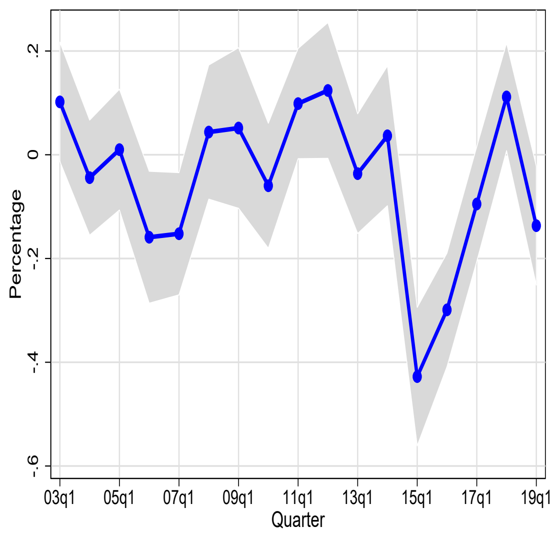
(a) Preferences for monetary policy



(b) Preferences for interest rates



(c) Diff. in Π^e: preference for inflation



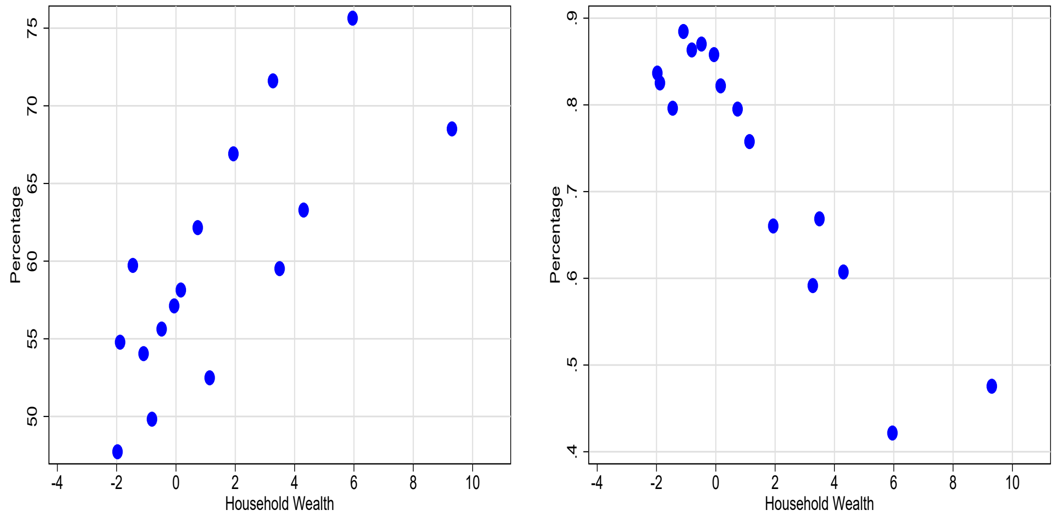
(d) Diff. in Π^e: preference for interest rates

Panel (a) plots the fraction of households who report to like and dislike inflation; panel (b) the fraction of households who prefers interest rate to go up, down or are indifferent. Panel (c) reports the difference in the (average) one-year expected inflation of households who like and dislike inflation. Panel (d) reports the difference in the (average) one-year expected inflation of households who like interest rates to go up and the expected inflation of households who prefer interest rates to go down.

3.2 Wealth and preferences

We relate the wealth of households to their preferences for monetary policy and interest rates. Result 1 suggests that wealthy households dislike inflation and prefer interest rates to go up, while poor (debtor) households likes inflation and prefer interest rate to go down. We construct 16 groups of households depending on whether the household belongs to one of the 4 economic class variables in the NRS ("Top Wealthy", "Upper Middle Wealthy", "Lower Middle Wealthy" or "Poor"), whether the household has a mortgage, and whether her annual income is above or below 25,000 pounds per year. For each group of households, we calculate their average wealth using the Wealth and Assets Survey (WAS) for wave 3 (2010-1012).[7] In calculating household's wealth we exclude the value of her main residence, add the value of all other real and financial assets of the household and then subtract all household's debt (the sum of the amount owed by the household on all mortgages and other loans). The value of wealth is expressed as a ratio of the average net annual income in the UK economy. Panel (a) of Figure 3 plots the fraction of households who dislike inflation as a function of the average household wealth in the group.[8] Wealthier

Figure 3: Preferences and Net wealth



(a) HHs who dislike inflation **(b) HHs who prefer interest rates down**

Wealth excludes value of main residence. Values are calculated as a ratio of average net income in the economy. They refer to 2010-2012. Data on wealth come from the Wealth and Assets Survey. Panel (a) plots the fraction of households in each wealth group that "like inflation". Panel (b) plots the fraction of households in each wealth group that report "prefer interest rate to go down" conditional on reporting to "like inflation".

households are more likely to dislike inflation. Roughly, a household with negative wealth equal to two times average UK annual labor income dislikes inflation with a probability of 50 percent compared with a probability of 70 per cent for a household with wealth greater than four times average yearly labor income. Panel (b) of Figure 3 analyzes the relation between household's wealth and the fraction of households who dislike both inflation and

[7]This is the first wave of WAS with the information required to reconstruct the 4 economic class variables by NRS in WAS. WAS is a survey conducted by the Office for National Statistics (ONS), which is unique in measuring UK households' assets, savings and debt. WAS over-samples wealthier households and is fully representative of the UK wealth distribution.

[8]The values underlying the scatter plots in Figure 3 are in Table A2 in the Appendix.

higher interest rates as a proportion of the number of households who dislike inflation, which is a way of reporting preferences for nominal interest rates after controlling for household's preferences for monetary policy. Consistent with the model, panel (b) indicates that wealthier households are less likely to prefer interest rate to go down. A household with negative wealth equal to two times average UK annual labor income prefer low interest rates with a probability of 90 percent. A household with wealth greater than four times average yearly labor income prefer interest rates to go down with a probability of just 40 per cent.

To study more formally how household's wealth affects household's preferences for monetary policy we run a multinomial Logit for whether the household likes, dislikes or has no idea about her preferences for inflation, which are mutually exclusive category. We control for a full set of time dummies, 5 geographical dummies (for leaving in Scotland, Wales, Northern Ireland, Midlands or South of England), 6 age dummies, a dummy for gender, a dummy for being employed, 5 income group dummies, and 3 educational dummies (for less than high school, high school degree and for having a college degree or more). Descriptive statistics for these variables are in Table A1 in the Appendix. These variables control for possible differences in the information set of households. The omitted category is "Poor" households. Table 2 reports the resulting average marginal effects on the probability of the 3 categorical variables for preferences for inflation. Households with a mortgage have

Table 2: Determinants of preferences for inflation

	(1)	(2)	(3)
VARIABLES	HH_dislikes_infl_	HH_likes_infl_	HH_does_not_know
Household with mortgage	-0.08***	0.10***	-0.03***
	(0.00)	(0.00)	(0.00)
Top Wealthy HH	0.10***	0.01*	-0.11***
	(0.01)	(0.01)	(0.00)
Upper Middle Wealthy HH	0.07***	0.00	-0.08***
	(0.01)	(0.00)	(0.00)
Lower Middle Wealthy HH	0.04***	0.01	-0.04***
	(0.01)	(0.00)	(0.00)
Observations	68,425	68,425	68,425

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

The table reports the average marginal effects on the probability of the three categorical variables for preferences for monetary policy from a Multinomial logit. The model contains a full set of time dummies, 5 geographical dummies for leaving in Scotland, Wales, Northern Ireland, Midlands or South of England, six age dummies, a dummy for gender, a dummy for being employed, five income group dummies, and educational dummies for Less than high school, High school degree and for having a College degree or more. The omitted category is the "Poor" household category.

a probability which is 10 percent higher to like inflation than a household without a mortgage. A top wealthy household has a 10 percent higher probability to dislike inflation than a poor household. Interestingly, this last marginal effect comes from a reduction in the probability that the household does not report her preferences for policy, which is an issue we will address later.

Given household's preferences for monetary policy, in Table 3 we study the determinants for whether the household prefers interest rates to go up, down, remain the same, whether the household has no idea or she does not know. We run a multinomial Logit over these

Table 3: Determinants of preferences for interest rate changes

VARIABLES	(1) Go_up	(2) Go_down	(3) Same	(4) Indifferent	(5) Not_know
HH dislikes Π	0.15***	-0.01*	-0.01**	0.03***	-0.16***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
HH prefers high Π	0.00	0.09***	0.05***	-0.06***	-0.07***
	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)
Household with mortgage	-0.12***	0.11***	0.10***	-0.07***	-0.03***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Top Wealthy HH	0.16***	-0.05***	-0.03***	-0.05***	-0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
Upper Middle Wealthy HH	0.12***	-0.04***	-0.01**	-0.04***	-0.02***
	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)
Lower Middle Wealthy HH	0.08***	-0.03***	-0.00	-0.04***	-0.01***
	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)
Observations	68,425	68,425	68,425	68,425	68,425

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.10

The table reports the average marginal effects from estimating a Multinomial logit on the probability of the five categorical variables for preferences for interest changes: whether the household would like interest rate to go up, go down, or stay where they are, whether interest rates make no difference to the household or whether the household has no idea about her preferences for interest rates. All regressions contain a full set of time dummies, 5 geographical dummies (for leaving in Scotland, Wales, Northern Ireland, Midlands or South of England), 6 age dummies, a dummy for gender, a dummy for being employed, 5 income group dummies, and 3 educational dummies (for Less than high school, High school degree and for having a College degree or more). The omitted category is a "Poor" household who does not know her preference for inflation.

five categorical variables. The controls are as in Table 2. We also control for household's preferences for inflation, since our interpretation for preferences for interest rates holds after controlling for household's preferences for monetary policy. The omitted category is a "Poor" household who does not know her preferences for monetary policy. A household who dislikes policy has a 15 percent higher probability to prefer interest rates to go up than a household who has no preference for inflation. A household with mortgages have a 21 percent higher probability to prefer interest rate to remain the same or to go down than a household without a mortgage. A top wealthy household has a 16 percent higher probability to prefer interest rates to go up than a poor household. This increase in probability comes roughly equally from all the other 4 categories for preferences on interest rates.

4 Effects of preferences on expectations

We now study in more details how preferences affect household expectations. In Section 4.1 we study the average effects of preferences on 1-year ahead expected inflation, over the entire sample period. In Section 4.2 we analyze the effects of preferences on expected inflation at 2 and 5 years time horizon. In Section 4.3 we look at their effects on expected future interest rate changes. In Section 4.4 we study whether the component of expected inflation due to preferences affects households' choices for consumption, savings, portfolio allocations and wages. In Section 4.5 we deal with possible biases due to selection or endogeneity of preferences.

4.1 Baseline evidence

Given (11) and Result 4, we run the following regression on the BEIAS data:

$$E_{it}(\Pi_{t+n}) = \bar{\pi}_t + \beta_m \, d^m_{it} + \beta_r \, d^r_{it} + \varkappa X_{it} + \epsilon_{it}. \tag{12}$$

The dependent variable is the 1 year ahead expected inflation of the household, $n = 1$, $\bar{\pi}_t$ is a time dummy capturing average expected inflation in the period, d^m_{it} is a dummy equal to one if household i reports to like inflation, d^r_{it} is a dummy equal to one if household i reports to prefer interest rates to go up and X_{it} are additional controls. Having (11) in mind, we would infer that β_m would be an estimate of $-\overline{\pi}_{m1} \, \overline{v}_{t_0} < 0$, while β_r would be one of $= \overline{\pi}_{z1} \, \overline{\epsilon}_{t_0} < 0$. In column 1 of Table 4 we just add as a regressor the dummy d^m_{it}. The regression is ran on the sample of households who report both their expected inflation and their preferences: for monetary policy in columns 1-2 as well as for interest rate changes in columns 3-4. On average a household who likes inflation has a one-year ahead expected inflation which is lower by 18 basis points. The regressions in columns 2-4 of Table 4 also control for 5 geographical dummies (for leaving in Scotland, Wales, Northern Ireland, Midlands or South of England), 6 age dummies, a dummy for gender, a dummy for being employed, 5 income group dummies, and 3 educational dummies (for less than high school, high school degree or a college degree or more). Their estimated coefficients are in Table A3 in the Appendix. The controls are intended to account for differences in the information set available to households or in their ability to process information, that might

Table 4: **Effects of Preferences on expected inflation**

VARIABLES	(1) Π^e	(2) Π^e	(3) Π^e	(4) Π^e
HH prefers high Π	-0.18***	-0.14***	-0.15***	-0.13***
	(0.02)	(0.02)	(0.02)	(0.02)
HH prefers i up			-0.13***	-0.08***
			(0.02)	(0.02)
HH prefers i unchanged			-0.16***	-0.13***
			(0.02)	(0.02)
HH is indifferent on i			-0.06**	-0.03
			(0.03)	(0.03)
BoE sets i				-0.13***
				(0.02)
HH knows Monetary Cmte.				-0.05**
				(0.02)
BoE is independent				-0.11***
				(0.02)
UK econ. needs high Π				-0.42***
				(0.03)
UK econ. is indifferent on Π				-0.33***
				(0.02)
Dk whether UK needs Π				-0.30***
				(0.03)
Observations	47,273	47,273	45,715	45,715
Method	OLS	OLS	OLS	OLS
R^2	0.08	0.09	0.09	0.10
Wald test	0.00	0.00	0.00	0.00

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

The table reports the coefficients of a regression where the dependent variable is expected inflation at a 1 year ahead time horizon. In addition to the regressors reported in the Table, the regressions in columns 2-4 also control for a full set of time dummies, 5 geographical dummies (for leaving in Scotland, Wales, Northern Ireland, Midlands or South of England), 6 age dummies, a dummy for gender, a dummy for being employed, 5 income group dummies, and 3 educational dummies (for less than high school, high school degree or a college degree or more). In columns 1-2, the excluded category is a household who dislikes inflation. In columns 3-4, it is a household who dislikes both inflation and interest rates to go down. The regression is ran on the sample of households who report their expected inflation and preferences: for monetary policy in columns 1-2 as well as for interest rate changes in columns 3-4. The last row in each column reports the p-value for the null hypothesis that all preference coefficients are equal to zero.

lead to differences in household expectations. In addition to these controls, the regression in columns 3 includes three dummies describing household's preferences for changes in interest rates. The regression in column 4 further adds information on household's knowledge about monetary policy—as proxied by whether the household knows about the Monetary Committee and is aware that the Bank of England is independent and sets the interest rates—as well as household's self-reported beliefs about whether the UK economy (rather than the household) would be better off by having higher inflation. The reference group in columns 3 and 4 is a household who dislikes inflation and would prefer interest rate to go down. We take the controls in column 4 to be quite conservative since the same reasons that might lead the household to believe that the UK would be better off by having higher inflation would also lead the household to distort her beliefs about future inflation. The last row in each column reports the p-value of a Wald-test for the null hypothesis that all preference coefficients (for monetary policy and interest rate changes) are equal to zero, which is strongly rejected in all specifications. On average, after including the full set of controls, a household who likes inflation has lower expected inflation by around 13 basis points. A household who would like interest rate to go up, after controlling for preferences for monetary policy, tends to have a lower expected inflation by around 10 basis points, which falls slightly to 8 basis point when considering the more restrictive specification of column 4. There is no statistically significant difference on expected inflation between a household who prefers interest rates to go up and a household who prefers interest rates to remain unchanged, which is consistent with the fact that, over our sample period, interest rates have a negative trend, see panel (d) in Figure 1: loosely speaking, interest rates either fall or remain the same. Later we are going to impose that the two regression coefficients are exactly equal, which will help in gaining statistical power. Thereafter we are going to focus on the more restrictive specification with the same full set of controls as in column 4 of Table 4.

4.2 Horizon of inflation expectations

Starting from 2009, BEIAS also asks households for their expected inflation at a 2 and 5 year time horizon, which correspond to $n = 2$ and $n = 5$ in the regression (12). We ran the same regression as in column 4 of Table 4 using expected inflation at these longer time horizons as a dependent variable. Given the change in the sample period, as a term of comparison, we also report the estimates using the 1 year expected inflation. Table 5 reports the results. The last row of each column reports the p-value for the null hypothesis that all preference coefficients are exactly equal to zero. The reference group is the same as in column 4 of Table 4: a household who dislikes inflation and would prefer interest rate to go down. Relative to this reference household, a household who prefers high inflation has a lower expected inflation by 23 basis point at a 1 year time horizon. This difference falls by around 5-7 basis points when looking at expected inflation at a 2 or 5 years ahead time horizon.

Table 5: Effects of Preferences on expectations: Additional evidence from 2009

VARIABLES	(1) 1yrΠ^e	(2) 2yrΠ^e	(3) 5yrΠ^e
HH prefers high Π	-0.23***	-0.14***	-0.19***
	(0.04)	(0.04)	(0.05)
HH prefers i up	-0.11**	-0.18***	-0.27***
	(0.05)	(0.05)	(0.06)
HH prefers i unchanged	-0.13***	-0.16***	-0.23***
	(0.04)	(0.04)	(0.05)
HH is indifferent on i	-0.02	-0.02	-0.09
	(0.05)	(0.05)	(0.06)
Observations	29,983	25,636	22,936
Method	OLS	OLS	OLS
R^2	0.10	0.07	0.02
Wald test	0.00	0.00	0.00

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

The table reports the coefficients of a regression where the dependent variable is expected inflation at 1 year, 2 years and 5 years time horizon in column 1 , 2 and 3, respectively. The specification is the same as in column 4 of Table 4. The last row reports the p-value for the null hypothesis that all preference coefficients are exactly equal to zero. The reference group is a household who dislikes inflation and would prefer interest rate to go down.

4.3 Interest rate expectations

For robustness, in Table 6 we also checked that a similar negative effect of preferences on expectations arises when households are asked to predict the future evolution of nominal interest rates, rather than future inflation. We estimate an ordered logit model using as dependent variable the categorical variables constructed using the following question: "How do you expect interest rates to change over the next twelve months?". The qualitative answers to the question allows us to construct the three following categorical variables: (i) interest rates will rise, (ii) interest rates will stay about the same, and (iii) interest rates will fall. On average, 47 percent of UK households believe that interest rates will rise, see Table 1. We then estimate an ordered logit model including households' preferences for future changes in interest rates as controls.[9] In the model we also include the full set of controls as in column 4 in Table 4.[10] The reference group is a household who prefer interest rates to remain unchanged. The model is estimated on the sample of households who report

[9]Table A5 reports analogous results using an Ordered Probit model rather than an ordered probit model.

[10]Table A4 in the Appendix reports the analogous results when the regressions do not contain any additional controls.

Table 6: **Effects of Preferences on expected interest rates, Ordered Logit**

VARIABLES	(1) ie_down	(2) ie_equal	(3) ie_up
HH prefers i up	0.01***	0.02***	-0.02***
	(0.00)	(0.00)	(0.01)
HH prefers i down	-0.02***	-0.05***	0.07***
	(0.00)	(0.00)	(0.01)
Observations	44,284	44,284	44,284
Method	Ordered Logit	Ordered Logit	Ordered Logit
Variables	Yes Controls	Yes Controls	Yes Controls
Wald test	0.00	0.00	0.00

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

The table reports the average marginal effects on the probability of the future dynamics of (nominal) interest rates, using an ordered logit model. The last row reports the p-value for the null hypothesis that all preference coefficients are all equal to zero. The controls are the same as in column 4 of Table 4.

their expectations on the future evolution of interest rates as well their personal preferences for nominal interest rate changes. The results in Table 6 indicate that a household who personally prefers interest rate to go down has a probability to believe that interest rates will go up which is 7 percentage point higher than the analogous probability by a household who prefers interest rates to remain unchanged.

4.4 Effects of preferences on choices

Even if households' preferences do affect households' self-reported beliefs, it might be that the component of beliefs due to preferences could have no or little effects on households' choices—i.e. they could be just a form of "cheap talking" with no material consequences on households' decisions. We investigate this issue in Tables 7 and 8 using a set of questions available in BEIAS since 2011. In particular, we estimate a linear probability model where the dependent variable is a dummy for whether in the light of household's expectations of price changes over the next twelve months the household "brings forward major purchases" (columns 1 and 2 of Table 7), "spends less" (columns 3 and 4 of Table 7), "shops around more" (columns 5 and 6 of Table 7), "pushes for a pay increase" (columns 7 and 8 of Table 7), "searches for more income" (columns 1 and 2 of Table 8), "saves more in financial assets" (column 3 and 4 of Table 8), "does something else" (column 5 and 6 of Table 8), and "takes no action" (columns 7 and 8 of Table 8). We report the estimated coefficients on expected inflation which measures how changes in the inflation expected by the household affects her choice. The odd columns of each Table correspond to the OLS estimates, the even columns to the IV estimates obtained by instrumenting household's expected inflation with their preferences for higher or lower inflation and higher or lower interest rate changes, as measured by the previously discussed dummies for households' preferences as in column 4 of Table 4. The IV estimates measure the effects on choices of the

Table 7: Effects of Expected Inflation on choices I

VARIABLES	(1) Major	(2) Major	(3) Cut Spend.	(4) Cut Spend.	(5) Shop	(6) Shop	(7) Pay	(8) Pay
Expected infl.	0.00	0.01	0.02***	0.40***	0.01***	0.49***	0.00***	0.04
	(0.00)	(0.02)	(0.00)	(0.10)	(0.00)	(0.12)	(0.00)	(0.04)
Observations	17,400	17,400	18,086	18,086	18,298	18,298	17,395	17,395
Method	OLS	IV	OLS	IV	OLS	IV	OLS	IV
R^2	0.12	0.12	0.15		0.12		0.13	
Durbin		0.73		0.00		0.00		0.36
Wu-Hausman		0.73		0.00		0.00		0.36

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

The Table reports the OLS and the IV coefficient on expected inflation in a regression where the dependent variable is a dummy for whether, in the light of household's expectations of price changes over the next twelve months, the household "brings forward a major purchase" (columns 1 and 2), "spends less" (columns 3 and 4), "shops around more" (columns 5 and 6), or "pushes for pay increase" (columns 7 and 8). The two rows at the bottom of each even column report the Durbin and the Wu-Hausman tests for the null hypothesis that the effects of inflation expectations on choices is the same in the OLS and the IV specification. In the IV specification, expected inflation is instrumented using households' preferences for inflation and interest rate changes as measured by the dummies in column 4 of Table 4. The other controls are the same as in column 4 of Table 4.

components of expected inflation due to household's preferences (say the effects of the distortion of beliefs due to Knightian uncertainty). The two rows at the bottom of each even column in the tables report the test by Durbin (1954) and the one by Hausman (1978) for the null hypothesis that the effects of expected inflation on choices are the same in the OLS and in the IV specification. In calculating the Durbin and the Hausman tests we use a robust Variance Covariance Matrix. Generally expected inflation increase the probability that the household cuts spending, shops around more, searches for more income, and does something else, which suggests that changes in the expected inflation by the household changes her actions. The estimates in Tables 7-8 also indicate that changes in inflation expectations due to preferences change the saving, consumption, and financial portfolio behavior of households in a way that is quantitatively similar to (and generally larger than) the component of expected inflation unrelated to preferences. This provides support to the idea, that households preferences not only distort their beliefs but also their actions.

Table 8: Effects of Expected Inflation on choices II

VARIABLES	(1) Income	(2) Income	(3) Save	(4) Save	(5) Other	(6) Other	(7) No act.	(8) No act.
Expected infl.	0.01***	0.18***	-0.00	-0.05	-0.02***	-0.33***	-0.00	-0.09***
	(0.00)	(0.06)	(0.00)	(0.04)	(0.00)	(0.09)	(0.00)	(0.03)
Observations	17,620	17,620	17,496	17,496	17,294	17,294	14,804	14,804
Method	OLS	IV	OLS	IV	OLS	IV	OLS	IV
R^2	0.18		0.13		0.12		0.17	
Durbin		0.00		0.14		0.00		0.00
Wu-Hausman		0.00		0.14		0.00		0.00

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.10

The Table reports the OLS and the IV coefficient on expected inflation in a regression where the dependent variable is a dummy for whether, in the light of household's expectations of price changes over the next twelve months, the household "searches for more income" (columns 1 and 2), "saves more in financial assets" (column 3 and 4), "does something else" (column 5 and 6), "takes no action" (columns 7 and 8). The two rows at the bottom of each even column report the Durbin and the Wu-Hausman tests for the null hypothesis that the effects of inflation expectations on choices is the same in the OLS and the IV specification. In the IV specification, expected inflation is instrumented using households' preferences for inflation and interest rate changes as measured by the dummies in column 4 of Table 4. The other controls are the same as in column 4 of Table 4.

4.5 Endogeneity and selection

Differences in preferences might be correlated with differences in the information set available to households, which in turn might affect expected inflation. This would cause an omitted variable bias. We address this issue in different ways. To fix ideas, notice that in the regression (12), the set of controls X_{it} and the residuals ϵ_{it} account for variation in the rational expectation beliefs of households $E^{\sigma}_{it}(\Pi_{it+1})$ (due to differences in information sets or consumption baskets). The dummy for household's preferences over inflation

$$d^m_i = d^m(s_i) \tag{13}$$

is function of the household's state variables s_i, including her wealth portfolio.[11] The specification in (12) relies on the assumption that some households always prefer higher inflation (to lower interest rates) while the other households always dislike inflation: this would imply that d^m_i is invariant to changes in $E^{\sigma}_{it}(\Pi_{it+1})$, would make d^m_i orthogonal to ϵ_{it} and would guarantee that the OLS estimate of β_m measures the effect of Knightian uncertainty on beliefs, as in (11). In practice, some households may have non-monotonic preferences over inflation, causing an upward bias in the estimated value of $|\beta_m|$ (β_m more negative) due to reverse causation. To see this point more formally assume that in the

[11]For simplicity, we omit discussing the dummy for household preferences over interest rates changes.

economy there are two types of households. A fraction α of households have preferences over inflation as in (13). The remaining fraction $1-\alpha$ have a desired level of inflation Π^* (possibly heterogenous across households) strictly within the empirically relevant range of variation of $E_t^\sigma(\Pi_{t+1})$, implying that their preferences dummy is

$$d_{i2}^m = \mathbb{I}\left(E_{it}^\sigma(\Pi_{it+1}) - \Pi^*(s_i) < 0\right), \tag{14}$$

where $\mathbb{I}$ is the indicator function. In brief d_2^m is a step function, decreasing in $\Delta_{it} \equiv E_{it}^\sigma(\Pi_{it+1}) - \Pi^*(s_i)$: equal to one if household's expected inflation is lower than her desired level of inflation, and zero otherwise. The presence of these households can make the OLS estimate of $|\beta_m|$ upward biased: since a fraction $1-\alpha$ of households are more likely to prefer higher inflation when $E_t^\sigma(\Pi_{it+1})$ is low, the dummy d_{it}^m in (12) is negatively correlated with the residual ϵ_{it}, causing a upward bias in the OLS estimate of β_m. We address this reverse causality problem in two ways. In one, we instrument d^m in (12) with some deep determinants of household preferences over inflation: say with some of the variables entering s in (13). If s is uncorrelated with ϵ this would be enough to correct for the possible correlation between d^m and ϵ in (12). One possible set of instruments suggested by the model is the household's wealth portfolio that determines household's preferences over inflation (and interest rate changes). In the other, we exploit the fact that the correlation between d_{it}^m and ϵ_{it} is smaller, when the fraction of households who switch preferences over inflation due to changes in rational expectation beliefs is smaller (greater α) and disappears when $\alpha = 1$. This suggests that the reverse causality problem should be less relevant in the tails of the distribution of expected inflation: changes in preferences due to variation in $E_{it}^\sigma(\Pi_{it+1})$ are more likely to occur when comparing households with very low $E_{it}^\sigma(\Pi_{it+1})$ (low ϵ_{it}) to households with very high $E_{it}^\sigma(\Pi_{it+1})$ (high ϵ_{it}). When instead households have consistently very low ϵ_{it} or very high ϵ_{it}, the variation of $E_{it}^\sigma(\Pi_{it+1})$ within the sample is unlikely to cause a switch in the preferences of type 2 households, which reduces the reverse causality bias (see the Appendix for a more formal analysis).

We exploit this idea by running quantile regressions. Table 9 reports the quantile regressions coefficients using one-year expected inflation as the dependent variable. The controls are the same as in column 4 in Table 4. The coefficients on preferences are listed by rows. The last row reports the p-value for the null hypothesis that all preference coefficients are equal to zero. The effects of preferences on beliefs appears to be present at all quintiles of the distribution of expected inflation. The effects at the median, at the mean, and at the top quintile are all similar, that suggests that our baseline estimates are not plagued by reverse causality. The effects of preferences on beliefs is just marginally greater at the top quintile than for households at the bottom quintile. In Table A6 in the Appendix, we also studied whether the effect of preferences on expected inflation varies across households with different educational levels, or different level of income. We find that the effects are not statistically different across groups.

Table 9: Effects of Preferences on expectations, quantile regressions

VARIABLES	(1) Bottom 20% Π^e	(2) Bottom 20% Π^e	(3) Median Π^e	(4) Median Π^e	(5) Top 20% Π^e	(6) Top 20% Π^e
HH prefers high Π	-0.07***	-0.07***	-0.11***	-0.11***	-0.10***	-0.11***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)
HH prefers i up		-0.03**		-0.06**		-0.10***
		(0.02)		(0.03)		(0.03)
HH prefers i unchanged		-0.05***		-0.12***		-0.12***
		(0.01)		(0.03)		(0.03)
HH is indifferent on i		-0.01		-0.02		-0.04
		(0.01)		(0.03)		(0.03)
Observations	47,273	45,715	47,273	45,715	47,273	45,715
Method	OLS	OLS	OLS	OLS	OLS	OLS
Controls	YES	YES	YES	YES	YES	YES
Wald test	0.00	0.00	0.00	0.00	0.00	0.00

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

The table reports the coefficients of quantile regressions where the dependent variable is expected inflation at a 1 year time horizon. The controls are the same as in column 4 in Table 4. The coefficients on preferences are listed by rows. The last row reports the p-value for the null hypothesis that all preference coefficients are equal to zero.

A more standard approach to deal with the omitted variable bias is based on instrumental variables. We pursue this strategy after observing that households self-select into reporting their preferences as well as their expected inflation. This implies that the regressions in Table 4 might be also plagued by a selection bias (in addition to the omitted variable bias). To deal with this issue, we consider a selection model based on the following three dummies: one for whether the household does not provide any estimate for "how prices have changed over the last twelve months"; one for whether the household agrees or strongly agrees with the statement that "a rise in interest rates makes prices in the high street rise more slowly in the short term (say a month or two)"; and finally one for whether the household agrees or strongly agrees with the statement that "a rise in interest rates makes prices rise more slowly in the medium term (say a year or two)". The first dummy exploits the fact that households are more likely to report their beliefs about future inflation and their preferences for inflation and interest rates if they provide an estimate for today inflation. The other two dummies require the household to understand and agree with the monetary policy trade-off between higher interest rates and higher inflation which lies at the core of the policy question in BEIAS that we use to elicit household preferences over inflation. Overall we interpret the three dummies as a measure of economics literacy. Column 1 of Table 10 reports the average marginal effects of a Probit regression for observing future inflation and preferences for inflation and interest rates, corresponding to the first stage regression used by Heckman (1979) to control for selection biases. Column 2 reports the average marginal effects on the analogous probabilities using a logit model rather than a probit model, which is the first stage regression used by Lee (1979, 1983) to control for the existence of a selection bias.

Table 10: Probit or Logit of observing future inflation, first stage

	(1)	(2)
VARIABLES	Observing Π^e and U	Observing Π^e and U
HH does not know past Π	-0.42***	-0.44***
	(0.01)	(0.01)
i affects Π in 1-2 months	0.06***	0.07***
	(0.01)	(0.01)
i affects Π in 1-2 yrs	0.09***	0.10***
	(0.01)	(0.01)
HH prefers high Π	0.29***	0.30***
	(0.01)	(0.01)
HH prefers i up or equal	0.44***	0.46***
	(0.00)	(0.00)
Observations	68,425	68,425
Method	Heckman-Probit	Lee-Logit
Wald test	0.00	0.00

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

Column (1) reports the average marginal effects for observing future inflation and households' preferences for inflation and interest rate changes using a Probit model. Column (2) reports the analogous average marginal effects using a logit model. The controls are the same as in column 4 of Table 4. The instruments for selection are obtained constructing the following three dummies: one for whether the household does not provide an estimate for how prices have changed over the last 12 months and one for whether she agrees or strongly agrees with the statement that "a rise in interest rates would make prices in the high street rise more slowly in the short term (say a month or two)" and a third one for whether she agrees on the statement that"a rise in interest rates would make prices in the high street rise more slowly in the medium term (say a year or two).

Columns 1 of Table 11 repeats the regression of column 4 of Table 4 on the subset of households who have a value of one in all the three previously described dummies for economics literacy. Estimates are very similar to those in Table 4. Columns 2 and 3 of Table 11 instead report the coefficients of a regression where we deal with the selection bias adding the inverse Mills ratio as obtained by estimating a Probit model (as in column 1 of Table 10) or a logit model (as in column 2 of Table 10) to the set of regressors present in the specification of column 4 in Table 4. Standard errors are calculated by bootstrapping the two-step procedure. A negative coefficients on the inverse Mills ratio indicates a negative correlation between the error in the structural equation (for the effects of preferences on expected inflation) and the error in the selection equation (for reporting expected inflation and preferences). The last row reports the p-value for the null hypothesis that all preference coefficients are equal to zero. Overall, controlling for selection into reporting expectations and preferences increases the magnitude of the estimated coefficients on household's preferences: by around 4 basis points when considering household's preferences for higher inflation and by more than 10 basis points when considering her preferences for higher (or equal) interest rates.

Table 11: Effects of Preferences on expectations, selection and IV

VARIABLES	(1) Π^e	(2) Π^e	(3) Π^e	(4) Π^e	(5) Π^e
HH prefers high Π	-0.14***	-0.20***	-0.19***	-3.06***	-3.05***
	(0.03)	(0.03)	(0.03)	(0.62)	(0.62)
HH prefers i up or equal	-0.07***	-0.22***	-0.21***	-2.40***	-2.40***
	(0.03)	(0.04)	(0.04)	(0.65)	(0.65)
Inverse Mill's ratio, probit		-0.19***		-0.26***	
		(0.05)		(0.08)	
Inverse Mill's ratio, logit			-0.18***		-0.26***
			(0.05)		(0.08)
Observations	21,495	37,031	37,031	37,031	37,031
Selection	Understand MP	Probit	Logit	Probit	Logit
2nd stage	OLS	OLS	OLS	IV	IV
Wald test	0.00	0.00	0.00	0.00	0.00

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

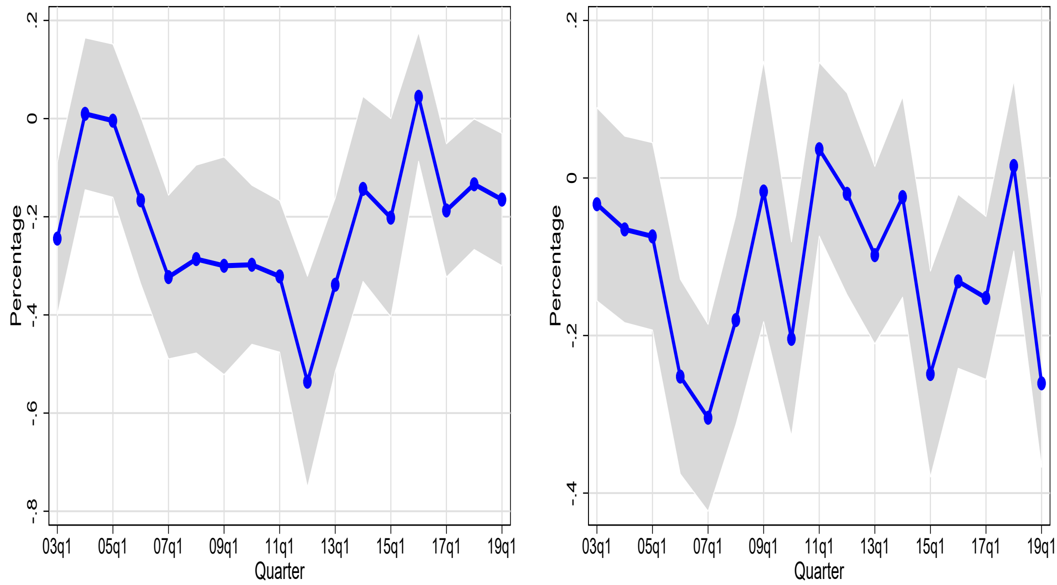
The table reports the coefficients of a regression where dependent variable is 1 year expected inflation and regressors are listed by rows. The last row reports the p-value for the null hypothesis that all preference coefficients are equal to zero. Column 1 estimates in column 4 of Table 4 on the sub-sample of households who agree with the statement that "a rise in interest rates makes prices in the high street rise more slowly in the short term (say a month or two)" or "in the medium term (say a year or two)" and report past inflation; Columns 2 and 4 deal with selection into reporting expectations and preferences by using a Probit model as in Heckman (1979). Columns 3 and 5 deals with selection using a logit model as in Lee (1979, 1983). The controls are the same as in column 4 of Table 4. The instruments for selection are the same as in Table 10. Columns 3 and 5 instrument household's preferences for inflation and interest rates using information on household's portfolios as measured by 4 dummy variables for household's wealth together with the dummy for whether the household has a mortgage.

Finally, we instrument household preferences by exploiting the idea that preferences over inflation and interest rate changes are at least partly caused by the wealth and financial portfolio of the household. Household's wealth portfolios are characterized by the previously discussed 4 dummy variables for wealth together with the dummy for whether the household has a mortgage. To help guaranteeing that the instrument satisfies the exclusion restriction, we again control for the same extensive set of controls as in column 4 of Table 4. We simultaneously deal with the selection bias and for the endogeneity of preferences following the procedure discussed in Section 19.6.2 in Wooldridge (2010). Essentially we first estimate a probit (or a logit) model for the selection indicator including all exogenous variables: those determining preferences and those determining selection into expectations and preferences and use the probit (or logit) model to obtain the inverse Mills ratios. Then we estimate the (structural) equation for expected inflation by two Stage Least Square (2SLS) adding the inverse Mills ratios as a regressor and using information on household's wealth portfolios as relevant instruments for household's preferences. Standard errors are calculated by bootstrapping the entire procedure. After simultaneously controlling for selection into reporting beliefs and preferences as well for the possible endogeneity of preferences, we still find that a household who prefers high inflation and higher or equal interest rates tends to have lower expected inflation. The effects remain statistically significant. Yet the size of the estimated coefficients substantially increase, with their standard errors also increasing by a similar order of magnitude.

5 Time series evolution

We now study how the preference coefficients in (12) change over the sample period. Figure A1 in the Appendix shows that the fraction of households who report their preference for inflation and interest rates as well as expected inflation is relatively stable over time at an average value around 70 percent. Yet it exhibits some fluctuations, which might cause changes in the importance of the selection bias over time. To address this issue, we estimate the same selection model as in column 2 of Table 11 after allowing all regression coefficients to vary over time. This means that the coefficients on all controls in the selection equation as well as all controls entering the structural equation for the effects of preferences on expected inflation, including the inverse Mill's ratio, are allowed to vary over time. Let β_{mt} denote the coefficient on the dummy for a preference for higher inflation at t and let β_{rt} denote the analogous coefficient for the preference for interest rates to go up or stay the same. We present the results based on the probit specification but quantitatively similar results are obtained when accounting for selection through a logit model. Panel (a) of Figure 4 plots the time series profile of the dummy variable coefficients for whether the household likes inflation β_{mt}. Panel (b) shows the analogous profile of the dummy variable coefficients for whether the household would personally prefer interest rate to go up or remain the same, β_{rt}. The grey areas represent 90 percent confidence intervals for the estimated coefficients. We interpret these coefficients as reflecting the amount of Knightian uncertainty in the economy. β_{mt} mainly reflects *monetary* uncertainty, β_{rt} *real* uncertainty, in the model due to technology shocks. The estimated coefficients are always negative and there is clear indication that the effect of preferences on expected inflation varies over time: both β_{mt} and β_{rt} are virtually zero in the early 2000's while they are larger in magnitude in the middle of the sample. Interestingly, the (absolute) value of β_{mt} and β_{rt} peaks at different points in time: β_{mt} peaks to around 60 basis points in 2012; β_{rt} peaks to roughly 30 basis in 2007 and in 2015. We now use these estimates to quantify the amount of monetary and real uncertainty present in the economy and study its effect on aggregate output.

Figure 4: Time series profile of preference coefficients



(a) Preference for inflation, β_{mt} **(b) Preference for interest rates,** β_{rt}

The controls are the same as in column 4 of Table 4. The specification is the same as in column 1 of Table 11 after allowing all coefficients to vary over time including those in the selection equation and the inverse Mill's ratio in the equation for the effects of preferences on expected inflation.

6 Quantifying uncertainty

We calibrate the model and back up the amount of monetary and real uncertainty in the economy using the coefficients β_{mt}'s and β_{rt}'s in Figure 4 as estimation targets. Then we study the effects of uncertainty on aggregate output.

6.1 Calibration

A period is a year. The subjective discount factor is $\beta = 0.95$, which matches the average yearly return on the UK stock market. As in Guvenen (2006) the elasticity of intertemporal substitution (EIS) is equal to 0.5, so $\sigma = 2$. The elasticity of substitution across goods is $\theta = 6$, consistent with micro level evidence (Nevo 2001, Chevalier, Kashyap, and Rossi 2003, and Broda and Weinstein 2006) and in the range of values typically used in macro models (Midrigan 2011). The output elasticity to labor is $\alpha = 0.4$ which yields a steady state labor share of 2/3, a common value in the literature. The parameter governing the convex cost of price adjustment is set to $\kappa_0 = 11.5$ which, together with θ and α, imply a slope of the linearized new Keynesian Phillips curve equal 0.44: under Calvo pricing, this value would imply a yearly frequency of price changes equal to one half, in line with the empirical evidence. The Taylor rule parameter is set to the standard value $\phi = 1.5$. We fit an AR(1) process for the logarithm of annual TFP over the period 1970-2018 and obtain $\rho_z = 0.98$.[12] We set $\rho_m = 0.6$ to match a serial correlation of inflation to the monetary shock of 60 percent. This follows from the estimates for expected inflation at 1-year and 2-years time horizon in Table 5 together with the observation from equation (11) that the estimated coefficients for the dummy d_{im} at different time horizons (in this case $n = 1$ and $n = 2$) measure the persistence of inflation to a monetary shock $\overline{\pi}_{mn}$. The tax rate on labor income and corporate profits are set to $\tau_w = 0.26$ and $\tau_d = 0.3$, respectively.[13] The supply of government bonds B represents 32% of the steady state asset supply. The firm overhead cost is set to $f = 0.055$ to yield a steady state value of household wealth equal to 1.55 times yearly labor income w, as in our data.

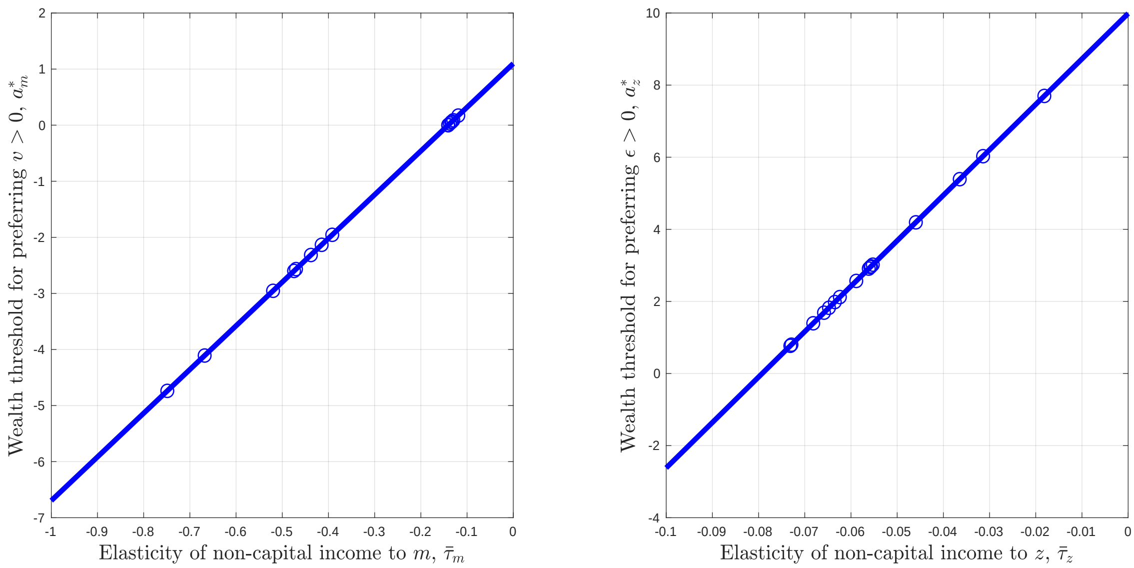
We set the steady state value of transfers to zero, $\bar{\tau} = 0$. The coefficients $\overline{\tau}_{im}$ and $\overline{\tau}_{iz}$ in (5) characterize all reasons, aside from financial returns, that affect household-i's preferences for inflation and interest rate changes: possibly due to the amount of indexation of household-i's wages and transfers to inflation and aggregate productivity. We consider the 16 groups of households discussed in Section 3.2 and assume that $\overline{\tau}_{im}$ and $\overline{\tau}_{iz}$ are

[12] The data for UK TFP come from the Office for National Statistics as available at https://www.ons.gov.uk/economy/economicoutputandproductivity.

[13] The former matches the average tax rate on labor income for UK workers as reported by the OECD at http://www.oecd.org/tax/tax-policy/taxing-wages-united-kingdom.pdf. The latter matches the UK corporate tax rate as estimated by KPMG, see https://home.kpmg/xx/en/home/services/tax/tax-tools-and-resources/tax-rates-online/corporate-tax-rates-table.html.

constant for all households in the same group $j = 1, 2...16$. The mass of households in group j corresponds to its relative size in the UK working age population, see Table A2 in the Appendix. The wealth distribution within group j is approximated by the corresponding ten deciles of wealth as obtained from WAS and it is assumed to be uniform within deciles.[14] In each group j, we target the fraction of households in the group that (i) prefer a monetary tightening $v_{t_0+1} < 0$ to a monetary loosing $v_{t_0+1} > 0$, and (ii) prefer interest rates to go up conditional on a technology shock $\epsilon_{t_0+1} < 0$, as reported in Figure 3. In each group j, for given $\overline{\tau}_{im}$ and $\overline{\tau}_{iz}$, we calculate the wealth thresholds a^*_m and a^*_z below which households prefer $v_{t_0+1} < 0$ to $v_{t_0+1} > 0$, and $\epsilon_{t_0+1} < 0$ to $\epsilon_{t_0+1} > 0$. Panels (a) of Figure 5 plots the relation between a^*_m and $\overline{\tau}_m$, while panel (b) characterizes the relation between a^*_z and $\overline{\tau}_z$. The wealth thresholds are expressed in units of yearly steady state labor income, w.

Figure 5: Beliefs wealth thresholds as a function of $\bar{\tau}_m$ and $\bar{\tau}_z$ in (5)



(a) Monetary shock

(b) Real shock

The left panel shows the level of wealth at the beginning of time t_0, a, below which the household prefers a monetary loosing $v_{t_0+1} > 0$ to a monetary tightening $v_{t_0+1} < 0$, for different values of the elasticity of the transfer function to the monetary shock $\overline{\tau}_{im}$ in (5). The right panel shows the level of wealth at the beginning of time t_0 below which the household prefers a technology improvement $\epsilon_{t_0+1} > 0$ to a technology regress $\epsilon_{t_0+1} < 0$ for different values of the elasticity of the transfer function to the technology shock $\overline{\tau}_{iz}$ in (5). The wealth threshold is expressed in units of yearly steady state labor income, w. The circles correspond to the values of $\overline{\tau}_{im}$ and $\overline{\tau}_{iz}$ for the 16 wealth groups from WAS.

Both functions are increasing: since a wealthier household is more likely to dislike $v_{t_0+1} > 0$ and $\epsilon_{t_0+1} > 0$ (Result 1), higher wealth should get compensated through higher transfer elasticities to make the household indifferent. Given the distribution of wealth within group

[14]This means that the economy is fully characterized by 160 types of households of mass equal to one tenth of the mass of the corresponding group $j = 1, 2...16$.

j, we search for the values of $\bar{\tau}_{im}$ and $\bar{\tau}_{im}$ that match the fraction of households in the group who like a monetary tightening and a technology regress. The circles in Figure 5 indicate the values of $\bar{\tau}_{im}$ and $\bar{\tau}_{iz}$ corresponding to our 16 groups of households.

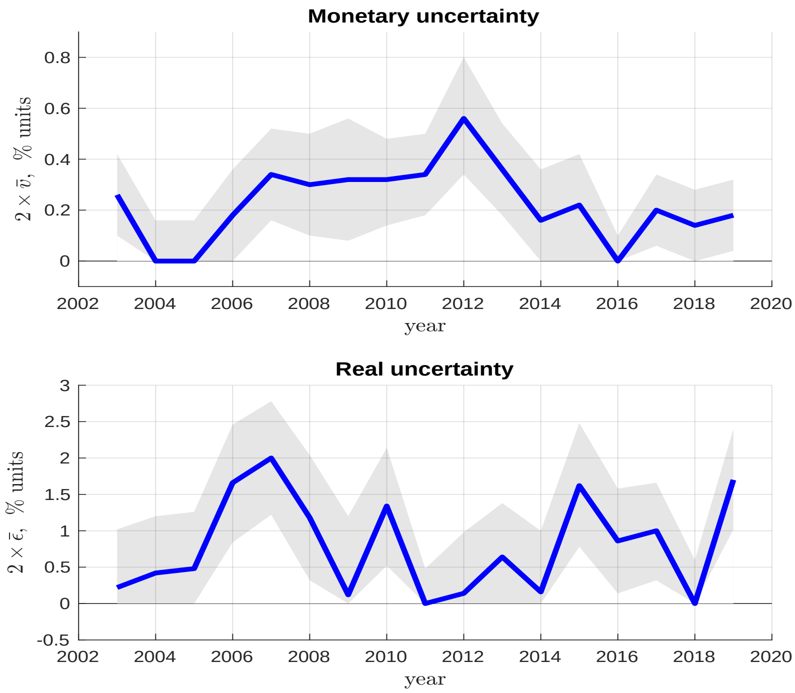
6.2 Results

As in Section 2, at t the economy receives unexpected shocks to uncertainty that households assume will get resolved in the following year. Households chooses consumption assuming that $v_{t+1} \in \{-\bar{v}_t, \bar{v}_t\}$ and $\epsilon_{t+1} \in \{-\bar{\epsilon}_t, \bar{\epsilon}_t\}$, and that thereafter m_T and z_T will evolve according to an AR(1) process. At each t, we search for the pair $\{\bar{v}_t, \bar{\epsilon}_t\}$ that allows the model to match the point estimates β_{mt} and β_{rt} in Figure 4. In particular, for given $\{\bar{v}_t, \bar{\epsilon}_t\}$, we calculate the worst-case and best-case beliefs of each household i in the economy, evaluate the dummy d_i^m and d_i^r, run the same regression as in (11) on the cross-sectional data simulated from the model and then search for the pair $\{\bar{v}_t, \bar{\epsilon}_t\}$ that best fits the estimated coefficients β_{mt} and β_{rt}.[15] The model matches well the profile of β_{mt} and β_{rt} reported in Figure 4.[16] Figure 6 plots the resulting estimated profiles of monetary policy uncertainty $\bar{v}_t$ (panel a) and real uncertainty due to technology shocks $\bar{\epsilon}_t$ (panel b), together with the 90% confidence intervals (grey area) computed by bootstrapping the estimates of β_{mt} and β_{rt} using their estimated variance covariance matrix. There is substantial variation over time in the two time series of uncertainty. Uncertainty about monetary policy and technology are just mildly correlated (correlation equal to -0.07) confirming that they indeed reflect two largely orthogonal sources of uncertainty.

[15]This indirect inference procedure allows us to characterize non linear effects in the household decision problem, which permits to compare the effects of risk (that matters only up to a second order effect) with those of uncertainty. Ilut, Krivenko, and Schneider (2018) propose a method to solve models with heterogeneous agents and Knightian uncertainty through linear approximation. Their method is hard to apply in our context with 160 different household types. Since our targets are estimated after controlling for the aggregate state of the economy through a full set of time dummies, we believe that the assumptions that the economy is initially in a steady state and that the shocks are unexpected matter little for the estimated time series profile of Knightian uncertainty that we back up from the data.

[16]There are a few exceptions where the point estimates of β_{mt} and β_{rt} are positive even if they are not statistically different from zero. In these cases we set $\bar{v}_t = 0$ and/or $\bar{\epsilon}_t = 0$ which yield β_{mt} and/or β_{rt} equal to zero.

Figure 6: Monetary policy and real uncertainty in the UK

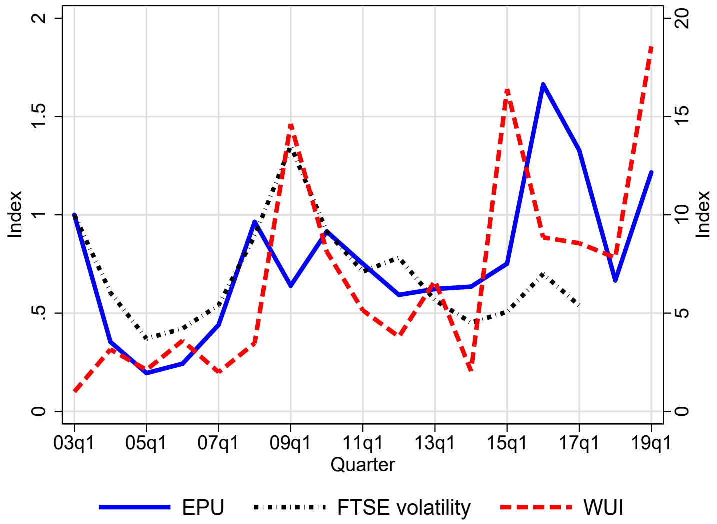


The top panel plots the point estimates for monetary policy uncertainty $\bar{v}_t$. The bottom panel plots the point estimates for real uncertainty, $\bar{\epsilon} - \underline{\epsilon}$. The grey areas corresponds to 90% confidence interval.

We compare the properties of $\bar{v}_t$ and $\bar{\epsilon}_t$ with those of other measures of uncertainty already proposed in the literature and plotted in Figure 7. The solid blue line corresponds to the Economic Policy Uncertainty (EPU) index by Baker, Bloom, and Davis (2016), the dashed red line to the World Uncertainty Index (WUI) by Ahir, Bloom, and Furceri (2018), constructed counting words related to uncertainty in official reports by the IMF, the dotted black line to the 360-day standard deviation of the return on the UK national stock market index (FTSE). Table 12 reports the correlation between our two measures of uncertainty (monetary and real) with the three measures in Figure 7. Monetary policy uncertainty is more strongly correlated with stock market volatility, suggesting that Knightian uncertainty about monetary policy is an important driver of the volatility of stock market returns, while its correlation with the EPU or WUI is quantitatively small, suggesting that monetary policy matters little for the overall amount of Economic Policy uncertainty present in the UK economy. Our measure of real uncertainty due to technology shocks is positively correlated with WUI and EPU, while its correlation with the volatility of stock market returns is even negative. This might suggest that the UK economy has faced some Knightian uncertainty over the period, but this uncertainty might fail to get reflected in stock market returns, whose volatility might mostly be due to the beliefs of the subset of creditor wealthy households who invest their financial wealth in stocks.

We now aggregate the consumption choices of all households in the economy and cal-

Figure 7: Other measures of uncertainty



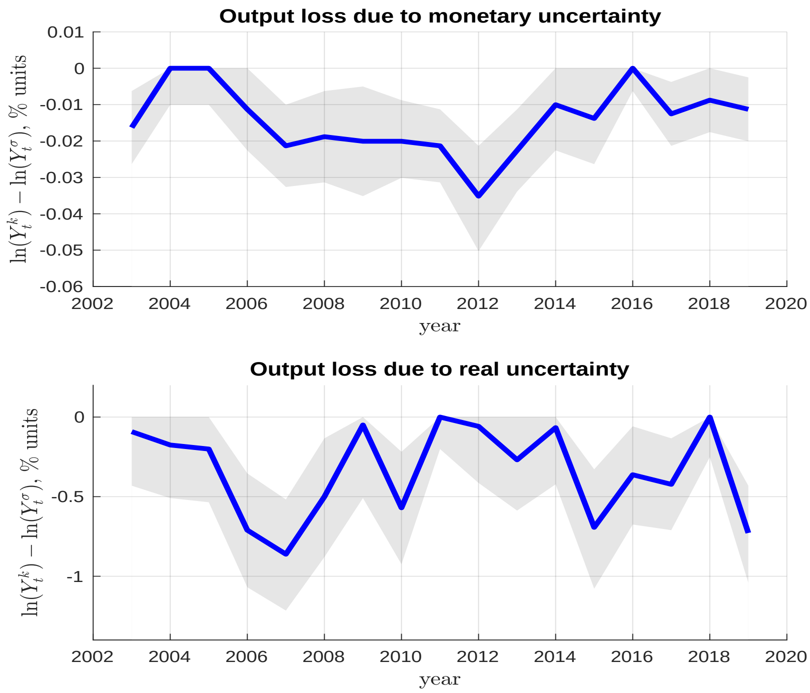
EPU stands for the Economic Policy Uncertainty index by Baker, Bloom, and Davis (2016) available at www.PolicyUncertainty.com. WUI is the World Uncertainty Index by Ahir, Bloom, and Furceri (2018). FTSE-Volatility is the 360-day standard deviation of the return on the national stock market index (FTSE) as calculated from the World-bank.

Table 12: Correlations with Knightian uncertainty

	Monetary: $\bar{v}_t$	Real: $\bar{\epsilon}_t$
EPU	-0.07	0.12
WUI	-0.06	0.29
Stock market volatility	0.41	-0.33

culate by how much aggregate output would have changed if households had processed uncertainty in the form of measurable risk. For each year t, we use our estimates for $\bar{v}_t$ and $\bar{\epsilon}_t$, aggregate the consumption choices of all households in the economy and then calculate by how much aggregate output would have changed (in general equilibrium) if households had processed uncertainty in the form of measurable risk with zero-mean innovations. Figure 8 plots the resulting deviation of output due to monetary uncertainty (top panel) and real uncertainty due to technology shocks (bottom panel). Monetary policy uncertainty has little effects on output while real uncertainty is highly contractionary on output. This happens because a large proportion of UK households tend to dislike inflation so when faced with uncertainty about monetary policy households act on the basis of subjective beliefs that tend to overpredict future inflation, which is expansionary on aggregate demand and stimulates the economy. The converse is true for technology shocks since households generally prefer a technology expansion to a technology regression. Real uncertainty has caused a reduction in aggregate output of almost a percentage point in 2007 and by more than half a percentage point in 2015.

Figure 8: Effects of uncertainty on output



The top panel plots the point estimates for the log-deviation of output under monetary uncertainty from output under measurable risk. The bottom panel plots the analogous contribution of uncertainty due to technology shocks. The grey areas correspond to the 90% confidence interval.

7 Conclusions

We found that under Knightian uncertainty, households base their actions on beliefs which are negatively distorted by their preferences, the more so the larger the amount of uncertainty they face. We used this insight to identify the amount of Knightian uncertainty about monetary policy and technology faced by UK households exploiting the Bank of England Inflation Attitudes Survey (BEIAS). A unique feature of BEIAS is that it inquires households about their expected inflation and their preferences about future inflation and future changes in nominal interest rates. We estimated the amount of Knightian uncertainty about monetary policy and technology using indirect inference, taking the regression coefficients for the effects of preferences on expected inflation as estimation targets. We find evidence that (i) Knightian uncertainty increases after major economic events such as the failure of Lehman Brothers or the referendum in favor of Brexit, (ii) it is driven partly by future monetary policy and partly by the economic environment, and (iii) it is only mildly correlated with other existing measures of uncertainty based on stock market volatility and counting of words in official reports or the social media. If households had treated uncertainty as measurable risk, output would have been substantially higher over the period at the beginning of the Great Recession and in recent years. Most of the contractionary effects of uncertainty are due to real uncertainty about technology shocks while monetary policy play little effects on output. Our measure of Knightian uncertainty can be calculated in real time, which might help policy makers in intervening to ameliorate households' perception about uncertainty to convert it into risk. If successful, these interventions be highly expansionary especially when uncertainty is about the economy (e.g. technology) rather than about monetary policy.

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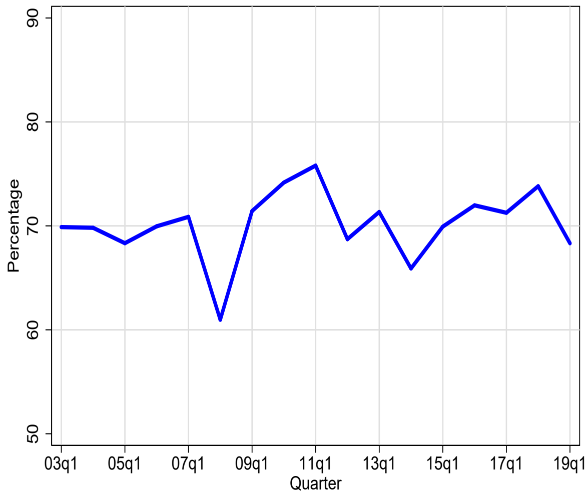
APPENDIX

Section A contains additional empirical results., Section B discusses computational details. Section C further analyzes the issue of reverse causality.

A Additional empirical results

Figure A1: Fraction of households reporting



The figure plots the fraction of households who report their preference for inflation and interest rates as well as their beliefs about future inflation.

Table A1: Descriptive statistics: Additional variables

VARIABLES	(1) mean	(2) sd	(3) N	(4) min	(5) max
Income below 9500	0.12	0.33	68,425.00	0.00	1.00
Income in 9500-17500 range	0.14	0.34	68,425.00	0.00	1.00
Income above 17500 below 25000	0.08	0.27	68,425.00	0.00	1.00
Income above 25000	0.66	0.47	68,425.00	0.00	1.00
Full or Part time employed	0.48	0.50	68,425.00	0.00	1.00
Dummy for male	0.47	0.50	68,425.00	0.00	1.00
Less than high school	0.25	0.43	68,425.00	0.00	1.00
High school degree	0.49	0.50	68,425.00	0.00	1.00
College degree or more	0.24	0.43	68,425.00	0.00	1.00
Dummy for age 15-24	0.13	0.33	68,425.00	0.00	1.00
Dummy for age 25-34	0.17	0.38	68,425.00	0.00	1.00
Dummy for age 35-44	0.17	0.37	68,425.00	0.00	1.00
Dummy for age 45-54	0.16	0.36	68,425.00	0.00	1.00
Dummy for age 55-64	0.14	0.35	68,425.00	0.00	1.00
Dummy for age 65+	0.24	0.43	68,425.00	0.00	1.00
Π^e brings forw. a major purchase	0.05	0.22	25,090.00	0.00	1.00
Π^e makes HH spend less	0.37	0.48	26,023.00	0.00	1.00
Π^e makes HH shop around more	0.48	0.50	26,259.00	0.00	1.00
Π^e makes HH push for pay increase	0.07	0.25	25,101.00	0.00	1.00
Π^e makes HH search for more inc.	0.13	0.34	25,383.00	0.00	1.00
Π^e makes HH save more in assets	0.09	0.29	25,205.00	0.00	1.00
Π^e makes HH do something else	0.30	0.46	24,973.00	0.00	1.00
Π^e makes HH takes no action	0.09	0.29	21,112.00	0.00	1.00
UK econ. needs high Π	0.08	0.27	68,425.00	0.00	1.00
UK econ. is indifferent on Π	0.21	0.41	68,425.00	0.00	1.00
UK econ. needs low Π	0.56	0.50	68,425.00	0.00	1.00
Dk whether UK needs Π	0.16	0.36	68,425.00	0.00	1.00
UK i should go up	0.18	0.38	68,425.00	0.00	1.00
UK i should go down	0.19	0.39	68,425.00	0.00	1.00
UK i should remain unchanged	0.36	0.48	68,425.00	0.00	1.00
UK i does no make anty difference	0.10	0.30	68,425.00	0.00	1.00
Dk whether UK needs change in i	0.18	0.38	68,425.00	0.00	1.00
BoE is independent	0.54	0.50	68,425.00	0.00	1.00
BoE sets i	0.67	0.47	68,425.00	0.00	1.00
HH knows Monetary Cmte.	0.33	0.47	68,425.00	0.00	1.00
Leaving in Northern Ireland	0.27	0.44	68,425.00	0.00	1.00
Leaving in Midlands	0.19	0.40	68,425.00	0.00	1.00
Leaving in Scotland	0.08	0.28	68,425.00	0.00	1.00
Leaving in Wales	0.13	0.34	68,425.00	0.00	1.00

Table A2: Table Calibration

NRS class × income × mortgage	Income (HH avg.)	Total Wealth (HH avg.)	NFA (HH avg.)	% who dislikes inflation	% who likes techn.	Mass of HHs
AB inc. <25 NO	0.17	5.96	5.20	0.76	0.42	0.09
AB inc. <25 YES	0.48	0.16	-1.74	0.58	0.82	0.02
AB inc. 25+ NO	2.27	9.31	7.21	0.69	0.48	0.04
AB inc. 25+ YES	2.39	-1.45	-4.07	0.60	0.80	0.10
C1 inc. <25 NO	0.16	3.27	2.80	0.72	0.59	0.13
C1 inc. <25 YES	0.46	-0.06	-1.81	0.57	0.86	0.03
C1 inc. 25+ NO	1.73	4.30	3.33	0.63	0.61	0.06
C1 inc. 25+ YES	2.06	-1.88	-3.83	0.55	0.83	0.14
C2 inc. <25 NO	0.19	1.94	1.33	0.67	0.66	0.14
C2 inc. <25 YES	0.47	-0.48	-2.71	0.56	0.87	0.03
C2 inc. 25+ NO	1.68	3.49	2.16	0.60	0.67	0.03
C2 inc. 25+ YES	1.78	-0.81	-4.43	0.50	0.86	0.04
DE inc. <25 NO	0.15	0.73	0.65	0.62	0.80	0.11
DE inc. <25 YES	0.40	-1.09	-2.26	0.54	0.88	0.01
DE inc. 25+ NO	1.66	1.14	0.91	0.52	0.76	0.01
DE inc. 25+ YES	1.54	-1.97	-2.62	0.48	0.84	0.02

Values are expressed as a fraction of average Annual net labor income of households in the economy (sum of employee income plus self-employed income) . Values are obtained from the Wealth and Assetts Suvey wave 3 (years 2010-2012). The fraction of households who likes technology corresponds to the fraction of households who dislikes inflation and likes low nominal interest rates among the population of households who dislikes inflation.

Table A3: Effects of Preferences on expected inflation: coefficients on controls

VARIABLES	(1) Π^e	(2) Π^e	(3) Π^e	(4) Π^e
Full or Part time employed		-0.06***	-0.06***	-0.05**
		(0.02)	(0.02)	(0.02)
Dummy for male		0.03**	0.04**	0.07***
		(0.02)	(0.02)	(0.02)
Less than high school		0.28***	0.29***	0.23***
		(0.07)	(0.07)	(0.07)
High school degree		0.17***	0.19***	0.16**
		(0.07)	(0.07)	(0.07)
College degree or more		0.06	0.08	0.08
		(0.07)	(0.07)	(0.07)
Dummy for age 25-34		-0.06*	-0.08**	-0.06*
		(0.03)	(0.03)	(0.03)
Dummy for age 35-44		0.15***	0.13***	0.18***
		(0.03)	(0.03)	(0.03)
Dummy for age 45-54		0.27***	0.27***	0.33***
		(0.03)	(0.03)	(0.03)
Dummy for age 55-64		0.29***	0.30***	0.38***
		(0.03)	(0.03)	(0.04)
Dummy for age 65+		0.13***	0.16***	0.27***
		(0.03)	(0.03)	(0.04)
Income below 9500		0.06	0.05	0.02
		(0.04)	(0.04)	(0.04)
Income in 9500-17500 range		0.05	0.04	0.02
		(0.03)	(0.04)	(0.03)
Income above 25000		-0.02	-0.03	-0.03
		(0.03)	(0.03)	(0.03)
Leaving in Northern Ireland		-0.02	-0.03	-0.04*
		(0.02)	(0.02)	(0.02)
Leaving in Midlands		0.00	0.01	-0.00
		(0.02)	(0.02)	(0.02)
Leaving in Scotland		-0.12***	-0.11***	-0.12***
		(0.03)	(0.03)	(0.03)
Leaving in Wales		-0.07**	-0.07**	-0.08***
		(0.03)	(0.03)	(0.03)
Observations	47,273	47,273	45,715	45,715
Method	OLS	OLS	OLS	OLS
R^2	0.08	0.09	0.09	0.10

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

The table reports the coefficients of a regression where dependent variable is expected inflation and regressors are listed by rows. The last row the p-value for the null hypothesis that all preference coefficients are equal to zero.

Table A4: Effects of Preferences on expected interest rates, Ordered Logit (No controls)

VARIABLES	(1) ie_down	(2) ie_equal	(3) ie_up
HH prefers i up	0.01***	0.04***	-0.05***
	(0.00)	(0.00)	(0.01)
HH prefers i down	-0.02***	-0.06***	0.09***
	(0.00)	(0.00)	(0.01)
Observations	44,284	44,284	44,284
Method	Ordered Logit	Ordered Logit	Ordered Logit
Variables	No Controls	No Controls	No Controls
Wald test	0.00	0.00	0.00

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

The table reports the average marginal effects on the probability of the future dynamics of (nominal) interest rates. The last row reports the p-value for the null hypothesis that all preference coefficients are all equal to zero.

Table A5: Effects of Preferences on expected interest rates, Ordered Probit

VARIABLES	(1) ie_down	(2) ie_equal	(3) ie_up
HH prefers i up	0.01***	0.02***	-0.03***
	(0.00)	(0.00)	(0.01)
HH prefers i down	-0.02***	-0.04***	0.06***
	(0.00)	(0.00)	(0.01)
Observations	44,284	44,284	44,284
Method	Ordered Probit	Ordered Probit	Ordered Probit
Variables	Yes Controls	Yes Controls	Yes Controls
Wald test	0.00	0.00	0.00

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

The table reports the average marginal effects on the probability of the future dynamics of (nominal) interest rates. The last row reports the p-value for the null hypothesis that all preference coefficients are all equal to zero. The controls are the same as in column 4 in Table 4.

Table A6: Effects of Preferences on expectations: Heterogeneity

VARIABLES	(1) Π^e	(2) Π^e
HH prefers high Π for low income	-0.17***	
	(0.06)	
HH prefers high Π for below median income	-0.12**	
	(0.05)	
HH prefers high Π for above median income	-0.15***	
	(0.02)	
HH prefers high Π for less than High School		-0.15***
		(0.05)
HH prefers high Π for High School		-0.13***
		(0.03)
HH prefers high Π for College Degree		-0.15***
		(0.04)
Observations	47,273	47,273
Method	OLS	OLS
R^2	0.10	0.10
Wald test for heterogeneity	0.82	0.88

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

The table reports the coefficients of a regression where dependent variable is expected inflation and regressors are listed by rows. Preferences for inflation varies by education, age and income. All regressions include as controls the same variables as in column (5) of Table 4.

B Model solution

We first derive some first order conditions that hold both at t_0 and at $t > t_0$. Then we solve for the equilibrium of the model at $t > t_0$. Finally we solve for the equilibrium at t_0. The solution method borrows from Michelacci and Paciello (2020).

Some first order conditions For given beliefs about the future, the path of consumption c_{it} and savings a_{it+1} of household i that maximize (2) solve the following Euler equation,

$$[(1-\tau_w)w_t + r_t a_{it} - a_{it+1} + \tau_{it}]^{-\sigma} = E_{it}\left[\beta r_{t+1}\left((1-\tau_w)w_{t+1} + r_{t+1}a_{it+1} - a_{it+2} + \tau_{it+1}\right)^{-\sigma}\right]. \tag{15}$$

with E_{it} denoting the expectations taken under the beliefs of household i. Under Knightian uncertainty, the household chooses her beliefs by minimizing the continuation utility in (2). Under measurable risk, all households have the same beliefs determined by the possible realization of shocks, which have equal probability in our case.

Firm j sets p_{jt} to maximize $E_{jt}\left[\sum_{T=t}^{\infty}\beta^{T-t}d_{jT}\right]$ where d_{jT} is defined in (3). While firms could have in principle different beliefs, they in practice set prices under the same expectations denoted by $E_t^f(\cdot)$ for all $j \in [0,1]$. This result follows from the assumption that firms set prices before the uncertainty/risk shock hits at $t = t_0$ and after the monetary and technology shocks gets realized at $t_0 + 1$. Hence firms post prices at $t = t_0$ under the belief that the economy is in steady state, and at $t > t_0$ under rational expectations. The first order condition for the firm pricing problem implies a standard New-Keynesian Phillips curve:

$$1 - \kappa_0\,\Pi_t\,(\Pi_t - 1) + \kappa_0\,E_t^f\left[\Pi_{t+1}\,(\Pi_{t+1} - 1)\frac{1}{r_{t+1}}\frac{Y_{t+1}}{Y_t}\right] = \theta\,(1 - s_t) \tag{16}$$

where the real interest rate is given by

$$r_t = R_{t-1}/\Pi_t, \tag{17}$$

and

$$s_t = \frac{w_t^{\alpha}e^{-\alpha\,z_t}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}$$

is the real marginal cost of production. The optimal input demand of firm j implies that

$$x_{it} = x_t = \frac{1-\alpha}{\alpha}\,w_t. \tag{18}$$

Using this result, aggregate output can be expressed as equal to

$$Y_t = y_{it} = e^{\alpha\,z_t}x_t^{1-\alpha} = e^{\alpha\,z_t}\left(\frac{1-\alpha}{\alpha}\,w_t\right)^{1-\alpha}. \tag{19}$$

We denote by $\bar{\tau}_t = \int \tau_{it}di$ the aggregate transfers to households at t.

The equilibrium at $t \geq t_0 + 1$ At $t \geq t_0 + 1$, there is perfect foresight, the economy aggregates into a representative household economy and (15) implies that real wages satisfy:

$$(1\text{-}\tau_w)w_t = (\beta r_{t+1})^{\frac{1}{\sigma}}(1\text{-}\tau_w)w_{t+1} + (\beta r_{t+1})^{\frac{1}{\sigma}}\bar{\tau}_{t+1} - \bar{\tau}_t + \left[(\beta r_{t+1})^{\frac{1}{\sigma}}(r_{t+1}A_{t+1}\text{-}A_{t+2}) - (r_t A_t\text{-}A_{t+1})\right],$$

where A_{t+1} is the supply of bonds at t determined by (7). Using this equation and the constraint of the government in (6) we obtain:

$$w_t = (\beta r_{t+1})^{\frac{1}{\sigma}}\left[w_{t+1} + D_{t+1} - G\right] - D_t - G, \tag{20}$$

where $D_t = Y_t - w_t - x_t - f - \kappa(\Pi_t, Y_t)$ denotes aggregate dividends (before taxes). Equations 16-20 determine the equilibrium dynamics of w_t, Π_t, x_t, Y_t and r_t at $t \geq t_0 + 1$ given the interest rate rule for R_t in (4), the aggregate transfers to households

$$\bar{\tau}_t = \bar{\tau} + m_t \int_0^1 \tau_{im} di + z_t \int_0^1 \tau_{iz} di,$$

and the law of motions of z_t and m_t:

$$z_t = \varrho_z\, z_{t-1} \quad \text{and} \quad m_t = \varrho_m\, m_{t-1}.$$

for given values z_{t_0+1} and m_{t_0+1}. We solve the model at $t \geq t_0 + 1$ by linearization. This yields the following expressions for inflation, nominal interest rates, real interest rates, real wages, and transfers for all $n = t - t_0 \geq 1$:

$$\begin{aligned}
\Pi_{t_0+n} &= 1 + \overline{\pi}_{mn}\, m_{t_0+1} + \overline{\pi}_{zn}\, z_{t_0+1}, &(21)\\
\ln R_{t_0+n} &= -\ln\beta + \overline{R}_{mn}\, m_{t_0+1} + \overline{R}_{zn}\, z_{t_0+1}, &(22)\\
r_{t_0+n} &= -\ln\beta + \overline{r}_{mn}\, m_{t_0+1} + \overline{r}_{zn}\, z_{t_0+1}, &(23)\\
\ln w_{t_0+n} &= \ln\overline{w} + \overline{w}_{mn}\, m_{t_0+1} + \overline{w}_{zn}\, z_{t_0+1}, &(24)\\
\ln \tau_{i\,t_0+n} &= \ln\bar{\tau} + \bar{\tau}_{im}\, \varrho_m^{n-1}\, m_{t_0+1} + \bar{\tau}_{iz}\, \varrho_z^{n-1}\, z_{t_0+1}. &(25)
\end{aligned}$$

Equilibrium under homogeneous beliefs When β_t evolves as in (??), the economy is fully characterized by the tuple $\left[D_t, Y_t, C_t, \Pi_t, R_t, w_t, r_t, q_t^b, q_t^e\right]$, where (i) D_t and Y_t are given by (??) and (??); (ii) inflation Π_t satisfies the Phillips curve in (??) under perfect foresight; (iii) the nominal interest rate is given by (??); (iv) the interest rate satisfies the identity $r_t = R_{t-1}/\Pi_t$; (v) aggregate labor supply and consumption solve a representative household problem that yields (??) and

$$C_t = \frac{\eta \sum_{s=t}^{\infty} m_{ts}\ (w_s + D_s)}{\sum_{s=t}^{\infty} \left(\frac{w_s}{w_t}\right)^{(1-\eta)\left(1-\frac{1}{\sigma}\right)} m_{ts}^{1-\frac{1}{\sigma}}\ \beta_{ts}^{\frac{1}{\sigma}}}; \tag{26}$$

and (vi) there is no trade in long-term bonds and equity at the equilibrium prices that satisfy

$$q_t^b = \frac{\nu_{t+1} + q_{t+1}^b}{r_{t+1}}, \tag{27}$$

$$q_t^e = \frac{d_{t+1} + q_{t+1}^e}{r_{t+1}}. \tag{28}$$

With our calibration we have standard predictions for the responses of the variables: $\overline{w}_{mn} > 0$, $\overline{w}_{zn} > 0$, $\overline{\pi}_{mn} > 0$, $\overline{\pi}_{zn} < 0$, $\overline{R}_{mn} < 0$, $\overline{R}_{zn} < 0$, $\overline{r}_{mn} < 0$ and $\overline{r}_{zn} < 0$ for all n. This means that both an increase in productivity or an inflationary monetary shock reduces capital income and increases labor income (albeit with different intensity) to all households. Transfers may increase or decrease after each shock and for a given household depending on the choice of the parameters $\bar{\tau}_{im}$ and $\bar{\tau}_{iz}$.

The equilibrium at $t = t_0$ under uncertainty In solving her problem at t_0, the household i takes the solution at $t_0 + 1$ as given. The economy is initially in steady state at t_0. Then the uncertainty shock about the possible realizations of z_{t_0+1} and m_{t_0+1} materializes. Index the realizations at t_0+1 by $u \in \mathscr{U} \equiv \{l, h\} \times \{l, h\}$: a two-dimensional vector containing the possible realizations of of z_{t_0+1} and m_{t_0+1}. Since firms have already set their price, we have $\Pi_{t_0} = 1$, implying $r_{t_0} = 1/\beta$ and $R_{t_0} = 1/\beta$. Equations (18) and (19) determine x_{t_0} and Y_{t_0} for given w_{t_0}. We only need to solve for w_{t_0} and the beliefs of households at $t = t_0$. We first characterize the equilibrium wage for given beliefs. Let $q_{tt} = 1$ and $q_{tT} = (\prod_{j=t+1}^{T} r_j)^{-1}$ $\forall T > t$. Conditional on the realization of the shocks $u \in \mathscr{U}$ at $t_0 + 1$, and after using (15) and the household budget constraint, we obtain that consumption at $t_0 + 1$ is equal to

$$c_{it_0+1}^u = (1 - s_{t_0+1}^u) \left\{ \sum_{T=t_0+1}^{\infty} q_{t_0+1T}^u \left[(1-\tau_w) w_T^u + \tau_{iT}^u\right] + r_{t_0+1}^u a_{it_0+1} \right\} \tag{29}$$

where $s_{t_0+1}^u$ is the saving rate out of the presented discounted value of income at $t_0 + 1$, and defined for all $t > t_0$ as

$$s_t^u = 1 - \frac{1}{\sum_{T=t}^{\infty} (q_{tT}^u)^{1-\frac{1}{\sigma}} \beta^{\frac{T-t}{\sigma}}}. \tag{30}$$

The values of w_t^u, τ_{it}^u and r_t^u are obtained from from the previously discussed solution of the model at $t \geq t_0 + 1$, and are independent of the distribution of households' beliefs at t_0 given the economy aggregates as a representative household economy at $t \geq t_0 + 1$. Then using (15) at t_0 conditional on agent i having degenerate beliefs u, we obtain

$$c_{it_0}^u = \left(\beta r_{t_0+1}^u\right)^{-\frac{1}{\sigma}} c_{it_0+1}^u.$$

Then we use the budget constraint in period t_0 to solve for a_{it_0+1}, which yields

$$a^u_{it_0+1} = \left[1 + \beta^{-\frac{1}{\sigma}} \left(r^u_{t_0+1}\right)^{1-\frac{1}{\sigma}} (1 - s^u_{t_0+1})\right]^{-1} \left[\frac{a_{it_0}}{\beta} + (1-\tau_w)w_{t_0} - \left(\beta r^u_{t_0+1}\right)^{-\frac{1}{\sigma}} (1 - s^u_{t_0+1})\, \tilde{y}^u_{t_0+1}\right], \tag{31}$$

where we have used $r_{t_0} = 1/\beta$, and we have defined

$$\tilde{y}^u_{t_0+1} \equiv \sum_{T=t_0+1}^{\infty} q^u_{t_0+1T} \left[(1-\tau_w)w^u_T + \tau^u_{iT}\right]$$

as the present discounted value of future labor income and transfers. Let u_i denote the beliefs of household i. We solve for the value of w_{t_0} that guarantees that the financial market clears at t_0:

$$\int a^{u_i}_{it_0+1} di = A_{t_0+1}. \tag{32}$$

given the supply of bonds A_{t_0+1} is determined with equations (6)-(7), and it's only a function of w_{t_0}:

$$A_{t_0+1} = \frac{\bar{A}}{\beta} + G + w_{t_0} \left(1 - \tau_w + \frac{1-\alpha}{\alpha}\right) + f - \left(\frac{1-\alpha}{\alpha} w_{t_0}\right)^{1-\alpha}. \tag{33}$$

where $\bar{A}$ is the steady state supply. Equation (32) determines the equilibrium wage at t_0 for given distribution of households' beliefs. We are left to determine the equilibrium worst-case beliefs of households under uncertainty: the value of u for each household i (previously denoted u_i). The continuation value of household i conditional on the combination u of the shocks at $t_0 + 1$ is given by

$$V^u_i = \sum_{t=t_0+1}^{\infty} \beta^{t-t_0-1} \frac{(c^u_{it})^{1-\sigma}}{1-\sigma}$$

where using the inter-temporal Euler equation we have that for all $t > t_0 + 1$

$$c^u_{it} = \left(\prod_{T=t_0+2}^{t} \beta\, r^u_T\right)^{\frac{1}{\sigma}} c^u_{it_0+1} = \beta^{\frac{t-t_0-1}{\sigma}} \left(q^u_{t_0+1t}\right)^{-\frac{1}{\sigma}} c^u_{it_0+1} \tag{34}$$

implying

$$V^u_i = \frac{(c^u_{it_0+1})^{1-\sigma}}{1-\sigma} \sum_{t=t_0+1}^{\infty} \beta^{\frac{t-t_0-1}{\sigma}} \left(q^u_{t_0+1t}\right)^{1-\frac{1}{\sigma}} = \frac{(c^u_{it_0+1})^{1-\sigma}}{1-\sigma} \frac{1}{1-s^u_{t_0+1}}.$$

where $c^u_{it_0+1}$ is given by (29) with a_{it_0+1} expressed as function of w_{t_0} as given by (35). Given V^u_i $\forall u$ and for each household i, we calculate the value of u that minimizes V^u_i, which yields the worst case beliefs of household i, u_i, given a value of w_{t_0}. We keep iterating over w_{t_0} until the w_{t_0} that makes (32) satisfied and households' worst case beliefs are consistent one with the others.

The equilibrium at $t = t_0$ under risk The model with risk is solved by assuming that all households in the economy attributes to each possible realization of $u \in \mathscr{U}$ at $t_0 + 1$ a probability of one-fourth. Equilibrium consumption at t_0 is given by

$$c_{it_0} = \frac{1}{4} \sum_{u \in \mathscr{U}} \left(\beta r^u_{t_0+1}\right)^{-\frac{1}{\sigma}} c^u_{it_0+1}.$$

where $c^u_{it_0+1}$ is still given by (29) for a given realization of u. Then we use the budget constraint in period t_0 to solve for a_{it_0+1}, which yields

$$a_{it_0+1} = \frac{\frac{a_{it_0}}{\beta} + (1 - \tau_w) w_{t_0} - \frac{1}{4} \sum_{u \in \mathscr{U}} \left(\beta r^u_{t_0+1}\right)^{-\frac{1}{\sigma}} \left(1 - s^u_{t_0+1}\right) \tilde{y}^u_{t_0+1}}{1 + \beta^{-\frac{1}{\sigma}} \frac{1}{4} \sum_{u \in \mathscr{U}} \left(r^u_{t_0+1}\right)^{1-\frac{1}{\sigma}} \left(1 - s^u_{t_0+1}\right)}. \tag{35}$$

The wage w_{t_0} should guarantee that the financial market clears at t_0, $\int a_{it_0+1} di = A_{t_0+1}$, which implies that

$$A_{t_0+1} = \frac{\frac{\bar{A}}{\beta} + (1 - \tau_w) w_{t_0} - \frac{1}{4} \sum_{u \in \mathscr{U}} \left(\beta r^u_{t_0+1}\right)^{-\frac{1}{\sigma}} \left(1 - s^u_{t_0+1}\right) \tilde{y}^u_{t_0+1}}{1 + \beta^{-\frac{1}{\sigma}} \frac{1}{4} \sum_{u \in \mathscr{U}} \left(r^u_{t_0+1}\right)^{1-\frac{1}{\sigma}} \left(1 - s^u_{t_0+1}\right)}.$$

We use this equation together with (33) to solve for w_{t_0} under risk.

C Reversed causality

We ran regressions of the type

$$\Pi^e_i = \varkappa X_i - \beta_m d^m_i + \epsilon_i, \tag{36}$$

where Π^e_i denotes household expected inflation, the set of control X_i plus the residuals ϵ_i accounts for variation in rational expectation beliefs $E^\sigma_i(\Pi_{t+1})$ across households and d^m_i is the household' preference dummy for inflation. For simplicity, we omit introducing the dummy for household preferences over interest rates changes. Assume that in the economy there are two types of households. A fraction α of households have preferences over inflation as in (13): for given s and over the empirically relevant range of variation of $E^\sigma_i(\Pi_{t+1})$, the dummy for preferences over inflation d^m never switches sign because of changes in rational expectation beliefs $E^\sigma_i(\Pi_{t+1})$. The second type of households, a fraction $1 - \alpha$ of the population, have a desired level of inflation Π^* (possibly heterogenous across households) strictly within the empirically relevant range of variation of $E^\sigma_i(\Pi_{t+1})$. Let $\Delta_i \equiv E^\sigma_i(\Pi_{t+1}) - \Pi^*(s_i)$ denote the difference between household's rational expectation beliefs and her desired level of inflation Π^*. Then household's preferences over inflation is characterized by a dummy

$$d_{i2}^m = \mathbb{I}\left(\Delta_i < 0\right), \tag{37}$$

which is a step function, decreasing in Δ_i, equal to one if household's expected inflation is lower than her desired level of inflation, $\Delta_i < 0$, and zero otherwise. For expositional simplicity, we also assume that these type 2 households behave as under rational expectations: they report beliefs $E_i^\sigma(\Pi_{t+1})$. The presence of some households with preferences over inflation affected by $E_i^\sigma(\Pi_{t+1})$ can cause an upward bias in our measure of Knightian uncertainty β_m obtained by estimating (36) with OLS: since a fraction $1-\alpha$ of households are more likely to prefer higher inflation when $E_i^\sigma(\Pi_{t+1})$ is low, the dummy d_i^m in (36) is negatively correlated with the residual ϵ_i, which makes the OLS estimate of β_m upward biased. The correlation between d^m and ϵ is smaller (in absolute value), when the fraction of households who switch preferences over inflation due to changes in rational expectation beliefs is smaller (greater α) and disappears when $\alpha = 1$.

In the paper we address this reverse causality problem in two ways. In one we instrument d^m in (36) with some deep determinants of household preferences over inflation. If s is uncorrelated with ϵ, this would be enough to correct for the possible correlation between d^m and ϵ in (36).

In the other we observe that the reverse causality problem is likely to be less relevant in the tails of the distribution of expected inflation. When households have consistently very low ϵ or very high ϵ, the variation of $E_i^\sigma(\Pi_{t+1})$ within the sample is unlikely to cause a switch in the sign of Δ_i of the type 2 households in the sample: for given Π^* the Δ_i's of type-2 households tend to be all negative when ϵ is sufficiently low, $\epsilon \in \underline{\Xi}$, all positive when ϵ is sufficiently high, $\epsilon \in \overline{\Xi}$. In the former case, all type-2 households in the sample end up having $d_2^m = 1$, in the latter case $d_2^m = 0$. Under this assumption, the self-reported average beliefs of households in the population conditional to $\epsilon \in \underline{\Xi}$ or $\epsilon \in \overline{\Xi}$ can be expressed as equal to

$$\Pi^e = \begin{cases} \alpha\underline{\Pi}_1^\sigma + \left[(1-\alpha)\underline{\Pi}_2^\sigma - \alpha\beta_m\right] d^m, & \text{if } \epsilon \in \underline{\Xi} \\ \alpha\overline{\Pi}_1^\sigma + (1-\alpha)\overline{\Pi}_2^\sigma - \alpha\beta_m d^m, & \text{if } \epsilon \in \overline{\Xi} \end{cases} \tag{38}$$

where $\underline{\Pi}_j^\sigma$ is the average rational expectation beliefs of households of type $j = 1, 2$ in the sample with $\epsilon \in \underline{\Xi}$, while $\overline{\Pi}_j^\sigma$ is the analogous average beliefs of type j households in the sample with $\epsilon \in \overline{\Xi}$. (38) implies that by comparing the coefficient β_m for d^m estimated in the full sample with the analogous coefficient estimated in the subsamples with $\epsilon \in \underline{\Xi}$ and $\epsilon \in \overline{\Xi}$, we can detect whether reverse causation drives our results. The estimate for β_m in the subsample where $\epsilon \in \underline{\Xi}$ is smaller than the estimate obtained in the subsample where $\epsilon \in \overline{\Xi}$. Importantly, when the estimated value of β_m in the full sample is equal to the estimated value in the sample with $\epsilon \in \overline{\Xi}$, we have evidence that $\alpha = 1$, which would indicate that reverse causation matters little for our empirical results.