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THE MANY SHADES OF UNCERTAINTY AND MONETARY POLICY

by Elisa Guglielminetti*, Alessandro Lin* and Andrea Tiseno*

Abstract

This paper reviews how different sources of uncertainty influence monetary policy design and transmission. Within a New Keynesian framework, we distinguish between uncertainty arising from non-linearities in the economy and that stemming from imperfect information held by either the central bank or the private sector. While uncertainty is neutral under linearity and full-information rational expectations, departures from these conditions render it consequential for monetary policy. Non-linearities and information frictions alter the optimal degree of policy gradualism and may warrant either more forceful or more cautious responses. The proposed taxonomy offers a structured approach for policy discussions concerning appropriate monetary responses and communication strategies in the face of different types of uncertainty.

JEL Classification: D81, D84, E52, E58, E61.

Keywords: uncertainty, monetary policy, non-linearities, information frictions.

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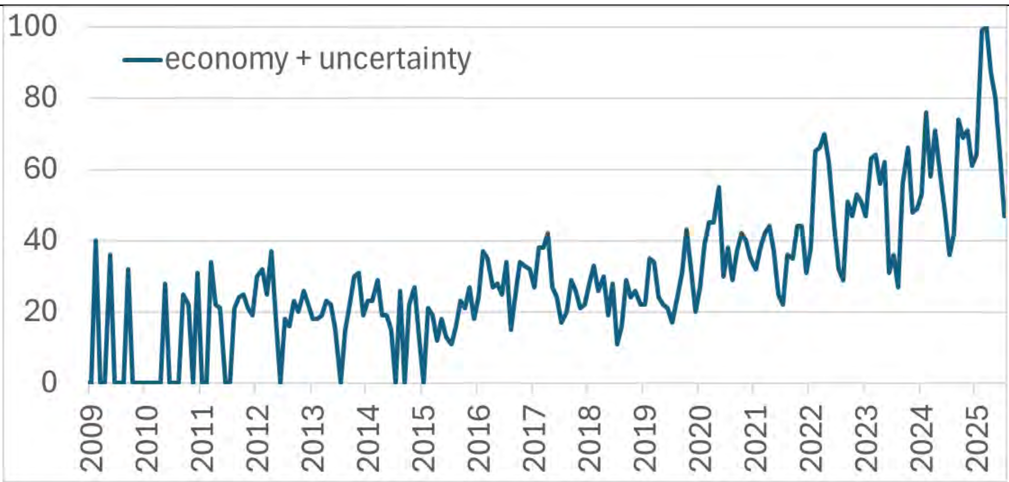
1. Introduction

Since 2020, the term uncertainty has gained prominence in public debate, academic research, and monetary policy discussions. Figure 1 shows Google search index for the couple "economy+uncertainty", starting from 2009. The series displays a clear upward trend since the outbreak of the Covid-19 pandemic, suggesting increased public attention to the topic.

Figure 1: Google search index for the words "economy" and "uncertainty"



Source: Google Trends. *Notes*: the figure reports the relative popularity over time of the Google searches that *jointly* include "economy" and "uncertainty". The series is normalized to 100 at the peak and corresponds to worldwide searches. Note that Google Trends uses random sampling of search data so that the same queries may yield different time series outputs.

Uncertainty has likewise become a central concern for policymakers. Importantly, uncertainty may stem from different sources, each with potentially distinct policy implications. This complexity is reflected, for example, in the ECB Monetary Policy Accounts from the March 2025 Governing Council meeting: *"Looking ahead, the point was made that the likely shocks on the horizon, including from escalating trade tensions, and uncertainty more generally, risked significantly weighing on growth. It was argued that these factors could increase the risk of undershooting the inflation target in the medium term. […] From this perspective, it was argued that being prudent in the face of uncertainty did not necessarily equate to being gradual in adjusting the interest rate. By contrast, it was contended that high levels of uncertainty, including in relation to trade policies, fiscal policy developments and sticky services and domestic inflation, called for caution in policy-setting and especially in communication."*

This quote highlights the multifaceted nature of uncertainty, which complicates the derivation of general prescriptions regarding the direction, the magnitude, and the pace of the monetary policy response. Throughout this note, "uncertainty" will denote the situation in which key aspects of the economic environment are not known with certainty today –

whether relating to the realization of future shocks or to structural parameters governing the economy.[1]

The objective of this note is to examine the implications of alternative forms of uncertainty for the conduct of monetary policy. We begin by offering a formal definition of uncertainty within the framework of a standard three-equation New Keynesian model. This setup is then used to organize and illustrate key findings from the literature on how different types of uncertainty affect economic decision-making.[2]

Our review highlights that uncertainty can originate from diverse sources and affect different economic agents in heterogeneous ways, often warranting differentiated policy responses. Table 1 summarizes these sources, by distinguishing (*i*) why uncertainty matters for decision-making – whether due to departures from the linearity assumption or the presence of imperfect information – and, in the latter case, *(ii)* which agents hold less information and are thus more uncertain (policymakers, the private sector, or both). For each category, we provide illustrative examples and highlight the main policy implications.

Table 1. different types of uncertainty and policy implications

Source of uncertainty relevance	Mechanism	Example	Policy implication
Departures from linearity	Aggregate non-linearities	I. Non-linear Phillips curve	Increased concerns for inflationary shocks
		II. Effective Lower Bound	Increased concerns for deflationary shocks
	Relevance of risk and uncertainty for households' and firms' decisions	III. Precautionary savings and reduced investment sensitivity to interest rates	Aggressive/prolonged easing
Departures from FIRE: uncertainty of the central bank	Imperfect information on the current state of the economy	IV. Uncertainty about the state of the economy even after the shock have materialized	Milder and slower response
	Imperfect information on structural parameters	V. Slope of the Phillips curve	Gradual response
		VI. + expectations de-anchoring	More aggressive response
	Imperfect information on shock distribution	VII. Knightian uncertainty	Robust policy
Departures from FIRE: uncertainty of the private sector	Imperfect information on the macroeconomy	VIII. Misinterpretation of the state of the economy	More aggressive response
		IX. Misinterpretation of policy actions and communication	Improve communication to guide agents' expectations

[1] Note that it is useful to clarify that our definition of uncertainty is conceptually different from that of risk. While a detailed distinction between the two concepts lies beyond the scope of this note, following the risk management guidelines ISO 31000, risk is the "effect of uncertainty on objectives". This implies that uncertainty precedes risk, and the latter can only be articulated in relation to specific goals. The definitions of uncertainty and risk we adopt in this note is only one among others proposed in the literature. It differs, for instance, from the distinction provided by Knight (1921), who posited that risk can be quantified using probabilities while uncertainty is not measurable.

[2] The list of situations we take into consideration is not meant to be exhaustive. For a complementary discussion on measurement, assessment, and communication of risks and uncertainty that are relevant for monetary policy, see Bauer et al. (2025).

2. Uncertainty in a simple New Keynesian model

In this section, we define uncertainty within the simple three-equation New Keynesian model (Gali, 2015, Woodford, 2003). This micro-founded dynamic general equilibrium model – widely used as a benchmark for monetary policy analysis – consists of the following equations:[3]

$$x_t = E_t x_{t+1} - \frac{1}{\sigma}(i_t - E_t \pi_{t+1} - r_t^n) \quad (1)$$
$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t \quad (2)$$
$$i_t = \bar{\iota} + \phi \pi_t + \mu_t \quad (3)$$

where x_t is output gap, π_t is inflation, i_t is the nominal interest rate. E_t is the expectation operator conditional on information available at time t. The discount factor β, the (inverse) elasticity of intertemporal substitution σ, and the slope of the Phillips curve κ are parameters that define the structure of the economy. The parameters $\bar{\iota}$ and ϕ govern the monetary policy rule. Finally, μ_t, u_t, and r_t^n represent exogenous stochastic processes also commonly known as monetary, cost-push, and natural rate (or more generally aggregate demand) shocks. Uncertainty around those processes translates into uncertainty in the outcome variables π_t and x_t, both of which are of interest to the central bank. The model allows in principle to also incorporate uncertainty regarding parameters; we abstract from it in the rest of this section and come back to it in Section 4.1.2.

The typical assumptions around the exogenous processes are: 1) they are independent from each other; and 2) each process is symmetric around the mean and has a finite second moment.[4] In some way, a natural interpretation of those second moments is that they represent the degree of unpredictability of the future equilibrium, i.e. a form of uncertainty.

Beyond the conditions of linearity (namely that the model is represented by (1)-(3) and that its parameters are known with certainty), an important assumption is that agents act under full information and rational expectations (FIRE). This essentially means that the model is internally consistent from the perspective of each agent (the central bank and private agents), that expectations around the stochastic processes are commonly shared, and that the expectation operator reflects the true (in a statistical sense) conditional expectation across all possible states of the world.

Under these conditions, the *current* equilibrium allocations depend on both *current* and *future* realizations of the exogenous processes. The presence of the expectation operator

[3] As in the typical setup, those equations are derived as first-order approximations of a nonlinear model around a deterministic steady state. See Benigno and Rossi (2021) for an analysis of the New Keynesian model with higher order approximation.

[4] A widely used assumption is for the exogenous processes to be normally distributed around a zero-mean, e.g.: $u_t \sim N(0, \sigma_u^2 < \infty)$. It is also not uncommon to introduce some persistence to these processes, e.g.: $u_t \sim N_{t-1}(\rho u_{t-1}, \sigma_u^2 < \infty)$ with $|\rho| < 1$.

means that the *current* equilibrium also depends on the foreseen *future* equilibrium allocations, which themselves depend on the realizations of *future* shocks.[5]

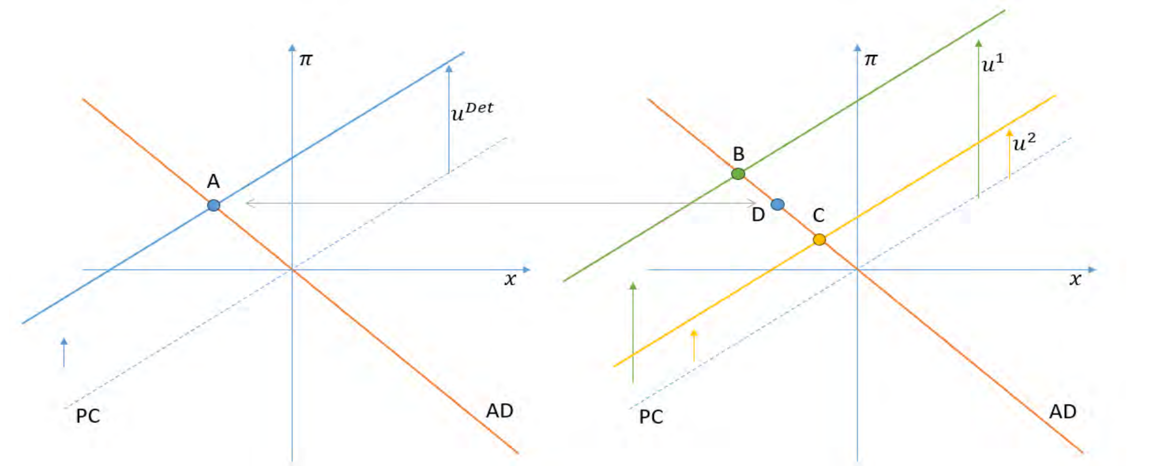
2.1 *The certainty equivalence result*

Under the described conditions, a well-known "certainty equivalence" result yields. This result implies that uncertainty is policy irrelevant: the optimal policy under uncertainty is the same as if all random variables were replaced by their expected values (Theil, 1957). In other words, it states that increasing the uncertainty around shocks (increasing their second moments) has no implications for the model dynamics and, consequently, there are also no implications for the optimal policy setup.

This result is represented with a simple example in Figure 2. Assume that all agents are informed at $t = 0$ that, with certainty, all exogenous processes are shut down except for a positive cost-push shock at $t = 1$, that is $u_{t \neq 1} = 0$ and $u_1 = u^{Det} > 0$. At $t = 1$, this moves the Phillips Curve (PC) and the equilibrium goes from the origin to A (Figure 2, panel a). The resulting equilibrium with higher inflation and lower output gap will also move the Aggregate Demand (AD) and Phillips curves at $t = 0$, by certain amounts, via expectations.

Figure 2: a graphical representation of the certainty equivalence result

a) Deterministic case	b) Stochastic case



Notes: the figure reports the effects of a cost-push shock in the simple New Keynesian model described by equations (1)-(3). Effects are shown in a deterministic world (left panel) and in a comparable stochastic world (right panel).

Now consider a similar world, with a small amount of uncertainty: agents are informed at $t = 0$ that u_1 will be $u^H > u^{Det}$, with probability α, or $u^L < u^{Det}$, with probability $1 - \alpha$ (Figure 2, panel b). Furthermore, assume that the expected value is equal to that in the first world, i.e.: $\alpha u^H + (1 - \alpha) u^L = u^{Det}$. In this case, there are two distinct possible states of the world at $t = 1$, with different equilibrium inflation rates and output gaps (represented by the equilibria B and C). Despite this, thanks to the linearity of the model, the expected

[5] For current shocks, a monetary policy shock μ_t or a natural rate change r_t^n results in output gap and inflation moving in the same direction, while a cost-push shock u_t moves them in opposite ways. See Figure A.1 for a graphical representation.

inflation rate and output gap, at $t = 1$ from the perspective of $t = 0$, will not differ from the first case (D in the right panel equals A on the left panel). Therefore, the consequent movements of AD and PC at $t = 0$ are identical to the first case.

Taken altogether uncertainty about the realization of shocks has no bearing on the optimal policy prescription in the standard linear framework. Once we depart from this benchmark, however, uncertainty can affect the central bank's optimal policy response.

Section 3 examines how departures from the linear framework modify policy prescriptions, even when uncertainty is confined to the realization of fundamental shocks - an inherent feature of any stochastic model. Section 4 still considers a linear setting but relaxes the FIRE assumption, introducing imperfect information on the part of either the central bank or the private sector. These informational frictions introduce additional uncertainty—specifically, about the measurement of variables or parameters—which persists even after shocks occur, due to limited observability.

3. Uncertainty and non-linearities

In this section we consider several cases in which uncertainty about fundamental shocks can influence monetary policy through the presence of non-linearities in the economy. In particular, uncertainty exacerbates the asymmetric effects implied by non-linearities, thereby affecting the incentives and the transmission of monetary policy. In this Section we examine a few examples.[6]

3.1 *Aggregate non-linearities*

3.1.1 Non-linear Phillips curve

We begin with the case of a non-linear Phillips curve. We modify equation (2) as:

$$\pi_t = \beta\, E_t\, \pi_{t+1} + \kappa\, x_t + u_t + 1_{x_t \geq \bar{x}_t}\, \psi\, (x_t - \bar{x}_t\,) \quad (4)$$

where ψ represents the ''additional steepness'' that the economy faces when the output gap x_t is above the threshold $\bar{x}_t$.

Interest in this hypothesis has revived in the aftermath of the recent inflation surge. Several micro-foundations have been proposed, including overheated labour market, supply bottlenecks, and capacity constraints, (see Benigno and Eggertsson, 2024, Comin et al., 2024, Gitti, 2024, among others). The common underlying idea is that in some states of the world, firms are no longer able to satisfy the demand at prevailing prices and therefore

[6] Other relevant examples not considered here include non-linearities stemming from financial amplification and price spirals.

increase prices more than they would in normal times. This behaviour effectively steepens the slope of the Phillips curve.[7]

To illustrate the mechanism, consider the impact of a demand shock, in a similar fashion as in the example in Section 2. Suppose that at $t = 0$, all agents know with certainty that all exogenous processes are shut down except for a positive demand shock occurring at $t = 1$. Formally, $r^n_{t\neq 1} = r^n_{ss}$ and $r^n_1 = r^{n,Det} > r^n_{ss}$. At $t = 1$, the AD shifts, moving the economy from the initial equilibrium (the origin) to point A (Figure 3, panel a). Knowing with certainty this new allocation – characterized by higher inflation and a positive output gap – the AD and the PC curves shift already at $t = 0$, implying an increase in inflation via expectations.

Now consider a similar environment with a small amount of uncertainty. At $t = 0$ agents are informed that r^n_1 will take one of two possible values: $r^{n,1} > r^{n,Det}$, with probability α, or $r^{n,2} < r^{n,Det}$, with probability $1 - \alpha$ (where $\alpha r^{n,1} + (1 - \alpha) r^{n,2} = r^{n,Det}$). At $t = 1$, the economy can thus be in one of two possible states, corresponding to equilibria B and C in Figure 3, panel b (equilibrium A is also shown for comparison).

As shown in Figure 3, the certainty equivalence result does not hold in this setting: the average inflation rate and output gap at $t = 1$, conditional on information at $t = 0$, differs from those of the deterministic case (point D in the right panel versus point A). In particular, the average inflation (output gap) at D is higher (lower), relative to A. This implies that the adjustment of AD and PC at $t = 0$ deviates from the deterministic case.[8] In other words, in the presence of aggregate uncertainty, when a demand shock faces a convex Phillips curve, the central bank has stronger incentives to respond more aggressively than it would under certainty.[9]

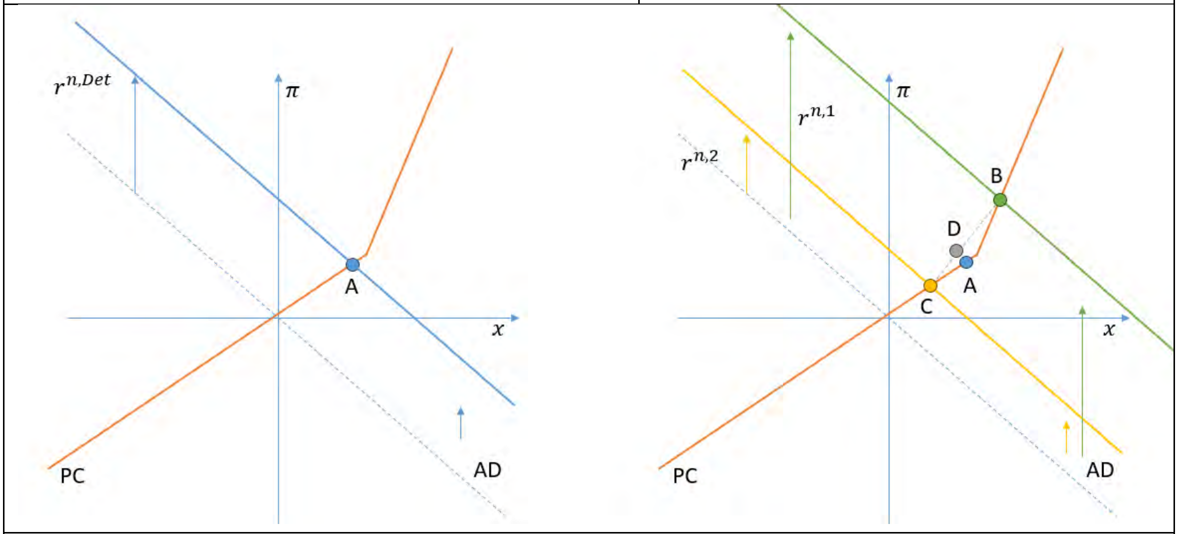
[7] A popular alternative in generating time-varying slopes of the Phillips curve are the state-dependent pricing models. Those models provide microfoundations to the firms' pricing decisions (both on the intensive and extensive margins) making the slope of the Phillips curve endogenous to the state of the economy. See for instance Ascari et al. (2025), Blanco et al. (2024,2025), Cavallo et al. (2024), Gasteiger and Grimaud (2023), among others.

[8] It is possible to show under typical parametrizations that the overall effect on inflation is positive.

[9] Gitti et al. (2025) find similar results: the appropriate response of the central bank to capacity shocks can be more aggressive if the environment is characterized by aggregate uncertainty and a convex PC.

Figure 3: demand shock with a nonlinear Phillips curve

a) Deterministic case | b) Stochastic case



Notes: the figure reports the effects of a positive demand shock in the New Keynesian model with nonlinear Phillips curve, as described by equations (1), (3), and (4). Effects are shown in a deterministic world (left panel) and in a comparable stochastic world (right panel).

3.1.2 Occasionally binding ELB

Consider an environment in which the nominal interest rate is close to the Effective Lower Bound (ELB). In the New-Keynesian model, this means changing equation (3) by imposing:

$$i_t = \max\{\bar{\imath} + \phi\, \pi_t + \mu_t, 0\}. \quad (5)$$

Once the interest rate reaches the ELB, the central bank cannot provide further stimulus by lowering the policy rate. This introduces a non-linearity that became particularly salient in the aftermath of the Great Recession and again following the outbreak of Covid-19.

The ELB inherent non-linearity, or asymmetry, implies that certainty equivalence may no longer hold.[10] In particular, if a shock raises inflation, the central bank faces no limit in hiking the policy rates to counteract inflationary pressures. On the contrary, if the shock is deflationary, the ELB prevents a symmetric policy response, limiting the central bank's ability to offset the downward pressure on inflation.

To illustrate the case, consider the same type of experiment as in the non-linear Phillips curve example above, but with negative shocks and the ELB constraint (5).[11] As shown in Figure 4, certainty equivalence breaks down: the average inflation rate and output gap at $t = 1$, conditional on information at $t = 0$, are both lower than in the deterministic case (point

[10] It is worth pointing out that the non-linearity associated with the ELB can also be interpreted as imposing different regimes. Consequently, fundamental uncertainties can translate to regime/state uncertainties.

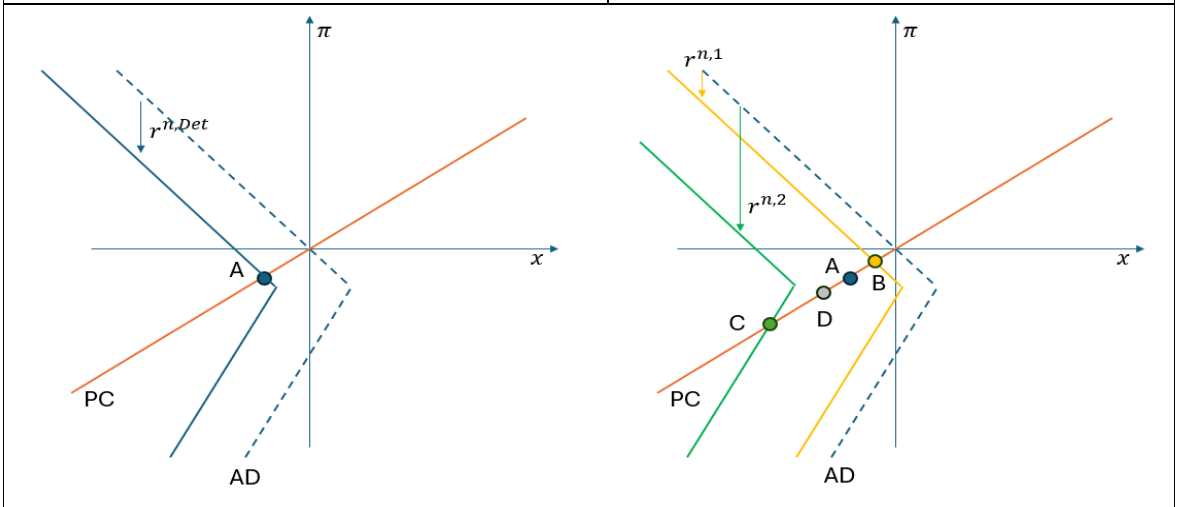
[11] The kink in AD of Figure 4 is determined by the fact that, below a certain level of inflation, the policy rule (5) implies that the policy rate is stuck at the ELB. Furthermore, note that in this case the slope of AD changes from negative to positive: as inflation increases but nominal rates remain fixed at the ELB, the real interest rate decreases, ultimately stimulating the economy. This phenomenon, also known as the Paradox of Toil (Eggertsson, 2010), generates a positive comovement between output gap and inflation.

D versus point A in the right panel). This asymmetry creates incentives for a more forceful easing at t=0, so as to reduce the probability of hitting the ELB in some future state of the world (see for instance Orphanides and Wieland, 2000, Reifschneider and Williams, 2000, Adam and Billi, 2006, among others).

These asymmetric effects are particularly relevant during recessions or disinflationary episodes (e.g. the Great Recession) and are exacerbated in the presence of aggregate uncertainty. Lin and Peruffo (2024), using a heterogeneous-agent New-Keynesian model (HANK), study the effects of a negative demand shock under aggregate uncertainty with the ELB constraint. They show that the average effect of shocks in a stochastic environment is larger than the effect of a comparable one-off shock in a deterministic environment. This is a direct result of the ELB non-linearity. Moreover, they show that policies designed to reduce regime uncertainty, such as forward guidance, are considerably more effective in the stochastic environment than under certainty.

Figure 4: demand shock with effective lower bound

a) Deterministic case | b) Stochastic case



Notes: the figure reports the effects of a negative demand shock in the New Keynesian model with effective lower bound, as described by equations (1), (2), and (5). Effects are shown in a deterministic world (left panel) and in a comparable stochastic world (right panel).

3.2 *Precautionary savings and non-convex investment adjustment costs*

Aggregate uncertainty can have real economic consequences through channels other than the aggregate non-linearities described above. These channels typically arise from non-linearities inherent in individual agents' problems, solutions, and preferences that are not captured by the linear representative-agent model. A common reduced-form approach is to embed such effects in the intertemporal elasticity of substitution or in the natural rate of interest, by allowing them to vary endogenously with some state variable.

As a first example, aggregate uncertainty can have real effects through households' precautionary motives. Because standard utility functions are convex, risk-averse agents facing income uncertainty or the prospects of adverse future shocks increase savings and reduce current consumption.[12] This mechanism, emphasized by Deaton (1991) and Carroll (1997), generates precautionary savings in the presence of uninsurable risks such as unemployment, health shocks, or macroeconomic volatility. The strength of this effect depends on institutional features of financial markets, including liquidity constraints and the incompleteness of insurance and credit markets (Aiyagari, 1994, Gourinchas and Parker, 2002). The general implications are twofold: precautionary savings increase the overall savings rate and could dampen the responsiveness of consumption to interest rates changes. Both effects are directly relevant for the calibration of monetary policy.

As a second example, an increase in aggregate uncertainty (i.e. in the dispersion of fundamental shock), can also have implications on firms' decisions. A well-established channel operates through firms' investment decisions under non-convex adjustment costs. A long-standing literature (Abel and Eberly, 1994, Dixit and Pindick, 1994) later revived by Bloom (2009) shows that fixed costs and partial irreversibility of investment decisions generate regions of inaction: firms hire and invest only when business conditions are sufficiently good, and only fire and disinvest when they are sufficiently bad. Higher uncertainty expands this region of inaction, making firms more cautious in adjusting to business conditions. Like for households, the implications are twofold. First, a higher *level* of uncertainty dampens the responsiveness of investment to any shock to business conditions. Second, irrespective of the current state of the economy, an *increase* in uncertainty (for instance, an increase in the volatility of technology shocks) triggers a contraction in investment and output (Bloom, 2009).

In summary, in both example, uncertainty affects consumption and investment in two ways due to an increase in precautionary savings and the expansion of the inaction region. First, uncertainty reduces consumption and investment levels, thus calling for a more accommodative monetary policy stance. Second, uncertainty weakens their sensitivity to interest rates, warranting a more aggressive monetary policy response.

4. Uncertainty and imperfect information

In this section we examine cases in which uncertainty arises from imperfect information held by either the central bank, the private sector, or both. Information is imperfect when agents are uncertain about each other's fundamentals (Angeletos and Lian, 2016). Some implications depend on whether information is symmetric or asymmetric—that is, whether the central bank holds superior information relative to the private sector or vice versa.[13] In what follows, we analyse separately the uncertainty faced by the central bank and the private sector, abstracting from their interaction.

[12] Formally, the necessary condition for the existence of precautionary savings is that the utility function displays prudence, namely that the marginal utility is convex $-\frac{u'''(c)}{u''(c)} > 0$.

[13] Here we do not address the broader issue of incomplete information in the sense of relaxing common knowledge and generating strategic behaviour.

4.1 *Uncertainty of the central bank*

4.1.1 Imperfect information of the central bank on fundamental shocks

Consider shocks to the natural rate of interest that shift the aggregate demand curve but are not perfectly observable by the central bank. Figure 5 illustrates the mechanism. Suppose the economy is initially at a steady state, at point A, where the AD curve intersects the Phillips Curve. At time *t+1*, a positive shock to the natural rate of interest shifts the AD curve upward to AD'_{t+1}. Absent monetary policy intervention, the economy moves to point B. If the central bank could observe the natural rate perfectly, it would fully offset the shock by raising the policy rate, thereby returning the AD curve to its original position and stabilizing the economy at A.

Now consider the case in which the central bank cannot directly observe the true natural rate of interest r_{t+1}^n, which follows a process with volatility *Q*, but receives a noisy signal:

$$\tilde{r}_{t+1}^n = r_{t+1}^n + \varepsilon_{t+1}, \qquad \varepsilon_t \sim N(0, R)$$

In a Bayesian learning framework, the central bank faces a signal extraction problem. It forms an estimate of r_{t+1}^n using the Kalman filter:

$$\hat{r}_{t+1|t+1}^n = \hat{r}_{t+1|t}^n + K\left(\tilde{r}_{t+1}^n - \hat{r}_{t+1|t}^n\right),$$

where $\hat{r}_{t+1|t}^n$ is the prior central bank's estimate of the natural rate of interest, $\hat{r}_{t+1|t+1}^n$ is the updated (posterior) estimate and K is the Kalman gain, which determines the weight placed on new information relative to the prior. The Kalman gain is increasing in the signal-to-noise ratio (SNR), which measures the volatility of the unobservable state relative to the noise in the signal: $SNR \equiv Q/_R$. An increase in the noise component R lowers the SNR, thereby reducing the Kalman gain and inducing the central bank to update its estimate of the natural rate more cautiously in response to new information.

As emphasized by Svensson and Woodford (2004), in this setting the optimal policy under commitment depends on past estimation errors. For example, following a positive shock to natural rate, the central bank—facing imperfect information—will initially underreact, raising the policy rate less than under full information. Referring to Figure 5, this results in only a partial correction, with the AD curve shifting to an intermediate position, AD''_{t+1}, rather than fully returning to its original level. Over time, as the central bank recognizes its initial underestimation, it maintains a higher policy rate for longer. Thus, noisier signals lead to a slower, yet more persistent, policy response.[14]

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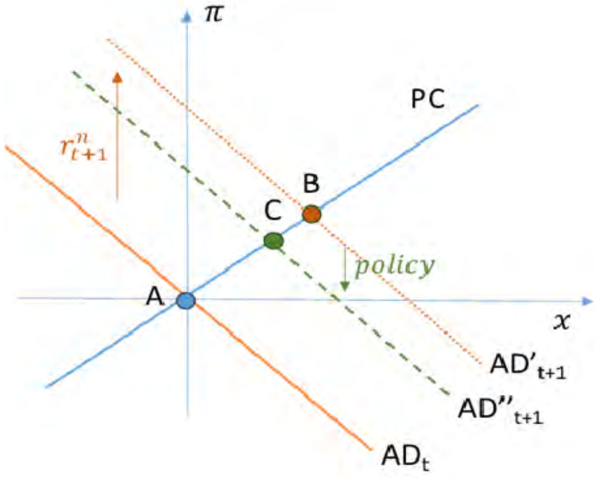
[14] Svensson and Woodford (2004) also demonstrate that, even under imperfect and asymmetric information as considered in this context, the certainty equivalence principle continues to hold when the optimal policy is defined by a reaction function in state-space form. However, when the optimal policy is instead expressed as a

Figure 5: uncertainty of the central bank on the natural rate



Notes: the figure reports the effects of a demand shift in the simple New Keynesian model described by equations (1)-(3), when the AD curve is not perfectly observable by the central bank.

In this case, uncertainty affects monetary policy decisions through the learning process of the central bank, which induces it to adopt a backward-looking perspective by relying on the observation of realized outcomes to infer the actual state of the economy. In contrast, when the economy is at steady state and there is no need of learning, the principle of certainty equivalence continues to apply if unobservable shocks enter the model additively (Ferrero, Pietrunti, and Tiseno, 2019).[15]

4.1.2 Imperfect information of the central bank on structural parameters

Suppose that the central bank does not (perfectly) observe certain parameters governing the monetary policy transmission. One of such parameters is the slope of the Phillips curve κ in equation (2).[16] This case is illustrated in Figure 6. The central bank is aware that a cost-push shock has shifted the Phillips Curve upward and that the economy is currently at point A. However, it is unsure whether the true Phillips Curve corresponds to PC’ or PC’’.

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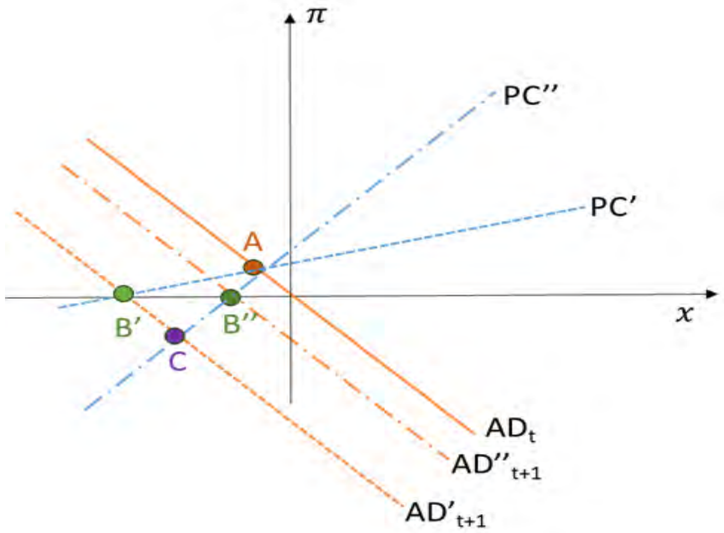
function of the history of the state vector, its formulation differs between the case of full information and that of asymmetric partial information, thereby indicating a breakdown of certainty equivalence.

[15] Ferrero, et al. (2019) demonstrate that when the central bank is uncertain about the persistence of technology shocks — and therefore about the natural rate of interest — the certainty equivalence principle still applies. The reason is that the persistence of technology shocks enters the model additively and does not interact with endogenous variables, allowing the uncertainty to be integrated out without affecting the policy formulation. In contrast, when the uncertainty concerns the slope of the Phillips Curve, the certainty equivalence principle no longer holds. In this case, the central bank must adjust its policy parameters because the slope interacts with endogenous variables like the output gap and its uncertainty cannot be simply integrated out, as its variance and covariances matter for the policy outcome.

[16] It is worth noting that the slope of the Phillips curve κ is a convolution of other deep parameters, so that uncertainty around it should be understood as uncertainty regarding the underlying deep parameters.

Figure 6: uncertainty of the central bank on the slope of the Phillips curve



Notes: the figure reports the effects of a demand shift in the simple New Keynesian model described by equations (1)-(3), when the slope of the Phillips curve is not observed by the central bank.

For illustrative purposes, assume the central bank is solely concerned with stabilizing inflation at its target (set to zero in this example). The size of the policy response required to achieve this objective depends critically on the slope of the Phillips Curve. If the Phillips Curve is relatively flat, as in PC′, a stronger contraction in demand is necessary. In this case, the central bank must shift aggregate demand to AD'_{t+1}, moving the economy to point B′ to restore inflation to target. By contrast, if the true Phillips Curve is steeper, as in PC″, a more modest increase in the interest rate—sufficient to shift the AD curve to AD''_{t+1}—achieves the same inflation stabilization, placing the economy at point B''.

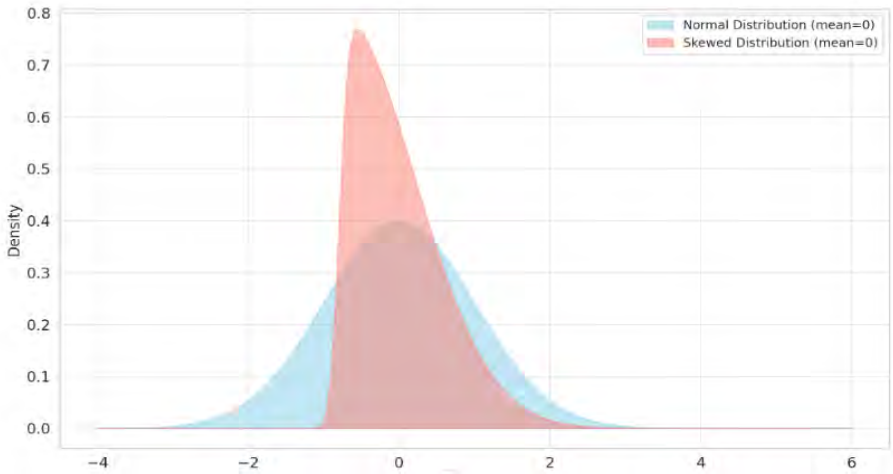
If the central bank incorrectly assumes a flatter Phillips Curve (PC′) when the true curve is steeper (PC″), the resulting policy response will be excessively contractionary. As shown by point C in Figure 6, output will fall unnecessarily low, and inflation will undershoot the target. Brainard (1967) demonstrates that, under parameter uncertainty, the optimal response is more cautious: policymakers should adjust gradually, a principle known as Brainard's conservatism (or gradualism) principle.

However, gradualism is not universally optimal. In particular, the central bank should take into account the endogenous reaction of the private sector's inflation expectations and prevent them to drift away from the inflation target (Ferrero et al., 2019, Dupraz et al., 2023). In the example of Figure 6, if supply shocks are persistent the AD curve may shift upward as agents observe prolonged deviations from the inflation target and revise their expectations accordingly, ultimately making it more difficult for the central bank to achieve its objectives. Hence, the implications of uncertainty about structural parameters may depend on the persistence of cost-push shocks (Kamps et al., 2025). If they are highly persistent, the central bank should react more forcefully compared to the situation in which the model parameters are known, but the recommendation is opposite if the persistence of cost-push shocks is low.

4.1.3 Uncertainty of the central bank about the distribution of the shocks

Up to this point, we have considered a stochastic economy in which the shock processes are known. Consider instead the case in which the probability distribution of shocks is unknown – a situation often referred to as Knightian uncertainty (Lane, 2024). For example, the central bank may be uncertain whether cost-push shocks follow a Normal distribution (depicted by the blue curve in Figure 7) or a skewed distribution (shown in red in Figure 7). These alternative distributions may share the same expected value (zero, in this illustration), yet imply different risks.

Figure 7: uncertainty on the distribution of the shocks



Notes: the figure shows two alternative shock distributions.

When faced with Knightian uncertainty, the central bank cannot rely on a single probabilistic model of the economy. A natural response is to adopt a scenario-analysis approach, assessing the effects of monetary policy under a range of plausible shock distributions. This framework supports the design of robust policies—those that limit potential damage in worst-case scenarios, even if they may perform sub-optimally under the baseline projection.[17] In recent years this approach has been increasingly adopted by the ECB and other central banks despite the challenges to operationalize it due to the difficulty in identifying a credible set of scenarios (Kamps et al, 2025, Garga et al. 2025). Risk-management considerations under Knightian uncertainty may justify either a more aggressive or a more cautious policy stance relative to the one the central bank would adopt under the baseline projection, depending on the nature and severity of the scenarios being considered.[18]

[17] Preference for robustness in monetary policy decisions can be operationalized in different ways. A policy is defined as robust according to the min-max criterion if it minimizes the worst-case outcome across a set of macroeconomic environments and policy tactics. Alternatively, the central bank may factor-in these considerations by responding to a risk-adjusted baseline outlook that takes into account asymmetric risks (De Polis, Melosi and Petrella, 2024).

[18] For example, in early 2025, mounting trade tensions prompted the ECB to evaluate alternative scenarios involving trade disruptions and tariffs. Tariffs imposed by the U.S. on imports from the European Union are expected to significantly dampen growth while exerting only modest upward pressure on inflation, suggesting

4.2 *Uncertainty of the private sector*

Households and firms may lack information, much like the central bank. In this context, central bank's actions and communications play a critical role in shaping private sector beliefs, giving rise to important strategic considerations in policy design and implementation. As private agents' uncertainty about the economic outlook rises, these issues become more salient, potentially leading to greater deviations from the policy prescriptions implied by the FIRE benchmark.[19] Depending on the circumstances, the central bank may need to react more forcefully or more cautiously, depending on whether its actions and communication effectively guide agents' expectations. The central bank's communication can be deployed as a strategic policy instrument that actively shapes expectation formation, the sensitivity of private sector's reaction to news, and, ultimately, the transmission and effectiveness of monetary policy (Cuciniello et al., 2025). To illustrate this context, we distinguish two cases.

4.2.1 The private sector misinterprets the state of the economy

Suppose the private sector cannot directly observe any aspect of the economic environment and instead must infer them from realized economic outcomes to form expectations and make decisions. Consider a temporary, positive cost-push shock: under full information, the central bank would typically "look through" the shock, refraining from action, as inflation would return to target before monetary policy could exert any effect. However, if the private sector is uncertain about the structure of the economy and tries to learn it from incoming data, inflation expectations may become persistently elevated and self-confirming (Orphanides and Williams, 2005). Hence, the degree to which long-run inflation expectations are anchored is a crucial determinant of the extent to which central banks can look through inflationary supply shocks (Nakamura et al., 2025). If inflation expectations are imperfectly anchored, the central bank may find it optimal to react more forcefully by raising interest rates to prevent a further destabilization.

4.2.2 The private sector misinterprets policy actions and communication

Due to their imperfect knowledge, agents may try to extract information about economic conditions and perspectives from the central bank's actions and communication. In this context, monetary policy has a signalling or information effect (Melosi, 2017, Nakamura and Steinsson, 2018).

For example, a rate hike aimed at countering inflationary pressures may be misperceived by the private sector as evidence of a movement of the natural rate of interest associated with an improvement in macroeconomic fundamentals. This misperception may in turn raise

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a case for more aggressive monetary easing. However, this policy recommendation is tempered by the possibility of retaliatory tariffs from the EU, which would raise the cost of U.S. imports and thereby contribute to higher inflation.

[19] Beaudry et al. (2023) show that the optimal policy prescriptions vary depending on the expectation formation mechanism of the private sector.

current consumption and investment, thereby impairing the monetary policy transmission (Nakamura and Steinsson, 2018).

Similarly, heightened uncertainty may amplify the information content attributed to central bank communication. *Forward guidance*, for instance, can be interpreted by private agents as revealing information about macroeconomic fundamentals, thereby influencing their beliefs in unintended ways. This interpretation is known as *Delphic* forward guidance, as opposed to *Odyssean* forward guidance, in which the central bank credibly commits future actions even if conditions later warrant a policy shift (Campbell et al., 2012). Under *Delphic* forward guidance, an announcement intended to be expansionary – such as keeping rates low until the inflation outlook does not improve – can have contractionary effects if agents downgrade their expectations about the economy (Eggertsson et al., 2021). This highlights the pivotal role of private-sector expectations and the importance of clear central bank communication. By reducing uncertainty, the central bank can help agents form more accurate beliefs and avoid self-fulfilling pessimism.

Yet, this informational advantage might also tempt central banks to withhold bad news to foster optimism. As Nakamura and Steinsson (2018) argue, sharing information about the natural rate—even unfavourable updates—is typically welfare-enhancing if policy rates can adjust accordingly. However, at the effective lower bound (ELB), where rate adjustments are constrained, concealing negative news might seem optimal. This view, however, neglects the potential long-term damage to the central bank's credibility, which is vital for guiding expectations.

5. Evolving uncertainties in recent times and conclusions

The proposed taxonomy provides a framework that helps shed light on the recent developments in uncertainty and its implications for the ECB's monetary policy stance.

During the inflation surge of 2021-22, uncertainty primarily concerned the nature (demand vs. supply) and persistence of inflationary shocks. According to our taxonomy, this situation corresponds to the case in which both the central bank and the private sector faced uncertainty about economic fundamentals (cases IV and VIII in Table 1). Additionally, there was mounting uncertainty about the slope the Phillips curve (case V in Table 1), as the frequency of price adjustments increased sharply in 2022 (Gautier, 2025). Initially, these uncertainties led the ECB to adopt a cautious approach, so that it refrained from raising the policy rate until July 2022. As the Governing Council gathered evidence on the persistence of the inflation surge and the risk of de-anchoring of expectations increased (case VI in Table 1), ECB's monetary policy swiftly shifted towards an unprecedented tightening in terms of both pace and magnitude. In June 2022, the ECB started emphasizing a data-dependent strategy, and in March 2023 it clarified that data dependence should be interpreted in terms of a three-pronged reaction function that relied more heavily on backward-looking indicators such as underlying inflation and transmission dynamics (Cuciniello et al., 2025). This is consistent with a strategy that aims at improving the precision of the signal on the evolution of inflation and economic activity, though in the short term this also exacerbated market sensitivity to macroeconomic news (Cuciniello et al., 2025). To mitigate this effect, the ECB repeatedly stressed the data-dependent nature of monetary policy.

More recently, the primary source of uncertainty has shifted to mounting geopolitical tensions and trade conflicts. Beyond the dampening of both consumption and investment that could arise in this situation (case III in Table 1), in the current context economic agents are highly uncertain about undergoing structural changes, such as increased fragmentation and ballooning military spending (case VII in Table 1). All these aspects bear important consequences for price stability but at this stage their ultimate effects remain unclear. In response, the ECB has increasingly relied on scenario analysis as a tool to assess risks and evaluate the robustness of its decisions in a highly uncertain environment. The relevance of risk assessment – beyond mean projections – has been lately explicitly recognized in the July 2025 monetary policy statement.[20]

In practice, various forms of uncertainty often coexist. As a result, policymakers must weigh the relevance of each type of uncertainty to appropriately calibrate monetary policy.

[20] "The Governing Council's interest rate decisions will be based on its assessment of the inflation outlook and the risks surrounding it, in light of the incoming economic and financial data, as well as the dynamics of underlying inflation and the strength of monetary policy transmission."

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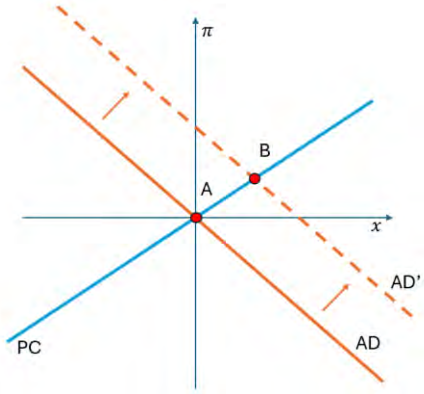
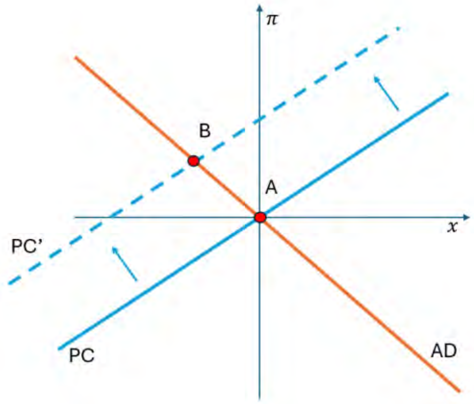
Appendix

Figure A1: effects of shocks in the New-Keynesian model	
(a) Demand or monetary shock	(b) Cost-push shock
	
Notes: the figure reports the effects of demand or monetary shock (left) and cost-push shock (right) in the simple New Keynesian model described by equations (1)-(3).	