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REASSESSING INFLATION TARGETING: A COMPARATIVE ANALYSIS OF ALTERNATIVE MONETARY POLICY REGIMES

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Abstract:

This dissertation compares the macroeconomic performance of six monetary policy rules in a New Keynesian DSGE model calibrated for the euro area: inflation targeting (IT), price-level targeting (PLT), average inflation targeting (AIT) with horizons of eight and sixteen quarters, temporary price-level targeting (TPLT), and nominal GDP level targeting (NGDPLT).

The analysis is motivated by recent episodes of persistently low interest rates and monetary policy constrained by the effective lower bound (ELB), which challenge the effectiveness of the conventional monetary policy regime of IT. All five alternative policy rules that we consider are, to some extent, history-dependent strategies that may improve macroeconomic stabilisation by committing policymakers to compensate for past deviations from their targets and by influencing the expectations of economic agents (Bernanke et al., 2019; Svensson, 2020).

We build on the framework of Busetti et al. (2021), regarding model, calibration, simulation, and assessment criteria. We introduce four main extensions to that framework: (i) simulation of policy responses to technological shocks, in addition to demand and supply shocks; (ii) analysis of nominal output targeting (NGDPLT); (iii) inclusion of the duration of ELB and the maximum deviation of inflation and output from targets as assessment criteria, in addition to macroeconomic Loss; (iv) search for the intensity of response to inflation (nominal output, in NGDPLT) that improves the most macroeconomic stabilisation.

The results show that history-dependent rules outperform IT following an adverse demand shock, under which IT reaches the ELB and generates the largest cumulative loss. For supply shocks, however, the results are much more nuanced. Across the three shocks analysed, NGDPLT achieves the lowest cumulative loss, although it does not always provide the strongest stabilisation of each individual macroeconomic variable. Our sensitivity analysis suggests that, in the face of a demand shock, macroeconomic stabilisation increases with the coefficient of inflation reaction in the policy rule, whereas under supply shocks, overall macroeconomic stabilisation is best achieved with a smaller reaction to inflation.

JEL codes: E42; E47; E52; E58

Keywords: Monetary Policy; Central Banks; Makeup strategies; Inflation targeting; Price-level targeting; Average inflation targeting; Nominal GDP Level targeting; Temporary price-level targeting;

Resumo:

Esta dissertação compara o desempenho macroeconómico de seis regras de política monetária num modelo DSGE novo keynesiano calibrado para a zona do euro: meta para a inflação (IT), meta para o nível de preços (PLT), meta para a inflação média (AIT) com horizontes de oito e dezasseis trimestres, meta temporária de nível de preços (TPLT) e meta para o nível do PIB nominal (NGDPLT).

A análise é motivada por episódios recentes de taxas de juro persistentemente baixas e de política monetária limitada pelo limite inferior efetivo (ELB), que põem em causa a eficácia do regime convencional de política monetária baseado na meta de inflação. Todas as cinco regras de política alternativas que consideramos são, em certa medida, estratégias com dependência histórica que podem melhorar a estabilização macroeconómica, comprometendo os decisores políticos a compensar desvios passados em relação às suas metas e influenciando as expectativas dos agentes económicos (Bernanke et al., 2019; Svensson, 2020).

Baseamo-nos no quadro de referência de Busetti et al. (2021) no que diz respeito aos critérios relativos ao modelo, à calibração, à simulação e à avaliação. Introduzimos quatro extensões principais a esse quadro: (i) simulação de respostas de política a choques tecnológicos, para além dos choques de procura e de oferta; (ii) análise da meta para PIB nominal (NGDPLT); (iii) inclusão da duração do ELB e do desvio máximo da inflação e do produto em relação às metas como critérios de avaliação, para além da *Loss* macroeconómica;

(iv) determinação da intensidade da resposta à inflação (produto nominal, no NGDPLT) que melhora ao máximo a estabilização macroeconómica.

Os resultados mostram que as regras com dependência histórica apresentam um desempenho superior ao da IT na sequência de um choque de procura adverso, situação em que a IT atinge o ELB e gera a maior perda cumulativa. No caso dos choques de oferta, contudo, os resultados são muito menos claros. Nos três choques analisados, o NGDPLT atinge a menor perda acumulada, embora nem sempre proporcione a maior estabilização de cada variável macroeconómica. A nossa análise de sensibilidade sugere que, face a um choque de procura, a estabilização macroeconómica aumenta com o coeficiente de reação à inflação na regra de política monetária, enquanto, em caso de choques de oferta, a estabilização macroeconómica global é melhor alcançada com uma reação menor à inflação.

Palavras-chave: Política Monetária; Bancos Centrais; Estratégias *makeup*; Meta para a inflação; Meta para o nível de preços; Meta para a inflação média; Meta para o PIB nominal; Meta temporária de nível de preços

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1. Introduction

Since the 1990s, inflation targeting (IT) has been the dominant monetary policy framework in many advanced economies. It combines a numerical inflation target, the short-term interest rate as the main policy instrument, and enhanced central-bank transparency and accountability (Bernanke & Mishkin, 1997; Kiley & Mishkin, 2025b; Svensson, 1999). However, structurally low natural interest rates, more frequent episodes at the effective lower bound (ELB), and the post-pandemic inflation surge have renewed the debate over whether alternative regimes can provide better macroeconomic stabilisation in particular circumstances (Kiley & Mishkin, 2025b; Svensson, 2020).

These concerns have increased the interest in strategies such as price-level targeting (PLT), average inflation targeting (AIT), temporary price-level targeting (TPLT), and nominal GDP level targeting (NGDPLT). Unlike conventional IT, which generally does not compensate for past target misses, these strategies introduce different forms and degrees of history dependence. By committing to offset previous deviations, they can influence expectations about future inflation and monetary policy and may strengthen stabilisation when the policy rate is constrained by the ELB. Their effectiveness nevertheless depends on the nature of the shock, the design of the rule, and the credibility of the commitment (Bernanke, 2017; Svensson, 2020).

Against this background, this dissertation compares inflation targeting with alternative history-dependent monetary policy rules in terms of their effectiveness in achieving macroeconomic stabilisation. In particular, its objective is to determine whether policy rules with history dependence improve upon IT, regarding the trade-offs between price stability and economic activity, under circumstances akin to several recent macroeconomic episodes.

The quantitative analysis uses a medium-scale New Keynesian dynamic stochastic general equilibrium model based on Busetti et al. (2021) and calibrated for the euro area. Six monetary policy specifications are compared: IT, PLT, AIT with averaging windows of eight and sixteen quarters, TPLT, and NGDPLT. Relative to Busetti et al. (2021), the set of policy rules and scenarios is extended by considering NGDPLT and a positive technology shock. Deterministic transition paths are solved under perfect foresight over a horizon of 150

quarters. Performance is assessed using responses in inflation, output, and effective and shadow interest rates, along with the duration of the ELB episode and a cumulative loss measure based on inflation and output deviations.

The results show that history-dependent rules are particularly effective following an adverse demand shock, as IT reaches the ELB, whereas their advantages are less clear under supply-side shocks. NGDPLT records the lowest cumulative loss across the three shocks, although no rule dominates every stabilisation dimension.

The remainder of the dissertation is organised as follows. Chapter 2 reviews the conceptual and institutional literature on IT and makeup strategies. Chapter 3 presents the model, its calibration, the monetary policy rules, and the simulation strategy. Chapter 4 reports and discusses the results. Chapter 5 extends the analysis by examining the sensitivity of the results to alternative policy-response coefficients. Chapter 6 summarises the main conclusions, limitations, and avenues for future research.

2. Literature Review

2.1 Conceptual framework: inflation targeting and makeup strategies

This section sets out the conceptual framework used in the literature to analyse inflation targeting (IT) and alternative makeup strategies. It first reviews the definition and objectives of IT and the standard New Keynesian framework in which these regimes are commonly studied. Subsequently, it presents alternative makeup strategies, including price-level targeting (PLT), average inflation targeting (AIT), and nominal GDP level targeting (NGDPLT), with particular emphasis on their differences regarding the target variable and the degree of history dependence. Finally, it highlights the importance of expectations, credibility, and communication in the context of these regimes, thereby providing the basis for the historical and institutional findings presented in the following section.

2.1.1 Origins, diffusion, and objectives of inflation targeting

The inflation targeting (IT) regime emerged in the early 1990s as a response to the episodes of high and unstable inflation that marked the 1980s. New Zealand is generally identified as the first country to formally adopt an IT regime, in 1990, quickly followed by other central banks in advanced economies seeking to consolidate successful disinflation with a more explicit nominal anchor, namely Canada, the United Kingdom, Sweden, Finland,

and Australia (Kiley & Mishkin, 2025b). The central idea of this regime may be summarized as follows: the central bank assumes a quantitative inflation target for a given time horizon, uses the short-term interest rate as the main instrument to achieve it, and communicates transparently how it intends to react to shocks that push inflation away from the target (Bernanke & Mishkin, 1997; Svensson, 1997).

In the formulation presented by Svensson (1999), inspired by early experiences with inflation targeting in economies such as New Zealand and Canada, IT can be understood as a targeting rule that minimises a loss function involving deviations of inflation from the target and the output gap from zero. Instead of following a mechanical rule for the instrument, the central bank practices constrained discretion, in which decisions on the interest rate path are made in a forward-looking manner based on internal projections for inflation and activity, an approach also known as inflation-forecast targeting. This approach combines a clear nominal target with some short-term flexibility, allowing for the accommodation of supply shocks and avoiding high costs in terms of output volatility, giving rise to the notion of flexible inflation targeting (Kiley & Mishkin, 2025b; Svensson, 1999).

The implementation of IT has been limited to the period from the mid-1990s onwards, in which the adoption of IT replaced the exchange-rate pegs[1] and monetary targets[2] that had become difficult to maintain in the context of financial liberalisation and the increased international mobility of capital. In these contexts, the implementation of IT has been accompanied by institutional measures such as the reinforcement of the autonomy of the central bank, the definition of the price stability objective, the development of domestic financial markets, and the enhancement of the quality of macroeconomic indicators (Kiley & Mishkin, 2025b; Unsal et al., 2022). According to the literature, IT is not merely a numerical objective but rather a framework that articulates four pillars: independence, policy strategy, clear communication and accountability, which can be summarised as transparency, coherence, consistency in the objectives and actions, and accountability for policy decisions and outcomes (Svensson, 1999; Unsal et al., 2022).

[1] An exchange-rate peg is a monetary regime in which the central bank uses the exchange rate as the nominal anchor, committing to keep the currency at a fixed rate (or within a narrow band) against another currency or a basket through interventions and supporting policy actions (International Monetary Fund, 2003; Stone & Bhundia, 2004).

[2] Monetary targeting refers to a strategy in which the central bank targets the growth (or path) of a monetary aggregate (e.g., M1/M2) as an intermediate nominal anchor, an approach that relies on a sufficiently stable relationship between money and inflation/output (Stone & Bhundia, 2004).

From a theoretical perspective, the IT regime is often analysed in linear New Keynesian models with a quadratic loss function. In this framework, the loss function summarises the central bank's stabilisation objectives by assigning a cost to deviations of inflation and real activity from their desired levels, thereby providing a tractable criterion for evaluating and comparing policy outcomes. The quadratic form captures the idea that both negative and positive deviations from targets are costly, and that welfare costs rise more than proportionally with the size of macroeconomic deviations; it further provides a convenient second-order approximation to household welfare in sticky-price models (Woodford, 2003). A standard representation of the central bank's intertemporal loss function can be written as (Svensson, 1999):

$$L_t = \mathbb{E}_t(1-\delta)\sum_{k=0}^{\infty}\delta^k\frac{1}{2}[(\pi_{t+k}-\pi^*)^2+\lambda y_{t+k}^2] \tag{2.1}$$

where L_t is the policymaker's intertemporal loss evaluated at time t, defined as the expected discounted average of future period losses. $\mathbb{E}_t$ denotes expectations conditional on information available at time t, and $\delta \in (0,1)$ is the discount factor that governs how future outcomes are weighted relative to current ones. The factor $(1-\delta)$ is a normalisation that converts the infinite discounted sum into a weighted average and does not affect the policy trade-offs. Inflation is denoted by π_{t+k}, $\pi^*$is the inflation target, and y_{t+k} is the output gap (the deviation of output from its efficient or potential level). Finally, $\lambda > 0$ captures the relative weight placed on stabilising real activity (the output gap) compared with stabilising inflation around the target.

In these models, a policy rule that reacts strongly enough to deviations of inflation from the target and, to a lesser extent, to the output gap, ensures determinacy of the equilibrium and results close to the optimal solution under commitment, especially when the Phillips curve has a relevant forward-looking component (Clarida et al., 1999; Svensson, 1999; Woodford, 2003).

2.1.2 Makeup strategies and alternatives to IT

Beyond the baseline inflation targeting framework, a substantial literature has examined alternative monetary policy regimes aimed at strengthening stabilisation and improving performance in challenging environments, particularly when conventional policy is constrained. Proposals include Price-Level Targeting (PLT), Average Inflation Targeting

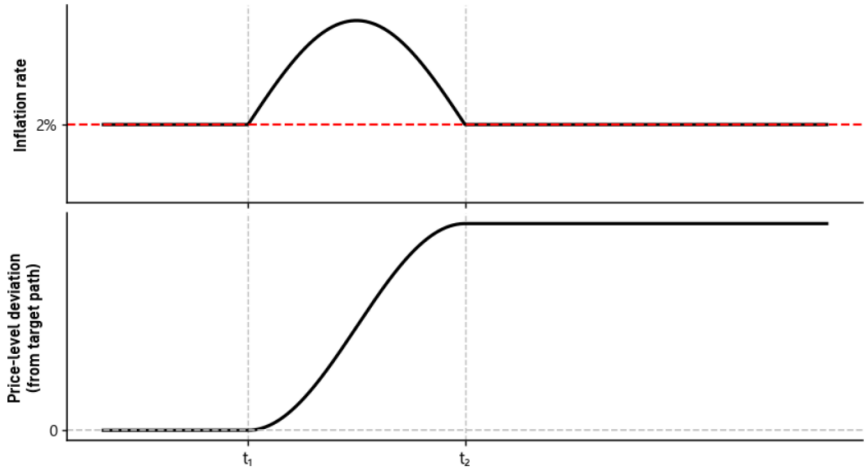
(AIT), and Nominal GDP Level Targeting (NGDPLT). Each of these regimes introduces some degree of makeup, where past deviations from target values are compensated by future overshooting, to better anchor expectations and reduce the risk of persistent shortfalls in inflation or output (Svensson, 2020).

2.1.2.1 Price-Level Targeting

Price-level targeting (PLT) sets a target for the path of the price level, rather than targeting only the annual inflation rate. Instead of seeking to keep inflation close to a target in each period, the authority commits to a path for the price index and promises to fully compensate for past deviations. Inflation below the target today implies that, in a PLT regime, future inflation will be systematically above the target until the price level returns to the desired trajectory, making the regime highly dependent on history (Ambler, 2009; Guender & Oh, 2006).

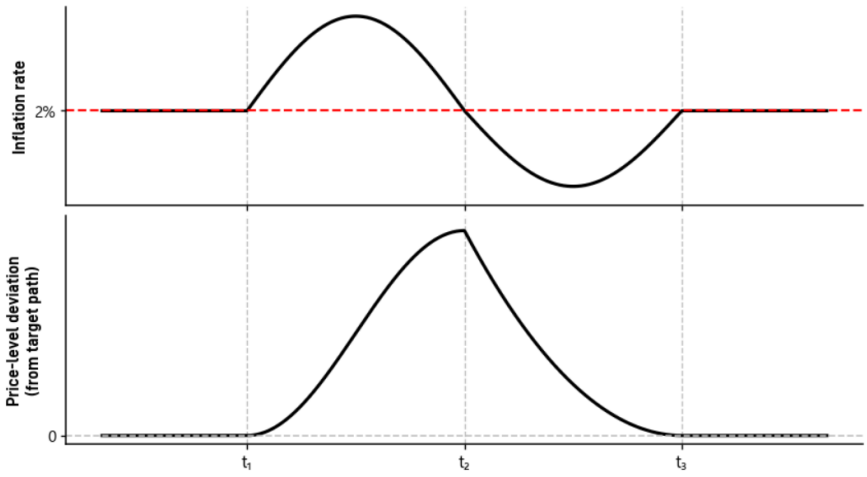
As noted by Svensson (2020), an inflation targeting regime that does not seek to correct past deviations from the target implies that past inflation misses are not corrected, so the price level becomes non-stationary, behaving like a "random walk with drift". In this case, the price level ceases to be trend-stationary, and uncertainty about the future price level increases without limit as the time horizon lengthens. In contrast, under a price-level targeting regime, the price level would be trend-stationary and would revert to the mean along a target path, thereby limiting the conditional variance of future price levels and reducing long-term uncertainty. Moreover, this framework would tend to stabilise inflation in the long term around an implicit target.

Figure 1. *Inflation and the price level under an inflation targeting regime.*



Note: Author's elaboration based on Fernandes and Mota (2021)

Figure 2. *Inflation and the price level under a price-level targeting regime.*



Note: Author's elaboration based on Fernandes and Mota (2021)

The theoretical literature on New Keynesian models with rational expectations tends to favour PLT. In extensions of the basic three-equation model, the policy that stabilises the price level reproduces results very close to the optimal solution under commitment, reducing the joint variance of inflation and the output gap relative to an IT regime that stabilises inflation period by period (Ambler, 2009; Guender & Oh, 2006; Vestin, 2006).

Several studies also highlight additional benefits of PLT, such as a lower probability of reaching the ELB and greater long-term price predictability (Bernanke, 2017; Kiley & Roberts, 2017). These arguments underpin proposals to use PLT as a tool to escape liquidity traps. Bernanke (2017) advocates a temporary price-level targeting, valid only while policy is at the ELB, returning afterward to a flexible IT regime, precisely to exploit the advantages of history dependence without making a permanent commitment that is difficult to communicate.

However, some literature recognises important practical challenges. First, the requirement to fully compensate for past deviations makes the regime sensitive to large adverse supply shocks, as attempts to force the price level back onto its path may imply significant fluctuations in the output gap if agents do not correctly anticipate this correction (Ambler, 2009; Bernanke, 2017). Second, the PLT is vulnerable to temporal inconsistency problems, given that, after a large inflationary overshoot, the central bank has incentives not to generate the deflation necessary to re-anchor the price level, which can undermine the credibility of the commitment (Ambler, 2009). Finally, using the price level as a

communication variable is less intuitive for the public than an annual inflation target, which complicates the communication strategy (Bernanke, 2017).

2.1.2.2 Average Inflation Targeting

Average inflation targeting (AIT) starts from the same nominal anchor as traditional inflation targeting (IT), a quantitative target for inflation, but changes the way the central bank deals with deviations from that target over time. Instead of trying to keep current inflation close to the target in each period, the central bank commits to ensuring that average inflation over a given horizon, usually spanning more than a year, coincides with the target, which implies compensating for periods of below-target inflation with future periods of above-target inflation, and vice versa (Nessén & Vestin, 2005; Svensson, 2020). In other words, AIT explicitly introduces a dimension of dependence on history in the conduct of monetary policy, approaching the logic of price-level-based strategies, but keeping communication focused on the inflation rate (Svensson, 2020).

From a theoretical point of view, Nessén and Vestin (2005) analyse AIT in a New Keynesian model and show that, under discretion, defining the central bank's objective in terms of average inflation over a finite horizon, rather than current inflation, introduces dependence on history and can improve the trade-off between inflation and output volatility compared to a simple IT. The mechanism is based on expectation management: inflation above the target today requires lower future inflation to restore the average, thereby reducing inflation expectations and contributing to greater price stability.

Furthermore, the formulation of AIT can be understood as an intermediate solution between an inflation-target regime and a general price-level target regime, insofar as the choice of the average horizon determines the degree of dependence on history that the regime incorporates. When the relevant horizon is very short, AIT is close to conventional IT, but as this horizon lengthens, the regime begins to behave more like a price-level-based strategy, implicitly anchoring the general price level to a trend path, even though this equivalence is only complete in particular cases, namely when the stabilisation of the output gap is not part of the central bank's objective function (Nessén, 2002). This gradability is relevant in effective lower bound (ELB) environments, especially when the Phillips curve is flat, as a longer horizon reinforces the makeup mechanism and can increase the stabilising effectiveness of the policy without requiring a complete shift to price-level targeting (Svensson, 2020). In a similar vein, the proposal for temporary price-level targeting during

the ELB, associated with Bernanke (2017), can be interpreted as an implicit AIT restricted to the period when rates are at the lower bound, with a return to an IT regime outside this context (Amano et al., 2020).

From an operational point of view, AIT uses forward guidance mechanisms similar to those of price-level-based strategies, but tends to be more systematic, since compensation for past deviations is incorporated into the design of the regime itself, reducing discretion in the management of episodes of persistently below-target inflation (Mertens & Williams, 2019; Budianto et al., 2023). At the same time, Svensson emphasises that this framework can be particularly useful in the context of structurally low inflation and that the relevant time window can be adjusted according to the performance of the regime, reinforcing institutional flexibility without losing the nominal anchor (Svensson, 2020).

The choice of the optimal horizon is not neutral and depends on the structure of the economy and the nature of shocks, including the slope of the Phillips curve, the central bank's preferences regarding output and interest rate volatility, and, crucially, its credibility and ability to influence expectations, which conditions the effectiveness of the intertemporal compensation mechanism. The literature suggests that a few-year horizon may be plausible, with estimates in the range of three to four years (Smets, 2000, 2002, 2003; Svensson, 2018).

2.1.2.3 Nominal GDP Level Targeting

Nominal GDP level targeting can be seen as an alternative to IT that seeks to directly stabilise the trajectory of aggregate nominal expenditure, i.e. the product of the price level and real GDP. Instead of targeting an annual inflation rate, the central bank sets a path for nominal GDP and adjusts policy to keep it as close as possible to that path, with a commitment to make up for deviations. In operational terms, this can take the form of a target for the nominal GDP growth rate or for the level, with past deviations compensated by higher or lower growth in the future. The literature distinguishes between NGDP growth targeting, where "bygones are bygones", and NGDP level targeting, where the central bank promises to return to the previously announced path (Pudner, 2025).

The theoretical arguments in favour of NGDP targeting are based on New Keynesian models with nominal rigidity and supply and demand shocks, in which the optimal policy seeks to stabilise a combination of inflation and output gap. Garín et al. (2016) show, in a medium-sized model with price and wage rigidity, that a rule that stabilises nominal GDP can come very close to the optimal policy under commitment, especially when wages are

more rigid than prices and supply shocks are important. In this configuration, NGDPLT tends to dominate simple rules focused solely on inflation and is relatively close to rules that directly target the output gap, although the latter show slightly lower average welfare losses. Furthermore, Garín et al. (2016) emphasise that the nominal GDP target has advantages when the output gap is poorly measured in real time, since the objective falls on an observable variable, avoiding some of the measurement errors associated with unobservable gaps, and ensuring equilibrium determinacy even with positive trend inflation, unlike some versions of gap targeting.

Another line of literature combines these fundamentals with the ELB problem and large supply shocks. Beckworth and Horan (2024) characterise NGDP level targeting as a "two-in-one solution" that allows the central bank to look through temporary supply shocks while preserving an implicit target for average inflation in the medium term. In a scenario where the NGDP target is around 4 percent per annum, the combination of potential output growth and the nominal GDP path implies average inflation of around 2 percent, with tolerance for temporary fluctuations in inflation that arise from supply shocks.

Sumner (2024) and Pudner (2025) argue that a nominal GDP target should replace inflation targeting as the reference framework for monetary policy, particularly in economies with a dual mandate that combines price stability and maximum employment. Sumner (2024) proposes an NGDP growth target of around 4 percent annually for the United States and argues that a credible commitment to this path would have mitigated both the nominal contraction in the 2007–2009 recession and the overshoot of 2021–2022, since expectations of future correction would induce automatic movements in market interest rates and private spending.

Pudner (2025) frames NGDP targeting as a form of rule rather than discretion, capable of reducing the inflationary bias associated with discretionary policies and improving the predictability of central bank decisions by stabilising aggregate nominal spending rather than attempting to finely separate supply and demand shocks.

Despite these theoretical advantages, literature highlights several practical challenges. One of the most discussed problems is the quality and availability of data on nominal GDP, which are released less frequently, with greater lag and more significant revisions than price indices and labour market indicators. Pudner (2025) notes that these revisions can lead to suboptimal policy decisions if the central bank reacts to inaccurate initial estimates, and

points out that this has been used to question the practical feasibility of NGDPLT. Beckworth and Horan (2024) and Sumner (2024) respond that the systematic use of consensus forecasts and nowcasts mitigates much of this issue and suggest that the very adoption of a nominal GDP target would make data collection denser and faster, making the quality of statistical information partly endogenous.

Another recurring criticism concerns the potential increase in inflation volatility. As the NGDPLT stabilises the sum of inflation and real growth, sharp fluctuations in output can translate into wider variations in inflation, which can be problematic if society strongly values price stability. There are also communication difficulties, since the concept of nominal GDP is less intuitive to the public than a simple inflation rate, which can weaken the regime's role as an anchor for expectations (Pudner, 2025). Svensson (2020) adds that, by treating GDP and the deflator as perfect substitutes, NGDPLT tends to merge into a single objective that, in dual mandates, are two conceptually distinct objectives, maximum employment and price stability, and that the problems of lags and data revisions help explain why no major central bank has yet adopted a pure NGDPLT regime.

2.1.3 Expectations and credibility in makeup strategies

A cross-cutting implication of the literature is that the comparative assessment of regimes such as inflation targeting (IT), average inflation targeting (AIT), price-level targeting (PLT), or nominal GDP level targeting (NGDPLT) depends critically on how expectations are formed and how well private agents understand the regime. In New Keynesian models with rational expectations and homogeneous agents, history-dependent strategies such as PLT or NGDPLT tend to outperform IT in terms of joint stabilisation of inflation and output, especially when the effective lower bound on interest rates is recurrent, because the commitment to make up for past deviations improves the control of expectations and reduces the time spent in the ELB (Ambler, 2009; Beckworth & Horan, 2024; Garín et al., 2016; Sumner, 2024; Svensson, 2020).

When the assumption of perfectly rational expectations is relaxed, the theoretical hierarchy between regimes becomes much less clear. For AIT, Coibion et al. (2023) show, using a daily survey of households in the United States combined with information experiments, that the Federal Reserve's formal shift to flexible average inflation targeting was hardly noticed by the public and that even explicit explanations of the new regime generate expectations responses very similar to those of a simple IT with a 2 percent target. Hoffmann

et al. (2022), in a survey experiment with German households, conclude that a hypothetical scenario of AIT by the ECB would only modestly increase inflation expectations, and only among respondents with medium or high levels of confidence in the central bank, suggesting that the makeup mechanism is not widely internalised by households.

In the case of the PLT, the literature is even more explicit about the regime's fragility when expectations are formed through heuristic rules or learning processes. Molnar (2021) shows, in a New Keynesian model with limited rationality, that PLT dominates IT only when agents form expectations directly on the price level and align their forecasts with the target trajectory; when expectations are formulated about inflation and combine fundamentalist components with extrapolation of past inflation, PLT tends to lose credibility over time and generates explosive trajectories, while IT remains stable for a wide range of calibrations. Experimental evidence in the laboratory points in the same direction, as Shukayev and Amano (2025) documented that, after a simulated change from IT to PLT, participants begin to partially use the price level to predict inflation, but the weight given to this information is much lower than predicted by theory, and the gains of PLT over IT in terms of reducing forecast errors and inflation volatility are modest and not very robust.

Dobrew et al. (2025) show that makeup strategies can, in principle, mitigate the macroeconomic costs of an effective lower bound (ELB) by reducing the incidence of the ELB and the biases in inflation and activity observed under IT through the management of expectations. However, when the assumption of fully rational expectations is relaxed, and a degree of limited rationality compatible with micro and experimental evidence is imposed, the relative gains of AIT over IT become small because agents do not fully internalise the logic of intertemporal compensation and, thus, the expectations channel loses strength.

Overall, the evidence suggests a structural trade-off between the theoretical sophistication of history-dependent regimes and their behavioural robustness. Strategies such as AIT, PLT, or NGDPLT offer clear gains in models with rational expectations and recurrent ELB (Ambler, 2009; Beckworth & Horan, 2024; Garín et al., 2016; Nessén & Vestin, 2005; Sumner, 2024), but their performance in the real world depends on demanding requirements of macroeconomic literacy, trust in the monetary authority, and very clear and persistent communication (Coibion et al., 2023; Hoffmann et al., 2022; Molnar, 2021; Shukayev & Amano, 2025). When these requirements are not met, the gains compared to a flexible IT may be small or even negative, which makes the dimension of expectations and

communication a central criterion in comparing monetary policy regimes, alongside traditional metrics such as output volatility, the average deviation of inflation from the target, or the frequency with which policy hits the lower bound on rates (Bernanke, 2017; Pudner, 2025).

2.2 Historical experience and institutional practice

This section examines how inflation targeting and makeup elements have been implemented in practice, drawing on historical experience and recent institutional episodes. It links the conceptual mechanisms discussed in the previous section to real-world policy choices, highlighting the conditions under which history dependence has been introduced, explicitly or implicitly, and the constraints that shape its effectiveness, including the policy environment, the nature of shocks, and the demands of credibility and communication.

2.2.1 Inflation targeting in practice: evolution and performance (1990s–2020s)

This subsection provides an overview of the evolution and performance of IT from its diffusion in the 1990s to the 2020s. Firstly, it briefly describes the pre-global financial crisis (GFC) period, which is traditionally associated with the so-called Great Moderation, a period of low and stable inflation (and output gap) in a large number of countries (Bernanke, 2004). Secondly, it deals with the impact of the GFC, which put traditional IT to the test, particularly in terms of the higher frequency and cost of episodes at the effective lower bound, as well as the increased use of non-traditional measures. Finally, it addresses the recent surge in inflation since the 2020s, viewed as a notable test of IT frameworks, particularly in terms of large shocks, uncertainty, and the phasing of policy normalisation.

2.2.1.1 IT performance before the global financial crisis and during the Great Moderation

Empirical literature from the 1990s and early 2000s often associates the spread of IT with the period known as the Great Moderation, characterised by lower average inflation and lower inflation and output volatility in advanced economies. After adopting explicit inflation targets, many countries managed to reduce both the level and variability of inflation in a lasting manner, bringing it closer to values in the range of 2 to 3 percent and anchoring medium-term expectations in that range (Bernanke, 2004; Kiley & Mishkin, 2025b; Mishkin & Schmidt-Hebbel, 2007). Although the empirical assessment of the IT impact is subject to identification difficulties, given that macroeconomic performance results from multiple

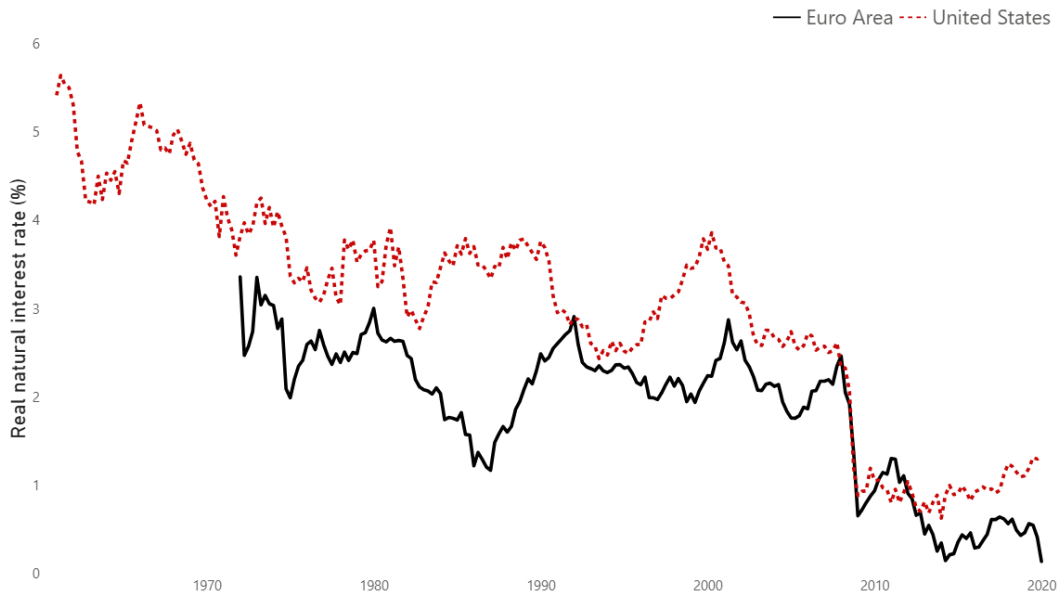
forces and shocks and not just the monetary framework, the literature highlights that regimes based on a nominal anchor and constrained discretion reinforce disinflationary credibility. In particular, by reducing the scope for inconsistent discretionary policies over time, these regimes help to mitigate the inflation bias associated with pure discretion, where decision-makers have an incentive to generate surprise inflation, but when this incentive is anticipated by the private sector, the result tends to be only higher inflation without permanent gains in activity (Kiley & Mishkin, 2025a).

At the same time, criticism began to emerge that the success of IT may have generated a certain financial blindness. In the context of globalisation, financial innovation, and credit liberalisation, the focus of monetary policy has been almost exclusively on inflation, which has arguably contributed to underestimating the dynamics of financial cycles, namely credit growth and asset prices, notably including real estate: as inflation remained low, the implicit reaction rule showed no signs of tightening, despite the significant increase in private leverage. This criticism would become more relevant considering the developments that led to the global financial crisis (Borio, 2024). Despite this interpretation, there is empirical evidence that discretionary monetary policy made only a limited contribution to the real estate boom, pointing instead to the loosening of credit and lending standards as the central mechanisms (Dokko et al., 2011).

2.2.1.2 Inflation targeting in the post-financial crisis period (2008–2019)

The global financial crisis of 2008 and the recession that followed posed a new challenge for the IT regime. In this period, the natural interest rate (r-star), an unobservable real short-term interest rate consistent with output at potential and stable inflation (Clarida, 2022; Laubach & Williams, 2003), has fallen to historically low levels across advanced economies.

Figure 3. *Estimated real natural interest rate in the euro area and the United States*



Note: Author's elaboration based on current model estimates from the Federal Reserve Bank of New York (n.d.), using the model described in Holston et al. (2023).

This secular decline of the equilibrium interest rate is the result of structural drivers such as a more modest productivity growth, demographic factors, and a rising global propensity to save (Kiley & Roberts, 2017; Williams, 2017). A decline in r-star increases the probability that policy rates reach the effective lower bound (ELB)[3] at which further cuts in the nominal interest rates are ineffective. Constrained by the ELB, monetary policy would lose its conventional stabilising power, that is, the capacity of monetary authorities to respond adequately to recessions or disinflationary pressures (Bernanke et al., 2019; Kiley & Roberts, 2017; Svensson, 2020).

These constraints have driven many central banks to implement unconventional monetary policies. While these measures may have helped mitigate the economic downturn, their effectiveness and long-term consequences are still widely debated. Evidence on the transmission mechanisms of these policies is mixed, and there is also lingering unease about possible side effects (Bernanke et al., 2019; Fernandes & Mota, 2021; Williams, 2017).

In this environment, as Svensson (2020) argued, the traditional framework of Inflation Targeting faced significant challenges. If inflation is persistently low and nominal rates are

[3] The effective lower bound (ELB) refers to the lowest practical level of the nominal policy rate at which further rate cuts provide little additional macroeconomic stimulus, due to institutional and market frictions and, ultimately, the availability of close substitutes such as cash or other near-zero-yield assets. The ELB need not coincide with the strict zero lower bound (ZLB) (i.e., when the minimum feasible nominal policy rate is zero) and may lie slightly below zero in some jurisdictions (Bernanke et al., 2019; McLeay et al., 2026).

constrained, this framework may lead to systematic undershooting of the inflation target, which could undermine credibility and anchor expectations below the desired level.

In a low r-star environment, the constraint imposed by the ELB makes the expectations channel particularly important. With limited scope for reducing nominal rates, macroeconomic stabilisation becomes more dependent on the monetary authority's ability to influence expected inflation and, in this way, keep ex-ante real interest rates sufficiently low, which requires credible forward guidance and a reaction function that is understood by agents. When inflation remains systematically below target, a flexible IT may generate the risk of an ELB trap, as medium-term expectations adjust downwards, reinforcing more restrictive real conditions and making it more difficult to return to the target. In this context, the debate surrounding makeup strategies has gained prominence. These strategies are designed to introduce history dependence more systematically and thus reinforce the credibility of the nominal anchor and reduce the frequency and costs of ELB episodes (Bernanke et al., 2019; Svensson, 2020; Williams, 2017).

2.2.1.3 Inflation targeting post-2020

The experience with IT frameworks since 2020 has been marked by significant inflation because of the post-pandemic period. While the level of global inflation has started to fall since 2022, it remained higher than the target in many advanced and emerging economies. The empirical results suggest that the extraordinary supply shocks, resulting from the long-lasting effects of the disruption of the supply chain due to the COVID-19 pandemic, as well as the effects of Russia's war in Ukraine on the energy and food supply, played an important role (Bernanke & Blanchard, 2024). Nevertheless, the more recent debate suggests that the way monetary policy was implemented under the IT frameworks may also have played a role, especially regarding the calibration of the response and the timing of the start of the normalisation (Kiley & Mishkin, 2025a, 2025b).

Among central banks that maintained formal inflation-targeting frameworks, responses to rising inflation post-2020 were heterogeneous. In many advanced economies with IT regimes, the combination of significant forecasting errors, linked to the difficulty of assessing the persistence of supply and demand shocks in real time, with less emphasis on preventive action, contributed to a relatively late start to the cycle of interest rate hikes, followed by rapid and pronounced tightening once the persistence of inflation was recognised (Kiley & Mishkin, 2025b).

In terms of institutional and regime design, the post-2020 inflation surge has revived the debate regarding the suitability of Inflation Targeting (IT) in an environment characterized by supply-side shocks and high real-time uncertainty. Recent literature suggests that the difficulties in assessing the persistence of shocks and forecast errors, and their interactions with revised approaches, have revived debates regarding compensation approaches and variations of IT (Kiley & Mishkin, 2025a).

Benchmarking studies treat the post-pandemic period as a direct test of different frameworks and alternative rules, analysing the costs and benefits of IT variants and compensation strategies during and after the inflationary surge (De Fiore et al., 2023). At the same time, recent evidence has been used to inform assessments of frameworks and to reassess instruments and communication, precisely because the episode exposed trade-offs and limitations in the context of global supply shocks (Clarida, 2025).

2.2.2 Recent institutional experience and framework debates

This subsection reviews practical experiences and institutional episodes that are relevant for assessing makeup strategies and alternative frameworks. It focuses first on the Federal Reserve and the European Central Bank in the 2020–2025 period, highlighting how strategy reviews, communication choices, and the interaction between inflation shocks and policy constraints influenced the evolution of their frameworks. It then complements these cases with selected experiences from other central banks and historical episodes, drawing lessons on the feasibility of history-dependent policies, the importance of credibility and expectations management, and the conditions under which makeup elements can be implemented in practice.

2.2.2.1 The United States Federal Reserve (2020–2025)

The recent experience of the United States Federal Reserve (Fed) between 2020 and 2025 is marked by two distinct moments: the strategic review that led to the adoption of flexible average inflation targeting (FAIT) and, subsequently, the reassessment of this framework after the post-pandemic inflationary surge (Federal Open Market Committee [FOMC], 2020; Powell, 2025). The 2019–2020 review was motivated by structural changes in the economy, in particular the fall in estimates of the real neutral interest rate (r-star) and the perception of a flatter Phillips curve, factors that increased the likelihood that monetary policy would be constrained by the effective lower bound (ELB) and that inflation would remain persistently below target (Clarida, 2022).

In this context, Clarida (2022) argues that, in a world of recurring ELB, flexible inflation targeting (FIT) can generate a downward bias in expectations and inflation, justifying the incorporation of makeup mechanisms to reinforce anchoring around 2 percent. The institutional response was to revise the Statement on Longer-Run Goals and Monetary Policy Strategy and adopt FAIT, with explicit communication that, after periods of inflation persistently below 2 percent, inflation moderately above 2 percent for some time could be appropriate for inflation to "average" around the target.

From a design perspective, Clarida (2022) interprets FAIT as a form of temporary price-level targeting in the ELB, which would revert to FIT after the start of normalisation, emphasising that the central role of the regime was to increase the effectiveness of the expectations channel in a very low interest rate environment. In parallel, Kiley and Mishkin (2025b) frame this evolution as part of the adaptation of IT to post-financial crisis constraints, with greater use of forward guidance and asset purchases, nonetheless noting that the 2020 framework remained relatively ambiguous about the specific horizon used to "average out" previous inflation shortfalls.

From 2021 onwards, inflation accelerated unexpectedly and put the new framework under scrutiny. Powell (2025) acknowledges that, like most analysts, the Fed initially assessed inflation as transitory and reacted late, then moved to a very rapid tightening cycle when persistence became evident. Kiley and Mishkin (2025b) highlight two key elements for understanding this dynamic in advanced economies: anticipation errors about the persistence of shocks and less emphasis on preventive action in a context where forward guidance and asset purchases also contributed to some inertia in the response. The analysis by Bernanke and Blanchard (2025) is consistent with the view that the initial inflationary impulse resulted mainly from goods-side shocks, i.e. price increases "given wages", associated with commodities and sectoral spikes generated by changes in the composition of demand and supply constraints.

In this context, the debate on the appropriateness of FAIT has shifted to its operationalisation and communication in a high-inflation environment. Powell (2025) argues that the focus of the 2020 text on the ELB and specific conditions may have complicated communication when inflation became the central problem and concludes that the Fed decided to return to a FIT framework, eliminating the makeup component. At the same time, the speech reaffirms that well-anchored inflation expectations were instrumental in achieving

disinflation without a sharp rise in unemployment and that the Fed cannot take this anchoring for granted but must act decisively to preserve it.

2.2.2.2 The European Central Bank (2020–2025)

Between 2020 and 2025, the European Central Bank (ECB) operated within a framework that remained *de jure* inflation targeting (IT), while its implementation reflected the logic of flexible inflation targeting (FIT). The 2021 strategy review is central in this regard, as it clarified the nominal anchor by adopting a symmetric 2 percent inflation target over the medium term, thereby reaffirming an inflation targeting regime rather than moving to an explicit makeup framework such as AIT or PLT (European Central Bank, 2021a, 2021b). At the same time, the ECB acknowledged that, when policy rates are close to the effective lower bound (ELB), achieving the inflation objective may require especially forceful or persistent policy measures, which strengthens the role of expectations and reinforces the medium-term orientation that characterises FIT in practice (European Central Bank, 2021a, 2021b).

Within this framework, the measures adopted between 2020 and 2025 altered the implementation of monetary policy rather than its target, with the aim of preserving policy transmission and stabilising inflation around the medium-term objective. The response to the pandemic aimed to safeguard transmission under acute stress, while the inflation surge from 2022 led the ECB to prioritise restoring price stability, combining rate hikes with measures to prevent disorderly fragmentation (European Central Bank, 2020, 2022). Subsequent balance-sheet normalisation and the gradual shift toward easing from mid-2024 onwards occurred as inflation declined and the assessment of underlying inflation pressures and transmission evolved, consistent with a flexible interpretation of the medium-term objective (European Central Bank, 2023, 2024a, 2024b, 2024c, 2025).

This recent evolution connects to the debate on makeup strategies because, even without formally adopting average inflation targeting (AIT), the ECB practice can be interpreted as reflecting an implicit average orientation over relatively long horizons. For example, Mota and Fernandes (2022) argue that the operational ambiguity of the medium term and the way policy reacts to inflation trajectories over several years are consistent with behaviour akin to an implicit AIT type approach, despite the absence of an explicit commitment to compensate past inflation misses.

2.2.2.3 Other experiences with makeup strategies

The Swedish experience is a standard historical example of price-level targeting (PLT). After abandoning the gold standard in 1931, Sweden adopted a price level target (targeting the CPI) a change that, according to Guender and Oh (2006), contributed to the sustained recovery that began in 1933–1934. CPI fluctuations were kept within a band of about 3 p.p. around the target value (the CPI for September 1931) until 1936, and despite a rise in 1937, the price level remained relatively stable until the start of World War II. In the same period, industrial production recovered from 1933 onwards, and unemployment, which peaked that year, fell to levels close to those recorded in 1928 by 1937.

In the process of renewing its inflation target in mid-2011, the Bank of Canada discussed PLT as an alternative to inflation targeting (IT) for two main reasons. First, because IT involves "base drift": temporary deviations from inflation can have permanent effects on the price level, increasing uncertainty about the price level as the horizon lengthens, whereas PLT would involve systematically reversing these deviations and limiting this uncertainty. Second, because PLT can reinforce macro stabilisation through the expectations channel and potentially reduce the frequency and costs of episodes at the zero lower bound (ZLB), since a larger undershoot would require more future stimulus and would tend to raise inflation expectations and reduce the real rate, facilitating the exit from the ZLB. Still, the document emphasises that the gains depend critically on the understanding and credibility of the regime (Bank of Canada, 2011).

Duarte et al. (2020) report that, amid a slowdown in the euro area and domestic fiscal consolidation, the Czech economy entered 2012 with inflation below the 2% target and output below potential. The Czech National Bank (CNB) cut its policy rate to the ELB in November 2012, but further accommodation remained necessary. In November 2013, it introduced an exchange-rate floor of CZK 27 per euro, which remained in place until April 2017. The policy rate was raised above the ELB a few months later. This measure resembled a makeup strategy because it provided a verifiable commitment to maintain accommodation until inflation returned to target, thereby influencing expectations through a clear exit condition. The subsequent normalisation suggests that the strategy was operationally successful.

Japan had faced deflationary pressures and very low interest rates since the 1990s, reaching the ELB in 1999, adopting quantitative easing in 2001, and returning to the ELB

after 2008 (Duarte et al., 2020). In September 2016, the Bank of Japan introduced its "overshooting commitment", pledging to expand the monetary base until inflation exceeded 2% and remained sustainably above target. This brought its forward guidance closer to a makeup strategy, aiming to compensate for prolonged below-target inflation. Assessing its success is difficult, however, because there was no subsequent liftoff from the ELB, the measure was introduced alongside yield curve control, and its horizon was unclear. After more than two decades of inflation below 2%, expectations may also have been difficult to shift. The authors accordingly find no clear break in inflation expectations or other macroeconomic variables after September 2016.

2.3 Synthesis and discussion

This section synthesises the main trade-offs highlighted in the literature when comparing conventional inflation targeting (IT) with makeup strategies and alternative nominal anchors. It focuses on comparative implications for stabilisation performance, the role of expectations and credibility, and lessons from recent institutional episodes and historical applications.

2.3.1 Key trade-offs across regimes

Flexible IT provides a clear nominal anchor and a pragmatic stabilisation framework, but it can generate "base drift" in the price level and may deliver persistent undershooting when constrained by the effective lower bound (ELB) or when inflation is structurally low (Svensson, 2020; Clarida, 2022). Makeup strategies are designed precisely to introduce systematic history dependence, thereby strengthening the expectations channel and reducing the likelihood that temporary shortfalls will become persistent.

Price-Level Targeting (PLT) is the most direct approach for addressing past misses in inflation targeting, given its focus on ensuring that the price level is targeted back to its target path. PLT reduces price level uncertainty in the long run compared to IT and may help alleviate ELB issues by increasing expected inflation following below-target outcomes (Bernanke et al., 2019; Svensson, 2020). However, offsetting past inflation shocks may be difficult to communicate and costly if supply shocks are dominant and relative price movements are persistent (Ambler, 2009; Bernanke, 2017).

Average Inflation Targeting (AIT) is often seen as a compromise between IT and PLT. The theoretical basis for AIT is that replacing the current inflation rate with the average

inflation rate may improve the performance of discretion by affecting expectations and price-level drift (Nessén & Vestin, 2005; Svensson, 2020). In practice, AIT's effectiveness hinges on whether the public can infer the averaging horizon and the implied reaction function, if these elements are not sufficiently clear, the expectations channel is likely to be weaker (Clarida, 2022; Powell, 2025; Svensson, 2020).

Nominal GDP Level Targeting (NGDPLT) incorporates makeup into the path of nominal GDP. The rationale for NGDPLT is that a credible commitment to a nominal GDP path anchors expectations of future nominal income, which smooths aggregate demand and could prevent the sharp demand-driven contractions and undershoots of the past (Sumner, 2024; Beckworth & Horan, 2024). NGDPLT is often considered relatively robust to adverse supply shocks (usually the major criticism to other makeup strategies) because it stabilises nominal spending while allowing inflation and real output to share the adjustment, rather than forcing inflation to offset supply-driven movements one-for-one (Beckworth & Horan, 2024). The main concern with this makeup strategy is that stabilising nominal GDP could involve greater short-run inflation variability in reaction to supply shocks, as the regime allows inflation to vary in the short run while real output responds (Beckworth & Horan, 2024; Binder, 2024). Related concerns are that inflation could become less predictable and more volatile if real output varies significantly (Pudner, 2025). These concerns may help explain why NGDPLT has never been adopted as an operational monetary policy framework in practice (Svensson, 2020).

The bottom-line is that makeup strategies could improve the efficacy of macroeconomic stabilisation in the face of insufficient aggregate demand and the risk of the ELB, but they could face sterner tests in the face of large and persistent supply shocks, relative price adjustments, and imperfect communication and credibility (Ambler, 2009; De Fiore et al., 2023; Svensson, 2020).

2.3.2 Communication, expectations, and credibility

Across these frameworks, the literature points repeatedly to expectations and credibility as the key factors. The theoretical benefits of history dependence hinge on private agents' expectations that the central bank will make up for past misses, thereby compressing the expected real interest rate and supporting private spending during negative shocks. The mechanism is strongest when the commitment is verifiable, the horizon is well understood,

and the public believes the central bank will allow the temporary overshooting if needed (Bernanke et al., 2019; Svensson, 2020).

Three issues are particularly salient in the literature:

1. Ambiguity of horizons and reaction functions. AIT-type frameworks may underperform if the public cannot discern how the average is calculated or how aggressively misses are being made up. This issue is accentuated in the analysis of the Fed's FAIT experience, where the lack of an explicit average window complicated communication as inflation took off (Kiley & Mishkin, 2025b; Powell, 2025).

2. Bounded rationality and imperfect internalisation. The makeup channel may lose power if agents do not fully internalise the intertemporal logic of the regime, limiting the gains relative to IT because of a weaker expectations channel (Bodenstein et al., 2022; Dobrew et al., 2025).

3. Time inconsistency and political economy. History-dependent strategies can be time-inconsistent because, once inflation rises, policymakers may have stronger incentives to avoid the implied overshooting – which makes credibility and communication central (Bernanke et al., 2019; Duarte et al., 2020). Such concern motivates proposals for temporary makeup approaches, particularly in ELB episodes (Bernanke, 2017).

These issues help explain why central banks may prefer frameworks that preserve the simplicity of an inflation target while allowing flexibility in implementation, rather than adopting a fully explicit makeup regime.

2.3.3 Lessons from institutional episodes

Recent institutional experiences confirm the relevance of the above considerations, as many central banks have formally remained within the IT regime while adapting their communication and implementation. The Fed's adoption of FAIT in 2020 should be interpreted as an attempt to "embed" a makeup logic in an ELB-prone environment, as the recent surge in inflation after the pandemic and the communication difficulties have led to a re-evaluation of the strategy towards a flexible IT (FOMC, 2020; Clarida, 2022; Powell, 2025). The ECB's 2021 strategy review reaffirmed a symmetric 2% inflation target over the medium term and acknowledged that, near the ELB, achieving the target may require especially forceful or persistent policy actions. However, the ECB did not adopt an explicit makeup rule. This matters for the broader debate because it highlights a key institutional

choice: central banks may strengthen the medium-term orientation and the expectations channel within a *de jure* IT/FIT framework, while avoiding the sharper communication and accountability requirements implied by formal makeup commitments. In this sense, interpretations of ECB practice as reflecting an implicit long-horizon averaging behaviour, rooted in the operational ambiguity of the medium term, help illustrate how history dependence can emerge de facto even when it is not codified de jure (European Central Bank, 2021a, 2021b; Mota & Fernandes, 2022).

Historical and cross-country episodes offer useful lessons about the conditions under which makeup strategies are likely to be effective. In particular, concrete commitments and verifiable exit conditions make the policy easier to communicate and more credible, thereby strengthening the expectations channel. Sweden's 1930s experience is often cited as a reference for PLT in a deflationary environment, illustrating how an explicit level objective can anchor expectations by committing to reverse past shortfalls (Guender & Oh, 2006). The Czech exchange-rate commitment at the ELB provides a more contemporary example of a makeup-like strategy with an observable exit condition, supporting the view that state-contingent commitments can substitute for conventional rate cuts when the policy rate is constrained (Duarte et al., 2020). By contrast, Japan's "overshooting commitment" underscores the practical difficulty of generating a decisive upward shift in inflation expectations after decades of below-target inflation, especially when the horizon for overshooting is perceived as distant or insufficiently clear, highlighting that credibility, salience, and communication design can be binding constraints on makeup strategies in practice (Duarte et al., 2020).

Overall, the literature does not point to a universally dominant framework. However, if the major challenge is the presence of persistent demand weakness and recurrent ELB problems, history-dependent strategies can provide significant gains in terms of macroeconomic stabilisation and could be helpful in terms of expectations (Bernanke et al., 2019; Svensson, 2020). If the environment is dominated by persistent supply shocks, large relative-price changes, or weak credibility, the net benefits are more ambiguous and may depend critically on communication design, institutional trust, and the extent to which the regime explicitly codifies its makeup component (Ambler, 2009; Dobrew et al., 2025).

3. Methodology

3.1. General framework of the model

The analysis in this dissertation is based on a New Keynesian-inspired dynamic stochastic general equilibrium (DSGE) model, constructed using the framework of Busetti et al. (2021). This type of model provides a coherent framework for analysing the dynamic interaction between intertemporal decisions, nominal rigidities, expectations, and monetary policy, and is particularly well-suited to comparing different monetary strategies in a context where the nominal interest rate may reach its effective lower bound (ELB).

The benchmark model by Busetti et al. (2021) is a medium-scale New Keynesian framework that closely follows the tradition of Smets and Wouters (2003), calibrated for the euro area. Households make decisions on consumption, savings, and capital accumulation, firms produce goods using capital and labour, prices and wages are subject to adjustment costs, and the monetary authority sets the interest rate via a systematic rule. Equations (3.1) to (3.21) presented in this chapter are based on the Online Technical Appendix to Busetti et al. (2021), with the notation adapted where necessary to the present implementation.

Nominal rigidities prevent prices and wages from adjusting instantly to shocks, meaning that changes in monetary policy have real effects in the short and medium term. Busetti et al. (2021) draw on this framework to compare inflation targeting (IT) with strategies that incorporate varying degrees of historical dependence, namely price-level targeting (PLT), average inflation targeting (AIT) and temporary price-level targeting (TPLT).

The implementation used in this dissertation seeks to preserve the economic logic and fundamental parameterisation of the model by Busetti et al. (2021) but does not constitute a full replication of the original exercise. In particular, the aim is not to reproduce all their stochastic simulations and quantitative results, but to construct a comparable structural framework that enables a controlled assessment of how different monetary rules respond to specific macroeconomic shocks. To this end, the main exercises are conducted in a deterministic setting, with expectations consistent with the model and with the future path of shocks known after the initial shock.

Our analysis features several extensions to the core framework of Busetti et al. (2021). The first one involves introducing a nominal GDP level targeting (NGDPLT) rule, under

which the interest rate responds to deviations of nominal GDP from its reference path. A second one consists of considering a positive technological shock as an additional scenario.

3.1.1. Consumption

Households determine their levels of consumption, savings, investment and labour supply by considering not only current conditions but also the expected future development of the economy. The model incorporates exogenous consumption habits, meaning that the marginal utility of current consumption depends on the difference between current consumption and a benchmark tied to past consumption. The marginal utility of consumption can be summarised as:

$$\lambda_t = \frac{1}{C_t - b_c C_{t-1}}, \tag{3.1}$$

where C_t represents consumption, b_c measures the intensity of the habit and λ_t corresponds to the marginal utility of consumption. This formulation introduces persistence in the consumption response to shocks.

The choice between consuming in the present and saving for the future is determined by an Euler condition. In the implementation used, this condition can be represented by:

$$\lambda_t = \beta E_t \left[\lambda_{t+1} \frac{R_t e^{b_t}}{\pi_{t+1}} \right], \tag{3.2}$$

where β corresponds to the discount factor, R_t to the gross nominal interest rate, π_{t+1} to expected inflation and b_t to the risk premium shock.

This term constitutes one of the model's main transmission channels. A reduction in the nominal rate, given a certain expected inflation rate, lowers the real rate relevant to intertemporal decision making, making it relatively less attractive to defer consumption to the future. Current consumption, therefore, tends to increase. Conversely, a rise in the real return on bonds encourages saving and reduces current demand.

It is precisely through this mechanism that the demand shock considered in the model operates. Busetti et al. (2021) interpret it as a positive risk premium shock, which increases the return on bonds relative to the policy rate and feeds directly into the Euler condition for consumption. In the implementation, this disturbance arises via the term e^{b_t}.

Consequently, an increase in b_t is contractionary in nature: it increases the incentive to save, reduces aggregate demand, and exerts downward pressure on output and inflation.

3.1.2. Capital and investment

Households also accumulate physical capital. Investment is subject to adjustment costs, so sudden changes in its rate of growth are costly. Capital accumulation is described by:

$$K_t = (1-\delta)K_{t-1} + \left[1 - \frac{\psi}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] I_t, \tag{3.3}$$

where K_t represents the capital stock, I_t investment, δ the depreciation rate and ψ the intensity of adjustment costs.

In the absence of changes in investment, that is, when $I_t/I_{t-1} = 1$, the adjustment term disappears. Conversely, more pronounced changes in investment reduce the efficiency with which current investment is transformed into new capital. This mechanism introduces persistence in the investment response and prevents excessively abrupt adjustments.

The decision between purchasing bonds and accumulating capital is linked by a no-arbitrage condition. The risk premium shock therefore affects not only consumption, through the relative return on bonds, but also the incentives for capital accumulation and, through this channel, investment. Busetti et al. (2021) explicitly identify these two channels in the transmission of the demand shock.

3.1.3. Production and the labour market

Production takes place using Cobb-Douglas technology, utilising capital carried over from the previous period and labour:

$$Y_t = e^{a_t} K_{t-1}^{\alpha} L_t^{1-\alpha}, \tag{3.4}$$

where Y_t corresponds to output, L_t to labour, α to the share of capital in production and a_t to the technological component.

An increase in a_t raises total factor productivity and allows for greater output to be produced using the same amount of capital and labour. The technological shock used in this dissertation, therefore, consists of a positive initial shock to a_t. This scenario is included as an extension to the core exercise in Busetti et al. (2021), allowing us to assess the behaviour

of different monetary rules in the face of a disturbance of a different nature from demand and markup shocks.

Firms' optimal conditions determine the demand for capital and labour as a function of their respective costs and the real marginal cost. Output is subsequently allocated between private consumption, investment, public consumption, and resources used in nominal adjustment and investment processes.

3.1.4. Price and wage rigidities

A key feature of the model are nominal rigidities. The adjustment of prices and wages involves Rotemberg (1982)-type quadratic costs, which is why firms and wage-setting agents do not instantly change their respective values in response to a shock.

For prices, the adjustment variable is given by:

$$adj_t^P = \frac{\pi_t}{\pi_{t-1}^{\iota_P} \bar{\pi}^{1-\iota_P}}, \tag{3.5}$$

where $\bar{\pi}$ represents steady state inflation and ι_P measures the degree of indexation to past inflation.

The costs associated with changing prices are proportional to:

$$\frac{\kappa_P}{2}(adj_t^P - 1)^2 Y_t, \tag{3.6}$$

where κ_P determines price rigidity. The higher this parameter, the more costly it is to change prices and, consequently, the more gradual the inflation response tends to be.

A similar structure is applied to nominal wages. The indexation of prices and wages to past inflation introduces an additional component of nominal persistence. The existence of these rigidities is essential for monetary policy to be effective. If prices and wages were completely flexible, changes in the nominal rate would tend to be reflected in nominal variables. With gradual nominal adjustment, changes in the real rate affect consumption, investment, labour and output, allowing different monetary strategies to have distinct implications for macroeconomic stabilisation.

3.1.5. Macroeconomic shocks

As standard in the literature, exogenous shocks follow first-order autoregressive processes:

$$x_t = \rho_x x_{t-1} + \sigma_x \varepsilon_t^x, \tag{3.7}$$

where ρ_x represents the persistence of the shock, σ_x the standard shock deviation and ε_t^x a standardised innovation.

Three types of disturbance are considered. The first is an adverse demand shock, modelled via an increase in the risk premium, b_t. The second is a price markup shock, of an inflationary nature, μ_t, which creates a more pronounced conflict between stabilising inflation and stabilising economic activity. The third is a positive technological shock, a_t, which is an extension that adds to the analysis in Busetti et al. (2021).

The demand shock is particularly relevant for comparing makeup strategies, as it simultaneously reduces output and inflation and may push the policy rate to the ELB. The markup shock, by contrast, tends to increase inflation whilst dampening economic activity, forcing the monetary authority to manage a more pronounced trade-off between its objectives. The technological shock allows us to assess how the rules respond when the source of the disturbance lies in the economy's productive capacity.

3.2. Calibration

3.2.1. Structural parameters

Our calibration follows, as closely as possible, that of Busetti et al. (2021). The parameters relating to preferences, technology, market structure, nominal rigidities, and the steady state are either taken directly from or derived from the calibration presented by the authors.

Table 1. *Model structural calibration*

Parameter	Symbol	Value
Steady State		
Gross quarterly inflation target	$\bar{\pi}$	1.005
Natural real interest rate	$\bar{r}^n$	≈ 0%
Consumption / output	C/Y	0.60
Public consumption / output	G/Y	≈ 0.20
Investment / output	I/Y	≈ 0.20
Preferences		
Discount Factor	β	0.99999
Elasticity of intertemporal substitution	EIS	1
Habit in consumption	b_c	0.57

Parameter	Symbol	Value
Frisch labour elasticity	$\frac{1}{\zeta}$	0.667
Technology		
Share of capital in production	α	0.24
Capital depreciation rate	δ	0.025
Investment adjustment cost	ψ	3
Elasticity of substitution (goods)	θ	6
Elasticity of substitution (labour)	θ_W	4.3
Nominal rigidities		
Price stickiness (Rotemberg)	κ_P	120
Wage stickiness (Rotemberg)	κ_W	300
Inflation indexation to previous-period inflation	ι_P	0.40
Wage indexation to previous-period inflation	ι_W	0.64

Note: Author's elaboration based on Busetti et al. (2021). The symbol "≈" indicates values implied by the model's steady state conditions and reported in rounded form.

3.2.2. Shocks

The parameters of the AR(1) shock processes defined in Eq. (3.7) are calibrated as follows: for risk premium and markup shocks, the persistences are set at 0.90, following Busetti et al. (2021). As the authors do not directly report the standard deviations used in the deterministic exercise, we adopt $\sigma_b = 0.0014$ and $\sigma_\mu = 0.0013$, based on Coenen et al. (2018), after conversion to decimal units. The technological shock, which is not present in Busetti et al. (2021), is calibrated following Moyen and Sahuc (2005), specifically setting $\rho_a = 0.95$ and $\sigma_a = 0.00775$.

Table 2. *Calibration of exogenous processes*

Shock type	Persistence	Standard deviation
Risk premium	0.90	0.0014
Markup	0.90	0.0013
Technology	0.95	0.00775

Note: Author's elaboration based on Busetti et al. (2021), Coenen et al. (2018) and Moyen and Sahuc (2005).

3.3. Model solution and simulation

The main simulations are carried out under model-consistent expectations: agents are initially surprised by the shock, but from that point onwards are aware of the future path determined by the shock process and the monetary rule. This assumption is relevant for the

assessment of makeup strategies, since part of their effectiveness stems precisely from their ability to alter expectations regarding the future conduct of monetary policy. As Busetti et al. (2021) emphasise, the performance of PLT, AIT and TPLT depends on the formation of expectations and the central bank's commitment to the announced strategy. All main deterministic transition paths are solved over a horizon of 150 quarters, with terminal values set at the deterministic steady state.

Computationally, the deterministic transition paths are solved using the perfect-foresight routines available in Dynare 7.0. The ELB is represented as an occasionally binding inequality in the monetary policy rule. The model is therefore formulated as a mixed complementarity problem and solved using the LMMCP (Levenberg–Marquardt mixed complementarity problem) algorithm. The complementarity condition leaves the unconstrained policy rule operative when it implies an interest rate above the ELB and fixes the policy rate at the ELB when the unconstrained rate would fall below it[4].

Each monetary rule implies a shadow interest rate, R_t^*, which is the unconstrained policy stance implied by the monetary rule, that may fall below the effective lower bound. The effective policy rate is constrained by the lower bound according to:

$$R_t = max\{R^{ELB}, R_t^*\}. \tag{3.8}$$

In the implementation, the effective lower bound is set at $R^{ELB} = 1$, corresponding to a quarterly net nominal interest rate of zero. The distinction between the effective policy rate and the shadow rate is particularly useful when interpreting the results. Whenever the shadow rate remains above the lower bound, the ELB is not binding, and the effective rate coincides with the rate prescribed by the monetary policy rule. Conversely, when the shadow rate falls below the effective lower bound, the monetary authority is constrained by the ELB, so that the effective rate remains fixed at R^{ELB}. The gap between the shadow rate and the lower bound provides an indication of the extent to which the ELB constrains monetary policy.

[4] All simulations were conducted in MATLAB R2026a (Update 2) using Dynare 7.0. The deterministic model was solved under perfect foresight using the LMMCP solver. This implementation is documented in Adjemian et al. (2026, Section 4.12.1, pp. 66–73); see also Alichi et al. (2015, Appendix 3, pp. 45–47) for an application to a model with a zero interest-rate floor.

The use of perfect foresight with LMMCP is an implementation choice and is not intended to exactly replicate the numerical algorithm used in Busetti et al. (2021). The aim is to consistently resolve the same type of non-linearity created by the ELB[5].

3.4. Monetary policy rules

All the rules analysed belong to the general class of interest rate policy rules with interest rate smoothing, whereby each period's shadow rate partly depends on the previous period actual rate and on one or more target variables.

In general, all policy rules are of the form:

$$\ln\left(\frac{R_t^*}{\bar{R}}\right) = \rho_r \ln\left(\frac{R_{t-1}}{\bar{R}}\right) + (1-\rho_r)\Omega_t, \tag{3.9}$$

where ρ_r represents the degree of interest rate smoothing and Ω_t contains the strategy-specific terms.

The use of R_{t-1}, that is, the observed rate rather than the past shadow rate, is consistent with the rules formulated by Busetti et al. (2021). Interest rate smoothing captures central banks' well-known tendency to adjust policy rates gradually, rather than fully responding to new macroeconomic conditions within a single period.

In the following subsections, we describe the monetary policy rules assessed in this dissertation.

3.4.1. Inflation targeting

The benchmark rule is inflation targeting (IT). Following Busetti et al. (2021), the interest rate reacts to the deviation of inflation from the target and to output growth:

$$\ln\left(\frac{R_t^*}{\bar{R}}\right) = \rho_r \ln\left(\frac{R_{t-1}}{\bar{R}}\right) + (1-\rho_r)\left[\rho_\pi \ln\left(\frac{\pi_t}{\bar{\pi}}\right) + \rho_y \ln\left(\frac{Y_t}{Y_{t-1}}\right)\right]. \tag{3.10}$$

As usual, $0<\rho_r<1$, $\rho_\pi>0$, and $\rho_y>0$. Moreover, $\rho_\pi>1$, so that when inflation is above (below) the target, the monetary authority raises (decreases) the nominal and the real interest rate, thereby increasing (decreasing) the real cost of borrowing and dampening (stimulating) demand.

[5] As a check, an alternative implementation based on an active-set Newton procedure led to the same binding regimes and virtually the same trajectories, reinforcing the robustness of the numerical solution used in the benchmark.

3.4.2. Price-level targeting

Under a price-level targeting regime (PLT), the central bank responds to the cumulative deviation of the price level from the path consistent with the inflation target. The relative price-level deviation can be expressed as:

$$\frac{P_t}{\bar{P}_t} = \prod_{i=0}^{t} \left(\frac{\pi_i}{\bar{\pi}}\right). \tag{3.11}$$

Taking logarithms:

$$\ln\left(\frac{P_t}{\bar{P}_t}\right) = \sum_{i=0}^{t} \ln\left(\frac{\pi_i}{\bar{\pi}}\right). \tag{3.12}$$

Accordingly, the price-level gap is defined as:

$$p_t^{gap} \equiv \ln\left(\frac{P_t}{\bar{P}_t}\right) \tag{3.13}$$

which can be written recursively as:

$$p_t^{gap} = p_{t-1}^{gap} + \ln\left(\frac{\pi_t}{\bar{\pi}}\right). \tag{3.14}$$

For example, an inflation rate of 1% when the target is 2% results in a negative deviation from the price level. Even if inflation subsequently returns to 2%, this deviation will accumulate and continue to influence monetary policy. Such policy memory is the key difference to IT. Under PLT, any inflation below (above) the target must be eventually followed by some inflation above (below) the target, in order to bring the price level back onto the desired path.

Following Busetti et al. (2021), the rule is:

$$\ln\left(\frac{R_t^*}{\bar{R}}\right) = \rho_r \ln\left(\frac{R_{t-1}}{\bar{R}}\right) + (1-\rho_r)\left[\rho_p\, p_t^{gap} + \rho_y \ln\left(\frac{Y_t}{Y_{t-1}}\right)\right]. \tag{3.15}$$

PLT is, therefore, a permanent makeup strategy: past errors do not simply disappear from the rule over time. Such feature allows future inflation expectations to be influenced; for example, agents may expect a reduction of the real rate during recessions, even before future reductions in the nominal rate are implemented.

3.4.3. Average inflation targeting

Average inflation targeting (AIT) seeks a degree of historical dependence intermediate to those of IT and PLT. Rather than reacting solely to current inflation or to all cumulative deviations from a starting point, the central bank reacts to the average inflation observed over a finite-time window.

Busetti et al. (2021) define average inflation geometrically. For a window of N quarters:

$$\pi_t^{avg} = \prod_{j=0}^{N-1} \left(\frac{\pi_{t-j}}{\bar{\pi}}\right)^{\frac{1}{N}}. \tag{3.16}$$

In the logarithmic representation used in the code, this expression is equivalent to:

$$\ln\left(\pi_t^{avg}\right) = \frac{1}{N}\sum_{j=0}^{N-1} \ln\left(\frac{\pi_{t-j}}{\bar{\pi}}\right). \tag{3.17}$$

The corresponding rule is:

$$\ln\left(\frac{R_t^*}{\bar{R}}\right) = \rho_r \ln\left(\frac{R_{t-1}}{\bar{R}}\right) + (1-\rho_r)\left[\rho_{avg} \ln\left(\pi_t^{avg}\right) + \rho_y \ln\left(\frac{Y_t}{Y_{t-1}}\right)\right]. \tag{3.18}$$

Following Busetti et al. (2021), in this dissertation we will analyse a two-year average and a four-year average, corresponding, at quarterly frequency, to windows of N=8 and N=16.

As is clear from the formulae, under AIT recent inflation deviations are partially offset, with older observations gradually falling out of the average to which policy reacts.

The length of the window significantly affects how the rule operates. A shorter window places greater weight on recent observations and adjusts more quickly to new conditions. A longer window introduces greater historical persistence, but makes the average less sensitive to recent changes in inflation.

3.4.4. Temporary price-level targeting

Temporary price-level targeting (TPLT) combines IT with a temporary PLT when conventional monetary policy is constrained by the ELB.

Specifically, following Busetti et al. (2021), the IT rule is augmented with a term capturing the cumulative deviation of inflation from the target since the beginning of the relevant ELB episode. This term is defined as:

$$Z_t = \prod_{i=t_1}^{t} \left(\frac{\pi_i}{\bar{\pi}}\right)^{\frac{1}{(i-t_1+1)}}, \tag{3.19}$$

where t_1 denotes the first period of the ELB episode identified under the benchmark IT rule.

In logarithms:

$$\ln Z_t = \sum_{i=t_1}^{t} \frac{1}{(i-t_1+1)} \ln\left(\frac{\pi_i}{\bar{\pi}}\right). \tag{3.20}$$

The TPLT shadow interest rate is determined by:

$$\begin{aligned} \ln\left(\frac{R_t^*}{\bar{R}}\right) = \rho_r \ \ln\left(\frac{R_{t-1}}{\bar{R}}\right) \\ + (1-\rho_r)\left[\rho_\pi \ \ln\left(\frac{\pi_t}{\bar{\pi}}\right) + \rho_{tplt} \ \ln(Z_t) + \rho_y \ \ln\left(\frac{Y_t}{Y_{t-1}}\right)\right]. \end{aligned} \tag{3.21}$$

The cumulative term $\ln Z_t$ introduces the makeup element of the strategy. Inflation below target during the relevant episode generates a negative shortfall, requiring a more accommodative policy stance than under conventional IT. TPLT therefore commits the central bank to maintaining monetary accommodation for longer, influencing expectations of future policy and inflation and, in turn, lowering the current real interest rate.

The implementation adopted in this dissertation preserves the central mechanism of Busetti et al. (2021) but adapts how the duration of the temporary regime is determined. First, the benchmark IT simulation is solved to identify the ELB episode. The first period in which IT reaches the ELB determines t_1, while the full IT ELB interval defines the initial TPLT commitment window. If the benchmark IT rule never reaches the ELB, TPLT is not activated and the regime is therefore equivalent to IT.

The model is then solved under TPLT using this initial window. If the resulting equilibrium still reaches the ELB, the commitment horizon is extended by one quarter, and the model is solved again. This process is repeated until the shortest horizon is found for which the TPLT equilibrium no longer reaches the ELB. Thus, the terminal date of the

temporary regime is neither imposed exogenously nor determined by requiring the cumulative inflation shortfall Z_t to be fully eliminated. Instead, it follows from a minimal no-ELB commitment criterion.

This implementation should therefore be interpreted as an adaptation, rather than as an exact reproduction, of the TPLT framework of Busetti et al. (2021). Entry into the regime remains anchored to the ELB episode identified under IT, while the duration of the makeup phase is determined endogenously by the minimum commitment required to prevent the ELB from becoming binding under TPLT.

3.4.5. Nominal GDP level targeting

Finally, we analyse the performance of nominal GDP level targeting (NGDPLT). While not analysed by Busetti et al. (2021), this monetary policy regime has often been addressed in the literature (see, e.g., Woodford, 2012) and has also been considered by policymakers (see, e.g., Carney, 2012). Busetti et al. (2021) exclude NGDPLT because their euro-area analysis focuses on strategies aimed at stabilising a measure of inflation, in line with the ECB's price-stability mandate, and because NGDPLT would represent a more substantial departure from IT in terms of communication. To operationalize NGDPLT, we follow the approach of Honkapohja and Mitra (2015), setting a target variable that combines the deviation of the price level from its target path with the deviation of output from its steady state level:

$$ngdplt_t^{gap} = p_t^{gap} + \ln\left(\frac{Y_t}{\bar{Y}}\right). \tag{3.22}$$

The rule is:

$$\ln\left(\frac{R_t^*}{\bar{R}}\right) = \rho_r \ln\left(\frac{R_{t-1}}{\bar{R}}\right) + (1-\rho_r)\rho_{ngdplt} ngdplt_t^{gap}. \tag{3.23}$$

NGDPLT differs from all the alternative regimes we analyse, in that it incorporates both a nominal and a real dimension within a single indicator. When inflation and output fall simultaneously, as typically occurs in the face of an adverse demand shock, both components reduce nominal GDP relative to its trajectory, reinforcing the monetary authority's expansionary response. In the face of supply shocks, given that movements in the price level and output partially offset one another, the policy response under NGDPLT is more measured and may manage the inflation-output trade-off in a more balanced way.

3.5. Calibration of monetary policy rules

The calibration of directly comparable rules follows Busetti et al. (2021). The interest rate smoothing coefficient is set at $\rho_r = 0.867$, whilst the response to inflation in the IT rule is $\rho_\pi = 1.9$, and the response to output growth is $\rho_y = 0.15$. The coefficients associated with the price-level gap in PLT, average inflation in AIT, and the cumulative inflation shortfall in TPLT are also set at 1.9, as in Busetti et al. (2021).

Table 3. *Calibration of monetary rules*

Parameter	Symbol	Value
Interest rate smoothing	ρ_r	0.867
Response to inflation	ρ_π	1.9
Response to output growth	ρ_y	0.15
Response to the price-level gap	ρ_p	1.9
Response to average inflation	ρ_{avg}	1.9
Response to the temporary price-level shortfall	ρ_{tplt}	1.9
Response to the nominal GDP gap	ρ_{ngdplt}	0.8

Note: Author's elaboration based on Busetti et al. (2021) and Honkapohja and Mitra (2015).

Setting $\rho_\pi = \rho_p = \rho_{avg} = \rho_{tplt} = 1.9$ is particularly important for the interpretation of the results. If each rule had, from the outset, a markedly different response intensity, it would be difficult to distinguish whether any improvement in performance resulted from the nature of the target variable or simply from a more aggressive monetary policy. The common calibration allows the comparison to focus primarily on the degree and form of historical dependence introduced by each regime.

In the case of NGDPLT, for which there is no directly transferable calibration from Busetti et al. (2021), we set $\rho_{ngdplt} = 0.8$, a calibration adopted from Honkapohja and Mitra (2015), who in turn followed Judd and Motley (1993), after accounting for the different annual and quarterly measurement conventions used in that study.

3.6. Simulation strategy and performance assessment

The different monetary policy rules are compared using deterministic simulations in the face of three shocks: an adverse risk premium shock, an inflationary markup shock and a positive technological shock.

The adverse demand shock is the main exercise for analysing monetary policy at the ELB. It is calibrated so that the benchmark IT rule remains constrained for several quarters,

allowing the alternative strategies to be compared when conventional policy is limited. The calibration seeks to reproduce the mechanism, rather than the exact duration, of the deterministic episode in Busetti et al. (2021).

The markup shock allows for the analysis of a distinct scenario, characterised by the coexistence of inflationary pressures and a deterioration in economic activity, creating a more evident trade-off between stabilising inflation and output. The positive technological shock enables an assessment of the rules' performance in the face of a different supply-side shock. In these cases, where the ELB does not bind under the benchmark IT rule, TPLT is not activated, and its results are therefore omitted from the main tables, as they are identical to those obtained under IT.

The first and foremost criterion to assess each rule's performance relies on the paths of inflation, output, and the interest rate. As a secondary criterion, we also consider the number of periods in which the ELB is binding, the timing of entry into and exit from it, and the minimum shadow rate. For the main criterion, the following quadratic loss function is calculated over the simulation horizon:

$$\mathcal{L} = \sum_{t=1}^{T} \left[{\pi^{\overline{\pi}}}^2_{t,ann} + 0.5 y_t^2 \right], \tag{3.24}$$

where

$$\pi^{\overline{\pi}}_{t,ann} = 400 \ln\left(\frac{\pi_t}{\overline{\pi}}\right), \tag{3.25}$$

represents the annualised deviation of inflation from the target and

$$\mathrm{y}_t = 100 \ln\left(\frac{Y_t}{\overline{Y}}\right) \tag{3.26}$$

corresponds to the percentage deviation of output from its steady state value.

The weight of 0.5 assigned to output maintains the relative importance considered by Busetti et al. (2021). A lower loss indicates that, over the entire horizon considered, a given rule was more effective in limiting deviations in inflation and output[6].

[6] The choice of loss function itself is a methodological issue. The objective attributed to the central bank need not coincide with social welfare and may differ across policy regimes. Verona et al. (2017), for example, consider alternative loss functions that include interest-rate and financial-stability objectives, distinguishing them from welfare-based measures derived from household utility. Busetti et al. (2021) also acknowledge that their quadratic loss function is *ad hoc* rather than micro-founded. In this dissertation, the same target variables and the same relative weight on output are applied uniformly across rules. However, the deterministic cumulative aggregation used here differs from the variance-based stochastic loss in Busetti et al. (2021).

The Loss function (3.24) is applied uniformly across all monetary strategies, enabling fair comparison. It is not, however, the only indicator considered. As a second criterion, we compare the duration of the ELB episode across policy rules to assess the extent to which each strategy reduces the impact of the ELB constraint on monetary policy, and the minimum unconstrained shadow rate, to assess the degree of accommodation that the rule would seek to implement in the absence of that constraint. Moreover, we compute the prescribed variation of the effective policy rate, to assess the extent and smoothness of the interest rate adjustments implied by each rule. These measures complement the loss function and allow for a more comprehensive interpretation of the mechanism through which each regime stabilises the economy.

Overall, our strategy seeks to assess not only the ability of different rules to stabilise inflation and output, but also the way this stabilisation is achieved. This aspect is particularly relevant in makeup strategies, whose functioning depends on the introduction of historical dependence and on the influence that the commitment to future policy exerts on agents' expectations.

4. Results

This chapter compares the performance of six monetary policy rules in a DSGE model with an ELB: IT, PLT, AIT with eight and sixteen-quarter windows, TPLT and NGDPLT. The presentation focuses on the main results for the three shocks, summarised in Tables 4.1 to 4.3 and supplemented by the paths shown in Figures 4.1 to 4.3. The deterministic cumulative loss is defined as the sum, over the 150-period simulation horizon, of squared annualised inflation deviations and 0.5 times squared output deviations. The figures display only the first 40 quarters[7].

4.1. Adverse demand shock

The adverse risk premium shock simultaneously reduces consumption, investment, output, and inflation, and is the only shock we consider that may be prone to the ELB

[7] As a robustness check, the model is re-solved with 200 quarters, and the first 150 quarters are compared with the benchmark. The ELB calendars and losses remain unchanged to the reported precision, while the maximum absolute path difference remains below 0.03 and the mean difference below 0.0007.

constraint. The disturbance is introduced at $t = 1$ as an innovation of $\varepsilon_1^b = 6.95$, given $\sigma_b = 0.0014$. This implies an initial increase in the risk-premium process of $b_1 = 0.00973$.

As shown in Table 4.1, under IT, the nominal rate remains at the ELB for six quarters, between t = 3 and t = 8. At their minimum, output falls by 4.094%, and inflation falls –3.066 p.p. relative to the target. The cumulative loss amounts to 93.005, the highest figure among the rules analysed. The unconstrained shadow rate would fall to -0.446% at its minimum.

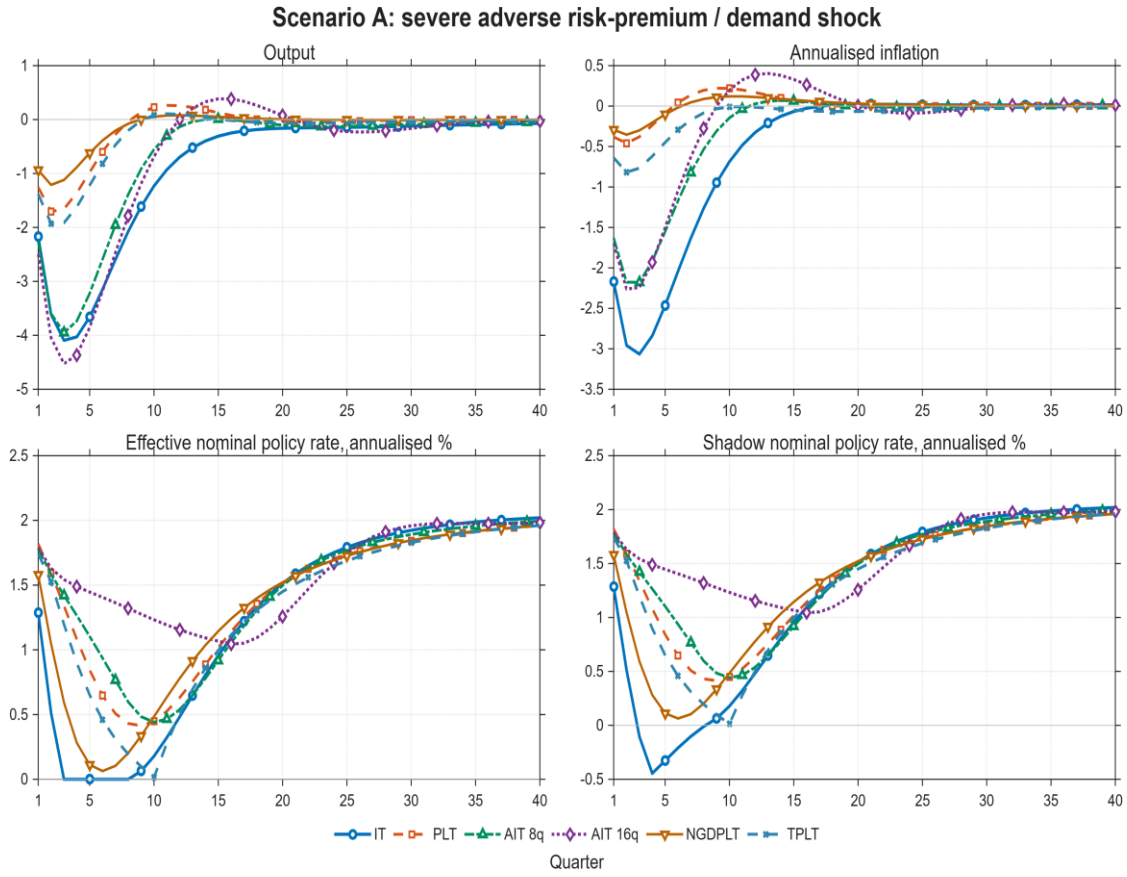
The contrast with the other rules is substantial. All of them avoid the ELB but do so with very different patterns and degrees of stabilisation. The comparison must therefore jointly consider inflation, output, and the loss.

Table 4.1. *Performance of policy rules following a demand shock.*

Rule	ELB duration (Qrt.)	Min. inflation	Min. output	Min. interest rate	Min. shadow rate	Cumulative loss
IT	6	-3.066	-4.094	0.000	-0.446	93.005
PLT	0	-0.459	-1.707	0.414	0.414	6.219
AIT 8	0	-2.178	-3.951	0.441	0.441	56.661
AIT 16	0	-2.263	-4.525	1.044	1.044	71.144
NGDPLT	0	-0.354	-1.210	0.064	0.064	2.950
TPLT	0*	-0.817	-1.929	0.014	0.014	9.632

Note: Inflation is measured as the annualised percentage point deviation from its steady state; output as a percentage deviation from steady state; the interest rate and shadow rate as an annualised percentage level. * In TPLT, the absence of ELB forms part of the selection criteria for the commitment horizon and does not constitute an independent outcome.

Figure 4.1. *Response to adverse demand shock.*



Note: Own elaboration based on the PF/LMMCP simulations.

NGDPLT produces the strongest joint stabilisation. Minimum inflation stands at -0.354 p.p., output falls by just 1.210%, and the cumulative loss is merely 2.950. As the shock simultaneously reduces the price level and output, the two components of the nominal GDP deviation reinforce the expansionary stance of monetary policy.

PLT yields the second lowest loss, 6.219, with a minimum inflation of -0.459 p.p. and a maximum fall in output of 1.707%. The commitment to correct accumulated deviations from the price level reduces expected deflation and limits the contraction in demand. Qualitatively, this pattern is consistent with Busetti et al. (2021), who find advantages for history-dependent rules when the ELB is relevant, and with the literature associating the PLT with more effective management of expectations under a commitment (Ambler, 2009).

AIT yields very limited gains compared to IT. The eight-quarter window reduces the loss to 56.661, but output still falls by 3.951% and inflation by 2.178 p.p.. The larger average

window, of sixteen quarters, generates different results: the loss falls to 71.144, and the maximum contraction in output is 4.525%, exceeding the 4.094% fall observed under IT. The longer time window dilutes the weight of recent deviations and keeps the nominal rate higher in the early stages of the recession; therefore, a longer averaging window does not automatically translate into greater accommodation in this model. Consistently, Nessén and Vestin (2005) show that the relative performance of AIT and the optimal averaging horizon depend on the degree of forward-looking behaviour and inflation persistence in the Phillips curve.

As for TPLT, the fall in output is reduced to 1.929%, the minimum inflation is limited to –0.817 p.p., and the loss amounts to 9.632. The commitment applies between t = 3 and t = 10 (the shortest horizon that eliminates the ELB in the TPLT equilibrium itself). The improvement in the stabilisation of inflation and output is economically significant.

Figure 4.1 shows the dynamics of inflation, output, and the interest rate (effective and shadow). IT and the two AIT rules show the sharpest falls in output and inflation, whilst NGDPLT, PLT, and TPLT cushion the impact from the very first quarters and lead to a faster recovery. AIT 16 maintains a particularly high interest rate in the 12 quarters after the shock, which surely explains the sharp contraction of output. In turn IT remains at the lower bound for several periods.

The inflation panels also show that rules with greater historical dependence generate a subsequent correction of the initial deviation, whilst IT returns to the target more slowly. The results seem consistent with the *lower-for-longer* literature: a credible commitment to maintaining low interest rates even after the economy begins to recover reduces expected future interest rates and, consequently, current real rates. This encourages households and firms to bring forward consumption and investment, allowing the future accommodation to support economic activity already at the time of the shock (Bernanke et al., 2019; Mertens & Williams, 2019).

4.2. Markup shock

An unfavourable price markup shock causes a rise in inflation and a fall in output. The disturbance is introduced at $t = 1$ as an innovation of $\varepsilon_1^{\mu} = 150$, given $\sigma_{\mu} = 0.0013$. This implies an initial increase in the price markup process of $\mu_1 = 0.195$. No rule hits the ELB and, therefore, TPLT is not activated, and its results coincide with those of IT. Table

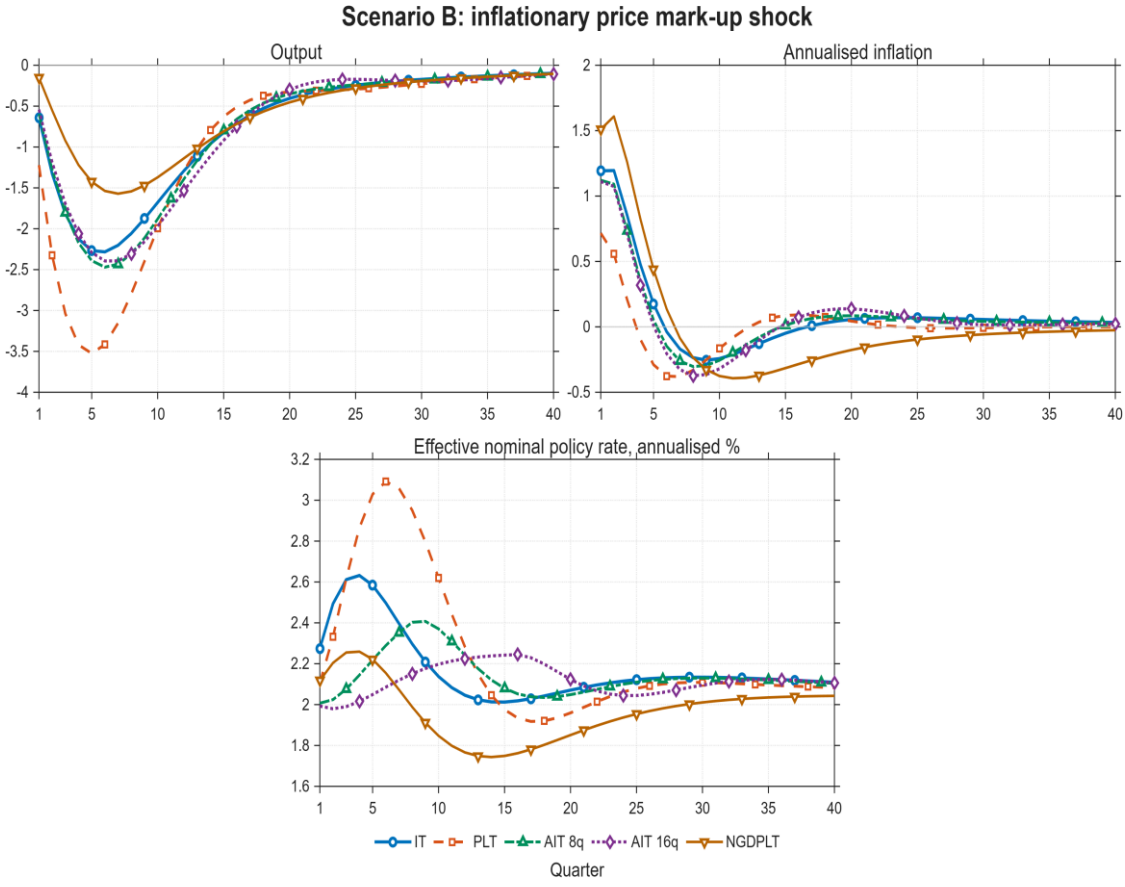
4.2 clearly highlights the trade-off between price stabilisation and output stabilisation under such a shock.

Table 4.2. *Performance of policy rules following a markup shock.*

Rule	Max. inflation	Min. output	Max. interest rate	Cumulative loss
IT	1.195	-2.283	2.632	26.669
PLT	0.716	-3.525	3.091	45.371
AIT 8	1.121	-2.470	2.407	28.905
AIT 16	1.111	-2.394	2.245	29.088
NGDPLT	1.609	-1.571	2.259	20.812

Note: Inflation is measured as the annualised percentage point deviation from its steady state; output as a percentage deviation from steady state; and the interest rate as an annualised percentage level.

Figure 4.2. *Response to the price markup shock.*



Note: Own elaboration based on the PF/LMMCP simulations

IT records a loss of 26.669, whilst AIT produces slightly higher figures, 28.905 for the eight-quarters window and 29.088 for the sixteen-quarter window. The trajectories of output, inflation, and the interest rate remain very similar across these three rules.

Consequently, the AIT's finite memory seems to offer no clear advantage when the central issue is the trade-off between inflation and economic activity in the context of a price-markup shock.

PLT is the most effective policy rule with respect to containing the rise in inflation, which peaks at 0.716 p.p. However, it does so at the cost of a greater contraction in output, 3.525%, and a cumulative loss, 45.371, larger than that of IT. Figure 4.2 shows that PLT features the sharpest rise in the interest rate and a subsequent correction in inflation to levels below the target. The memory effect, which is useful when demand is insufficient, makes the policy response more restrictive in the case of a price-markup shock.

The NGDPLT rule yields the smallest loss, 20.812, and the smallest fall in output, 1.571%, although it allows for the largest rise in inflation, 1.609 p.p.. As shown in Figure 4.2, a more moderate interest rate response helps preserve economic activity but makes the initial inflationary deviation larger and more persistent. The rule does not, therefore, prioritise price stabilisation. This finding is in line with Garín et al. (2016) and Beckworth and Horan (2024), who highlight the ability of the nominal GDP target to distribute the adjustment between inflation and output in the face of supply shocks.

4.3. Positive technological shock

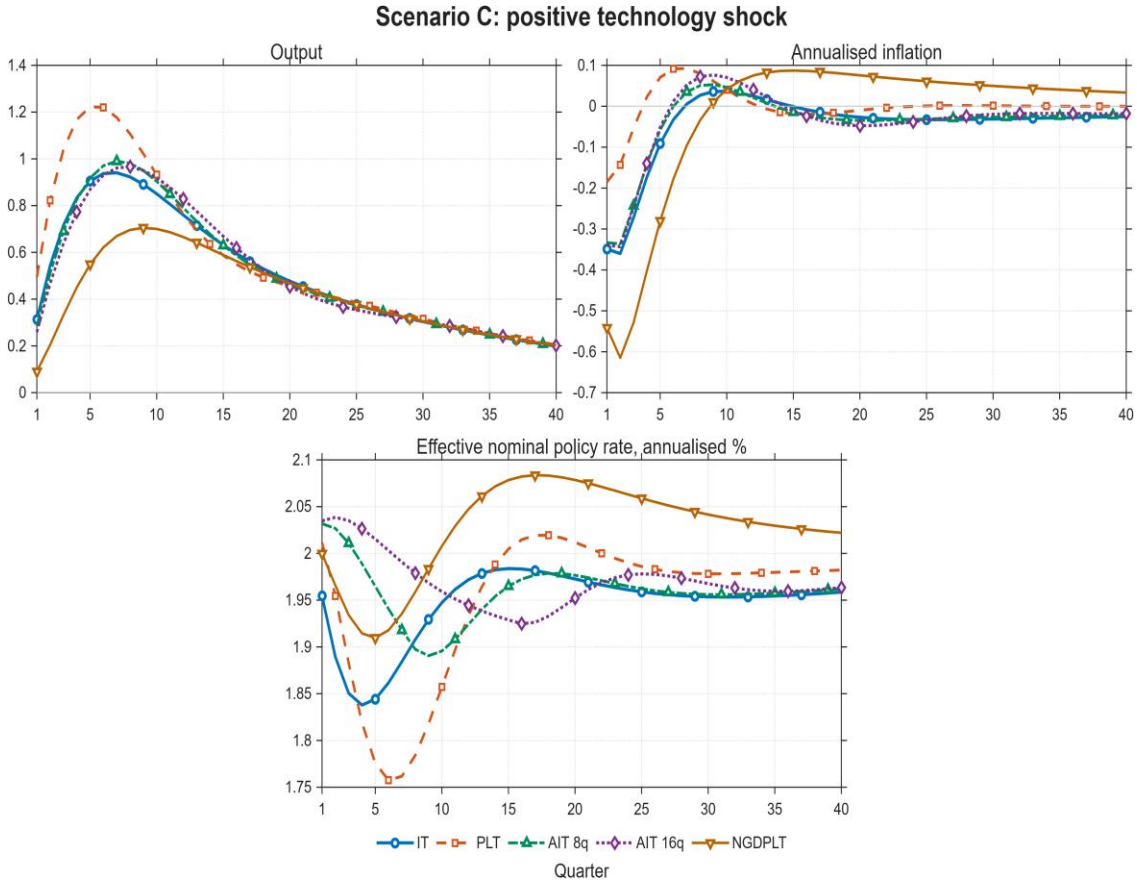
A positive technology shock increases output and reduces inflation. The disturbance is introduced at $t = 1$ as an innovation of $\varepsilon_1^a = 1$, given $\sigma_a = 0.00775$. This implies an initial increase in the technology process of $a_1 = 0.00775$. No policy rule reaches the ELB; therefore, the TPLT remains inactive, and its dynamics coincide with those of IT. Table 4.3 summarises the results obtained across the five distinct policy rules.

Table 4.3. *Performance of policy rules following a technological shock.*

Rule	Min. inflation	Max. output	Min. interest rate	Cumulative loss
IT	-0.360	0.941	1.838	6.911
PLT	-0.185	1.223	1.757	8.699
AIT 8	-0.336	0.990	1.891	7.084
AIT 16	-0.343	0.966	1.925	7.025
NGDPLT	-0.615	0.705	1.910	5.783

Note: Inflation is measured as the annualised percentage point deviation from its steady state; output as a percentage deviation from steady state; and the interest rate as an annualised percentage level.

Figure 4.3. *Responses to the positive technological shock.*



Note: Own elaboration based on the PF/LMMCP simulations.

PLT is the most effective policy rule for stabilising inflation, limiting its fall to 0.185 p.p., but is the least effective for stabilising output, allowing output to increase by up to 1.223%. Overall, this policy rule records the largest loss: 8.699. IT and the two versions of AIT produce very similar responses, with losses ranging from 6.911 to 7.084. Figure 4.3 confirms the similarity of results across these three policy rules.

NGDPLT, once again, features the smallest loss, 5.783, combining the most subdued expansion in output, 0.705%, with the largest fall in inflation, 0.615 p.p.. As with the markup shock, the NGDPLT favours joint stabilisation rather than minimising the price deviation in isolation, a pattern consistent with Garín et al. (2016).

4.4. Summary of results

The results do not identify a universally dominant rule across all dimensions. In the case of a demand shock, history dependence is clearly beneficial: PLT, NGDPLT, and TPLT reduce deflation, limit the fall in output, and prevent the effective interest rate from

remaining at the ELB for an extended period. This conclusion is qualitatively consistent with Busetti et al. (2021) and the literature on *lower-for-longer* strategies (Bernanke et al., 2019; Mertens & Williams, 2019).

In the face of supply shocks, the choice entails a clearer trade-off. PLT stabilises prices more effectively but generates larger fluctuations in output. NGDPLT accepts greater variation in inflation to stabilise output and incurs the smallest loss. This evidence is consistent with the literature that interprets nominal GDP as a target capable of distributing the adjustment between inflation and output (Garín et al., 2016; Beckworth & Horan, 2024).

TPLT reveals significant potential following a demand shock, but its performance depends on the duration of the commitment and on its influence on expectations. AIT, in turn, confirms that finite memory constitutes an intermediate solution, without automatically guaranteeing better stabilisation: the eight-quarter window outperforms the sixteen-quarter window following the demand shock, whilst the two yield very similar results in the remaining scenarios. Nevertheless, the AIT specifications, particularly the sixteen-quarter variant, generally produce comparatively smoother interest-rate paths. This advantage is not reflected in the reported cumulative loss, since the loss function includes only inflation and output deviations and does not penalise interest-rate variability.

NGDPLT exhibits the smallest loss across the three shocks and is the rule with the best aggregate performance. This ranking is, however, conditional on the perfect-foresight environment, the adopted calibration, and the model's structural specification.

5. Sensitivity analyses

This chapter examines how the cumulative deterministic loss varies with the intensity of the monetary policy response. Only one rule-specific coefficient is varied at a time. Under IT, ρ_{π} measures the response to the current inflation gap. Under PLT, TPLT, and AIT, ρ_{p}, ρ_{tplt}, and ρ_{avg} scale the response to the price-level gap and the average inflation gap, respectively (with the two AIT windows evaluated separately but using the same coefficient notation). These are inflation-based target variables with different degrees of history dependence. NGDPLT is the exception: ρ_{ngdplt} measures the interest-rate response to the nominal GDP level gap, which combines the price level and real output.

The benchmark calibration is $\rho_\pi = \rho_p = \rho_{avg} = \rho_{tplt} = 1.9$ and $\rho_{ngdplt} = 0.8$. Interest-rate smoothing, the response to output growth, the structural parameters, shock sizes, all other rule features, and the simulation horizon (150 quarters) all remain fixed, and so differences within each panel can be attributed to the coefficient being varied.

5.1 Design and interpretation of the exercise

The analysis is conceptually motivated by Hofmann et al. (2025), who allow a Taylor rule to react differently to demand and supply-driven inflation, but it does not follow their approach or specification. In their analysis, inflation is decomposed by origin, and two shock-specific coefficients are estimated. Instead, we solve each monetary rule separately under an adverse demand shock and an inflationary price markup shock, while its own response coefficient is varied over the grids in Table 5.1. The exercise asks whether the degree of aggressiveness favoured by the adopted loss function changes with the nature of the shock.

Table 5.1. *Coefficients varied in the sensitivity exercise.*

Rule	Coefficient	Benchmark	Grid Demand shock	Grid Markup shock
IT	ρ_π	1.9	0.5–5.0	0.5–5.0
PLT	ρ_p	1.9	0.5–5.0	0.1–5.0
AIT 8Q	ρ_{avg}	1.9	0.5–5.0	0.5–5.0
AIT 16Q	ρ_{avg}	1.9	0.5–5.0	0.5–5.0
TPLT	ρ_{tplt}	1.9	0.5–5.0	n.a.
NGDPLT	ρ_{ngdplt}	0.8	0.2–2.5	0.2–2.5

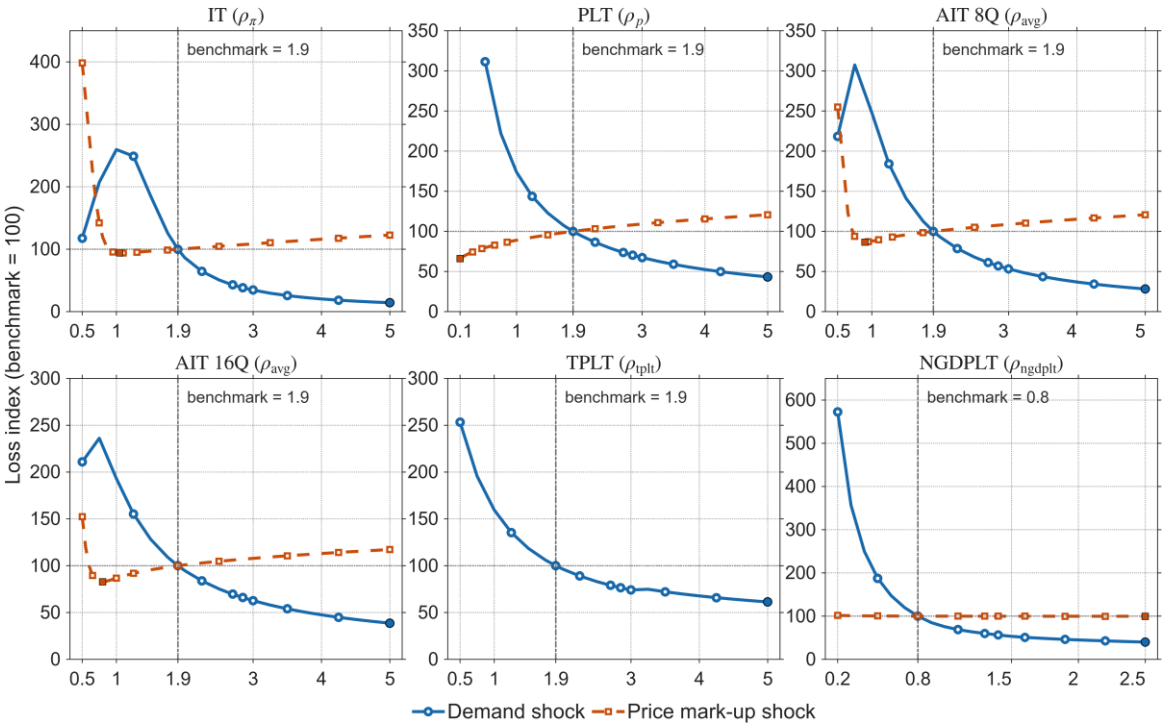
Note: TPLT is not evaluated under the markup shock because the benchmark IT rule does not reach the ELB, in that case TPLT is not activated and coincides with IT.

Because absolute loss levels differ markedly across some rules/shocks, we normalize loss setting $\mathcal{L} = 100$ for the benchmark calibration, along all policy rules and shocks. This places the results on a common scale and facilitates comparison of how the loss responds to changes in the policy coefficient. For shock s and coefficient ρ, the Loss index is:

$$Loss\ index_s(\rho) = 100 * \frac{\mathcal{L}_s(\rho)}{\mathcal{L}_s(\rho^B)},$$

where ρ^B is the benchmark coefficient. A value of 100 reproduces the benchmark loss; values below (above) 100 indicate a lower (higher) loss than under the baseline calibration.

Figure 5.1. *Sensitivity of cumulative loss to the actual values of the policy-response coefficients*



Note: The Loss is indexed to 100 at the benchmark calibration for each rule and shock. Filled markers identify the lowest loss observed within the tested grid and should not be interpreted as global optima. The vertical dash-dot line identifies the benchmark coefficient

5.2 Results

Under an adverse demand shock, the cumulative loss generally declines as the policy response strengthens. The lowest values occur at the upper boundary of the tested grid: 5.0 for IT, PLT, both AIT specifications, and TPLT, and 2.5 for NGDPLT. Since these minima are located at the grid boundary, they cannot be interpreted as global optima. They indicate only that, within the range considered, the adopted loss function favours a more forceful response. In this scenario, inflation and output fall simultaneously, allowing stronger monetary accommodation to stabilise both variables. Under the history-dependent rules, a stronger response also reinforces the expected future path of accommodation and the associated makeup mechanism.

The price markup shock produces a different pattern because it raises inflation while reducing output. A stronger monetary response may contain inflation more rapidly, but can also deepen the contraction in activity. The loss, therefore, generally favours more moderate coefficients: 1.05 for IT, 0.9 for AIT 8Q, 0.8 for AIT 16Q, and 0.1 for PLT. The PLT result lies at the lower boundary and should consequently be interpreted as directional evidence

rather than as a precise optimum. For IT, values at or below one remain exploratory because they do not satisfy the usual Taylor principle condition for the determinacy of forward-looking models. NGDPLT is the main exception, as its loss changes very little across the tested coefficients. This relative insensitivity may reflect the partial offset between movements in prices and real output within the nominal GDP target.

5.3 Implications

The exercise does not identify a degree of policy aggressiveness that is unequivocally preferable across both shocks. The loss criterion favours stronger responses when inflation and output fall together following a demand shock but generally favours more moderate responses when a markup shock creates a trade-off between price and output stabilisation. This qualitative asymmetry is reminiscent of the results in Hofmann et al. (2025), although the present exercise is a model-based sensitivity analysis rather than an econometric exercise of estimating policy rules with shock-dependent coefficients.

As several minima occur at the boundaries of the grids, the results indicate the direction of the relationship rather than global optima. They are also conditional on the shocks considered, the perfect-foresight environment, the model calibration, and a Loss function that does not penalise interest-rate volatility. The exercise should therefore be interpreted as sensitivity evidence rather than as a welfare-based optimisation of the monetary policy rules.

6. Conclusions

This dissertation analysed the performance of different monetary policy rules in a New Keynesian DSGE model. Building on the model by Busetti et al. (2021), the following rules were compared: an inflation targeting regime (IT), price-level targeting (PLT), two specifications of average inflation targeting (AIT) with windows of eight and sixteen quarters, a temporary price-level targeting rule (TPLT), and nominal GDP level targeting (NGDPLT, a policy rule not assessed in Busetti et al. (2021)). The analysis considered demand, markup, and technological shocks in an environment of perfect foresight and under a calibration representative of the euro area.

The results show that the advantages of alternative strategies to IT are particularly evident in the face of an adverse demand shock strong enough to push the interest rate down

to ELB. In this scenario, IT results in the sharpest falls in inflation and output, and the greatest cumulative loss. Rules that depend on past performance yield a faster recovery, as commitment to future monetary accommodation influences expectations and reduces the expected real interest rate at the time of the shock. This mechanism is consistent with the literature on *lower-for-longer* policies and on the advantages of historical dependence when monetary policy is constrained by the ELB (Ambler, 2009; Bernanke et al., 2019; Mertens & Williams, 2019).

NGDPLT shows the smallest cumulative loss under the demand shock, followed by PLT and TPLT. TPLT's result highlights the potential of a temporary strategy to offset past deviations, although this depends on the duration of the commitment and the central bank's ability to guide expectations. Its results should therefore be interpreted as conditional on the selected duration and on the assumption that economic agents understand and believe in the announced commitment, a difficulty also highlighted by Bernanke (2017).

The AIT rules also improve stabilisation, compared with IT, but a longer memory does not necessarily lead to superior performance. The eight-quarter window yields a lower loss than the sixteen-quarter window, suggesting that the appropriate length of the compensation period depends on the persistence of shocks and the structure of the economy, in line with Nessén and Vestin (2005). Although it does not minimise the loss function, AIT still produces relatively smooth interest rate paths. This characteristic is not directly captured by our loss function, which includes only deviations in inflation and output.

In the case of markup and technological shocks, the interest rate does not reach the ELB under the IT rule. Consequently, the TPLT is not triggered, and that regime produces results equivalent to those of IT. In these scenarios, the differences between the rules mainly reflect the distribution of the adjustment between inflation and economic activity. PLT stabilises inflation more strongly but causes greater fluctuations in output. By contrast, NGDPLT allows for greater price adjustment and reduces the output response, resulting in the smallest cumulative loss under both shocks. This result is consistent with the literature highlighting the NGDPLT's ability to distribute the adjustment between prices and output in the face of supply shocks (Beckworth & Horan, 2024; Garín et al., 2016).

Overall, the results do not identify a rule that is universally superior across all dimensions. NGDPLT minimises the loss function under the three shocks analysed, but does not always produce the smallest change in inflation or interest rate. PLT offers stronger

price stabilisation in the face of supply shocks, albeit at the cost of greater volatility of output. AIT represents an intermediate solution, whilst TPLT delivers significant benefits in ELB situations without requiring a permanent change to the regime. The assessment of each rule, therefore, depends on the objectives assigned to monetary policy and the relative importance attached to the stability of inflation, output, and interest rates.

The sensitivity analysis carried out in Chapter 5 reinforces the view that the performance of each rule depends not only on its structure, but also on the nature of the shock and the intensity of the monetary policy response to deviations of the goal variable from its target. Under an adverse demand shock, macroeconomic stabilisation improves with the intensity of the policy reaction. Under a markup shock, as there is a trade-off between stabilising output and inflation, overall macroeconomic stabilisation improves with more moderate responses. Our analysis further shows that NGDPLT is the policy regime least sensitive to changes in its policy coefficient.

These conclusions should be interpreted in light of the limitations of the exercise. The analysis is based on a specific structural model with its theoretical assumptions and calibration, and does not constitute an empirical assessment of an actual economic event. The results are therefore contingent on the model's structure, the calibration of the parameters, and the magnitude and persistence of the shocks. Furthermore, the assumption of perfect foresight implies that, following the initial shock, agents are aware of its future trajectory and correctly understand the central bank's rule. In practice, households and firms may not fully understand strategies that compensate for past deviations, as suggested by Coibion et al. (2023) and Hoffmann et al. (2022). Under bounded rationality, their benefits may therefore be lower than those obtained in this model (Molnar, 2021).

The loss function used constitutes a further limitation. Whilst it allows for a transparent comparison of the stabilisation of inflation and output, it does not take into account interest rate volatility, possible alternative measures of welfare, communication costs, or operational difficulties. In the case of NGDPLT, issues such as the revision of nominal output data and the potential difficulty in communicating the target to the public are also not considered (Pudner (2025)).

Future research could introduce adaptive expectations or learning mechanisms, enabling assessment of whether the benefits of these rules hold when agents lack perfect knowledge of the economy or the policy regime somehow lacks credibility. This extension

would be particularly relevant because the effectiveness of path-dependent strategies depends on the ability to adjust expectations about future policy. The literature shows that the results can change significantly when expectations are formed through learning processes or when there is uncertainty about the monetary regime (Bodenstein et al., 2022; Honkapohja & Mitra, 2015).

Further useful analyses include estimating the model with more recent Euro Area data, accounting for combined shocks, and introducing heterogeneity among households and firms. Yet further extensions could compare alternative loss functions, including those that account for interest rate volatility, or conduct a welfare analysis derived directly from agents' preferences.

In summary, this dissertation shows that incorporating the past into the conduct of monetary policy can substantially improve macroeconomic stabilisation when the ELB constrains the central bank's action. However, these benefits depend on the type of shock, the rule's specification, the model's structure, and the central bank's ability to influence expectations. The results thus support a cautious assessment of alternatives to the conventional inflation targeting regime, whilst recognising both their potential and the difficulties associated with their implementation.

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8. Annex

Table A.1. *Sensitivity to the size of the adverse demand shock.*

Panel A. Shock size: $\varepsilon_b = 4$					
Rule	**ELB duration (qtrs.)**	**Min. inflation**	**Min. output**	**Min. interest rate**	**Cumulative loss**
IT	0	-1.359	-1.903	0.738	18.353
PLT	0	-0.265	-0.981	1.091	2.053
AIT 8	0	-1.273	-2.282	1.104	18.915
AIT 16	0	-1.327	-2.611	1.452	23.710
NGDPLT	0	-0.205	-0.697	0.889	0.978
TPLT	0	-1.359	-1.903	0.738	18.353
Panel B. Shock size: $\varepsilon_b = 5.5$					
Rule	**ELB duration (qtrs.)**	**Min. inflation**	**Min. output**	**Min. interest rate**	**Cumulative loss**
IT	0	-1.860	-2.603	0.266	34.464
PLT	0	-0.364	-1.350	0.746	3.888
AIT 8	0	-1.736	-3.132	0.766	35.607
AIT 16	0	-1.807	-3.585	1.244	44.669
NGDPLT	0	-0.281	-0.958	0.468	1.849
TPLT	0	-1.860	-2.603	0.266	34.464
Panel C. Shock size: $\varepsilon_b = 8$					
Rule	**ELB duration (qtrs.)**	**Min. inflation**	**Min. output**	**Min. interest rate**	**Cumulative loss**
IT	10	-8.498	-11.134	0.000	758.413
PLT	0	-0.528	-1.966	0.174	8.251
AIT 8	0	-2.500	-4.543	0.208	74.920
AIT 16	0	-2.588	-5.206	0.901	94.140
NGDPLT	4	-0.467	-1.494	0.000	4.930
TPLT	0*	-0.722	-2.100	0.161	10.432

Note: Only the shock size changes relative to the benchmark specification, and the simulation horizon remains 150 quarters. Inflation is measured as the annualised percentage point deviation from steady state; output as the percentage deviation from steady state; and the interest rate as an annualised percentage level. Cumulative loss is calculated using the same loss function as in the main results. * For TPLT in Panel C, zero ELB periods is the criterion used to select the minimum commitment horizon. TPLT is inactive in Panels A and B because IT does not reach the ELB and therefore coincides with IT.

Table A.2. *Sensitivity to the size of the inflationary markup shock.*

Panel A. Shock size: $\varepsilon_\mu = 100$				
Rule	**Max. inflation**	**Min. output**	**Max. interest rate**	**Cumulative loss**
IT	0.798	-1.501	2.423	11.587
PLT	0.478	-2.298	2.720	19.317
AIT 8	0.750	-1.625	2.273	12.534
AIT 16	0.743	-1.578	2.166	12.625
NGDPLT	1.075	-1.039	2.172	9.152
Panel B. Shock size: $\varepsilon_\mu = 200$				
Rule	**Max. inflation**	**Min. output**	**Max. interest rate**	**Cumulative loss**
IT	1.600	-3.085	2.844	48.498
PLT	0.953	-4.807	3.477	84.264
AIT 8	1.489	-3.335	2.546	52.667
AIT 16	1.475	-3.234	2.327	52.953
NGDPLT	2.140	-2.111	2.354	37.387
Panel C. Shock size: $\varepsilon_\mu = 250$				
Rule	**Max. inflation**	**Min. output**	**Max. interest rate**	**Cumulative loss**
IT	2.007	-3.906	3.061	77.510
PLT	1.188	-6.144	3.878	137.660
AIT 8	1.855	-4.221	2.690	84.336
AIT 16	1.836	-4.096	2.413	84.717
NGDPLT	2.668	-2.658	2.456	59.020

Note: Only the shock size changes relative to the benchmark specification, and the simulation horizon remains 150 quarters. Inflation is measured as the annualised percentage point deviation from steady state; output as the percentage deviation from steady state; and the interest rate as an annualised percentage level. Cumulative loss is calculated using the same loss function as in the main results. TPLT is inactive in all panels because IT does not reach the ELB and therefore coincides with IT; it is consequently omitted from the table.

Table A.3. *Sensitivity to the size of the positive technological shock.*

Panel A. Shock size: $\varepsilon_a = 0.5$				
Rule	**Min. inflation**	**Max. output**	**Min. interest rate**	**Cumulative loss**
IT	-0.180	0.470	1.928	1.728
PLT	-0.093	0.612	1.887	2.179
AIT 8	-0.169	0.495	1.955	1.772
AIT 16	-0.172	0.483	1.972	1.757
NGDPLT	-0.308	0.353	1.964	1.446
Panel B. Shock size: $\varepsilon_a = 1.5$				
Rule	**Min. inflation**	**Max. output**	**Min. interest rate**	**Cumulative loss**
IT	-0.539	1.410	1.748	15.547
PLT	-0.277	1.831	1.629	19.536
AIT 8	-0.503	1.484	1.827	15.932
AIT 16	-0.513	1.448	1.878	15.799
NGDPLT	-0.922	1.057	1.857	13.004
Panel C. Shock size: $\varepsilon_a = 2$				
Rule	**Min. inflation**	**Max. output**	**Min. interest rate**	**Cumulative loss**
IT	-0.716	1.880	1.659	27.632
PLT	-0.368	2.437	1.502	34.668
AIT 8	-0.669	1.978	1.764	28.311
AIT 16	-0.682	1.930	1.832	28.074
NGDPLT	-1.229	1.409	1.805	23.107

Note: Only the shock size changes relative to the benchmark specification, and the simulation horizon remains 150 quarters. Inflation is measured as the annualised percentage point deviation from steady state; output as the percentage deviation from steady state; and the interest rate as an annualised percentage level. Cumulative loss is calculated using the same loss function as in the main results. TPLT is inactive in all panels because IT does not reach the ELB and therefore coincides with IT; it is consequently omitted from the table.