The Optimal Inflation Target: Bridging the Gap Between Theory and Policy[1]

Klaus Adam (University of Mannheim & CEPR)

Henning Weber (Deutsche Bundesbank)

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Abstract

Many central banks worldwide announce numerical inflation targets, typically ranging from zero to two percent in advanced economies and higher in developing countries. Historically, a significant gap existed between the inflation targets pursued by central banks and those recommended by academic studies. This paper reviews traditional economic forces advocating for zero or negative inflation targets and surveys new forces justifying positive targets. Key factors include (i) trends in relative prices, (ii) the lower bound constraint on nominal interest rates, (iii) (downward) wage rigidity, and (iv) effects of product entry and aggregation. By examining these forces, we assess whether current inflation targets are optimal or require adjustment, and identify areas for future research on optimal inflation targets.

1 Introduction

Many central banks around the globe announce numerical inflation targets or target ranges that they aim to achieve over a certain horizon. In advanced economies, these targets typically range between zero and two percent, whereas in developing countries they can be significantly higher. Inflation targets are also regularly reviewed and occasionally adjusted, as illustrated in Table 1.

Until recently, a significant gap existed between the optimal inflation targets derived in the academic literature and those pursued by central banks. While central banks often aim for significantly positive inflation targets, the academic literature prior to 2010 predominantly recommended slightly or substantially negative targets, as noted by Schmitt-Grohé and Uribe (2010).

Central bank	Current target	Prior target
Swiss National Bank	0% – 2%	monetary base target
Bank of England	2%	2.5%
Bank of Japan	2%	no target announced
European Central Bank	2%	close to but below 2%
U.S. Federal Reserve	2%	no target announced
Brazilian Central Bank	3%	gradual decrease from 4.5%
Reserve Bank of India	4%	6%

Table 1: Inflation targets of selected central banks

This discrepancy raises the question of whether the academic literature overlooks important factors that motivate central bank behavior or if central banks' inflation targets are suboptimally high. To address this question, we review the traditional economic forces that have led to the recommendation of zero or negative optimal inflation targets in monetary models. We then explore the new economic forces incorporated into monetary models over the past 15 years that justify positive inflation targets. Ultimately, it is up to the reader to assess whether these new forces support central banks' actual inflation targets or suggest the need for adjustment. Besides reviewing existing research we highlight open questions about the optimal inflation target and suggests areas for further research.

Our review focuses on the academic literature that quantitatively investigates the economic determinants of the welfare-optimal inflation target. We thus examine the normative question of the (average or long-run) rate of inflation that a central bank should commit to. While the optimal stabilization policy in response to economic disturbances is also a critical research topic, we discuss it only insofar as it impacts the optimal inflation target. In particular, this the case when stabilization responses exhibit important non-linearities, such as the lower-bound constraint on nominal interest rates or downward rigidities in nominal wages. In such settings, stabilization policy cannot be separated from the question of what is the optimal average inflation rate.

The dominant approach in the academic literature for studying the optimal inflation target is the Ramsey approach, which seeks the best possible economic outcome given the available policy instruments and the constraints imposed by the optimizing behavior of agents in a market economy. However, some studies determine the optimal inflation target through an optimized monetary policy rule, such as a Taylor rule with an optimized intercept term. Since this alternative approach sometimes yields different results for the optimal inflation target, we consider both perspectives.

We begin with a bird's-eye review of the academic literature on optimal inflation targets over the past 60 years. We show that initially the literature predominantly recommended negative inflation targets, which then shifted to zero inflation as the optimal rate. It was only after the year 2010 that a substantial portion of academic contributions has found positive optimal inflation targets. We review this intellectual history in the next section and then present the main economic arguments supporting a positive optimal inflation target. Specifically, section 3 explains how efficient trends in the relative price between products can raise the optimal inflation target above zero. Section 4 discusses the role of the lower-bound constraint on nominal interest rates, which has significantly constrained monetary policy in many economies over the past two decades. Section 5 addresses nominal wage rigidity and section 6 considers the effects of product aggregation and endogenous product entry. Our final section 7 discusses promising directions for future research on the optimal inflation target.

2 Evolving views about the optimal inflation target

The literature's key findings about the optimal inflation target have changed significantly over time. Figure 1 illustrates this fact by depicting the optimal inflation target of academic studies published between 1960 and 2020, weighting papers by their citation counts.[1] Papers published between 1960 and the mid 1990's exclusively found negative inflation rates to be optimal. These papers predominantly focused on the money demand distortions induced by inflation. Since society can produce money at essentially zero cost, it is socially optimal to eliminate the private opportunity cost of holding money (Friedman rule). This is achieved by setting the safe short-term *nominal* interest rate to zero. When the *real* return on safe short-term assets is positive, a nominal interest of zero requires an appropriate amount of deflation. For instance, if the short-term real rate is equal to 4%, a commonly used number

[1] The numbers are taken from Diercks (2019) and are updated until 2020 using the website tool available at www.optimalinflation.com.

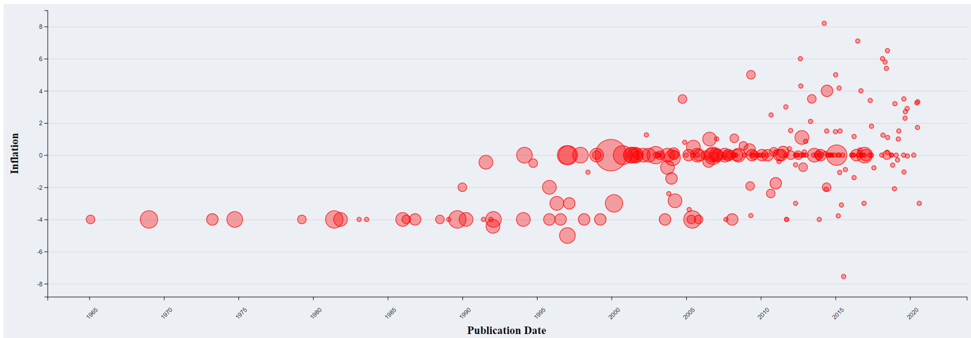

Figure 1: The optimal inflation target by publication date (Diercks (2019))

up to the early 2000's, the required rate of deflation is 4%. This amount of deflation causes the real return on money to be equal to that on other safe assets, so that the private opportunity cost of holding money is equal to the social cost of producing money, i.e., zero. Papers in this tradition often take an optimal taxation or public finance perspective on inflation, see Chari, Christiano and Kehoe (1996) for a prominent example.[2] Interestingly, to the extent that the short-term real interest rates consistent with stable inflation have fallen (Holsten, Laubach and Williams (2007)), eliminating the opportunity costs of holding money justifies nowadays less strong deflation than before. And to the extent that these short-term real rates have even fallen to negative levels, which recent evidence is consistent with, the desire to eliminate the opportunity cost of holding money would justify positive rates of inflation.

With the advent of sticky price models in the mid 1990's (Goodfriend and King (1997), Rotemberg and Woodford (1997)), the dominant finding for the optimal inflation target in the literature moved substantially upwards, as can be seen in figure 1. Sticky price models introduced a new motive for optimal monetary policy that was not present in the earlier flexible price frameworks, namely keeping relative product prices aligned with relative marginal costs. Doing so in a setup with sticky prices is important to prevent prices from providing socially inefficient scarcity signals and hence leading to socially costly misallocations.

In basic sticky price models with time-dependent price adjustment frictions (Calvo (1983)), the motive to align relative prices with relative marginal costs requires inflation to be equal to zero in the long run in the absence of shocks (Clarida, Gali and Gertler (1999), King and Wolman (1999), Woodford (2003)).[3] An optimal inflation rate of zero is a robust feature of basic

[2] An exception is Schmitt-Grohé and Uribe (2004) who show that the desire to tax monopoly profits can make positive inflation rates optimal when profits cannot be directly taxed.

[3] If firms' monopoly power is not corrected by a Pigouvian tax, then temporary deviations from price stability are optimal in the dynamic Ramsey plan, see King and Wolman (1999) or chapter 5 in Galí (2015). Even with a Pigouvian tax, temporary deviations from price

sticky price models, because both inflation and deflation induce trends in relative product prices during periods in which the product price does not get adjusted.[4] Such relative price trends are undesirable in welfare terms because basic sticky price models typically assume that the socially-efficient relative price is stable over time. Inflation and deflation therefore give rise to socially inefficient distortions in relative prices in these models. In recent work, Adam, Alexandrov and Weber (2023) use micro price data to show that deviations of inflation from its optimal level indeed give rise to considerable distortions in relative prices. These distortions also imply that suboptimal levels of inflation give rise to output losses, which rise particularly fast for significantly positive inflation rates (Ascari (2004) and Ascari and Sbordone (2014)). Ascari, Bonomolo and Haque (2022) provide empirical evidence in support of this theoretical prediction.

More elaborate sticky-price models allow for the presence of efficient trends in relative prices over time. As discussed in section 3, the inflation rate that minimizes relative price distortions then generally differs from zero. Yet, in line with the predictions of basic sticky-price models, deviations of inflation from the non-zero optimal level also increase relative price distortions and the associated output losses.

Khan, King and Wolman (2003) were the first to analyze the trade-off between minimizing the opportunity costs of holding money, emphasized in the earlier literature, and the desire to minimize relative price distortions, emphasized in the sticky price literature. While the former calls for deflation, as long as real rates are positive, the latter calls for zero inflation in the absence of relative price trends. Using a quantitative setup, they show that the desire to minimize relative price distortions is the dominant force in welfare terms: the optimal inflation rate is significantly closer to zero than to the rate of deflation called for by the Friedman rule.[5] This finding turned out to be rather robust, provided price stickiness is time dependent with firms facing a fixed exogenous probability of adjusting prices every period (Schmitt-Grohé and Uribe (2010)). However, different price setting frictions, e.g., ones where price adjustments induce so-called menu costs, lead to less pronounced relative price distortions in the presence of non-zero inflation. They imply that the most misaligned prices are adjusted instead of a randomly sampled set of prices. As a result, the relative price distortions induced by non-zero inflation rates are substantially smaller, which causes more negative rates of inflation to be again optimal, see Hellwig and Burstein (2008). The same holds true for setups in which money serves the role of a special medium of exchange in markets where other forms of payment are unavailable (Aruoba and Schorfheide (2011)).

stability can be optimal if there is a sufficient amount of price dispersion in the initial period, see Yun (2005).

[4]This requires that price adjustments are not fully synchronized across producers, as implied by conventional assumptions on nominal price stickiness.

[5]Bilbiie and Ragot (2021) show that this result extends to a setting with heterogeneous households facing liquidity constraints.

Overall, the academic literature up to the year 2010 suggests that the optimal inflation target is either slightly or substantially negative. In contrast, many central banks adopted positive inflation targets by that time. As illustrated by figure 1, after the year 2010 an increasing number of academic papers find positive inflation rates to be welfare optimal, causing the disagreement in the academic literature regarding the optimal rate of inflation to increase over time. This reflects the fact that the recent academic literature has studied a range of additional factors influencing the optimal inflation target such as efficient trends in relative prices, the lower-bound constraint on nominal interest rates, nominal wage rigidity, and the role of product turnover and product aggregation. The next sections review the main contributions since the year 2010 along these lines.

3 Trends in relative prices from productivity or unaccounted quality progress

A key reason why the optimal inflation rate can differ from zero in the presence of sticky prices is that efficiency might require relative prices to display a trend over time. This can occur because of biases in price measurement, which does not (fully) account for quality progress embodied in newly entering products (Boskin (1996), Gordon (2006)). As new higher-quality products enter the market, the relative price of incumbent products should fall over time when price indices do not (fully) account for the higher quality of newly entering products. Similarly, the relative price of products should fall over time if learning-by-doing effects cause the production of existing products to become more efficient over their lifetime. In fact, the literature shows that both of these features imply that the optimal inflation rate is positive in the presence of sticky prices.[6] Basic sticky price models abstract from the presence of relative price trends, despite the fact that relative price trends are a ubiquitous feature of the data.

Traditionally, the literature has highlighted trends in the relative price across broad economic sectors that feature different rates of productivity progress. This includes trends in the relative price between goods and services (Wolman (2011)), between investment goods and installed capital (Fisher (2006)), and between investment and consumption goods (Ikeda (2015)).[7] More recently, the literature highlighted the existence of trends in the relative price of products within narrowly-defined consumer expenditure categories. Specifically, within narrow expenditure categories the relative price of products tends to fall over the product's lifetime. This pattern is present in most CPI expenditure categories and has been documented for a number of

[6]For the case with unaccounted quality progress, the optimal rate refers to the inflation rate that does not fully account for quality progress. For the case with learning-by-doing, the optimal rate refers to a correctly measured inflation rate.

[7]The literature also emphasized labor productivity trends that manifest themselves in a trend in the relative price between labor and consumer goods, e.g., Amano, Moran, Murchison and Rennison (2009). The discussion of real wage trends is relegated to section 5.

advanced economies (Adam and Weber (2023), Adam, Gautier, Santoro and Weber (2022), Argente, Lee and Moreira (2024)).

The presence of declining relative product prices in a broad set of countries and expenditure categories suggests that the underlying sources of these trends are equally broad. In fact, quality biases in the measurement of inflation or general productivity trends are plausible candidates for the observed empirical regularities.[8] To the extent that the observed trends in relative prices reflect such fundamental factors, relative price trends are efficient.[9]

Replicating these efficient trends in relative prices requires that some nominal prices rise, or others fall, or a combination of both features. Within a setting with nominal price stickiness, it can be optimal that the increase in one price is not exactly offset by the decrease in the other price, so that relative price adjustments give rise to either aggregate inflation or deflation. The key question is thus: which features determine whether inflation or deflation is optimal in the presence of trends in the efficient relative price?

We review below a stylized framework featuring relative price trends across expenditure categories and relative price trends over the product life within expenditure categories, using a simplified version of Adam and Weber (2023). We then discuss the implications of these trends for the optimal inflation target. To simplify the exposition, we assume that that relative price trends are the result of learning-by-doing effects. Yet, identical results for the optimal inflation target apply when observed relative price trends are instead the result of unaccounted quality progress. [10]

Section 3.1 presents the framework and section 3.2 considers the optimal inflation target for the case with small amounts of heterogeneity across expenditure categories. Section 3.3 then considers a non-linear result for the optimal inflation target.

3.1 A simple setup with relative price trends across and within expenditure categories

We consider a setup with only two expenditure categories ($z = 1, 2$) and a unit mass of products $j \in [0, 1]$ within each category. To include relative price trends over the product life, we allow for product turnover: products randomly exit with probability $\delta_z \in (0, 1)$ each period and are replaced upon exit by new products that carry the same product index. Newly entering products can freely choose their price but subsequent price adjustments are

[8]When quality progress is not embodied in new products but occurs simultaneously for all products, as considered in Schmitt-Grohe and Uribe (2012), it does not induce trends in the efficient relative price of products. The optimal inflation rate, defined in terms of the sticky price, is then not affected by the presence of quality progress.

[9]Price stickiness does not drive a wedge between the time trend of actual relative prices and efficient relative prices. However, one can not exclude the possibility that the observed trends in relative prices are partly due to changes in relative mark-ups. Evidence in Adam, Züllig and Renkin (2024) suggests that mark-up trends over the firm life can be quite pronounced.

[10]See section 8 in Adam and Weber (2023).

subject to frictions.

Products in each expenditure category are aggregated according to a Dixit-Stiglitz aggregator with substitution elasticity $\theta > 1$. Category consumption C_{zt} in period t is thus given by

$$C_{zt} = \left(\int_0^1 (C_{jzt})^{\frac{\theta-1}{\theta}} \, \mathrm{dj} \right)^{\frac{\theta}{\theta-1}}, \tag{1}$$

where C_{jzt} denotes consumption of product j in category z. Across expenditure categories, consumption is aggregated according to the Cobb-Douglas function

$$C_t = (C_{1t})^{\psi_1} \cdot (C_{2t})^{1-\psi_1}, \tag{2}$$

where $\psi_1 \in (0,1)$ denotes the expenditure share of category one. Consumers have balanced-growth consistent preferences over the final good C_t and leisure.

Given this demand structure, the category price level is[11]

$$P_{zt} = \left(\int_0^1 (P_{jzt})^{1-\theta} \, \mathrm{dj} \right)^{\frac{1}{1-\theta}}, \tag{3}$$

where P_{jzt} denotes the nominal price charged for product j in category z, and the aggregate price level is given by[12]

$$P_t = \left(\frac{P_{1t}}{\psi_1} \right)^{\psi_1} \left(\frac{P_{2t}}{1-\psi_1} \right)^{1-\psi_1}. \tag{4}$$

Note that the aggregate price level includes all products, independently of how sticky their prices are, in line with the approach pursued by statistical agencies. The aggregate inflation rate is then defined in terms of the aggregate price level according to

$$\Pi_t = P_t / P_{t-1}. \tag{5}$$

It thus follows from equation (4) that the log of aggregate inflation is equal to the expenditure weighted sum of the log of the category inflation rates P_{zt}/P_{zt-1}.

We now introduce a simple production function that gives rise to (i) efficient relative price trends *across* expenditure categories and (ii) efficient relative price trends over the product life *within* expenditure categories. Specifically, output Y_{jzt} of good jz at time t is given by

$$Y_{jzt} = A_{zt} G_{jzt} (K_{jzt})^{1-\frac{1}{\phi}} (L_{jzt})^{\frac{1}{\phi}}, \tag{6}$$

where K_{jzt} denotes capital input, L_{jzt} labor input, A_{zt} a category-wide productivity level, G_{jzt} a product-specific productivity level and $\phi > 1$ is the

[11] This price level determines the minimum nominal expenditure required to obtain one unit of category consumption C_{zt}, when choosing across different product combinations $\{C_{jzt}\}_{j \in [0,1]}$.

[12] Similarly, the aggregate price level provides the minimum nominal expenditure required to obtain one unit of the final consumption good C_t.

inverse labor share in production. Labor and capital markets are competitive and frictionless.

The category-wide productivity level evolves according to

$$A_{zt} = a_z A_{zt-1}$$

with $a_z \geq 1$. Heterogeneous productivity trends ($a_1 \neq a_2$) give rise to trends in the efficient relative price across categories.

The product-specific productivity level evolves according to

$$G_{jzt} = \begin{cases} 1 & \text{upon entry of product } jz \\ g_z G_{jzt-1} & \text{after entry,} \end{cases} \tag{7}$$

where $g_z \geq 1$ captures experience accumulation or learning-by-doing effects. Since all products eventually exit, experience trends do not affect the trend in relative productivity across expenditure categories. In fact, the balanced growth rate of the aggregate economy is given by

$$a = (a_1)^{\psi_1}(a_2)^{(1-\psi_1)} \tag{8}$$

and thus is independent of experience trends. However, the accumulation of experience induces trends in the efficient relative price over the product life within expenditure categories: as products age, their productivity increases relative to the average product in the category, causing the efficient relative price to fall over the product life.

The next sections explore the implications of the various relative price trends for the optimal inflation target.

3.2 The optimal inflation target: a first-order approximation

This section considers the optimal inflation target in the presence of small amounts of heterogeneity across expenditure categories, using a first-order approximation. This yields transparent results and highlights which economic forces affect the optimal inflation target to first order.[13] Interstingly, the first-order approximation presented below applies to both the case with Calvo pricing frictions and the case with menu-cost frictions.

We start by considering Calvo frictions, according to which the price of each product cannot adjust with idiosyncratic probability $\alpha_z \in (0, 1)$ in category z in a given period. We approximate the optimal inflation target around a point at which expenditure categories have identical pricing frictions ($\alpha_1 = \alpha_2$), identical product turnover rates ($\delta_1 = \delta_2$), identical category-level productivity trends ($a_1 = a_2$), and identical experience trends ($g_1 = g_2$), and then consider the first-order effects of allowing for heterogeneity along all these dimensions. The optimal (gross) inflation target is then given by:

[13] In this section and the next, we consider the limiting case where the steady-state discount factor approaches one at the balanced growth path, to insure that relative price distortions and relative mark-up distortions are minimized by the same inflation rate. Choosing slightly lower discount factors has quantitatively only negligible effects, see the classic discussion in Goodfriend and King (1997).

$$\Pi^* = \psi_1 \frac{a_1}{a} g_1 + (1-\psi_1)\frac{a_2}{a} g_2 + O(2), \quad (9)$$

where $O(2)$ denotes a second-order approximation error.[14] The optimal inflation rate (9) is a weighted average of the category-specific experience trends. It features a double set of weights, consisting of expenditure weights (ψ_z) and relative growth rates (a_z/a). Interestingly, neither the level nor the heterogeneity in price stickiness or product turnover rates matter for the optimal inflation target to first order.

Two special cases illustrate the economic forces giving rise to the result in equation (9):

Only relative price trends across sectors. Suppose there are no experience trends ($g_1 = g_2 = 1$). The optimal (gross) inflation target implied by equation (9) is then given by[15]

$$\Pi^* = 1 + O(2). \quad (10)$$

This shows that relative price trends across expenditure categories alone do not give rise to a first-order deviations of the optimal (gross) inflation rate from one. This explains why relative price trends across expenditure categories had only quantitatively modest implications for the optimal inflation target in Wolman (2011).

Only relative price trends over the product age. Consider the polar case without relative price trends across expenditure categories ($a_1 = a_2 = a$). The optimal (gross) inflation target is then strictly larger than one, whenever there are experience trends ($g_1 > 1$ and/or $g_2 > 1$):

$$\Pi^* = \psi_1 g_1 + (1-\psi_1) g_2 + O(2). \quad (11)$$

Experience trends thus have first-order implications for the optimal inflation rate. The optimality of a (gross) inflation rate larger than one does not depend on there being heterogeneity in relative price trends across expenditure categories. With identical relative price trends over the product age ($g_1 = g_2 = g$) or only one sector ($\psi_1 = 1$), the optimal (gross) inflation target is simply given by

$$\Pi^* = g + O(2). \quad (12)$$

A gross inflation rate equal to g implies that incumbent products, which are subject to pricing frictions, never have to adjust their prices because their relative price falls already at the efficient rate due to inflation. Inflation is thereby exclusively generated via new products choosing higher relative prices. This situation avoids all relative price distortions and implements efficient

[14] Equation (9) is a special case of Lemma 2 in Adam and Weber (2023).

[15] This uses the fact that the inflation target implied by equation (9) is then equal to $\frac{\psi_1 a_1 + (1-\psi_1) a_2}{a_1^{\psi_1} a_2^{1-\psi_1}}$ and does not move to first order at the point of approximation where $a_1 = a_2$ and $g_1 = g_2 = 1$.

relative prices. However, in the more realistic case with heterogeneity across categories in the efficient relative price trends over the product life ($g_1 \neq g_2$), achieving full efficiency is no longer feasible, as relative price distortions in at least one sector have to be accepted.[16]

Quantitative relevance of relative price trends for optimal inflation. A number of papers use micro price data to estimate relative price trends over the product life for different expenditure categories and aggregate estimated trends to an optimal inflation target using generalized expressions of the form provided in equation (9). These papers find optimal inflation targets that come close to the actual inflation targets pursued by central banks.[17] For the United Kingdom, Adam and Weber (2019) report that the optimal inflation target has increased from 1.6% to 2.6% between 1996 and 2016, due to accelerated relative price declines over the product life. Adam, Gautier, Santoro and Weber (2022) report optimal inflation rates of 1.8% for France and Germany and 0.8% for Italy, based on CPI micro price data for the period 2015-2019.

The optimal inflation target with menu-cost frictions. With menu-cost frictions, prices can adjust in every period, but adjustments generate resource costs, which we assume to be equal to a share $\kappa_z > 0$ of the flexible price profits. The desire to minimize menu costs introduces additional motives for optimal monetary policy that are absent under Calvo frictions. In general, this causes different inflation rates to be optimal, but Adam and Weber (2023) provide two cases with alternative sufficient conditions under which equation (9) continues to apply in a setting with menu-cost frictions. In the first case, menu costs are assumed to be small (κ_z is of first order), so that they do not matter for optimal inflation to a first-order approximation.[18] In the second case, menu costs are large (of order zero), but deviations of inflation from its optimal level generate menu costs that are (to second order) proportional to the category's expenditure weight. In this case, aggregate menu costs are minimized by the same inflation rate that minimizes aggregate relative price (and mark-up) distortions.

3.3 The optimal inflation target: the nonlinear case

For the case with Calvo pricing frictions, there exists a nonlinear closed-form expression for the optimal inflation target. This result is of interest because

[16] For the case where $g < 1$, the framework implies deflation to be optimal. While a negative learning-by-doing effect ($g < 1$) is implausible on a-priori grounds, a negative learning-by-doing effect is isomorphic to a setting in which newly entering products have higher quality than incumbent products and quality progress is fully accounted for in the price index; see Adam and Weber (2019) who consider a setup with exogenous quality progress and Oikawa and Ueda (2018), who consider an endogenous growth framework in which firms climb a quality ladder.

[17] This is true although in some expenditure CPI categories, relative prices actually increase over the product life, which is a force causing deflation to be optimal.

[18] This is so because in a menu-cost setting, the price adjustment frequency does not respond to first order to deviations of inflation from its optimal level.

it shows that the effects of heterogeneity in price adjustment frictions can be rather nonlinear, so that a first-order approximation can become inaccurate for sufficient amounts of heterogeneity along this dimension. With Calvo frictions, the nonlinear optimal (gross) inflation target is given by[19]

$$\Pi^{\star} = \omega_1 \frac{a_1}{a} g_1 + \omega_2 \frac{a_2}{a} g_2, \tag{13}$$

where the generalized weights $\omega_z \geq 0$ are modified expenditure weights and are given by

$$\omega_z \equiv \frac{\tilde{\omega}_z}{\tilde{\omega}_1 + \tilde{\omega}_2},$$

for $z = 1, 2$, with

$$\tilde{\omega}_z \equiv \psi_z \frac{\theta \alpha_z (1-\delta_z)(a/a_z)^{\theta} (\Pi^{\star})^{\theta}}{[g_z - \alpha_z(1-\delta_z)(a/a_z)^{\theta}(\Pi^{\star})^{\theta}] \; [1 - \alpha_z(1-\delta_z)(a/a_z)^{\theta-1}(\Pi^{\star})^{\theta-1}]}, \tag{14}$$

where $\psi_2 = 1 - \psi_1$. The nonlinear optimal target (13) has the same structure as the first-order approximation (9) but features the generalized weights ω_z instead of the expenditure weights ψ_z.

In the special case where expenditure categories feature identical price rigidities ($\alpha_1 = \alpha_2$), product turnover rates ($\delta_1 = \delta_2$), category-level productivity trends ($a_1 = a_2 = a$) and experience trends ($g_1 = g_2$), the generalized weights ω_z are equal to the expenditure weights ψ_z, but this fails to be true more generally. In fact, the nonlinear weights ω_z can dramatically differ from expenditure weights, as the following examples show.

One flexible price and one sticky price category. Suppose prices are flexible in the first expenditure category ($\alpha_1 = 0$) but sticky in the second category ($\alpha_2 > 0$). The generalized weight for the flexible price sector is then equal to zero ($\omega_1 = 0$) and that for the sticky price sector is equal to one ($\omega_z = 1$), independently of the expenditure weights. From equation (13) follows that the optimal inflation rate is given by the growth-rate-adjusted experience trend in category 2:

$$\Pi^{*} = \frac{a_2}{a} g_2. \tag{15}$$

This aggregate inflation rate causes the inflation rate in category 2 to be equal to g_2, achieving efficient relative prices within that category. In addition, the relative price between categories evolves to reflect the differential trends in category-level productivity a_z.[20] In the special case where $g_2 = 1$, we obtain the result derived in Aoki (2001), which calls for a gross inflation rate of one in the sticky price category (but deflation/inflation in the flexible price sector depending on whether or not a_1 exceeds/falls short of a_2). The next example

[19]The following result is a special case of Proposition 1 in Adam and Weber (2023).

[20]Recall that the definition of inflation includes all prices including those in the flexible price sector.

highlights that similarly strong deviations of the weights ω_z from expenditure weights can emerge, even if products in both expenditure categories feature sticky prices.

Two sticky price categories. Consider a setup where prices are sticky in both expenditure categories ($\alpha_z > 0$ for $z = 1, 2$). As the stickiness of prices in category 2 (α_2) increases, one of the two terms in brackets in the denominator of equation (14) will approach zero, so that the weight $\tilde{\omega}_2$ will increase without bound. As a result, we get $\omega_1 \to 0$ and $\omega_2 \to 1$. The second expenditure category thus receives all the weight and the optimal inflation rate is again given by equation (15), again independent of expenditure weights. Results in Ikeda (2015) show that one sector can essentially "take over" the determination of optimal inflation, provided price stickiness differs sufficiently across sectors.

4 The lower bound constraint on nominal rates

Since cash offers a nominal return of zero, short-term nominal interest rates on central bank reserves cannot fall significantly below zero.[21] The resulting lower bound constraint on nominal interest rates gives rise to a potentially important macroeconomic non-linearity, which causes economic disturbances to *interact* with the optimal inflation target, i.e., with the average inflation rate that emerges under optimal monetary policy.

The lower bound constrains the policy response to natural rate shocks. To understand why the lower bound constraint affects the optimal inflation target, consider a central bank facing a *positive* shock to the natural real interest rate.[22] This higher real rate can be implemented purely by an increase in nominal rates, without the need for inflation to move. This fails to be true for a *negative* shock. In particular, if the shock to the natural real rate is sufficiently negative, lowering nominal rates all the way to the lower bound alone will be insufficient for bringing real interest rates down to the natural level. A policy trade-off arises: the policymaker can either accept real interest rates that are higher than the natural rate, which is generally a deflationary policy, or seek to lower real interest rates further by raising inflation expectations, i.e., by promising more inflation in the future. In fact, the promise of future inflation is an integral part of Ramsey optimal monetary policy when the policymaker is constrained by the lower bound (Eggertsson and Woodford (2003)). Since the promise of future inflation is only required for negative shocks, an occasionally binding lower bound constraint raises the average rate of inflation under optimal policy. This effect is more pronounced if the lower bound is reached more frequently in equilibrium.

[21]This is true as a long as central banks stand ready to swap on demand central bank reserves into cash. The lower bound is slightly negative because storing cash requires renting or constructing vaults.

[22]The natural rate of interest is the real interest rate consistent with stable inflation, see Woodford (2003) for a definition.

Interestingly, disturbances that cause the natural real rate to be sufficiently low generate both inflationary and deflationary pressures under optimal monetary policy. Specifically, the lower bound constraint implies that policymakers have to use a socially costly policy (promises of future inflation) to lower real interest rates. As a result, the real interest rate will fall by less than in a situation where cost-free nominal rate cuts could be used. This results in real interest rates that are higher than the natural rate which exerts deflationary pressures. This counteracts the inflationary pressures that result from inflation promises. This effect is also more pronounced if the lower bound is reached more frequently. The net effect on optimal inflation is a quantitative question.[23]

Ramsey optimal policy. Under Ramsey optimal monetary policy and when private agents entertain rational expectations, the net effect of an occasionally binding lower bound is quantitatively small: the inflationary and deflationary forces thus nearly cancel each other (Adam and Billi (2006), Billi (2011), section 6.1 in Coibion, Gorodnichenko and Wieland (2012)). This conclusion continues to be true, when taking into account that the real interest rate consistent with stable inflation has fallen in many advanced economies (Holsten, Laubach and Williams (2017)). While this causes the lower bound to become a more binding constraint it barely matters for the optimal average inflation rate under rational expectations (Adam, Pfäuti, Reinelt (2020)). Only when the steady-state natural rate is negative does Ramsey optimal policy call for a significantly positive inflation target in the presence of a lower bound and rational expectations: Billi, Gali and Nakov (2024) show that the optimal inflation target is then positive and approaches the absolute value of the natural rate for sufficiently negative natural rates. This shows that implementing the negative steady-state natural real rate is – in welfare terms – more relevant than minimizing relative price distortions.

Optimized Taylor Rules. The effect of the lower bound constraint on inflation is very different if policy follows a Taylor rule instead of Ramsey optimal monetary policy. [24] While Taylor rules typically fall short of providing a normative benchmark from the viewpoint of the underlying economic model, they may provide a descriptively more realistic view of how monetary policy is actually conducted. For this reason, a number of contributions determine the welfare optimal intercept in the Taylor rule and report the resulting average inflation rate associated with the optimized rule. Using a calibrated model for the U.S. economy, Coibion, Gorodnichenko and Wieland (2012)

[23]Since the promise of future inflation is only credible under commitment, discretionary optimal monetary policy produces a deflationary bias in the presence of a lower bound constraint, see Nakov (2008).

[24]In the presence of a lower-bound constraint, Taylor rules can be consistent with equilibrium outcomes other than the targeted equilibrium. This was first shown by Benhabib, Schmitt-Grohé and Uribe (2002) for the case with flexible prices and extended to the case with sticky prices by Mertens and Ravn (2014). In the following discussion, we abstract from this issue and focus on the targeted equilibrium outcome.

find that the optimal inflation rate is significantly positive but below 2% per year. Depending on the precise specification, the optimal inflation rate typically reaches levels around 1% to 1.5%, even when taking into account that non-zero steady-state inflation rates affect the linearized structural equations in the New Keynesian model (Ascari and Ropele (2007), Ascari and Sbordone (2014)).

Relatedly, Andrade, Gali, Le Bihan and Matheron (2019) analyze how the average inflation rate associated with an optimized Taylo rule depends on the steady-state level of the natural rate of interest in the presence of a lower bound constraint. Using an estimated model for the U.S. economy with price and wage stickiness, they show that a one percent drop in the steady-state natural rate calls for a near one percent increase in the rule's optimal inflation target.[25] They also show that this result depends strongly on the assumed policy rule. A rule that incorporates so-called "make-up" components, which compensate prior inflation shortfalls via higher inflation rates at a later stage, justifies much smaller increases in the inflation target, following a drop in the steady-state natural rate. This is in line with findings under Ramsey optimal policy.

Reasons for overestimating the optimal inflation target. The economic gains of a higher inflation target arise from a less frequently binding lower bound constraint. This allows implementing more appropriate real interest rates in response to negative natural rate shocks. The cost of higher inflation targets, however, depends on a range of model ingredients. In particular, Ascari, Phaneuf and Sims (2018) show that models featuring only price stickiness tend to underestimate the welfare costs of higher inflation in quantitatively important ways. Incorporating also wage stickiness, working capital requirements for firms, a more elaborate input-output production structure and economic growth, increases the costs of moving the inflation target from 2% to 4% by a factor of two to three in consumption-equivalent terms. For these reasons, existing models may underestimate the welfare costs associated with higher inflation targets.

Also, Coibion, Gorodnichenko and Wieland (2012) show that positive inflation targets are less beneficial in a setting with an occasionally binding lower bound constraint and sticky prices when wages are downwardly rigid. Downward wage rigidity reduces the recessionary costs of lower-bound episodes: the inability of nominal wages to fall during lower-bound episodes supports inflation and thus lowers real interest rates. This reduces the probability of hitting the lower-bound constraint. Amano and Gnocchi (2023) show that downwardly rigid nominal wages also reduce the duration of lower bound

[25] Andrade, Gali, Le Bihan and Matheron (2021) report quantitatively similar findings for the relationship between the steady-state natural rate and the optimal inflation target using an estimated model for the Euro Area. L'Huillier and Schoenle (2024) consider a setup in which the price adjustment frequency depends positively on the inflation target. They find that the optimal inflation target increases more strongly as the steady-state value of the natural rate of interest falls than in a setup with fixed price adjustment frequency.

episodes which causes a lower inflation target to be optimal in the Taylor rule.[26]

Reasons for underestimating the optimal inflation target. Standard models may also overestimate the costs of higher inflation targets for a variety of reasons. First, many models abstract from the presence of relative price trends. As discussed in section 3, declining relative prices result in positive inflation rates to be optimal, even in the absence of a lower bound constraint. Standard models may thus feature a suboptimally low "starting point" for the inflation target even before introducing the lower bound constraint. Second, virtually all models featuring a lower bound constraint consider time-dependent pricing frictions along the lines of Calvo (1983). Such pricing frictions generate a rather strong relationship between trend inflation and inefficient price dispersion and thus give rise to relatively high welfare costs of higher inflation targets. In contrast, state-dependent pricing models imply a less tight relationship between inflation and price dispersion, see for instance Nakamura, Steinsson, Sun and Villar (2018), which moderates the welfare costs of higher inflation targets.[27] Third, most monetary models imply that lower bound episodes last only for a few quarters under optimal monetary policy, while the available empirical evidence shows that these episodes typically last several years if not decades. While this could be the result of suboptimal policy choices, Dordal i Carreras, Coibion, Gorodnichenko and Wieland (2016) show that exogenous shock processes that give rise to longer lasting lower-bound episodes can justify significantly higher inflation targets in optimized policy rules.

The lower bound constraint in state-dependent pricing models. Overall, it seems desirable to construct models featuring a lower bound that replicate empirical micro pricing moments. This requires incorporating both time and state-dependent price setting features, see for instance Alvarez, Le Bihan and Lippi (2016) and Nakov and Costain (2024). Blanco (2021) is the only paper we are aware of investigating the optimal inflation target in a lower-bound setup with state-dependent pricing. Relying on the simple rule approach, he finds considerably larger optimal inflation targets, which range between 2.5% and 4%. He also shows that optimal targets are two to three times higher than in a corresponding setup with time-dependent pricing frictions.

An interesting new effect arising in menu-cost model featuring positive inflation is that the mass of price setters is close to their lower sS-adjustment bound, so that many price setters are close to finding it optimal to *increase* their price but are hesitant to decrease it. This stabilizes the economy in response to deflationary natural rate shocks, because price setters are simply not prone to cutting prices. Since inflation falls by less in response to a

[26]However, considering an endogenous growth framework, Abritti, Consolo and Weber (2021) find a substantially higher optimal inflation target despite incorporating a lower-bound constraint and downward nominal wage rigidity.

[27]These models also imply lower welfare costs of deflation, see the results in Burstein and Hellwig (2008).

deflationary shock, real interest rates are lower which stabilizes the economy. In fact, Alexandrov (2020) analytically shows that positive inflation causes prices to respond less strongly to deflationary shocks and more strongly to inflationary shocks. This prediction receives empirical support in U.S. sector-level price data.

Deviations from full information rational expectations. Another strand of the literature considers optimal monetary policy with a lower bound constraint in settings featuring deviations from full-information rational expectations. Specifically, Pfäuti (2023) considers a setting with optimal attention choice and a lower bound constraint in which consumers pay limited attention to inflation. In such an environment, monetary policy is less effective in influencing the private sector's inflation expectations, so that shocks that cause the lower bound to bind have more detrimental effects on the economy than under rational expectations. As a result, Ramsey optimal monetary policy implies a significantly higher average inflation rate, which ranges between 1% and 2%, despite considering time-dependent pricing frictions. Adam, Pfäuti and Reinelt (2020) consider a model with a lower bound constraint in which agents entertain subjective housing price beliefs, but hold otherwise rational expectations. In this model, Ramsey optimal monetary policy implies that average inflation rises as the steady-state level of the natural rate of interest falls, unlike in a setup with fully rational expectations.

Summing up, with Ramsey optimal monetary policy and rational expectations, the lower bound constraint tends to give rise only to quantitatively minor deviations of optimal average inflation from optimal steady-state inflation, provided the steady-state natural interest rate is not too negative.[28] However, the lower bound constraint is quantitatively important for the optimal inflation target when policy follows a simple Taylor rule or in the presence of deviations from full-information rational expectations.

5 Nominal wage and price rigidity

This section reviews the literature on the optimal inflation rate in settings in which the adjustment of both wages and prices is subject to frictions. Wage and price stickiness interact to determine how the real wage adjusts to aggregate or idiosyncratic shocks or fundamental economic trends. This may have implications for the optimal inflation target, especially when nominal wages are downwardly rigid, as we discuss in section 5.1, but also in the presence of symmetric upward and downward wage rigidities, as we discuss in section 5.2.

5.1 Asymmetric wage rigidities and economic disturbances

As in section 4, economic shocks can matter for the optimal inflation rate to the extent that it is optimal to have inflation respond asymmetrically to pos-

[28]Other occasionally binding constraints, such as financial constraints, can have a larger positive effect on optimal long-run inflation, see Abo-Zaid (2015).

itive and negative shocks. One important economic force making asymmetric inflation responses optimal is the widely held notion that nominal wage cuts are more difficult to implement than nominal wage increases. Downward wage rigidity arises when past nominal wages are treated as the default outcome in wage negotiations (e.g., Holden (1994)) or when nominal wage cuts undermine worker morale and hence productivity (Bewley (1999)). Empirical evidence seems to confirm the presence of downward nominal wage rigidity (DNWR). Grigsby, Hurst and Yildirmaz (2021) show that in administrative U.S. payroll data, nominal wage cuts are quite rare, arising for only 2% of job stayers, whereas wage freezes (zero changes) are much more common arising for about 35% of workers.[29] The absence of wage cuts and the abundance of wages freezes is generally considered as evidence in favor of DNWR.

Importantly, following an adverse supply shock, real wages should fall to reflect lower worker productivity. If nominal wages cannot fall, firms will cut back on hours worked or might even decide to fire workers, which may be socially costly. To dampen these outcomes, it can become optimal to let inflation rise following the shock. This reduces real wages and causes firms to cut back less on labor input. This can be optimal even if increased inflation is socially costly, e.g., due to the stickiness of nominal prices and the relative price distortions associated with higher inflation. However, note the asymmetry: inflation is not required in response to a positive productivity shock, as nominal wage increases alone can insure that the efficient amount of labor input is provided by workers.

The classical argument just described emphasizes the benefits of positive inflation via its effect on "greasing the wheels" of the labor market (Tobin (1972), Akerlof, Dickens and Perry (1996)). Central banks often refer to this argument to justify why they target positive rates of inflation.[30]

To assess the quantitative importance of DNWR for the optimal inflation target, it is key to understand to what extent spot wages are allocative, i.e., matter for determining employment and work effort. The most basic model of the labor market treats wages as "prices" in an instantaneous market in which firms contract period-by-period with the workers they require for production. In this case, DNWR can lead to inefficiently large reductions in employment and hours worked following adverse supply shocks. A fundamental objection to this way of portraying the labor market is that workers and firms are typically engaged in longer-term employment relationships, which possibly last for several years. Elsby and Solon (2019) argue that in the presence of longer-term employment relationships the effective price of labor is no longer given by the spot wage, but by the discounted present value of the sequence of wages

[29]These figures refer to base wages that exclude other forms of compensation such as overtime premiums and bonuses. Barattieri, Basu and Gottschalk (2014) show that 12% of hourly wage changes for U.S. job stayers are wage cuts. However, summarizing international evidence from payroll records and pay slips, Elsby and Solon (2019) find that 15 to 25% of job stayers experience nominal wage cuts.

[30]See, for example, Consolo, Koester, Nickel, Porqueddu and Smets (2021).

anticipated over the remaining duration of the worker-firm match. From this perspective, what matters for allocative efficiency is no longer whether the spot wage adjusts to the shock but rather whether the present value of wages can adjust. The latter can happen via adjustments in future wages. For instance, it may be sufficient that a future pay increase, which would have materialized in the absence of the shock, no longer takes place or is postponed in time. This implies that the empirically observed behavior of spot wages can be the result of DNWR, i.e., wages may remain constant most of the time and upon adjustment may more often increase than fall as a result of inflation or productivity growth. At the same time, this behavior of nominal wages could be fully consistent with allocative efficiency in the labor market.

Against this background, we first review the literature considering the optimal inflation target in setups with DNWR and spot labor markets and then turn to setups with longer-term employment relationships.

Spot labor markets. Kim and Ruge-Murcia (2009) show that a Ramsey planner chooses a positive average inflation rate equal to 0.4% in a representative-agent economy with a spot market for labor, asymmetric wage and price adjustment costs and productivity shocks. The Ramsey planner prefers to constantly incur the small price and wage adjustment costs associated with mildly positive inflation because this reduces the relatively large adjustment costs associated with lowering nominal wages in response to negative productivity shocks.[31]

Benigno and Ricci (2011) suggest that the optimal inflation rate is significantly (more) positive in an economy in which workers face idiosyncratic productivity shocks. Assuming a spot market for labor, they show that the long-run Phillips curve between wage inflation and the output gap is nonlinear in the presence of DNWR and flexible product prices: it is almost vertical at high inflation rates but flatter at inflation rates closer to zero. Due to the assumed flexibility of product prices, the output gap is minimized for very high rates of price inflation. Mineyama (2022) adds stickiness of product prices to a similar setup and uses a calibration that features significant DNWR to fit the moments of individual wage data. Considering a simple interest rate rule, the optimal inflation target is then equal to 2.3%.[32] This shows that idiosyncratic productivity shocks paired with DNWR can rationalize significantly positive inflation targets.[33]

[31]Kim and Ruge-Murcia (2011) extend this setting to include monetary frictions and show that the Ramsey planner continues to choose a positive average inflation rate equal to 0.4%. Kim and Ruge-Murcia (2019) extend the setting to the case with extreme value shocks with a negatively skewed distribution and show that the Ramsey planner chooses a zero average inflation rate. Coibion, Gorodnichenko and Wieland (2012) study the case with downwardly rigid wages, sticky prices and a lower bound on nominal rates, as discussed in section 4.

[32]In related work, Fagan and Messina (2009) calibrate a model with worker heterogeneity and DNWR to cross-sectional moments of individual wage changes using data for the US, Germany, Portugal, Belgium and Finland. They find optimal steady-state inflation rates between zero and 5% abstracting from aggregate dynamics.

[33]This is so despite the presence of important offsetting forces, namely sticky prices and

To sum up, in the presence of DNWR, frameworks with representative agents, spot labor markets and aggregate productivity shocks imply only mildly positive optimal inflation rates, whereas frameworks incorporating idiosyncratic productivity shocks imply substantially larger optimal inflation rates in line with central banks' inflation targets. Idiosyncratic shocks are quantitatively relevant because they tend to be substantially more volatile than aggregate shocks.

Longer-term work relationships. Elsby and Solon (2019) argue that longer-lasting relationships between workers and firms matter for the allocative distortions associated with DNWR. However, explorations of this argument in general equilibrium settings studying the optimal inflation target are rare. Abo-Zaid (2013) appears to be the only paper incorporating a frictional labor market (with intensive and extensive adjustment margins) into a framework with sticky prices and DNWR. He finds an Ramsey optimal inflation target of 1%. Positive price inflation helps reducing the adverse affects of DNWR and through this partly remedies the lack of job creation by firms.

5.2 Symmetric wage rigidities and steady-state distortions

Even in the absence of DNWR, symmetric upward and downward stickiness of wages and prices can motivate deviations of the optimal inflation target from zero. What motivates these deviations is the desire to minimize steady-state distortions, rather than the intention to deal with economic disturbances.

Amano, Moran, Murchison and Rennison (2009) consider the optimal inflation target in a setting with growth in aggregate labor productivity and sticky wage and prices. With 2% productivity growth, the price of labor relative to goods must rise at this rate along the balanced growth path. This can happen via an increase in the nominal wage, a decrease in the nominal price of goods, or both.[34] They find an optimal inflation target of -1.9% in a setting with spot labor market, so that real wages increase almost exclusively via goods price deflation. This result is driven by the asymmetry in wage-setters' objective function to deviations of wages from the optimal level, which is stronger than the corresponding asymmetry for price setters. This causes wage inflation to be more detrimental to welfare than price deflation, because wage mark-ups respond stronger to wage inflation than price mark-ups respond to price deflation.

Carlsson and Westermark (2016) also consider a setup with wage and price stickiness, but assume state-dependent nominal frictions and a frictional labor market, in which newly hired workers draw a random wage from the existing wage distribution of incumbent workers. The Ramsey optimal inflation target

a positive productivity growth trend. Absent idiosyncratic shocks and asymmetric wage rigdity, this growth trend calls for negative optimal inflation targets, see the discussion of Amano, Moran, Murchison and Rennison (2009) in the next section.

[34]This is similar to the case with relative price trends between different goods discussed in section 3.3.

in their setting is positive and slightly above 1%.[35] The specific form of wage frictions imply that inflation reduces the equilibrium real wage of new hires, which is inefficiently high due to a violation of the Hosios (1990) condition.[36]

6 Product aggregation and product entry

This section reviews how the optimal inflation target depends on (i) deviations from constant elasticity of substitution (CES) aggregation of products and (ii) endogenous product entry, which are standard assumptions entertained in monetary economics.

Kurozumi and Van Zandweghe (2024) replace the conventional CES product aggregator by the Kimball (1995) aggregator. The latter implies that the elasticity of product demand depends on a product's relative price: it is low when the relative price is low and high when the relative price is high. This demand specification implies a trade-off for monetary policy between minimizing relative price distortions versus the average mark-up charged by firms. With a CES demand specification, these two objectives are very closely aligned[37] but this ceases to be the case with Kimball aggregation. A positive steady-state inflation rate then reduces the average mark-up charged by firms and this is desirable whenever monopoly power causes the mark-up to be inefficiently high.[38] While positive inflation rates create distortions in relative prices (in the absence of efficient trends in relative prices as considered in section 3), these distortions are of second-order relevance for welfare, while the welfare gains from mark-up reductions are of first order. Kurozumi and Van Zandweghe (2024) show that this causes optimal steady state inflation to be positive. Santoro and Viviano (2022) go beyond the effect of inflation on the average markup and show that inflation also affects the cross-section of markups under Kimball aggregation. When firms are differently productive, highly productive firms charge low relative prices. However, since they face a low demand elastiticity, they charge higher mark-ups than less productive firms, which is socially inefficient. Since positive inflation particularly depresses the high mark-ups of productive firms, the optimal inflation rate can be significantly positive.

Bilbiie, Fujiwara and Ghironi (2014) consider various deviations from CES aggregation in a framework with endogenous product entry. The Ramsey steady state can then feature positive or negative inflation, depending on

[35] With time-dependent nominal stickiness, optimal inflation increases to 3%.

[36] This contrasts with Amano, Moran, Murchison and Rennison (2009) where inflation increases real wages. It also contrasts with Arseneau and Chugh (2008), where inflation acts as a tax on vacancy creation. Both papers consider different nominal wage frictions than Carlsson and Westermark (2016).

[37] This holds true approximately and becomes exact in the limit with no time discounting, see footnote 13.

[38] Shirota (2015) shows that with Kimball aggregation, the average mark-up declines with positive inflation because the firm optimally sets a price that weighs current marginal revenues more and future marginal revenues less compared to the case with CES aggregation. The stronger emphasis on current outcomes reduces front-loading of price increases in price adjustment periods and thus reduces the average mark-up.

(i) the product aggregator considered and (ii) whether the product entry rate under flexible prices is too high or too low relative to its efficient level. Positive inflation rates reduce firm entry by reducing firm mark-ups and are thus optimal when firm entry is too high under flexible prices. For their empirically preferred (translog) aggregator, the optimal inflation rate is equal to 1% while zero inflation is optimal with CES aggregation.[39]

The introduction of new products with better quality than embodied in existing products is often considered an important source of economic growth. This makes it natural to consider the optimal inflation rate in settings in which economic growth arises endogenously from product entry. Oikawa and Ueda (2018) consider such a setting with menu costs. Augmenting this setting by introducing firm heterogeneity, Miyakawa, Oikawa and Ueda (2022) show that inflation tilts the composition of newly entering and incumbent firms towards higher quality firms. This increases the growth rate and causes positive inflation rates to be optimal.

7 Possible directions for future research

This section concludes by discussing a number of promising directions for further research on the optimal inflation target. We particularly highlight aspects that appear important from a policy perspective but have received relatively little attention in the literature so far. This may partly be due to the existence of conceptual and technical difficulties.

Deviations from rational expectations. The macroeconomic expectations of households, firms and professional forecasters deviate in systematic ways from those implied by a full-information rational expectations (FIRE) setup (Coibion and Gorodnichenko (2012, 2015)). Nevertheless, the vast majority of papers rely on a FIRE setup to derive their policy recommendations for the optimal inflation target. Given the relevance of expectations for macroeconomic outcomes in structural models, it appears desirable to design monetary policies that are optimal in a way that properly takes into account how the private sector actually forms its expectations.

While being desirable, this raises important conceptual issues. It requires an alternative expectations theory that is (i) empirically credible in light of the available survey data and (ii) predicts how expectations change with alternative policy configurations. Achieving both features simultaneously is challenging and existing papers studying optimal inflation targets in the presence of non-rational expectations place different emphasis on these aspects.

Woodford (2011) and Adam and Woodford (2012, 2021) develop a microfounded framework to study the optimal monetary policy design with near-rational private expectations that satisfy an upper bound on how much expectations can deviate from rational ones. The policymaker then seeks to max-

[39] Relatedly, Bilbiie, Ghironi and Melitz (2008) and Bergin and Corsetti (2008) show that the optimal inflation rate is zero if the entry and mark-up distortions can be corrected via other policy instruments.

imize the worst outcome associated with all near-rational expectations and a particular monetary policy. This theory of expectations formation scores high on dimension (ii) mentioned above, but does not necessarily result in the policymaker considering the empirically most plausible deviations from FIRE (point (i) above). They find that the optimal inflation target continues to be zero in the standard New Keynesian model despite near-rationality of expectations. However, in the presence of shocks, the price level under optimal monetary policy now follows a random walk, while it is stationary when the private sector holds rational expectations.

Adam, Pfäuti and Reinelt (2020) consider monetary policy in a setup with subjective beliefs about future housing prices that are calibrated to match survey evidence on housing price expectations. The belief setup addresses point (i) above and side-steps point (ii) by considering a setting where policy cannot affect the dynamics of objects that the private sector is learning about. Relatedly, Pfäuti (2023) considers a setup in which households pay limited attention to inflation in a way that captures actual attention patterns inferred from survey data. This approach addresses point (i) but also does not endogenize how the private sector's attention choice depends on monetary policy.

Further research on the optimal inflation target in settings where private sector expectations are not fully rational and where deviations satisfy points (i) and (ii) above would be of considerable interest.

Incomplete markets and household heterogeneity. A relatively large literature studies the welfare and distributional implications of different steady-state inflation rates, with most contributions considering flexible price setups. Starting with Imhoroglu (1992), the literature analyzed the distributional and welfare implications of inflation as a tax on savings. Subsequently, Erosa and Ventura (2002) studied inflation as a tax on transaction services in a heterogeneous agent setup. More recently, Adam and Zhu (2016) study the redistributive effects of a surprise change in the price level across Euro Area households, firms, governments and the rest of the world. They show that redistributive effects can be sizeable and fairly heterogeneous across households. Older households loose from inflation as they hold most nominal assets while young middle-class households gain. Recently, Pallotti, Paz-Pardo, Slacalek, Tristani and Violante (2024) extended the analysis in Adam and Zhu (2016) by considering additional redistributive channels of inflation using a first-order approach to derive the welfare implications of surprise inflation. Cao, Meh, Rios-Rull, and Terajima (2021) study the redistribution and welfare implications of a surprise change in steady-state inflation using a rich overlapping generation framework that takes into account the distributional effects associated with money and non-money nominal holdings. They find that an increase in the inflation target from 2% to 5% leads to large welfare losses. Brunnermeier and Sannikov (2013) also show that market incompleteness can have strong implications for the optimal inflation rate, using a setup where households can invest in money, which is safe, and physical capital, which generates non-diversifiable idiosyncratic income risk. Taxing money via positive inflation is optimal in their setup because it induces households to increase investment in physical capital. Investment is inefficiently low because private agents fail to internalize that higher investment increases growth and thereby lowers the real interest rate.

Bilbiie (2008) considers optimal inflation in a tractable, two-agent New Keynesian model. In recent work, Bilbiie (2024) extended the analysis to a setting with cyclical inequality and risk. Both papers show that zero long-run inflation continues to be Ramsey optimal if the model is approximated around a flexible-price equilibrium without steady-state distortions and without inequality between households. A number of papers find non-zero optimal inflation rates in setups featuring both heterogeneous agents and nominal rigidities. Lepetit (2022) studies a sticky price setup with overlapping generations in which private and social discount rates differ. By choosing positive inflation rates, the social planner reduces firms' mark-ups, thereby raising wages and the consumption of relatively poor younger cohorts, which increases overall welfare. Hahn and Schuerle (2024) consider a setup with firm and worker life cycles, sticky prices and sticky wages. They show that optimal inflation is positive with price stickiness alone, but that deflation becomes optimal once wage stickiness is introduced. Overall, the literature studying Ramsey optimal monetary policy in heterogeneous agent frameworks with sticky prices is still in its infancy.

Worker heterogeneity and downwardly rigid wages. The optimal inflation rate has apparently not been quantified in frameworks that combine frictional labor markets and DNWR with empirically relevant amounts of worker heterogeneity. Furthermore, there seems to be scope for, and benefits from, a more explicit modelling of the sources of DNWR in general equilibrium, beyond imposing the adhoc constraint that nominal wages cannot fall. In partial equilibrium, Elsby (2009) derives the optimal wage policy of a firm-worker pair assuming that wage cuts undermine worker morale and hence reduce worker productivity. Accounting for productivity declines from wage cuts, forward-looking firms limit their wage increases to precaution against situations in which wage cuts are required otherwise. While this feature also arises in settings with adhoc DNWR, firms in Elsby (2009) also find it optimal to accept the productivity decline from wage cuts and reduce wages after large negative shocks. For example, Kurmann and McEntarfer (2019) find that the share of wage cuts during the Great Recession increases substantially. Equilibrium properties like this seem crucial for assessing the the desirability of different monetary policy regimes quantitatively.

Open economy. Our review has not discussed how open-economy considerations affect the optimal inflation target. In a setup with sticky prices and vanishingly small money demand, open-economy considerations do not lead to deviations of the optimal inflation target from zero, provided inflation is defined in terms of domestically produced goods (Gali and Monacelli

(2005)). However, when foreigners demand domestic currency for transaction purposes, taxing money holdings via inflation can become optimal (Schmitt-Grohe and Uribe (2012)). Also, domestic shocks can partly get absorbed by the rest of the world which causes policy constraints such as the lower bound on nominal interest rates to be less relevant, leading to lower optimal inflation targets (Cho, Kim, Kim and Kim (2023)). Finally, chapter 9 in Uribe and Schmitt-Grohe (2017) shows how open-economy considerations affect the optimal inflation target in a setting with downward nominal wage rigidity. Overall, there exists no comprehensive assessment of how open-economy dimensions affect the optimal inflation target.

The green transition. Over the coming decades, the world economy will structurally change in important ways due to the requirement to decarbonize the economy. Decarbonization will introduce a number of new relative price trends into the economy because carbon taxation will cause so-called brown production, which relies on fossil fuel, to become more expensive relative to green production. It will be important to understand whether these trends in relative prices have repercussions for the optimal inflation target. At present only few studies investigate this issue. For instance, Nakov and Thomas (2023) show that the trade-off between climate goals and price stability is overwhelmingly resolved in favor of price stability. Del Negro, Di Giovanni and Dogra (2023) show that the trade-off between output stabilization and inflation stabilization associated with increased carbon taxes depends on the relative stickiness of prices in green versus brown industries. The implications of the green transition for the optimal inflation target are far from being settled and require further study.

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