The Case for a Positive Euro Area Inflation Target: Evidence from France, Germany and Italy*

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Abstract

Using the micro price data underlying the Harmonized Index of Consumer Prices, we estimate relative price trends over the product life cycle in France, Germany and Italy. We show that minimizing the welfare consequences of relative price distortions in the presence of these trends requires targeting a significantly positive inflation rate: the steady-state inflation rate jointly maximizing welfare in all three countries ranges between 1.1%-1.7%. The optimal target range for individual countries is 1.1%-2.1% in France, 1.2%-2.0% in Germany and 0.8%-1.0% in Italy. Differences across countries emerge due to systematic differences in the strength of relative price trends. The welfare costs associated with targeting an inflation rate of zero in the Euro Area, as suggested by standard monetary models without relative price trends, amount to 4.5% of consumption in present-value terms.

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1 Introduction

This paper estimates the inflation rate that minimizes the welfare consequences of relative price distortions in France, Germany and Italy. The idea that inflation creates misalignments in relative prices, whenever prices fail to flexibly adjust, goes back all the way to Lucas (1972) and Phelps (1970). It is enshrined in its modern form, following Woodford (2003), in virtually all structural economic models entertained by central banks.

Inflation creates misalignments in relative prices trough two main channels: inflation erodes the relative price of goods over time in the absence of price adjustments. And when prices get adjusted, the anticipation of this effect makes it optimal to choose higher relative prices upon adjustment than in the absence of inflation. Inflation (but also deflation) thus affects the distribution of relative prices in the economy and through the associated demand distortions economic welfare. The present paper makes progress by estimating - for the three largest Euro Area countries - the optimal inflation target, i.e., the steady-state inflation rate minimizing the welfare costs associated with inflation-induced distortions in relative prices.[1]

Widely used structural models, for instance the ones routinely employed in central banks, consider settings in which the *efficient* relative price of products neither increases nor decreases over time.[2] Since positive or negative rates of inflation introduce trends into relative prices (absent price adjustment), these models imply that the optimal steady-state inflation rate is zero or very close to zero, see Schmitt-Grohé and Uribe (2010) for a literature overview.

The optimal inflation rate in standard models can deviate from zero due to a range of considerations that go beyond relative price concerns. These include the desire to minimize cash distortions (Khan, King and Wolman (2003)), the existence of a lower bound constraint on nominal rates (Adam and Billi (2006, 2007), Coibion, Gorodnichenko and Wieland (2012), L'Huillier and Schoenle (2020)), or the (downward) rigidity of nominal wages (Kim and Ruge-Murcia (2009)). Yet, these additional considerations typically generate only quantitatively small deviations of the average inflation rate from zero inflation under (Ramsey) optimal monetary policy.[3] As a result, the zero inflation rate has become an important normative reference

[1]The optimal inflation target also minimizes the welfare consequences of mark-up distortions. Under the conditions analyzed, mark-up distortions are proportional to relative price distortions, we can thus focus on relative price distortions.

[2]The relative price is defined as the product price relative to the average price of a narrowly defined set of competing products.

[3]There are exceptions to this. Adam, Pfaeuti and Reinelt (2020), for instance, show how the effective lower bound on nominal rates can - in combination with low natural rates of interest - justify targeting significantly positive rates of inflation under optimal monetary policy. This, however, requires deviations from the standard model in the form of subjective housing price expectations.

point in monetary economics.

Interestingly, policymakers have - at least implicitly - taken this message on board. For instance, in its 2021 strategy review, the European Central Bank lists a number of reasons why it is desirable to have an 'inflation buffer above zero', thereby implicitly acknowledging the relevance of the zero inflation reference point.[4]

The goal of the present paper is to show that the reference point of zero inflation is severely misguided when it comes to determining the optimal inflation rate that minimizes relative price distortions for the Euro Area. In fact, we show that the inflation target that jointly minimizes the welfare costs associated with steady-state distortions in relative prices in France, Germany and Italy is significantly higher than zero. This is the case because the *efficient* trend of relative prices tends to be negative (on average across goods and services) in the three considered economies. It is thus optimal to slightly erode relative prices over time, causing positive rates of inflation to be optimal.

Combining evidence on relative price trends from France, Germany and Italy, which jointly account for close to two thirds of Euro Area GDP, we find that the distortion-minimizing inflation rate ranges between 1.1% and 1.7%, depending on the details of the estimation approach. This is significantly above the zero rate generally considered optimal according to standard monetary policy models, which abstract from the presence of efficient trends in relative prices.

We arrive at this conclusion by estimating the efficient relative price trends for a large number of expenditure categories. We then use these estimates to provide a theory-consistent estimate of the optimal inflation rate. Relative price trends are estimated using the micro price data underlying the construction of the Euro Area's Harmonized Index of Consumer Prices (HICP), using the insight that the efficient trend in relative prices is unaffected by the presence of price stickiness and by a potentially suboptimal conduct of monetary policy.[5]

Our micro price data has recently become available under the Eurosystem's PRISMA (Price-setting Microdata Analysis) research network and contains more than 80 million price observations for the period 2010-2019. The data covers between 64% and 83% of the HICP expenditure basket in

[4]In its point 4, the ECB's monetary policy strategy statement lists three reasons for having a positive inflation buffer: (1) the lower-bound constraint and the decline in natural rates of interest, (2) downward rigidities in nominal wages, and (3) the potential overstatement of the true inflation rate due to unaccounted quality progress. Our estimates will encompass reason (3), because unaccounted quality progress of new products causes the relative price of existing products to fall (in not quality-adjusted terms). The ECB's monetary policy strategy statement can be found here: `https://www.ecb.europa.eu/home/search/review/html/ecb.strategyreview_monpol_strategy_statement.en.html`.

[5]While price stickiness and suboptimal inflation can affect the level of relative prices, they do not effect the time trend of relative prices, see Adam and Weber (2019).

the considered countries, making the present paper the first one to analyze Euro Area micro price data with a comprehensive coverage of households' expenditure basket. Prior analyses of Euro Area micro price data, e.g., the ones conducted shortly after inception of the Euro Area under the Eurosystem's Inflation Persistence Network, achieved a considerably narrower expenditure coverage. The descriptive statistics computed in Dhyne et al. (2006), for instance, are based on approximately 10% of the official basket.

Our estimates for the period 2015-2019 show that the optimal inflation rate minimizing the welfare costs associated with relative price distortions ranges between 1.1% and 2.1% in France, between 1.2% and 2.0% in Germany and between 0.8% and 1.0% in Italy.[6] The optimal inflation rates are thus all significantly above zero but also display quite some heterogeneity.

In the cross-section of expenditures, we find that the positive rate for optimal inflation is exclusively driven by the presence of a downward trend in the relative price of non-energy industrial goods. Depending on the country, the relative price of these goods declines at a rate of 2.6%-5.5% per year over the product lifetime.[7] Food and service prices show no relevant trends in relative prices over the product life, with the exception of the relative price of services in Germany, which increases at a rate close to 1% per year and thus represents a force that makes deflation optimal.[8]

Differences across countries emerge because of important differences in the strength of relative price trends in non-energy industrial goods. Rates of relative price decline in this category are about twice as strong in France and Germany compared to Italy. This is the main reason why the optimal inflation rate in the former two countries is higher than in Italy.

We find that relative price trends display a considerable amount of positive correlation across France and Germany at the disaggregated level (COICOP3).[9] Yet, Italy looks different: relative price trends in Italy are overall weaker and covary only weakly with the ones in Germany at the disaggregate level (COICOP3). We show that this is partly due to the fact that the rates of same-good price inflation in Italy are uncorrelated with the ones in Germany. In contrast, disaggregate inflation, which includes inflation contributions from old *and* new goods, comoves positively between Germany and Italy across expenditure categories.[10]

We also investigate how the optimal inflation rate has changed over time,

[6]Estimates for Italy are for the period 2016-2019, for reasons discussed below.

[7]This is the case, even though our data sample does not contain many consumer electronic goods, whose prices are collected centrally by statistical agencies. Arguably, the downward trend in relative prices over the product lifetime can be expected to be particularly pronounced in this product category.

[8]This force, however, is more than compensated by the downward trend in goods prices in Germany.

[9]COICOP denotes Classification of Individual Consumption by Purpose.

[10]This said, the average level of inflation is generally lower in Italy during our sample period.

by analyzing how efficient relative price trends vary with time. Comparing the baseline period (2015/6-2019) to an equally long period preceding the baseline period, we find that optimal inflation was either very stable over time or might have declined somewhat. A remarkable feature of the data is that there exists a strong positive correlation over time of the efficient trends in relative prices at the disaggregate expenditure level (COICOP3) in each of the three countries. The fact that relative price trends tend to be rather stable over time, with correlations of 0.85 or more in each of the countries, suggests that our estimates for the optimal inflation rate for the baseline period (2015/6-2019) are also relevant for the optimal inflation rate in the not too distant future, i.e., once the effects of the Covid crisis will have dissipated.

Beyond providing estimates of optimal inflation rates, the paper adds to the literature by quantifying the welfare costs associated with suboptimal rates of inflation. To this end it derives a new analytic result that allows computing (to second-order accuracy) the consumption-equivalent welfare costs of suboptimal inflation rates for a setting with heterogeneous trends in efficient prices across expenditure categories. This closed-form result allows us to parsimoniously determine the present value of consumption-equivalent welfare costs in the Euro Area for a number of alternative scenarios.

The first scenario assumes that inflation stays permanently at the low average levels displayed over the period 2015/6-2019 in the considered countries. Aggregate welfare losses due to price distortions are then small and do not exceed 0.5% of consumption in present-value terms. The second scenario counterfactually assumes that the European Central Bank targets an inflation rate of zero percent, as would be (close to) optimal when considering standard monetary policy models that abstract from the presence of relative price trends. Aggregate welfare losses then become substantial and easily reach 4.5% of consumption in present-value terms. The third and extreme scenario assumes that inflation stays permanently at its currently elevated level of 4.1% (Euro Area HICP inflation rate for October 2021). This results in a staggering welfare loss equal to 11% of consumption.

Overall, the three scenarios show how the welfare costs quickly rise with the deviation from the optimal target and how the normative prescriptions coming out of standard sticky price models (zero inflation) give rise to severely suboptimal outcomes, as would permanently higher levels of inflation of the magnitude currently experienced in the Euro Area.

Section 2 explains how one can estimate the optimal inflation target and derives our new analytic result characterizing the consumption-equivalent welfare losses associated with suboptimal inflation rates. Section 3 describes the underlying micro price data, presents key descriptive statistics and explains in detail the specification of the estimation approach. The main results on the optimal target estimates and how they change over time are presented in section 4. Section 5 discusses the quantitative welfare implications of suboptimal inflation rates. Section 6 takes a closer look at the underlying heterogeneity in relative price trends that gives rise to different levels for the optimal inflation rate at the country level. A conclusion briefly summarizes our main findings and provides an outlook on future work.

2 The Optimal Target and the Welfare Costs of Suboptimal Inflation

This section explains how we estimate the optimal inflation target and derives a new closed-form result allowing us to parsimoniously quantify the welfare costs of suboptimal inflation rates.

Consider a setting where aggregate consumption is a Cobb-Douglas aggregate of Z different expenditure categories, each of which enters with expenditure weight $\psi_z > 0$ $(z = 1, ..., Z)$ and with weights satisfying $\sum_z \psi_z = 1$. Adam and Weber (2020) show that the optimal inflation target for the aggregate economy $\Pi^\star$ in such a setting depends - among other things - on the *efficient* rates of relative price decline b_z in the different expenditure categories.

The *efficient* rates of relative price decline can thereby be estimated from the *actual* rates of relative price decline, because price-setting frictions and suboptimal conduct of monetary policy generate at most *level* distortions to relative prices, but leave their time trend unaffected. This allows estimating the efficient rates of relative price decline via linear panel regressions of the form

$$\ln \frac{P_{jzt}}{P_{zt}} = f_{jz} - \ln (b_z) \cdot s_{jzt} + u_{jzt}, \tag{1}$$

where P_{jzt} denotes the price of product j in expenditure category z at time t, P_{zt} the price index in category z, f_{jz} a product and category-specific intercept term, s_{jzt} the in-sample age of the product (normalized to zero at the date of product entry), and u_{jzt} a mean zero residual potentially displaying serial and cross-sectional dependence. The coefficient of interest is the slope coefficient b_z, which measures the (gross) average rate of relative price decline over the product lifetime in expenditure category z.

The optimal (gross) inflation target $\Pi^\star$ for the aggregate economy is then given (to a first-order approximation) by the expenditure-weighted average of the different rates of (efficient) relative price decline:

$$\Pi^\star = \sum_{z=1}^{Z} \psi_z \cdot \frac{\gamma_z^e}{\gamma^e} \cdot b_z, \tag{2}$$

where γ_z^e/γ^e is a growth rate adjustment factor, with γ_z^e denoting the (efficient gross real) growth rate of expenditures in category z and γ^e the (efficient gross real) growth rate for overall expenditures. The result in equation (2) holds true independently of whether price-setting frictions are time dependent, as with Calvo frictions, or state-dependent, as in menu cost settings.[11]

When the efficient relative price of products declines over time, we have $b_z > 1$. This contributes to an optimal gross inflation target above one in equation (2), as it becomes desirable to gradually erode relative prices over time. Conversely, if it is efficient that relative prices rise, we have $b_z < 1$, which causes deflation to be optimal. Equation (2) shows that relative price trends pertaining to expenditure categories with a high expenditure weight (ψ_z) or a high relative growth rate (γ_z^e/γ^e) have a larger impact on the optimal inflation target. This is so because distortions in such categories affect economic welfare relatively more.

We shall use equations (1) and (2) to determine country-level optimal inflation targets, using the HICP expenditure weights for ψ_z and using estimates for the relative growth rates γ_z^e/γ^e. Given the linear structure embedded in equation (2), one can aggregate the nationally optimal inflation targets further to the level of a currency union, using country-level expenditure weights and expenditure growth rates. We shall do so using France, Germany and Italy jointly as proxy for the Euro Area.

We are also interested in determining the welfare costs associated with suboptimal inflation rates for the setup with Calvo stickiness considered in Adam and Weber (2020). In this setup, each expenditure category z is a Dixit-Stiglitz aggregate of a continuum of individual goods with demand elasticity $\theta > 1$. Individual product prices are sticky with Calvo stickiness parameter $\alpha_z \in (0, 1)$ and individual products enter and exit the economy at the exogenous rate $\delta_z \in (0, 1)$ per period. The efficient lifetime trends in relative product prices, b_z, emerge due to productivity and quality trends that are present at the level of the expenditure categories. These trends - together with category-specific trends in total factor productivity - cause real expenditures for category z to increase at the (efficient gross) balanced growth rate γ_z^e, while the aggregate economy expands at the (efficient gross) balanced growth rate γ^e. Discounted steady-state utility grows at the rate $\beta(\gamma^e)^{1-\sigma} < 1$, where β is the representative households' time discount factor and $\sigma > 0$ the coefficient of relative risk aversion. In the steady state, the government may pay an arbitrary output subsidy τ (or levy an output tax if τ is negative), which may ameliorate (amplify) the distortionary effects of monopolistic competition.

For this setup, we can derive the following analytic result about the consumption-equivalent welfare losses associated with a suboptimal inflation

[11] With Calvo frictions, heterogeneity in price stickiness across expenditure categories does not affect the optimal inflation target to first order. With menu cost frictions, this holds true if either menu costs are of first order or - with larger menu costs - when they increase proportionally to the expenditure weight ψ_z as inflation deviates from its category-specific optimal level, see Adam and Weber (2020) for details.

rate:

Proposition 1 *Suppose the output subsidy/tax satisfies* $1+\tau \in (0, \theta/(\theta-1)]$ *and consider the limit* $\beta(\gamma^e)^{1-\sigma} \to 1$*. The per-period consumption-equivalent welfare loss associated with a deviation of the (gross) steady-state inflation rate* Π *from its optimal rate* $\Pi^\star$ *is*

$$\frac{c(\Pi) - c(\Pi^\star)}{c(\Pi^\star)} = -\frac{1}{2}\phi \left.\frac{\mu''(\Pi)}{\mu(\Pi)}\right|_{\Pi=\Pi^\star} (\Pi - \Pi^\star)^2 + O(3) \tag{3}$$

where $O(3)$ *denotes a third-order approximation error,* ϕ *is the inverse of the labor share in production, and* $\mu''(\Pi)/\mu(\Pi)$ *captures the convexity of the aggregate mark-up* μ *with respect to the inflation rate. Evaluating the latter term at the optimal inflation rate* $\Pi^\star$ *delivers*

$$\left.\frac{\mu''(\Pi)}{\mu(\Pi)}\right|_{\Pi=\Pi^\star} = \frac{\theta\tilde{\alpha}\left(\Pi^\star\right)^{\theta-3}}{\left(1-\tilde{\alpha}\left(\Pi^\star\right)^{\theta-1}\right)\left(1-\tilde{\alpha}\left(\Pi^\star\right)^{\theta-1}\right)}. \tag{4}$$

The welfare-equivalent consumption loss in equation (3) is approximated at a point where $b_z\frac{\gamma_z^e}{\gamma^e}$ *and* $\widetilde{\alpha}_z \equiv \alpha_z(1-\delta_z)(\gamma^e/\gamma_z^e)^{\theta-1}$ *are constant across across expenditure categories* $z = 1, \ldots Z$ *and is valid for first-order variations in both of these variables across categories* z*.*

Proof. See appendix A. ■

Proposition 1 contains the first closed-form expression available in the literature determining the welfare losses of suboptimal inflation in an economy featuring heterogeneous efficient trends in relative prices.

The conditions regarding the output subsidy and the discount factor in proposition 1 are identical to the ones required to insure that the optimal inflation target $\Pi^\star$ is given by equation (2). These conditions are rather weak, as they do not require that the subsidy eliminates the effects of monopoly power. The condition on the discount factor $\beta\left(\gamma^e\right)^{1-\sigma}$ insures that mark-up and price distortions are proportional to each other. Minimizing the welfare consequences of relative price distortions is then equivalent to minimizing the welfare consequences of mark-up distortions and we can use price and mark-up distortions interchangeably.[12]

Proposition 1 shows that the steady-state welfare losses are a quadratic function of the deviation of inflation Π from its optimal level $\Pi^\star$.[13] The factors pre-multiplying the squared inflation deviation depend positively on the inverse of the labor share in production (ϕ) and positively on the convexity

[12]See lemma 2 in Adam and Weber (2020). This simplifies the analytic derivations, but is not of quantitative relevance for our findings, as long as the discount factor assumes values close to one, as is routinely assumed in monetary economics.

[13]The aggregate inflation rate Π is the expenditure-weighted average of the category-specific inflation rates Π_z, i.e., $\ln\Pi = \sum_z \psi_z \ln\Pi_z$.

of the aggregate mark-up with respect to aggregate inflation, as captured by the term $\mu''(\Pi^\star)/\mu(\Pi^\star)$.

Intuitively, when labor is the only input in production ($\phi = 1$), price and mark-up distortions affect adversely only the allocation of labor across goods and expenditure categories. When capital is also a production factor ($\phi > 1$), then price and mark-up distortions also adversely affect the steady-state capital to labor ratio. This latter effect amplifies the welfare implications of price and mark-up distortions.

The mark-up term ($\mu''(\Pi^\star)/\mu(\Pi^\star)$) shows up as a pre-multiplying factor in equation (3) because it captures the welfare costs of suboptimal inflation in a setting in which there are no first-order costs: since the optimal inflation rate $\Pi^\star$ defined in equation (2) minimizes the aggregate welfare consequences of mark-up (and relative price) distortions, we have $\mu'(\Pi^\star) = 0$, so that deviations of inflation generate only second-order costs. The mark-up term depends itself on a small number of structural parameters, as shown by equation (4). Provided the optimal (gross) inflation rate is not too different from one ($\Pi^\star \approx 1$), the welfare costs are approximately proportional to the price elasticity of demand (θ). This is so because any given amount of price distortion causes larger quantity distortions the more elastic demand reacts to relative price distortions. Similarly and perhaps not surprisingly, the welfare costs also increase in the parameter $\widetilde{\alpha}$, which captures the effective degree of price stickiness at the point of approximation.[14]

The remainder of the paper will use micro price data to estimate the optimal inflation rate for France, Germany and Italy, using equations (1) and (2), and will quantify the welfare implications of suboptimal inflation rates in the Euro Area using proposition 1.

3 Micro Price Data for France, Germany and Italy

This section describes the underlying data set, which consists of micro price data for the period 2010-2019 used in the construction of the Harmonized Index of Consumer Prices (HICP) in France, Germany and Italy. Data access has been provided to us via the Eurosystem's PRISMA (Price-setting Microdata Analysis) research network.

Euro Area micro price data has previously been analyzed in a period covering the inception of the Euro Area. In particular, Dhyne et al. (2006) document a number of key descriptive statistics for a common sample of 50 goods and services over the period 1998-2003. Their data for France, Germany and Italy covered only around 10% of the official basket (see Gautier

[14]If all sectors grow at approximately the same rate ($\gamma_z^e \approx \gamma^e$), we have $\widetilde{\alpha} \approx \alpha_z(1-\delta_z)$, where α_z is the Calvo stickiness parameter and $(1-\delta_z)$ the probability that the product survives into the next period. The effective degree of price stickiness $\widetilde{\alpha}$ depends negatively on the product turnover rate δ_z because the prices for new products can be choosen freely.

et al. (2021)), which required performing cross-country comparisons on a relatively small share of the total basket. We are in the fortunate position that the data cover a much larger share of the basket, i.e., 83.3% for Germany, 64% for Italy and 67.2% for France. The coverage is still incomplete because our data does not include most of the so-called centrally collected prices and - for the case of France and Italy - excludes rent prices. Like Dhyne et al. (2006), we make a significant effort to harmonize the data preparation and the empirical approach across countries, see appendix B for details.

The data is collected on a monthly basis and contains product-level price information for goods and services purchased by private households. For most products, price collectors visit different types of outlets and shops, or request price information in a decentralized manner. For some products, price collection is centralized and based on publicly available sources on the internet. The data also contains survey-based information on the average expenditure shares at the national level on which official weights are based.

Our analysis considers all price observations that enter the computation of the national CPI and also includes information on quality adjustments performed by statistical agencies. We omit all price observations that are not originally sampled, i.e., we exclude all interpolated and imputed prices for seasonal products and for products that are out of stock. We do so because interpolation at the product level is often performed in a way that it does not alter the dynamics of elementary price indices and hence the aggregate CPI. This, however, can severely affect price trajectories at the product level and thereby bias estimates of relative price trends towards zero.

We also refine the product definition originally provided to us by national statistical institutes to avoid lumping products together over time that are effectively different. In particular, we split the price trajectories of the product time series, whenever (1) price observations are missing for more than one month, (2) comparable or non-comparable product substitutions occur, and (3) when there are changes in either the product quality or the product quantity.

3.1 The Considered Sample Periods

Our baseline sample period uses data for the five-year period from January 2015 to December 2019. For France, since data ends in September 2019, we use the period starting in October 2014 and ending in September 2019. To simplify the exposition, we refer to the French baseline sample also as covering the years 2015-2019. For Italy, we consider data from January 2016 to December 2019. We use a 4-year period because there has been a classification break for products in December 2015.[15] All in all, the baseline sample periods are quite comparable across countries and strike a balance between maximizing the sample length for each country and harmonization across countries.

We also consider an earlier sample period for the three countries. For Germany, this is the 5-year period from January 2010 to December 2014. For France, the earlier sample period comprises data from October 2009 to September 2014, so as to avoid overlap with the baseline sample period. Following similar conventions as for the baseline sample, we refer to the French sample as the 2010-2014 sample. To achieve comparability over time in Italy, we consider the 4-year sample period covering January 2012 to December 2015.

3.2 Sample Construction and Descriptive Statistics

Starting from all prices in the national CPI sample, we first eliminate all imputed and interpolated prices, as explained before. The fraction of imputed prices differs considerably across countries. For the baseline sample period (2015/6-2019), the share of imputed prices is 11.5% in France, 4.2% in Germany and 8.0% in Italy. This significant variation suggests that imputation procedures are far from being fully harmonized across the countries, which provides an additional reason for excluding imputed prices from our analysis.

Table 1 reports a number of descriptive statistics for the baseline sample period (2015/6-2019), after excluding imputed prices.[16] The reported statistics highlight considerable differences across countries.

The German sample is the most comprehensive one in terms of number of price observations, number of COICOP5 expenditure categories and the percentage of the expenditure share covered. The French sample contains nearly the same number of COICOP5 categories as the German sample, but significantly fewer price observations. This reflects different sampling strategies across the two countries, which might partly be due to the Federal structure of data collection in Germany, where samples are collected to be informative at the level of federal states (Länder). The Italian sample covers the smallest number of COICOP5 categories. In terms of the number of price observations, it is located between Germany and France, especially when taking into account that the sample period is one year shorter.

Table 1 shows that the underlying micro price data covers a large part of the total HICP basket of consumption expenditures in each country. The covered expenditure share is highest in Germany because it includes, unlike

[15] This break makes it impossible to trace product prices from December 2015 to January 2016 and prevents us from estimating relative price trends over the turn of the year 2015/2016, see appendix B.3 for details.

[16] Corresponding numbers for the earlier samples are reported in appendix C.

	France	Germany	Italy
Total number of price observations	8.0m	30.1m	11.6m
Number of COICOP5 expenditure categories	223	234	168
Covered expenditure share (of total HICP basket)	67.2%	83.3%	64.0%
Number of price observations per COICOP5			
Mean	36.1k	128.8k	69.1k
Median	15.4k	55.7k	42.2k
Number of products per COICOP5			
Mean	3.3k	10.1k	3.9k
Median	1.0k	2.2k	1.8k

Table 1: Descriptive statistics (2015/6-2019, country-specific sample)

in other countries, information on rent payments. Table 1 also shows that the mean and median number of price observations at the COICOP5 level is sufficiently large in all countries to allow us to reliably estimate relative price trends. There is also a large mean and median number of products at the COICOP5 level.

While the country-specific samples in table 1 are the ones most representative at the level of each country, they are not comparable across countries. Therefore, to obtain meaningful cross-country comparisons, our baseline approach considers only COICOP5 expenditure categories that are present in all three countries. We will refer to this selection of the data sample as the 'harmonized sample'. This rules out that country differences are driven purely by differences in the coverage of the underlying expenditure categories in national samples. We analyze the full country-specific samples in robustness exercises.

Table 2 reports the same descriptive statistics as table 1 for the sample harmonized across countries. This sample covers 145 common COICOP5 expenditure categories. For Italy, the total number of price observations drops by merely 9% as a result of harmonization, but the drop is more pronounced in France (24%) and Germany (18%), as the national data sets for these countries contain a significantly larger number of COICOP5 categories. There is a corresponding drop in the expenditure weights vis-a-vis the full samples available to us. Again, this effect is least pronounced for the Italian sample.

Interestingly, the mean and median number of price observations per COICOP5 category rises as a result of harmonization. The same holds true for the mean and median number of products per expenditure category. This shows that the harmonized sample mainly leaves out expenditure categories containing relatively few price observations and products.

Since we wish to estimate relative price trends over the product lifetime

	France	Germany	Italy
Total number of price observations	6.1m	24.6m	10.6m
Number of COICOP5 expenditure categories	145	145	145
Covered expenditure share (of country-specific sample)	68.2%	51.0%	87.9%
Number of price observations per COICOP5			
Mean	41.8k	169.6k	72.8k
Median	24.7k	104.0k	49.7k
Number of products per COICOP5			
Mean	3.4k	14.2k	4.2k
Median	1.7k	3.6k	2.1k

Table 2: Descriptive statistics (2015/6-2019, harmonized sample)

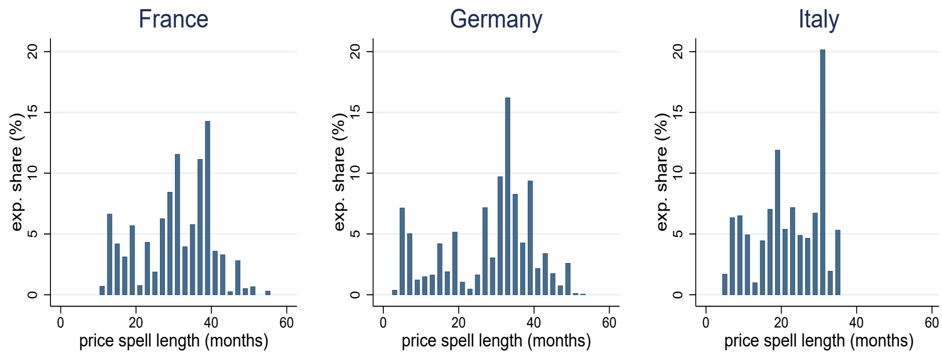

Figure 1: Average number of price observations per product at COICOP5 level (2015/6-2019, harmonized sample, expenditure-weighted distribution)

in a large number of expenditure categories, we also analyze for how long products are present on average in these categories within the harmonized baseline sample and using our refined product definition. Figure 1 reports the average number of months for which products are present, for each of the 145 COICOP5 categories. For the vast majority of COICOP5 categories, the average sample length of products is longer than 10 months, with average values (across categories) slightly above 20 months for Italy and close to 30 months for France and Germany. Given this, we conclude that one can reliably estimate (relative) price trends at the product level.

Figure 2 reports a number of descriptive joint distributions for France and Italy vis-a-vis Germany at the COICOP5 level.[17] Each point in the figure represents a COICOP5 expenditure category and the dashed line is the 45 degree line. The panel on the top left of the figure shows that there is a

[17]To increase readability, the panels in the top row of figure 2 have truncated axis.

strong positive correlation in the number of outlets that statistical agencies sample at the COICOP5 level and that all three countries sample approximately the same number of outlets. The center and right panels in the top row of figure 2 illustrate that there is also a strong positive correlation in the number of price quotes per months, and the number of products sampled, across COICOP5 categories, even if the German sample generally contains more price observations and in some cases a significantly larger number of products. The left panel in the bottom row of figure 2 shows that expenditure weights across COICOP5 categories correlate strongly across countries and are centered around the 45 degree line.[18] The same holds true for the price adjustment frequencies (center panel in the bottom row) and the average product age at the time of exit from the sample (right panel in the bottom row).[19] Overall, the panels in figure 2 show that the micro price samples of the three countries share many features and thus allow us to make meaningful cross-country comparisons.

3.3 The Estimation Approach

This section presents our baseline approach for estimating b_z in equation (1). Further details are described in appendix B.

We estimate the coefficients b_z at the COICOP8 level using the monthly panel regression equation (1). We set ψ_z equal to the time average of the official COICOP8 expenditure weights after normalizing them to one over the considered sample period. We set the relative expenditure growth term γ_z^e/γ^e in equation (2) equal to Π/Π_z, which is consistent with Cobb-Douglas aggregation, and where Π_z denotes the average inflation rate in expenditure category z over the considered sample period and $\ln \Pi = \sum_z \psi_z \ln \Pi_z$ is the expenditure-weighted average inflation rate across categories. When reporting results at various levels of disaggregation, e.g., at the COICOP3 level, we compute these as expenditure-weighted averages of the underlying COICOP8 level results, in line with how we compute aggregate results.[20]

For France we need to slightly deviate from the baseline approach, as official expenditure weights are only available at the COICOP6 level. We thus estimate b_z in equation (1) at the elementary level and then use, in a first step, unweighted averages to obtain an average estimate at the COICOP6 level. In a second step, we aggregate average estimates further

[18]The outlier for Italy in the top right corner of this panel is COICOP 11111, "Restaurants, cafes and dancing establishments", which has a much higher expenditure weight in Italy than in Germany.

[19]One issue with computing price adjustment frequencies in the presence of product turnover is how one takes into account new products. We treat the price associated with the entry of new product as a price adjustment.

[20]All optimal inflation rates are reported in annual terms and in percentage points, and have been computed by transforming the monthly regression coefficients from equation (1) in yearly coefficients and using annual inflation rates to determine γ_z^e/γ_z.

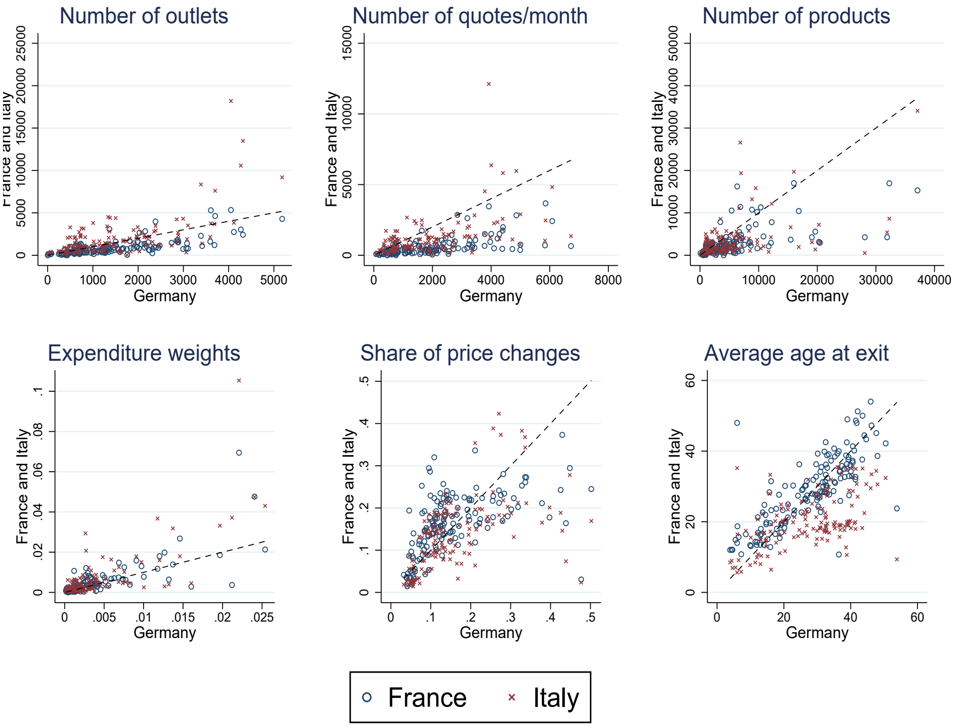

Figure 2: Descriptive joint distributions at the COICOP5 level (harmonized sample, 2015/16-2019)

using COICOP6 official expenditure weights. Applying the French aggregation procedure to the German data produces only minor differences to estimated optimal inflation rates.[21]

The baseline estimation approach uses the simple unweighted average of product prices in category z at time t as the category price level P_{zt} in equation (1), following the approach in Adam and Weber (2020). This has the advantage that we only take non-imputed prices into account in the regressions. Yet, we also consider an alternative approach which uses the official price index for P_{zt}, as computed by the statistical agencies. For Germany and Italy, these indices are available at the COICOP8 level. For France we use price indices at COICOP5 level, as official indices are not available at finer levels of disaggregation.

4 The Optimal Inflation Target: Main Results

This section describes our main estimates of the optimal inflation targets for France, Germany and Italy and for the Euro Area (consumption-weighted

[21]The optimal inflation target for Germany increases only slightly by fifteen basis points.

three country average).

Table 3 reports the estimated optimal inflation targets using the baseline sample period and the expenditure sample harmonized across countries. The table shows that the optimal inflation target is significantly above zero in all three countries: the presence of downward sloping efficient relative price trends thus strongly affects the optimal inflation rate in the presence of nominal rigidities. There is, however, a considerable degree of heterogeneity across the three countries. While the optimal target is 0.8% for Italy, it is a full percentage point higher for France and Germany. This shows that in France and Germany the (weighted) rate of relative price decline is more than twice as strong as in Italy.

According to the underlying theory, this difference could emerge for a number of reasons. One possibility is that quality progress associated with product replacements is better accounted for in Italy by the national statistical institute. Alternatively, productivity improvements over the product lifetime could be weaker in Italy than in France and Germany. Identifying which force is actually at play is not feasible with the available price data alone but appears to be is an interesting target for future research.

Given that France, Germany and Italy jointly account for about 64% of Euro Area GDP, we aggregate the nationally optimal inflation targets to obtain an estimate for the optimal Euro Area inflation target. We do so by weighting the optimal inflation rates of individual countries with their respective 2019 consumption expenditure shares.[22] The optimal Euro Area inflation rate thus computed is sizable and equal to 1.5%. This shows that price stickiness and the presence of efficient trends in relative prices alone justify targeting significantly positive inflation rates in the Euro Area. Additional considerations, such as falling levels for natural interest rates and the presence of a lower bound constraint on nominal rates may move this number up even further, e.g., see Adam, Pfaeuti and Reinelt (2020).

Table 3 also provides an Olley-Pakes decomposition of the optimal inflation rate in equation (2) at the COICOP5 level. Using the fact that the sum of weights $\sum_z \frac{\gamma_z^e}{\gamma^e}\psi_z$ is very close to one, we can decompose the optimal inflation rate into the contribution from the *unweighted* mean of efficient relative price declines $E[b_z]$ and the contribution from the covariance between (growth-adjusted) expenditure weights and rates of relative price decline:

$$\Pi^\star \approx E[b_z] + Z \cdot cov((\gamma_z^e/\gamma^e)\,\psi_z, b_z)$$

where Z denotes here the number of COICOP5 categories at which the Olley-Pakes decomposition is performed.

[22]We use final consumption expenditure by household for the year 2019. The resulting consumption shares are 42.2% for Germany, 31.1% for France and 26.7% for Italy. Strictly speaking, the aggregation result in equation (2) requires also using relative consumption growth rates (γ_z^e/γ^e). This, however, has quantitatively only negligible effects on the result.

	France 2015-19	Germany 2015-19	Italy 2016-19	Euro Area (FR, GER, IT)
Optimal Inflation Target	1.8%	1.8%	0.8%	1.5%
Olley-Pakes Decomposition				
$E[b_z]$	1.8%	1.4%	0.7%	-
$Z \cdot cov((\gamma_z^e/\gamma^e)\,\psi_z, b_z)$	0.0%	0.4%	0.1%	-

Table 3: Optimal inflation estimates (2015/6-2019, harmonized sample, baseline approach)

As table 3 indicates, the contribution of the covariance term is relevant only in Germany, where it contributes 0.4% to the optimal inflation target. In the two other countries, the unweighted average of the rates of relative price decline delivers very similar conclusions for the optimal inflation rate as the weighted average. This is due to the fact that for France and Italy, there is virtually no covariance between the estimated efficient rates of relative price decline (b_z) and the growth-adjusted expenditure weights ($(\gamma_z^e/\gamma^e)\,\psi_z$).

Table 4 explores the robustness of our main findings to using alternative estimation approaches. The alternative approaches deviate significantly from out baseline approach, but nevertheless yield broadly similar conclusions.

The first alternative approach in table 4 uses the official price indices for P_{zt} in the panel regressions (1) instead of the unweighted average product price. The way statistical agencies compute price indices differs substantially from simply averaging across prices, not least because official indices use product, shop and regional weights, in addition to using nonlinear (log-exponential) aggregation formulae in some countries and/or some expenditure categories. The official price indices also use all imputed prices, while these are excluded in our baseline approach. When using official price indices to compute relative price trends, the optimal inflation rates for France and Germany increase slightly, while the optimal rate for Italy remains largely unchanged. As a result, the optimal inflation target for the Euro Area increases slightly to 1.7%.

The second robustness exercise in table 4 drops the requirement that consumption baskets must be comparable across countries, but instead makes use of all available micro price data in each country to estimate the optimal inflation target.[23] Especially for France and Germany, this results in a significant change in the considered expenditure baskets, see table 2. While

[23]As before, we drop all imputed prices.

the optimal inflation target remains unchanged for Italy, the optimal targets decline considerably in France and Germany. In Germany, this is partly due to the fact that the German data set contains information on rent prices, which display low rates of relative price decline.[24] In France, the presence of fresh food, and to some extent gasoline, in the country-specific sample contributes to the decline in the optimal inflation. Overall, the Euro Area optimal inflation target drops by 0.4% to 1.1% when relying on country-specific expenditure samples.

The third robustness exercise in table 4 again departs from the harmonized expenditure sample, but this time uses the German expenditure weights ψ_z in all countries. The optimal inflation rates in France and Italy then slightly increase by 0.3 and 0.2 percentage points, respectively, relative to the baseline outcome. This shows that differences in expenditure weights across countries have only a modest impact on country-level results.

The last robustness exercise in table 4 eliminates the relative growth weights γ_z^e/γ^e, setting them equal to one in all countries, instead of computing them consistent with Cobb-Douglas aggregation in household preferences ($\gamma_z^e/\gamma^e = \Pi/\Pi_z$). Inflation rates differ quite substantially across different expenditure categories, especially when considering a fine level of disaggregation (COICOP8). One might thus suspect that these weights might have a rather large quantitative impact on results. Table 4 shows, however, that results are essentially unchanged for Germany and Italy. The biggest change occurs in France, where optimal inflation drops by about 0.4 percentage points, but the implied Euro Area rate drops by merely 0.1 percentage points relative to the baseline.

Taken together, the robustness exercises show that the baseline results are very stable for Italy. Furthermore, the baseline results obtained from the harmonized sample for France and Germany are roughly in the middle of the alternative approaches considered in table 4 and so is the baseline result for the optimal Euro Area inflation target.

Overall, the optimal inflation target that minimizes the welfare effects of relative price distortions in the Euro Area ranges between 1.1% and 1.7%, which is significantly larger than the zero inflation benchmark implied by monetary models that abstract from the presence of product turnover and trends in relative prices.

4.1 The Optimal Inflation Targets Over Time

This section analyzes the trend of optimal inflation targets over time in the considered countries. To this end, we compare estimates of the optimal

[24]The expenditure weight on rents (normalized and time-averaged) is sizable in Germany and equal to 11.7%. At the same time, relative price trends in this expenditure category are relatively weak, justifying optimal inflation rates of just around 1.2%, which is considerably below the German baseline estimate of the optimal target.

	France 2015-19	Germany 2015-19	Italy 2016-19	Euro Area Average (FR, GER, IT)
Optimal inflation target baseline estimate:	1.8%	1.8%	0.8%	1.5%
Official price index for P_{zt} in equation (1):	2.1%	2.0%	0.8%	1.7%
Country-specific COICOP sample:	1.1%	1.2%	0.8%	1.1%
German expenditure weights ($\psi_z \gamma_z^e / \gamma^e$)	2.1%	1.8%	1.0%	1.7%
No relative growth weights ($\gamma_z^e / \gamma^e = 1$)	1.4%	1.8%	0.8%	1.4%

Table 4: Optimal inflation target: alternative estimation approaches and micro price samples

inflation target obtained from the baseline sample period (2015/6-2019) to the corresponding estimates obtained from an earlier sample period (2010-14 for France and Germany, 2012-2015 for Italy).

The sample comparison is complicated by the fact that national statistical institutes changed the basket of expenditure categories underlying national CPIs as well as the base period at the end of 2014. In addition, the integration of European harmonized expenditure weights into national statistics took place around the same time, but introduction dates varied across countries and also depended on the level of disaggregation.

As a result of these reclassifications and changes, only a relatively small set of COICOP categories is available across all three countries and across both sample periods jointly, which makes comparisons that are valid across countries *and* across time unattractive, as they would have to rely on a rather small subset of the data.

Given these data constraints, we focus our analysis on a reliable time comparison by selecting the largest set of COICOP categories that is available in both sample periods for any given country under consideration. As a result, the estimates for the baseline sample period (2015/16-2019) obtained in the present section will differ from the ones presented in tables 3 and 4.

Matching the expenditure categories at the country level (COICOP8 level for Germany and Italy, elementary level for France), we cover 64.6% of the official expenditure basket for France, 74.5% for Germany, but only 27.5% for Italy.[25] To isolate the effect of changes in the slope coefficient

[25] Table 9 in Appendix C reports the descriptive statistics for the resulting samples. The table shows that for each country, the two sample periods are very similar in terms of the number of observations and the number of products.

	France		Germany		Italy	
	2010-14	2015-19	2010-14	2015-19	2012-15	2016-19
Baseline approach:	1.5%	1.2%	1.7%	1.2%	1.3%	1.4%
Official price index for P_{zt} in equation (2):	1.4%	1.3%	1.1%	1.1%	1.6%	1.0%

Table 5: The optimal inflation target over time (country-specific samples harmonized over time)

b_z over time, we use the expenditure weights (ψ_z) and growth rate weights (γ_z^e/γ^e) from the latter sample period (2015/6-20) to compute the optimal inflation rates in the earlier sample period.

Table 5 reports the outcomes for the optimal inflation rates over time. For the case where the slope coefficients b_z are estimated using the average price for P_{zt} in equation (1), there is a general tendency for the optimal inflation target to fall. This effect is quite pronounced in Germany but also present in France. Italy displays a very small increase, but this is based on a much smaller coverage of the expenditure basket. When the slope coefficients b_z are estimated using the official price index for P_{zt} in equation (1), the decrease in the optimal inflation targets largely disappears in France and Germany but the Italian estimates now display a considerable decrease.

Overall, these somewhat mixed results suggest that the optimal inflation rate might have declined over time or could have been broadly stable. Reassuringly, however, the estimates for the earlier sample period are in the same ballpark as the estimates in the latter period, which shows that relative price trends tend to display considerable stability over time. This fact is further illustrated in figure 3, which depicts the optimal inflation rates at the level of COICOP3 expenditure categories across time for each of the three countries. As indicated by the 45 degree lines in the figure and the correlations reported at the top of each panel, there is a surprisingly strong positive comovement of the optimal inflation rates over time at this disaggregated expenditure level. This stability over time suggests that the baseline optimal inflation rates estimated in table 3 bear some relevance also for what is the optimal inflation rate in the not too distant future, i.e., once the effects of the COVID-induced recession have vanished.

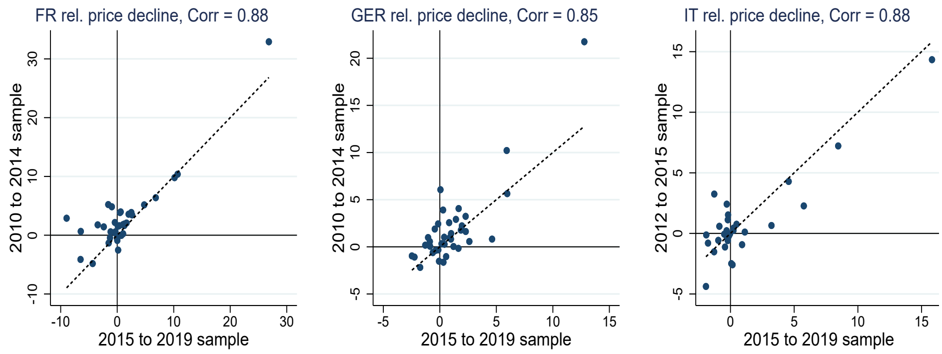

Figure 3: Optimal inflation rates at the COICOP3 level over time (country-specific samples harmonized over time)

5 The Welfare Costs of Suboptimal Inflation in the Euro Area

This section evaluates the welfare costs of suboptimal inflation rates by comparing the estimated optimal inflation rate for the Euro Area with the actual inflation rates prevailing over the considered time period and with two counterfactual settings in which the central bank targets either zero inflation or an elevated inflation rate equal to its current level of 4.1 percent.

Welfare losses are computed using proposition 1, which requires specifying only three parameters of interest, namely the demand elasticity θ, the inverse labor share ϕ and the (growth-adjusted) effective degree of price stickiness $\widetilde{\alpha} = (1-\alpha_z)\delta_z(\gamma^e/\gamma_z^e)^{\theta-1}$ at the point of approximation.

Following much of the literature in monetary economics, we set $\theta = 7$ and $\phi = 3/2$. As discussed before, welfare losses are approximately proportional to the values chosen for both of these parameters. For example, setting $\theta = 3.8$, as in Bilbiie, Ghironi and Melitz (2012), leads to roughly half the welfare losses.

For each country, we set the effective degree of price stickiness $\widetilde{\alpha}$ equal to the median value of $(1-\alpha_z)\delta_z(\gamma^e/\gamma_z^e)^{\theta-1}$ across expenditure categories z.[26] Transforming inflation rates into monthly gross rates and using the parameter values just described, one obtains consumption-equivalent welfare losses using equation (3) in proposition 1 for each of the considered countries, which we then aggregate to the Euro Area level using again the 2019 consumption weights of the three countries.

[26] The resulting median values (at the monthly frequency) are 0.828 (France), 0.870 (Germany) and 0.862 (Italy) and thus quite similar across the three considered countries. Considering expenditure–weighted medians, instead, makes very little difference for our results.

	Euro Area (2015/6-2019) harmonized sample
Optimal inflation	1.5%
Present value of consumption-equivalent welfare losses:	
Actual HICP inflation (2015/6-2019)	0.5%
Zero inflation	4.5%
Permanent inflation of 4.1%	11.0%

Table 6: Welfare costs of suboptimal inflation

Table 6 reports these welfare losses by transforming them into present discounted losses using an annual real interest rate of 1%. The reported discounted losses are expressed in percent of annual consumption and are computed using the optimal inflation targets implied by the harmonized sample in table 3. Table 6 reports the welfare losses implied by the actual inflation rates experienced in each of the three countries over the baseline period[27] and the counterfactual losses for inflation targets equal to zero and 4.1%, respectively.

For the actually experienced inflation rates, table 6 shows that the present value of welfare losses amount to merely 0.5% of consumption. This indicates that the actual inflation outcomes implemented by the European Central Bank were nearly optimal from the perspective of minimizing relative price distortions.

Table 6 also reveals that the welfare losses associated with targeting an inflation rate of zero are substantial and amount to 4.5% of consumption.[28] For the extreme scenario that inflation permanently continues at its currently elevated level (4.1%), welfare losses increase to a staggering 11% of consumption. This shows how welfare losses quickly rise with the distance from the optimal target. Moreover, targeting an inflation rate of zero would be severely suboptimal. The same is true for targeting an inflation rate significantly above 2%.

[27]The actual HICP inflation rate was 1.25% in Germany (2015-19), 1.01% in France (2015-19), and 0.8% in Italy (2016-19).

[28]Using the optimal Euro Area inflation rate implied by the country-specific samples (1.1%), the losses are lower but still substantial: they amount to 2.1% of consumption in present value terms.

6 A Disaggregated View on the Optimal Inflation Targets

This section delves deeper into the underlying heterogeneities that give rise to different optimal inflation targets across countries. To be able to make meaningful cross-country comparisons, the section focuses on the harmonized sample for the baseline period (2015/6-19).

Section 6.1 reports the optimal inflation rates at the level of so-called special aggregates (food, non-energy industrial goods and services) and also illustrates optimal rates for the COICOP5 categories of each special aggregate.[29] It shows that the positive inflation rates at the aggregate level are almost entirely due to the presence of relative price trends in (non-energy industrial) goods. Therefore, the subsequent section 6.2 considers the goods category in greater detail, showing that rates of relative price declines are strongest for electronic products and fashion products, but are also substantial for many other subcategories. Finally, section 6.3 documents the degree of covariation of relative price trends, same good price inflation, and overall inflation rates across countries at the COICOP3 expenditure level. It shows that inflation rates and the rates of same good price inflation covary very strongly across countries. For relative price trends the situation is different. These trends covary strongly between France and Germany, but trends in Italy are only weakly correlated with those in the other two countries.

6.1 Breakdown into Food, Goods and Services

Table 7 presents optimal inflation rates for food, goods and services by aggregating the underlying lower-level categories using the corresponding expenditure and relative growth weights. It shows that in all three countries, the optimal inflation rates for food and services tend to be very close to zero. The only exception is the optimal inflation rate for services in Germany, which is significantly negative and indicates that services become (in relative terms) more expensive over their lifetime. Overall, however, relative price trends tend to be rather weak in the food and service categories, especially when compared to the goods category, where optimal inflation rates are close to 5% in France and Germany and about half this rate in Italy.

Thus, table 7 shows that the positive optimal inflation rates at the aggregate level are to a large extent driven by the behavior of goods prices. The downward trend in the efficient relative price of goods can arise due to a number of fundamental forces. For instance, learning-by-doing effects can induce productivity progress over the lifetime of the good and thereby cause the efficient relative price to fall. Alternatively, the presence of unaccounted

[29]Special aggregates also feature energy goods as separate expenditure category. The harmonized sample, however, has only one COICOP5 observation in this category with an expenditure weight below 0.5%. We thus do not report this category.

	Food		Goods		Services	
	Π^*	Exp. Weight	Π^*	Exp. Weight	Π^*	Exp. Weight
France	0.2%	30.9%	4.9%	34.5%	0.1%	34.3%
Germany	-0.1%	26.5%	5.5%	39.3%	-0.9%	34.0%
Italy	0.0%	26.4%	2.6%	34.4%	-0.1%	38.7%

Table 7: Optimal inflation for special aggregates (2015/6-2019, harmonized sample)

quality progress associated with the introduction of new goods may seemingly cause the relative price of goods to fall over time. Newly introduced products are then more expensive than discontinued products so that the relative price of continuing products falls over time.[30] Finally, the usage period of products may shrink as products age, as is the case with certain seasonal products, e.g., winter boots.

The downward trends in the relative price of goods suggest that these effects are stronger for goods than services or food-related products. While perishability or shrinking usage time is also an issue for food products, the monthly frequency at which we observe prices does not allow us to observe these features as many food products cannot be stored beyond a few weeks.

Figure 4 reports the expenditure-weighted distribution of optimal inflation rates at COICOP5 level for each of the three special aggregates in each countries considered.[31] The optimal inflation rates for services are tightly centered around zero in France and Italy and around a slightly negative rate in Germany. The optimal inflation rates for food show somewhat more dispersion, but most dispersion is present for goods. In France and Germany, the optimal goods price inflation is positive for almost all COICOP5 expenditure categories. The distribution in Italy looks similar to that in France and Germany but is shifted several percentage points to the left. As a result, the distribution of optimal inflation rates across all expenditure categories is considerably less dispersed in Italy than in France or Germany. The next section looks in greater detail at the different subcomponents of the goods expenditure category.

[30] As shown in Adam and Weber (2020), our estimate for the optimal inflation rate remains correct, even in the presence of unaccounted quality progress.

[31] The optimal inflation rate at the level of a COICOP5 expenditure category z is equal to the estimated rate of relative price decline $\log b_z$ (appropriately weighted, annualized and expressed in net terms). The optimal inflation rate minimizes relative price and mark-up distortions in the expenditure category z.

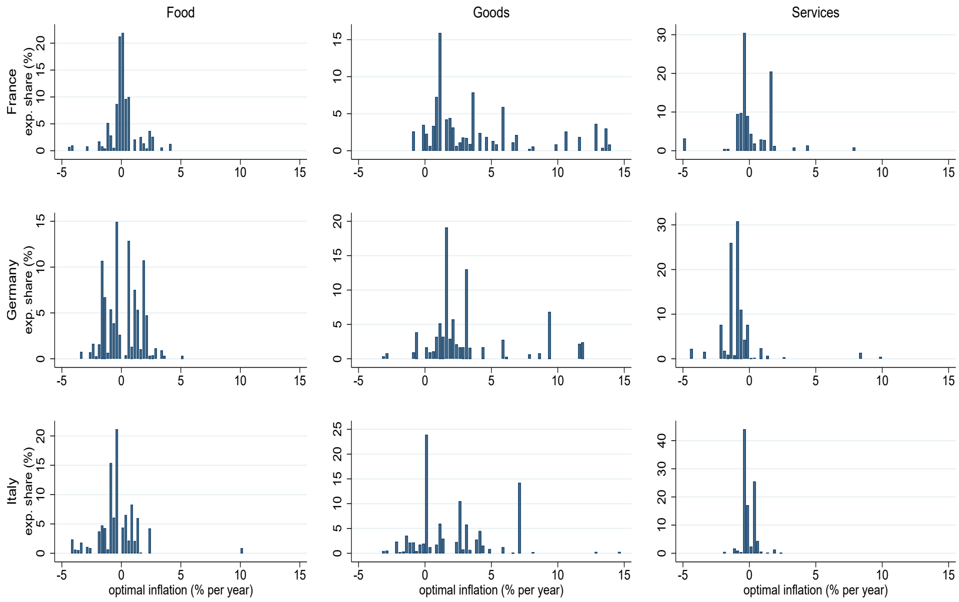

Figure 4: Optimal inflation, COICOP5 level (2015/6-2019, harmonized sample, expenditure-weighted distribution)

6.2 Decomposing Goods Expenditures

Table 8 reports the weighted average optimal inflation rates across countries for goods expenditures at the COICOP3 level, including the (unweighted) average of the expenditure weight across the three countries (expressed in terms of contribution to the goods expenditure category). The table reports all COICOP3 expenditure categories with an average expenditure share of at least 1% and sorts categories from high to low optimal inflation rates.

The table shows that the average optimal inflation rates are positive for all (except one) categories, with many rates being substantially positive. The category with the largest optimal inflation rate is "Audio-visual, photographic and information processing equipment" (for short, "Information processing equipment"). This category includes electronic music and video appliances, as well as computer equipment. Arguably, this is an expenditure category in which technological and quality progress is very pronounced. The next highest categories are "Clothing" and "Footwear". They contain goods subject to “fashion effects” and goods for which technological constraints, such as outlets running into storage capacity limits at the turn of a season, affect relative price trends. Finally, "Household appliances", which has the fourth highest rate of relative price decline, arguably also features considerable increases in product quality over time.

COICOP3 expenditure category	Exp. weight	Optimal inflation rate $\Pi^\star$ (%) Average	FR	DE	IT
Information processing equipment	2.82	11.75	11.11	9.32	18.27
Clothing	25.31	9.58	10.91	15.49	4.58
Footwear	6.47	6.83	11.43	6.06	4.10
Household appliances	4.42	5.04	5.98	2.27	8.04
Other recreational items	10.76	2.10	3.03	1.68	1.20
Personal care	9.20	1.82	1.41	3.08	1.11
Medical products, appliances & equipment	3.74	1.77	1.13	2.72	−0.07
Operation of personal transport equipment	3.55	1.55	2.06	3.11	−0.02
Personal effects n.e.c.	5.82	1.47	2.35	1.82	0.31
Furniture and furnishings	11.27	1.43	3.41	1.61	−0.02
Tools & equipment for house & garden	2.50	1.42	1.83	1.64	0.28
Household textiles	1.92	1.29	2.26	−0.26	2.13
Maintenance & repair of dwelling	1.72	0.86	0.86	1.62	−1.31
Goods/services for household maintenance	4.88	0.45	0.92	1.96	−0.80
Newspapers, books & stationery	1.50	0.04	0.76	−0.45	−0.86
Glassware, tableware & household utensils	3.13	−0.15	0.25	0.16	−1.21

Table 8: Optimal inflation for COICOP3-level expenditure categories (2015/6-2019, harmonized sample)

Importantly, the expenditure weight of "Information processing equipment" is comparatively small, with a weight of 2.82% in the harmonized sample. The weight is so small because most prices in this category are collected centrally and hence are not contained in our sample. This reduces the expenditure weight in our sample by approximately 50% and suggests that we might underestimate the aggregate optimal inflation rate. The effect from this expenditure category alone downward biases the optimal inflation rate by 0.07 percentage points.

6.3 The Comovement of Relative Price Trends, Same Good Inflation and Overall Inflation

This section documents the extent of comovement in relative price trends, same good inflation and overall inflation across the three countries. Figure 5 depicts joint distributions of these variables at the COICOP3 level.[32] The top row presents joint distributions for France and Germany and the bottom row joint distributions for Italy and Germany. Each plot also depicts the 45 degree line as a reference point for a situation with perfect alignment across countries and also reports the correlations between the variables.

The graphs in the left column of figure 5 depict rates of relative price decline, i.e., optimal inflation rates, at the COICOP3 level. The graphs in

[32]To increase readability, the support for the axis has been truncated. The non-truncated version of the figure can be found in appendix C, see figure 6.

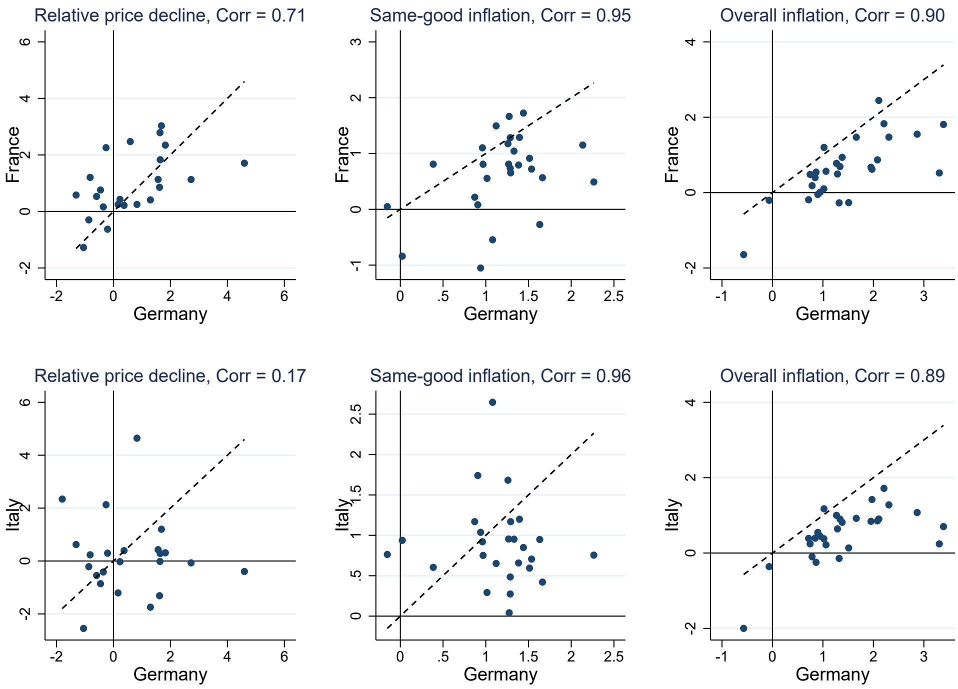

Figure 5: Joint distributions at the COICOP3 level (2015/6-2019, harmonized sample)

the center column report the rate of same good price inflation at this level of disaggregation. Same good price inflation in each country is obtained by running the panel regression

$$\ln P_{jzt} = f_{jz}^{n} - \ln\left(b_{z}^{n}\right) \cdot s_{jzt} + u_{jzt}^{n},$$

which replaces $\ln P_{jzt}/P_{zt}$ on the left-hand side in equation (1) by the log nominal price.[33] Finally, the graphs in the right-hand side column of figure 5 present the average annual inflation rate at the COICOP3 level.

The top left graph in figure 5 illustrates that the estimated optimal inflation rates covary considerably for France and Germany and are approximately centred around the 45 degree line. The top center and right-hand graphs, however, reveal quite some differences across the two countries. While same good price inflation rates in France and Germany covary positively, most French rates are considerably lower than corresponding German rates. Optimal inflation rates in France are nevertheless similar to the ones

[33] We run these regression at the same level of disaggregation as our relative price regressions and then aggregate the slope coefficients b_z^n to the COICOP3 level using the same approach as used to aggregate the coefficients of the relative price regressions. Monthly gross rates have been transformed into annual net rates in percentage points.

in Germany because overall inflation, depicted on the right-hand side, is also lower in France.

The bottom row in figure 5 compares joint distributions for Italy and Germany. The optimal inflation rates for Italy and Germany, shown in the left column, covary only weakly across COICOP3 expenditure categories. This is the case because the same good price inflation rates, shown in the center column, display little comovement across these countries.[34] The graph on the right shows, that the overall inflation rates in Italy covary nevertheless considerably with those in Germany, even if they are (with one exception) lower than in Germany.

Summing up, the rates of relative price decline in France and Germany are rather similar to each, but they differ from those in Italy. Understanding better the fundamental forces generating these similarities and differences across countries appears important, but requires better information about productivity and quality dynamics. Since these dynamics arise on the production side, they cannot be easily analyzed using price data alone.

7 Conclusions

In France, Germany and Italy, relative prices tend to fall over the lifetime of products. We show that this justifies targeting significantly positive rates of steady-state inflation: the optimal inflation rates minimizing the welfare effects of price and mark-up distortions range from slightly below one percent to slightly above two percent, depending on the details of the estimation approach. In all cases, they are significantly larger than zero, i.e., well above the optimal rate emerging from standard monetary policy models that abstract from product turnover.

We show that this finding is mainly due to the behavior of goods prices, for which the decline in relative prices is strongest in all three countries. In contrast, relative price trends tend to be weak or largely absent in service prices and food prices. As a result of the behavior of goods prices, price stickiness alone makes it optimal to target an inflation rate between 1.1% and 1.7% for the Euro Area. Deviations from this range either towards significantly larger inflation rates, say 4%, or towards the zero inflation reference point tend to produce large welfare costs.

The optimal inflation rate is also affected by other considerations not taken into account in the present paper, for example the presence of a lower bound constraint on nominal rates or the presence of downward rigidity in nominal wages. These may push up the optimal inflation targets further. Future work should thus explore the implications of these features in

[34]The high value of the reported correlation is only due to a few outliers not shown in figure 5 . See figure 6 in appendix C for the non-truncated version of the figure.

combination with relative price trends for the optimal conduct of monetary policy.

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A Proof of Proposition 1

Appendix E.2.2 in Adam and Weber (2020) shows that - under the conditions stated in the proposition - hours worked in steady-state do not depend on the steady-state inflation rate. Household welfare thus only depends on consumption, which is given by

$$c(\Pi) = K \left(\frac{1}{\mu(\Pi)} \right)^{\phi}, \tag{5}$$

where $K > 0$ is a proportionality constant and $\mu(\cdot)$ the aggregate markup. Taking a second order expansion of the previous equation at the point $\Pi = \Pi^{\star}$ yields:

$$\begin{aligned} c(\Pi) = c(\Pi^{\star}) &- \left(\phi c(\Pi) \frac{\partial \mu(\Pi)/\partial \Pi}{\mu(\Pi)} \right) \Bigg|_{\Pi=\Pi^{\star}} (\Pi - \Pi^{\star}) \\ &+ \frac{1}{2} \left(\phi \left(1+\phi\right) c(\Pi) \left(\frac{\partial \mu(\Pi)/\partial \Pi}{\mu(\Pi)} \right)^2 - \phi c(\Pi) \frac{\partial^2 \mu(\Pi)/(\partial \Pi)^2}{\mu(\Pi)} \right) \Bigg|_{\Pi=\Pi^{\star}} (\Pi - \Pi^{\star})^2 + O(3). \end{aligned}$$

Since $\mu(\Pi)/\partial \Pi = 0$ at the point $\Pi = \Pi^{\star}$, we get

$$\frac{c(\Pi) - c(\Pi^{\star})}{c(\Pi^{\star})} = -\frac{1}{2} \phi \left. \frac{\partial^2 \mu(\Pi)/(\partial \Pi)^2}{\mu(\Pi)} \right|_{\Pi=\Pi^{\star}} (\Pi - \Pi^{\star})^2 + O(3),$$

which is equation (3) in proposition 1. The challenge consists of determining $\frac{\partial^2\mu(\Pi)/(\partial\Pi)^2}{\mu(\Pi)}$ in terms of deep model parameters. Appendix E.2.3 in Adam and Weber (2020) shows that

$$\frac{\partial\mu(\Pi)}{\partial\Pi} = \sum_{z=1}^{Z} \psi_z \mu_z(\Pi)^{\psi_z - 1}[\partial\mu_z(\Pi)/\partial\Pi] \left(\prod_{z^C} \mu_z(\Pi)^{\psi_z}\right) = 0, \tag{6}$$

where z^C denotes the set of all expenditure categories except for category z. Using the definition of the aggregate mark-up

$$\mu(\Pi) \equiv \prod_{z=1}^{Z} \mu_z(\Pi)^{\psi_z}$$

and the notation $\mu'(\Pi) = \partial\mu(\Pi)/\partial\Pi$, one can express equation (6) as

$$\mu'(\Pi) = \mu(\Pi) \sum_{z=1}^{Z} \psi_z \frac{\mu_z'(\Pi)}{\mu_z(\Pi)}, \tag{7}$$

Taking the derivative of equation (7) with respect to Π yields

$$\mu''(\Pi) = \mu'(\Pi) \left(\sum_{z=1}^{Z} \psi_z \frac{\mu_z'(\Pi)}{\mu_z(\Pi)}\right) + \mu(\Pi) \left(\sum_{z=1}^{Z} \psi_z \frac{\mu_z'(\Pi)}{\mu_z(\Pi)}\right)'.$$

At the point of approximation $\Pi = \Pi^\star$, we have $\mu'(\Pi) = 0$, so that

$$\left.\frac{\mu''(\Pi)}{\mu(\Pi)}\right|_{\Pi=\Pi^\star} = \sum_{z=1}^{Z} \psi_z \left(\frac{\mu_z'(\Pi^\star)}{\mu_z(\Pi^\star)}\right)'. \tag{8}$$

To compute the derivatives on the r.h.s. in the previous equation, we use the third equation in Appendix E.2.3 in Adam and Weber (2020), reproduced here for convenience, using the notation $b_z \equiv g_z/q_z$:

$$\frac{\mu_z'(\Pi)}{\mu_z(\Pi)} = \Phi_z(\Pi) \left[\Pi - b_z \frac{\gamma_z^e}{\gamma^e}\right], \tag{9}$$

where

$$\Phi_z(\Pi) = \frac{\theta\tilde{\alpha}_z \Pi^{\theta-2} \left(\frac{\gamma^e}{b_z \gamma_z^e}\right)}{\left(1 - \tilde{\alpha}_z \Pi^\theta \left(\frac{\gamma^e}{b_z\gamma_z^e}\right)\right)(1 - \tilde{\alpha}_z \Pi^{\theta-1})}, \tag{10}$$

and where $\tilde{\alpha}_z = \alpha_z(1 - \delta_z)(\gamma^e/\gamma_z^e)^{\theta-1}$.

Using equation (9), we can determine the derivatives on the r.h.s. in equation (8). This yields

$$\left(\frac{\mu_z'(\Pi)}{\mu_z(\Pi)}\right)' = \Phi_z(\Pi)' \left[\Pi - b_z \frac{\gamma_z^e}{\gamma^e}\right] + \Phi_z(\Pi).$$

Substituting this expression into equation (8) yields

$$\left.\frac{\mu''(\Pi)}{\mu(\Pi)}\right|_{\Pi=\Pi^\star} = \sum_{z=1}^{Z} \psi_z \Phi_z(\Pi^\star)' \left[\Pi^\star - b_z \frac{\gamma_z^e}{\gamma^e}\right] + \sum_{z=1}^{Z} \psi_z \Phi_z(\Pi^\star). \tag{11}$$

Using the fact that $b_z\gamma_z^e/\gamma^e = \Pi^\star$ for all $z = 1, \ldots Z$ at the point of approximation and the expression for $\Phi_z(\Pi)$ in equation (10), we obtain

$$\left.\frac{\mu''(\Pi)}{\mu(\Pi)}\right|_{\Pi=\Pi^\star} = \sum_{z=1}^{Z} \psi_z \frac{\theta\tilde{\alpha}_z \Pi^{\star\theta-3}}{\left(1-\tilde{\alpha}_z\Pi^{\star\theta-1}\right)\left(1-\tilde{\alpha}_z\Pi^{\star\theta-1}\right)}.$$

Using also the fact that $\widetilde{\alpha}_z \equiv \widetilde{\alpha}$ for all $z = 1, \ldots Z$ at the point of approximation and that $\sum_{z=1}^{Z} \psi_z = 1$ delivers equation (4) in proposition 1.

B Appendix

This appendix describes the harmonized data transformations that we perform for all national micro price data sets alike and the country-specific characteristics of each data set (see appendices B.1, B.2 and B.3).

For each of the three economies, we employ the micro price data that underlie the official consumer price index (CPI). The data is at monthly frequency and contains product-level price information for goods and (private and public) services which are consumed by private households. For most products, price collectors visit different types of outlets and shops, or request price information and tariffs from the service sector in a decentralized manner. For some products, price collection is centralized and refers to publicly available sources such as the internet. The data also contain survey-based information on expenditure shares that a typical household in the respective country spends on a product category.

In the analysis, we consider only price observations that enter the computation of the national CPI, and omit all price observations flagged as not originally sampled, i.e., imputed or interpolated price observations. To harmonize the product definition across countries, we refine the product definition originally provided by national statistical institutes as follows. We split the price trajectory of an original product whenever price observations are missing for more than one month (including missing quotes that results from dropping imputed prices); comparable or non-comparable product substitutions occur; and product quality or quantity sold (such as package size) change. As described in the main text, we use expenditure weights to aggregate statistics across expenditure categories. We compute the normalized average expenditure weight according to

$$\psi_z = \frac{\frac{1}{T_z-t_z+1}\sum_{t=t_z}^{T_z} \widetilde{\psi}_{zt}}{\sum_{z=1}^{Z} \frac{1}{T_z-t_z+1}\sum_{t=t_z}^{T_z} \widetilde{\psi}_{zt}}, \tag{12}$$

where $\widetilde{\psi}_{zt}$ is the expenditure weight of category z at time t, t_z is the first observation in this category for a given economy and T_z is the last observation in this category.

B.1 French Data

We rely on the longitudinal dataset of monthly price quotes collected by the Institut National de la Statistique et des Études Économiques (INSEE) to compute the monthly French CPI and HICP. The raw data set contains about 9.5 million price quotes for the baseline period from October 2014 to September 2019 and 7.6 million price quotes for the reference period from October 2009 to September 2014. Centrally collected prices, such as car prices, administered prices (e.g. tobacco), public utility prices (e.g. electricity), and rents, are not part of the data set. Individual products are classified in about 4000 product categories at the most disaggregate (elementary) level of product classification, which is used to compute elementary price indices. These categories are grouped in 334 COICOP categories at the 6-digit level and 230 ECOICOP categories at the 5-digit level.

The price variable employed in the present analysis are the prices that enter the computation of elementary price indices (i.e., quality/quantity-adjusted prices of individual products sold in shops). The data set also contains information to recover the collected price (i.e., before quality/quantity adjustments) and various flags indicating changes in quantities or packaging. Furthermore, the data flags imputed prices. Prices are imputed for seasonal products that are out-of-season, when products are temporarily unavailable, or when products are in the process of being replaced. A qualitative variable in the data set documents the reasons for having a "non-normal" observed price (which does not necessarily mean price imputation): product is temporarily not available (6%); outlet is temporarily closed (1.5%); no valid replacement outlet is available (0.5%); no price collection (1.5%); non-comparable product substitution (3%); and comparable product substitution (2.5%).

Data for official monthly price indices, HICP expenditure weights at the 5-digit ECOICOP level and national CPI expenditure weights at the 6-digit ECOICOP level is obtained from the INSEE website.

Data preparation. We drop the price quotes that are imputed by INSEE. About 15% of all price quotes are imputed, with the bulk of imputations in food categories or non-energy industrial goods. Most prices are imputed only for very short periods of time, for example because of temporary shop closing. Longer price imputation spells are observed in categories with seasonal products, but are overall rare. Dropping imputed prices leaves us with 8 million observations in the baseline sample and 7 million observations in the sample covering the period 2009-2014.

Product definition and regression analysis. In the French data, the individual product identifier allows to track prices for a given product over time and any product replacement (comparable or not) over the period of the price collection for this product. In particular, INSEE flags a comparable or non-comparable product substitution but also provides information allowing to track by which new product an old product has been replaced (in case of forced substitution). We refine the original product identifier by splitting price trajectories into subcomponents, as described in the beginning of appendix B. This increases the number of products from about 641k products to 736k products for the 2014-2019 sample and from 489k products to 544k products for the 2010-2014 sample.

For the baseline specification of the regression equation (1), we compute relative prices using the cross-sectional average price calculated at the most disaggregate (elementary) level. For robustness, we also compute relative prices using official price indices for the 5-digit ECOICOP level.[35] For most categories in the baseline sample, slope estimates from the baseline regression correlate highly with slope estimates from the alternative specification that uses the official price index to deflate product prices. However, for some categories, substantial differences between slope estimates emerge because in these cases, price deflators exhibit different dynamics and/or volatility. Thus, for French baseline results, we drop 10 (out of 4000) elementary categories and three (out of 300) 6-digit COICOP categories ('Natural gas' 04.5.2.2.1, 'Pharmaceutical products' 06.1.1.0.1 and 'Canteens' 11.1.2.0.1). The three categories represent about 4% of total expenditure in the product basket. For the 2009-2014 sample, we drop one category ('Camper vans, caravans and trailers' 09.2.1.1.1) for the same reason.

Expenditure weights used for aggregation. We aggregate statistics from the elementary level to higher levels in three steps. First, we compute the simple average of statistics at the elementary level to obtain statistics at the 6-digit COICOP level. Second, we use national expenditure weights at 6-digit COICOP level to obtain weighted aggregate statistics at 5-digit level. Finally, we use French HICP expenditure weights at 5-digit COICOP level to obtain statistics at the 2- or 3-digit COICOP level or for the aggregate level.

B.2 German Data

We use the German monthly micro price data that underlie both the computation of the CPI and the HICP. Most price observations are collected by Statistical Offices of the German Federal States, where each statistical office

[35] This is the most disaggregated level at which INSEE publishes official price indices at a monthly frequency.

collects product prices for its state.[36] In most product categories, prices are collected decentralized in physical outlets. For some product categories, however, price collection is centralized and thus takes place either at the federal level or by a single state office for all federal states together.[37] Product prices are collected in each month, preferably in the middle of the month. Information on product prices and expenditure weights is accompanied by information on quality adjustments (in Euros) and quantity adjustments of product prices. This information is provided by price collectors and reflects changes in product characteristics or package size. In our analysis, we only employ quality/quantity-adjusted product prices. Individual products are classified according to 10-digit COICOP.

Data preparation. The following describes preparation of the baseline sample from 2015:01 to 2019:12. Data for the 2010:01 to 2014:12 sample is prepared identically. The raw data for the baseline sample contain 36 million observations. We restrict this sample to price observations which are also used to compute the official CPI and drop observations with tiny prices (less than 5 cents) and observations for which the price deviates by more than minus 99% or plus 10000% from the average price at the stratum level.

We further restrict the sample to 10-digit COICOP categories with price observations collected for more than one outlet and more than one product to obtain meaningful relative price regressions.[38] We also exclude 10-digit COICOP categories for which official price indices are not available, which allows us to complement our baseline regression specification with an alternative specification.[39]

From the resulting sample, we drop the price observations that are imputed by Federal Statistical Offices.[40] About 5.9% of all price observations

[36]Data are provided by the Research Data Center (RDC) of the Federal
Statistical Office and Statistical Offices of the Data are provided by the Research Data Center (RDC) of the Federal Statistical Office and Statistical Offices of the Federal States, "Einzeldaten des Verbraucherpreisindex 2018," EVAS-Nummer 61111, 2010 - 2019, DOI: 10.21242/61111.2010.00.00.1.1.0 to 10.21242/61111.2019.00.00.1.1.0.

[37]The Federal Statistical Office (Destatis) also collects product prices centrally for all federal states jointly. These price observations are not part of our data set.

[38]In particular, we exclude 731111100 Bahnfahrt, Nahverkehr; 820200200 Mobiltelefon ohne Vertrag; 913221100 Tintenstrahldrucker; 913221200 Laserdrucker; 1111203400 Speise zum Verzehr in öffentlichem Verkehrsmittel; 1111203500 Getränk zum Verzehr in öffentlichem Verkehrsmittel.

[39]We obtain official price indices for the baseline sample from `https://www-genesis.destatis.de/genesis/online?operation=previous&levelindex=3&step=2&titel=Tabellenaufbau&levelid=1611219556060&levelid=1611219502477#abreadcrumb`.

[40]Imputation events are the following: a seasonal product out-of-season; product temporarily not available; non-comparable product substitution; replacement product declined; abstain from replacement product; no valid replacement product available; outlet temporarily closed; replacement outlet declined; abstain from replacement outlet; no valid

in the raw data are imputed, with a larger share of imputed price observations in categories for seasonal products, such as clothing. After these adjustments, the data set contains 30 million price observations, classified in approximately 700 expenditure categories at 10-digit COICOP level. At this stage of the analysis, the informational content of the German 10-digit COICOP is equivalent to the German 8-digit COICOP.

Product definition. In the German data, the original product identifier provided by Federal Statistical Offices yields a unique mapping of price observations to individual products. We refine the original identifier by splitting price trajectories into subcomponents as described in the beginning of appendix B. We also drop all products (refined identifier) with less than two price observations. Refining the product definition in this way increases the number of products from 808k to 2.37 million.

Expenditure weights used for aggregation. We aggregate statistics from the 8-digit COICOP level to higher levels in two steps. First, we use national expenditure weights at the 8-digit COICOP level to compute weighted aggregate statistics at 5-digit COICOP level. Second, we use harmonized expenditure weights at 5-digit COICOP level to compute even more aggregate statistics, such as those in table 1 in the main text.[41]

Sample comparison. For reasons of data availability, we do not use disaggregate official price indices to compute relative product prices in equation (1) when we compare estimates of the optimal inflation rate over time (see table 5). Instead, in this case, we compute relative product prices using elementary price indices which are part of the German micro price data. For the baseline sample from January 2015 to December 2019, both elementary and official price indices are available and yield essentially identical estimates for the optimal inflation rate.

B.3 Italian Data

We use the monthly micro price data that underlie the computation of the CPI and the HICP. The data is provided to us by the Italian National Statistical Institute (ISTAT). In particular, we use prices collected locally once a month by municipal statistics offices in over 70 provincial capitals; hence our sample neither includes prices collected centrally (e.g., cars), nor those collected locally more than once a month (e.g., some unprocessed

replacement outlet available.

[41]Harmonized expenditure weights at 5-digit COICOP level come from the ECB statistical data warehouse, `https://www.ecb.europa.eu/stats/ecb_statistics/escb/html/table.en.html?id=JDF_ICP_COICOP_INW`.

food). The baseline sample spans the 4-years period January 2016 - December 2019, and contains around 3.3 million observations per year. Prices collected belong on average to 612 10-digit COICOP categories, grouped in 263 8-digit COICOP categories. Besides information on product prices, the Italian micro data also contain information on imputation, sales and product replacement. The price variable we use in the analysis is the price collected at stores, divided by the corresponding quantity (to account for changes in packaging). The data on official indices and expenditure weights at the 8-digit COICOP level are provided by ISTAT; both indices and expenditure weights are those used to compute the official HICP index, and differ from the national CPI statistics mainly for the treatment of sales and health-related items.

We choose to consider in the baseline sample only data starting from January 2016, as between 2015 and 2016 the classification of Italian consumer prices data adopted by ISTAT underwent a substantial change, reflecting the wider adoption of the new classification ECOICOP (European Classification of Individual Consumption by Purpose). Before 2016, the Italian classification coincided with ECOICOP only up to the 4-digits level, while from January 2016 it also coincided at 5- and 6-digits categories, which causes some categories to non-connectable over the 2015-2016 period.[42]

Data preparation. From the raw data we drop the imputed price quotes, as indicated by imputation flags. A price is imputed by ISTAT if (i) a store is closed, either temporarily (e.g., during summer vacations) or for good; (2) an individual product sampled in a store is not present, either temporarily for reasons different from seasonality or for good; (3) the product is out-of-season (for seasonal products); (4) the price could not be collected for extraordinary reasons;[43] (5) missing observations for other reasons. Slightly less than 9% of all price observations are imputed; more than one half are imputations due to seasonality, especially concentrated in categories such as clothing. We control for outliers dropping some prices that take very high values, and dropping the observations smaller than the 1st percentile and larger than the 99th percentile of the price distribution computed for each month of the sample at the 10-digit COICOP level.

Product definition and regression analysis. The meta data available for each elementary price enable us to track the price of a product (defined at the 10-digit COICOP level) of a given brand at a given retailer over time, i.e. to trace what we call a price trajectory. We refine the original

[42] For more details on the classification change, see the methodological note at `https://www.istat.it/it/files//2016/02/EN_Basket_2016.pdf`.

[43] This last flag has been extensively used during the 2020 lockdown, when collectors could not go to the stores to collect prices.

	France		Germany		Italy	
	2010-14	2015-19	2010-14	2015-19	2012-15	2016-19
Total # of price quotes	6.4m	6.2m	22.8m	26.6m	2.2m	2.2m
# of COICOP5 categories	214	214	197	197	94	94
Coverage of HICP basket	.	64.6%	.	74.5%	.	27.5%
# of quotes per COICOP5						
Mean	29.8k	28.8k	115.6k	134.9k	23.4k	23.7k
Median	15.6k	13.4k	53.9k	63.8k	19.0k	19.6k
# of products per COICOP5						
Mean	2.4k	2.3k	8.9k	10.6k	1.3k	1.3k
Median	1.0k	1.0k	2.3k	2.4k	1.2k	1.1k

Table 9: Descriptive statistics for samples with harmonized set of COICOP5 categories over time, but not across countries.

identifier by splitting price trajectories into subcomponents as described in the beginning of appendix B. Refining the product definition in this way increases the number of products from around 407k to 655k. At this stage, we also drop all price observations that belong to refined product identifiers with less than two price observations. Dropping products with less than two observations, imputed prices, and outlier observations reduces the number of observations from roughly 13.3 million to 11.7 million.

We run the regressions in equation (1) under two possible specifications; in both of them we define relative prices and run the regressions at the 8-digit COICOP level. In the baseline specification, we compute relative prices using as denominator the average of collected prices. In the second specification, we compute relative prices using official price indices as denominator. In computing aggregate results, we drop the coefficients of the 8-digit category related to garden furniture (code 05.1.1.2.0.00), as it is present only in 2019 and shows abnormally wide price swings, and the coefficients of a 10-digit COICOP category related to long-term public parking, as it is highly dependent on a sharp price change adopted in a single province (code 07.2.4.2.1.00.03).

C Additional Tables and Figures

This appendix provides additional descriptive statistics and figures to complement the analysis in the main text. Table 9 provides descriptive statistics for the two sample periods for each country, with harmonized set of COICOPs over time, but not across countries. These samples underlie the estimates of the optimal inflation rate in section 4.1. The table omits the covered expenditure share of the HICP basket for the early sample because harmonized expenditure weights at 5-digit COICOP level are available only for the later sample.

Figure 6 presents the joint distributions of optimal inflation rates across countries at the COICOP3 level. It is the non-truncated version of figure 5 discussed in the main text in section 6.3.

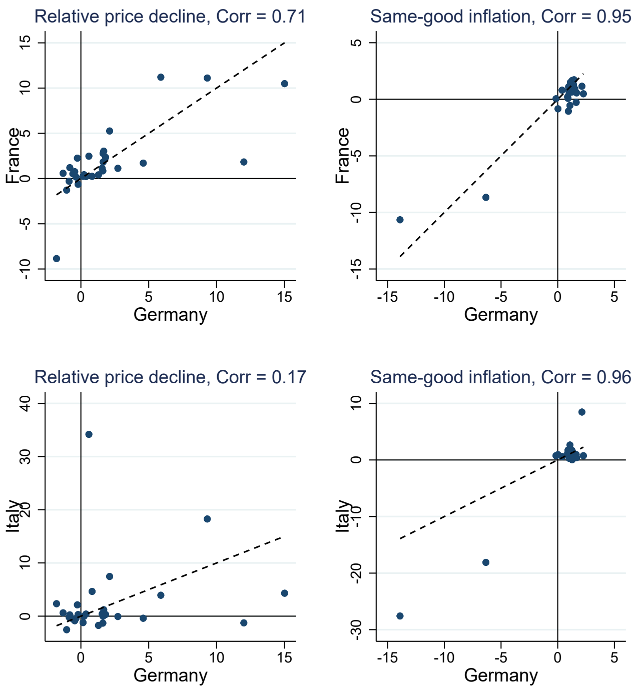

Figure 6: Non-truncated version of figure 5