A Policy-Sensible Benchmark Core Inflation Measure.

An Application to Euro Area and US Data *

Stefano Siviero and Giovanni Veronese

(Bank of Italy, Economic Outlook and Monetary Policy Department)

May 3, 2010

Core —or underlying— inflation indicators feature prominently in the economic debate and in central banks' external communication and internal policy discussions. Notwithstanding their popularity, whether core inflation measures should play a role in the monetary policy-making process is questionable. Indeed, most of them are based exclusively on statistical criteria and, as a consequence, a firm theoretical justification is generally lacking; furthermore, their usefulness for policy-making purposes is not firmly established. In this paper, we propose an approach to build a benchmark measure of core inflation that aims at overcoming the latter limitation directly and may thus be used to appraise the merits of existing popular core inflation indicators. Specifically, our benchmark measure is derived on the basis of a criterion that explicitly treats core inflation as an artificial concept whose usefulness rests with its being helpful to improving monetary policy effectiveness. Using that measure —built on the basis of the solution to a standard optimal monetary policy problem— as a yardstick, the performance and policy usefulness of other, popular core inflation indicators may be appraised. The approach is illustrated by means of an application to euro area and US data. For the euro area, the under-performance of exclusion core inflation indicators is generally limited, with the exception of the case in which inflation is the monetary policymaker overriding concern; other underlying inflation measures, by contrast, perform rather poorly. For the US, exclusion core inflation indicators fare systematically well compared with the benchmark; however, the welfare performance of monetary policy would not sensibly deteriorate if the policymaker was to rely on a standard monetary policy reaction function.

*Previous versions of this paper were presented at: EcoMod2004 - International Conference on Policy Modeling, University of Paris I Pantheon-Sorbonne, 30 June-2 July 2004; Conference on "Price Measurement for Monetary Policy," Federal Reserve Bank of Dallas, 24-25 May 2007; we thank the participants in those conferences —in particular John Williams, our discussant in the latter one— and two anonymous referees for their helpful comments and suggestions. The usual disclaimer applies. The views expressed here are the authors' own and do not necessarily reflect those of the Bank of Italy. Correspondence: stefano.siviero@bancaditalia.it; giovanni.veronese@bancaditalia.it.

1 Introduction

Similarly to a number of other macroeconomic phenomena, overall inflation is often conveniently thought of as being the observable outcome of two sets of unobservable driving forces: on the one side, price developments are (viewed as being) driven by long-lasting factors, whose influence is likely to persist for at least some time into the future; on the other side, aggregate price dynamics also reflect the vagaries in a number of volatile factors, whose effects are expected to be short-lived. When it comes to predicting future price dynamics, only the former components of overall inflation are arguably valuable; the latter should better be ignored, as the information they carry amounts to short-term noise, of little relevance for predicting the future.

In the literature various measures of core (or underlying) inflation have been proposed, differing in the way transient noise is defined and removed, but not in the basic underlying principle (first described by Blinder (1982)). Indeed, all methods share one key feature: they are constructed by applying (cross-section or time-series) filters to available information. In many cases, the construction of core inflation indicators is relatively simple, which makes them an ideal tool for communication with the public.

Underlying inflation measures feature prominently in the economic debate and in central banks' external communication and internal policy discussions, as testified, e.g., by the following quote, taken from the very beginning of a recent speech by the then Governor Mishkin (2007), of the US Federal Reserve Board: "In *discussing and thinking* about the conduct of monetary policy, *many central bankers focus on core inflation* —that is, a measure of inflation that excludes the rate of increase of prices for certain volatile components in price indexes. The Federal Reserve, for example, pays particular attention to the rate of growth of the core personal consumption expenditure (PCE) deflator, which *excludes food and energy prices*" (emphasis added).

However, whether existing core inflation indicators *should* play a role in the monetary policy decision-making process —whether they would prove valuable in that context— has not been subjected to systematic scrutiny. Indeed, while the concept of core inflation is apparently well defined and intuitively appealing, its practical policy usefulness has often been questioned on at least two accounts: first, being exclusively based on statistical criteria, existing core inflation measures lack a firm theoretical justification; second, there appears to be no generally accepted and intuitively plausible criterion to assess the policy usefulness of competing core inflation measures directly. It is striking indeed that, while one of the main justifications for building core inflation measures rests with their supposed ability to help the policy-making process, such criterion does not normally play any role in their construction.

An exception is Aoki (2001), who first provided a normative argument in support of the construction and use of core inflation indicators, using a New Keynesian model.[1] Aoki shows that, in an economy where the degree of price stickiness differs from sector to sector, the central bank should aim at stabilizing inflation in sectors where prices are stickier. In Aoki's set-up, core inflation should play a role in the monetary policy-making process not because it helps forecasting future aggregate inflation, but, rather, because targeting that measure of inflation helps achieving the socially optimal allocation of resources. More recently, Bodenstein, Erceg and Guerrieri (2008), using a calibrated DSGE model for the US with wage and price rigidities, found that sizeable welfare gains may be attained by reacting to forecast of inflation excluding energy rather than to headline inflation. Indeed, available microeconomic evidence on sectoral price rigidity for both the euro area and the US (Dhyne *et al.* (2006); Nakamura and Steinsson (2008)) shows that consumer prices tend to be more flexible precisely in the energy and food sectors, thereby providing empirical support for targeting a measure of core inflation which excludes the latter prices. Building on these findings, Eusepi, Hobijn and Tambalotti (2009) use a calibrated DSGE model of the US economy to construct a personal-consumption-expenditure-based price index, with weights chosen to minimize the welfare costs of nominal distortions arising from heterogeneity in price rigidity across sectors.[2]

In this paper we propose an approach to building a benchmark measure of core inflation which, in the same vein as the contributions quoted above, is explicitly derived from solving a policy optimization problem. Similarly to Eusepi, Hobijn and Tambalotti (2009), in our set-up the monetary policymaker is allowed to respond to sectoral inflationary developments with intensities that may not be proportional to each sector's weight in the overall inflation, thereby introducing more flexibility as to the way in which the information conveyed by the various components of overall inflation may be exploited for policy-making purposes.[3] Differently from Eusepi, Hobijn and Tambalotti (2009), in our set-up the scope for selective reaction to sectoral inflation rates does not reflect the

[1]Benigno (2004) extends Aoki's (2001) results to a multiple country setting.

[2]Eusepi, Hobijn and Tambalotti (2009) allow for heterogeneity both in the degree of price rigidity and in the value of the labor share. However, only the former results in sizeable distortions.

[3]The exercise is in the same vein of Angelini et al. (2002), where the policy-maker selectively responds to national developments within the Euro area.

monetary policymaker's attempt to reduce distortions arising from price rigidities; rather, s/he is assumed to be solely concerned about volatility in (overall) inflation, the output gap as well as instrument variability. Also, in our empirical application the output gap is defined as the deviation of actual output from its trend, whereas in the New Keynesian and DSGE literatures it is given by the deviation from the efficient level of production.

Our benchmark core inflation measure is explicitly built as (a function of) the solution of the policymaker's optimization problem; specifically, it is given by a linear combination of the disaggregate inflation components, with weights which are derived from the optimized reaction function parameters. This differs from standard core inflation measures, whose weights are normally selected solely on the basis of statistical criteria. By contrast, our underlying inflation indicator is explicitly based on economic criteria, being thus more sensible from a policy-making viewpoint; as such, it may serve as a benchmark to appraise the policy usefulness of alternative measures.

To illustrate the functioning and the potential merits of the approach, we apply it to euro area and US data; we build, for each economy, a benchmark indicator of core inflation and use it to evaluate the performance of a few popular core inflation indicators, which have been selected because of their featuring prominently in central banks' communication and internal analyses.

We first estimate, for both economies, a simple multi-sectoral model —which for the US closely resembles, in both its appearance and main features, the model of Rudebusch and Svennson (1999). The model developed here departs from the latter in that it describes separately the dynamics of prices in four sectors: industrial goods; services; energy; food. For the US, the impulse responses of the multi-sectoral model to a number of standard shocks are very much in line with those of Rudebusch and Svensson's (1999). For the euro area, the properties of the model are consistent with the wealth of evidence collected in Angeloni, Kashyap and Mojon(2003).

Optimising a standard loss function (whose arguments are overall inflation, the output gap and the volatility of the policy instrument) subject to the rule being an extended Taylor-type one (including the four sectoral inflation rates, instead of aggregate inflation only, as well as the other standard ingredients, i.e., the output gap and the lagged interest rate) delivers the sets of weights that are then used to compute our core inflation measure, which we refer to below as "benchmark".

This "benchmark "measure is then used to appraise the performance of alternative popular underlying inflation indicators. Specifically, "exclusion" core inflation indicators and the so-called Edgeworth measure can be easily simulated in our set-up, by imposing appropriate constraints on the specification of the (unconstrained) rule underlying the benchmark measure. We then assume the monetary policymaker to make the best possible use of those indicators, and compute the optimal coefficients of the constrained rules; the resulting loss is then compared with that associated with the (unconstrained) benchmark measure.

The resulting benchmark measure is just barely less volatile than overall inflation itself, for both the euro area and the US. However, in the euro area, reacting to core inflation measures that remove volatile components does not seriously impair monetary policy effectiveness, with the sole exception of the case in which keeping inflation under control is the policymaker's overriding concern. The underperformance of other core inflation measures is instead not only large but also systematic.

By contrast, in case the US monetary policymaker reacts to inflation net of the energy and food components, her/his performance would be only slightly —and not significantly— worse than it would be if s/he relied on the benchmark indicator. However, if the monetary authority was to follow an optimized standard Taylor rule (hence doing away with core inflation altogether), the resulting loss would be basically the same. In this sense, the usefulness of that core inflation measure as a guidance for monetary policy is limited. As to other core inflation indicators, our results suggest that their under-performance is not trivial.

Our results thus suggest that adopting the same definition of core inflation for both areas is not necessarily advisable, even if policymakers across the Atlantic were to share the same objectives and preferences. The differences between the euro area and the US may be related to the different degree of persistence of sectoral inflation rates in our estimated models. In particular, reacting to headline inflation is clearly sub-optimal in the euro area (where energy and food prices are less persistent) whereas it is not seriously harmful in the US (where, according to our estimates, inflation persistence is higher).

Our empirical results are mainly meant to illustrate how the approach works in practice. To mention just one limitation of the empirical application, the simple backward-looking models used here, while sharing the main features of the work-horse model of Rudebusch and Svensson (1999), are not immune from the Lucas Critique. However, the approach may be straighforwardly extended to other models as well.

The paper is organised as follows: Section 2 presents a brief overview of the literature; Section 3 exposes our approach; Section 4 presents an empirical illustration of the approach; Section 5 concludes.

2 Core inflation: the statistical approach

With the introduction of explicit inflation targets in many countries, the last decade has witnessed a sizeable growth in the number of core inflation indicators routinely monitored by central banks; at the same time, the degree of sophistication underlying their construction has increased. Nonetheless, the ultimate goal of these indicators has remained the same, namely, to extract a signal regarding the underlying inflation trend, which may be more informative, regarding future price dynamics, than current headline inflation itself.

Statistical approaches suggested in the literature to extract core inflation measures differ essentially as to the information set deemed relevant for the extraction of the underlying signal. In the most straightforward approach, core inflation computation relies on excluding the price changes for selected classes of products; their exclusion is typically justified on the grounds that their signal-to-noise ratio is too low to convey useful information on the underlying price dynamics. One of the best known underlying inflation indicators, the CPI Excluding Food and Energy, belongs to this class of core inflation measures.

Indicators relying on "limited influence estimators," first introduced by Bryan and Cecchetti (1994), require a relatively high degree of disaggregation of the CPI, since the full cross-section of the distribution of price changes is used to remove the most extreme observations in every month.[4] In a similar vein, Diewert (1995) proposed not to scrap altogether the information in the tails of the distribution of price ranges, but rather to assign to each individual price change a weight which is inversely related to its historical variance (so-called Edgeworth core inflation measure).

Univariate time series models have also been used to remove high frequency noise from inflation series; the resulting smoothed series are taken to provide an estimate of core inflation. More recently, Cogley (2002) has proposed a univariate one-sided filter designed to estimate the persistent component of inflation resulting from monetary policy regime changes.

Bryan and Cecchetti (1993) were the first to build a core inflation measure based on the

[4]Such measures (typically: median, weighted median, trimmed mean) aim at capturing the central tendency of the distribution of price changes in a more efficient way than the mean does. For a detailed description and assessment of these measures see Vega and Wynne (2001).

dynamic factor index model of Stock and Watson (1991). A recent extension of the factor index approach is in Cristadoro *et al.* (2005), who construct a core inflation indicator for the euro area, using a large panel of euro-area time series containing national/sectoral price variables as well as monetary and real variables.

Economic theory plays a more direct, though limited, role in the SVAR-based approach, which aims at identifying the unobserved core and non-core components of inflation on the basis of theoretically-grounded restrictions. Quah and Vahey (1995), using a bivariate SVAR, define core inflation as the component of headline inflation that has no impact on output in the medium- to long-run. Blix (1995) and Bagliano, Golinelli and Morana (2002) extend the Quah and Vahey (1995) methodology.

To date, lacking a clear theoretical definition, existing core inflation measures are appraised empirically on the basis of three main criteria: their ability to track past movements in overall inflation; their degree of smoothness; their ability to predict future headline inflation movements (Clark (2001), Dolmas (2005), Khettry and Mesler (2006), Le Bihan and Sedillot (2000), Marques, Neves and Sarmento (2003), Rich and Steindel (2007), Smith (2004, 2006), Vega and Wynne (2001) and Velde (2006)).

3 Towards a policy-effectiveness-based approach

Before proceeding to describe our approach, it is convenient to give an explicit definition of core inflation. We adopt the following functional, policy-effectiveness-based, definition: core inflation is an appropriate combination of currently available information on disaggregate price developments, such that, by basing her/his policy decisions on that measure, the monetary policymaker maximises policy effectiveness (i.e., minimises a given standard welfare loss). Note that standard core-inflation selection criteria (e.g.: good headline inflation forecasting properties, smoothness) play no role in our definition.

Our concept of core inflation thus explicitly recognises that, for any underlying inflation indicator to be of use in the decision-making process, it must be the case that it provides valuable information that helps the monetary policymaker to pursue her/his objectives. Since enhancing policy-effectiveness is, ultimately, the main if not the sole motivation behind the construction of core inflation measures, it is just natural to adopt policy effectiveness as the main guiding criterion in the search for such measures.

To build a core inflation indicator consistent with our definition above, we rely on the standard toolbox used in the literature on optimal monetary policy rules (see Taylor

(1999) for an overview).[5] However, we depart from the standard framework in that we assume that the policymaker does not need to react to headline aggregate inflation only; rather, his/her optimal reaction to individual sectoral inflation rates may well not be proportional to the weights of those components in overall inflation.

Regarding the policymaker's preferences, we assume the following standard quadratic time-separable loss function:

$$L_t = (1-\delta)E_t \sum_{\tau=0}^{\infty} \delta^\tau [(\widetilde{\pi}_{t+\tau})^2 + \lambda y_{t+\tau}^2 + \mu(\Delta i_{t+\tau})^2], \tag{1}$$

where π_t is quarterly inflation at an annual rate and hence $\widetilde{\pi}_t = (\pi_t + \pi_{t-1} + \pi_{t-2} + \pi_{t-3})/4$ is a four-quarter moving average of inflation, y_t is the output gap, i_t is the policy interest rate controlled by the central bank, δ is a discount factor, λ and μ are parameters that reflect the weights attached by the policymaker to the variability of the output gap and of the policy interest rate changes relative to the variability of inflation around its target (without loss of generality, the latter is assumed to be zero).

Note that in our set-up the monetary policymaker is assumed to be interested solely in aggregate inflation; sectoral inflationary developments may be of interest if they improve monetary policy effectiveness, but they are of no interest *per se*. While it may be argued that eq. (1) embeds the Fed's and ECB's stated objective functions, it may be argued that sectoral inflation rates should be considered separately, as the latter could reflect distortions arising from differentiated price rigidies across sectors (see Aoki (2001), Benigno (2004) and Eusepi, Hobjin and Tambalotti (2009)). In our set-up, core-inflation may or may not play a role depending on whether or not it helps the policymaker to pursue her/his objective, even though relative prices do not enter the objetive function.

For $\delta \longrightarrow 1$ the intertemporal loss function can be interpreted as the unconditional mean of the period loss functions, which in turn is given by the weighted sum of the unconditional variances of the target variables (see Rudebusch and Svensson (1999)):

$$L_t = \text{var}(\widetilde{\pi}_t) + \lambda \text{var}(y_t) + \mu \text{var}(\Delta i_t). \tag{2}$$

Let us now assume that monetary policy decision-making is supported by a model which not only includes aggregate inflation, but also models the evolution of a number

[5] Since our focus is on combining currently available disaggregate information in an optimal way, we ignore a number of suggestions which may be found in the literature to increase the degree of sophistication of monetary policy rules. In particular, we are not interested in appraising the performance of forward-looking rules such as the ones proposed in Batini and Haldane (1999) and, more recently and in the context of core inflation indicators, by Bodenstein, Erceg and Guerreri (2008)).

of sub-components of the aggregate inflation index. In particular, that information on n sub-components is available.

The policymaker is faced with the task of combining the available disaggregate information into a measure of underlying inflation which provides best guidance when it comes to choosing monetary policy. It is thus natural to combine available information on individual sectoral price dynamics by postulating a generic monetary policy reaction function in which all different pieces of information enter separately, and letting the optimal combination of disaggregate sectoral information be determined by the solution of the policymaker's loss minimisation problem. Accordingly, we posit the following extended Taylor-type monetary policy rule:

$$i_t = \sum_{j=1}^{n} \gamma_{1,j} \pi_{j,t} + \gamma_2 y_t + \gamma_3 i_{t-1}. \tag{3}$$

where $\pi_{j,t}$ is quarterly inflation at an annual rate in sector j, $\gamma_{1,1}, ..., \gamma_{1,n}, \gamma_2$ and γ_3 are $n+2$ coefficients to be determined by minimising eq. (1) subject to the constraints given by the available empirical model and to eq. (3).[6]

Let the optimal values of the n parameters $\gamma_{1,j}$ be $\widehat{\gamma}_{1,j}$. We define the benchmark core inflation π_t^C to be the following linear combination of sectoral inflation rates:

$$\pi_t^C = \sum_{j=1}^{n} \frac{\widehat{\gamma}_{1,j}}{\widehat{\gamma}_1} \pi_{j,t} = \sum_{j=1}^{n} \omega_j \pi_{j,t} \tag{4}$$

where $\widehat{\gamma}_1$ is the optimal policymaker's reaction to core inflation itself (see below). Thus, the resulting monetary policy rule may be viewed as being similar to a standard Taylor rule, except that overall inflation is replaced by core inflation:

$$i_t = \widehat{\gamma}_1 \pi_t^C + \widehat{\gamma}_2 y_t + \widehat{\gamma}_3 i_{t-1}. \tag{5}$$

Note that the benchmark core inflation measure is up to this point identified except for the scale parameter $\widehat{\gamma}_1$. Hence, to set the *level* of π_t^C, an additional restriction is needed. One possibility would be to choose $\widehat{\gamma}_1$ so that core inflation coincides with actual headline inflation on average over the whole available sample period. A second straightforward possibility would be to impose $\sum_{j=1}^{n} \omega_j = 1$ in eq. (4). For the empirical application

[6] In the empirical applications below, $n = 4$; in principle, however, the approach would be feasible with a model of the economy including any number of sectors.

below the first option was chosen.[7]

Let us remark at this stage that π_t^C built as described above is not necessarily a smooth series; this contrasts with most, if not all, other measures of underlying inflation, which usually are, and are in fact typically required to be, substantially smoother than headline inflation. By contrast, our derived series π_t^C might not be smooth at all if smooth filtering is sub-optimal in that it seriously hampers policy effectiveness.

Whether or not popular core inflation indicators are appropriate and desirable may be assessed by measuring their relative performance with respect to the ideal measure π_t^C. A number of those indicators may be easily appraised within our framework, by simply imposing the appropriate constraints on the coefficients of the optimal rule.

Consider first the case in which underlying inflation is simply given by headline inflation itself, so that the policy interest rate is set on the basis of a standard Taylor rule. This case may be explored by imposing the following constraint: $\gamma_{1j} = w_j \gamma_1$, where w_j represents the weight of the j-th sector in the overall index (so that: $\sum_j w_j = 1$ and $\pi_t = \sum_j w_j \pi_{j,t}$).

Widely-used measures of core inflation are computed by removing the most volatile components of headline inflation. Such measures are very easy to build, which is the main reason for their popularity. To appraise the performance of the indicator given by inflation net of, say, the last m components, we solve the loss minimisation problem above subject to the constraint that the rule be given by:

$$i_t = \gamma_1 \pi_t^{-[n-m+1,n]} + \gamma_2 y_t + \gamma_3 i_{t-1} \tag{6}$$

where:

$$\pi_t^{-[n-m+1,n]} = \sum_{j=1}^{n-m} \frac{w_j}{\sum_{i=1}^{n-m} w_i} \pi_{j,t} \tag{7}$$

Other popular measures may also be mimicked in a similar fashion. The restrictions corresponding to the core inflation indicators we consider are shown in Table 1. In all cases, we require that the monetary policymaker's reaction to the chosen core inflation indicator be optimal. All measures are thus given a fair chance to prove their worth.

[TABLE 1 APPROXIMATELY HERE]

[7] Note that while the choice of the identification restriction affects the *level* of the benchmark core inflation indicator, it affects *neither its dynamics nor, most importantly, its performance*, as the latter only depends on the parameters of the rule (3), which of course are unaffected by the restriction.

4 An example: Appraising the policy effectiveness of popular core inflation measures

4.1 The models

4.1.1 The euro area model

The euro area model is a simple 5-equation model, consisting of an aggregate demand equation (also referred to as IS curve), and four sectoral inflation equations (also referred to as supply or Phillips curves). The first equation relates the overall output gap of the euro area economy to its own lags and the real interest rate. The sectoral inflation equations relate inflation in each sector to its own lags and to those of inflation in other sectors, as well as to the overall output gap.[8] Thus:

$$
\begin{aligned}
y_{t+1} &= \sum_{k=1}^{p} \theta_{j,k} y_{t+1-k} + \sum_{k=1}^{p} \psi_k (i_{t+1-k} - 4 \cdot \pi_{t+1-k}) + v_{t+1} \\
\pi_{j,t+1} &= \sum_{k=1}^{p} \alpha_{j,k} \pi_{j,t+1-k} + \sum_{i \neq j}^{4} \sum_{k=0}^{p} \beta_{j,i,k} \pi_{i,t+1-k} + \sum_{k=0}^{p} \eta_{j,k} y_{t+1-k} + u_{t+1}^{j}
\end{aligned}
$$

The estimation sample ranges from 1992Q1 to 2008Q2. The choice of the sample period is driven in part from data considerations, as euro area sectoral inflation rates are not available before the 1990's. Furthermore, it is only from the early nineties, ensuing the adoption of the Maastricht Treaty criteria, that low inflation explicitly became the primary monetary policy objective in the countries that later joined the euro area.

A general-to-specific approach was adopted in searching for the appropriate empirical specification, starting with 4 lags of all relevant variables on the right-hand-side of each equation. After dropping all insignificant lags, the parsimonious specification reported in Table 2 was found. The restriction that the sum of the coefficients on lagged inflation be equal to one could not be rejected for the services and goods sectors, and was retained in the final model estimation. This implies an accelerationist-type Phillips curve for overall inflation.

[8] Unlike the US case, no official measure of the euro area output gap is available. To construct the euro area output gap, we extracted the cyclical component of output using the band-pass filter proposed by Christiano and Fitzgerald (2003). The end-sample-bias arising from the two-sided nature of the filter and its impact on real-time monetary policymaking are not investigated in this paper. For further details on data construction see the Appendix.

[TABLE 2 APPROXIMATELY HERE]

Closing the model with a standard (non-optimised) monetary policy reaction function, its impulse responses are in line with well-established stylised facts regarding the monetary transmission mechanism in the euro area (see, e.g., Angeloni, Kashyap and Mojon (2003)).

4.1.2 The US model

The US model has the same structure and sectoral breakdown as the one for the euro area. Following Rudebusch and Svensson (1999), we use the output gap measure estimated by the Congressional Budget Office on the basis of a production-function approach. After dropping all insignificant lags, the parsimonious specification shown in Table 3 was achieved, using data from 1971Q1 to 2008Q3. This sample period is likely to include a monetary policy regime change; this, however, does not necessarily imply instability of the estimated AS and AD equations. The restriction that the sum of the coefficients on lagged inflation be equal to one could not be rejected in any of the sectoral inflation equations, and was retained in the final model estimation.

[TABLE 3 APPROXIMATELY HERE]

Once augmented with the same monetary policy rule as that underlying Figure 4 in Rudebusch and Svensson (1999), our US model shares much of the features of their work-horse model. The impulse responses are also generally consistent with the main stylised facts about the timing and size of the effects of monetary policy on the economy. Interestingly, the estimated output gap coefficient of the Phillips curves tends to be higher in the food and energy sectors. This is consistent with the predictions of the most recent literature, where the sectors in which prices are stickier are characterized by flatter Phillips curves.[9]

4.2 The results

We first apply the approach presented in Section 3 to the estimated multi-sectoral euro area and US models illustrated above; we then appraise, using the benchmark core inflation measures thus obtained, the policy-effectiveness of a few popular core inflation indicators.

[9]We thank an anonymous referee for pointing out this feature.

4.2.1 Results for the euro area

Our approach relies on ascertaining the best combination of disaggregate information on sectoral inflation rates, where by "best" we mean that particular combination which optimises a given criterion function. We thus need to specify, as a preliminary step, the policymaker's preferences.

If our goal was to build an inflation indicator that performs best when it comes to reining in only future inflationary pressures, it would be natural to assume the monetary policymaker to be interested solely in inflation (an extreme case of pure inflation targeting, with $\lambda = \mu = 0$). However, we consider a more general (and arguably more realistic) set-up, and appraise the sensitivity of the results to changes in the policymaker's preferences; hence, the optimisation problem was solved for a range of values for both λ and μ (specifically, equally spaced values between 0 and 0.5 were considered for both preference parameters).

Optimal values of the coefficients in eq. (3) (with $n = 4$ and j =services (S), goods (G), food (F) and energy (E) sectors) were then found by minimising eq. (2).

The results for the benchmark core inflation measure are summarised in Table 4, together with the corresponding outcomes for other core inflation indicators and those computed on the basis of a standard Taylor-type rule.

[TABLE 4 APPROXIMATELY HERE]

The underperformance of the standard Taylor-type rule appears to be large: the worsening of the loss ranges between about 20 and 50 percent for the various combinations of preference parameters. This result reflects the fact that in the benchmark approach the response to both food and energy inflation is extremely muted (columns labelled $\alpha - food$ and $\alpha - energy$; the former parameter is actually often nil), while the reaction to services and goods inflation (columns labelled $\alpha - services$ and $\alpha - goods$) is relatively aggressive and far exceeds the reaction implied by the standard Taylor rule, in which the policymaker responds to headline inflation. This finding is largely consistent with recent results based on New Keynesian and DSGE models (see the Introduction). It is worth remarking, however, that, differently from those contributions, in our set-up sectoral prices do not show in the policymaker's objective function. If, in our experiments, the weights of the sectoral inflation rates in the loss function were determined on the basis of the prescriptions in the NK literature (rather than being given by the CPI weights), the benchmark indicator would most likely further downweight the food and energy sectors, thus getting even closer to the findings in the NK literature.

[FIGURE 1 APPROXIMATELY HERE]

Having found the optimal parameters of the extended policy rule, we construct our measure of core inflation by imposing the constraint that the latter be the same as actual inflation on average over the whole sample period.[10] The resulting measure —based on the optimised policy coefficients when $\lambda = \mu = 0$— is shown in Figure 1, together with actual aggregate inflation and inflation excluding energy and food. Despite the small weight assigned to the energy component, the benchmark measure may depart from core inflation excluding energy and food when large energy price swings are observed (see, e.g., the 2007-2008 episode).

Not all measures which have been proposed in the literature may be easily included in our framework. We chose to restrict our analysis to a set of indicators which: (i) are being used, have been used or have been considered for use, for policy-making purposes,[11] and (ii) may be straightforwardly appraised in our linear-quadratic framework, not requiring any additional *ad hoc* assumption. Adopting these criteria, the following measures were considered: (1) consumer price inflation net of energy; (2) consumer price inflation net of energy and food; (3) Edgeworth measure of core inflation (see Diewert, 1995). The latter core-inflation indicator gives proportionately less weight to the most volatile components of the index; specifically, it is computed as a weigthed average of sectoral inflation rates, the weights being inversely proportional to the respective sample variances. The dynamics of both the benchmark core inflation indicator and the popular core inflation indicator obtained by excluding energy and food price inflation are displayed in Figure 1. The former does not entail a sharp reduction in volatility compared with overall inflation, contrary to the requirement routinely imposed in building core inflation measures.

The relative performance of those three measures may be easily appraised within our framework, by imposing appropriate constraints to the monetary policy rule, as shown in Table 1 (see above).

We assume the monetary policymaker to make the best use of each measure (all measures are thus given a fair chance); accordingly, for each measure, we compute the corresponding optimal monetary policy rule, by minimising the loss function in eq. (2), under the additional constraints indicated in Table 1.

[10] EHT (2009) use an alternative normalization assumption constraining the weights to sum to 1.

[11] See Mishkin (2007).

As shown in Table 4, when the policymaker attaches no weight to the volatility of the interest rates and to the output gap ($\mu = 0$ and $\lambda = 0$), the relative losses incurred with respect to using the benchmark indicator are far from trivial.

The under-performance of monetary policy relying on the most popular "exclusion core inflation indicators" is very sizeable in the case of extreme inflation targeting (when the weight attributed to the output gap and to interest rate volatility in the monetary policymaker's loss function is nil) and remains relatively large if $\mu = 0$ (Figure 2), but it is negligible otherwise. By contrast, it is always sizeable for headline inflation; the Edgeworth measure systematically scores very poorly.

[FIGURE 2 APPROXIMATELY HERE]

Comparing the impulse response function of the interest rates to an inflation shock (uniform across all sectors), the response implied by the rule relying on the benchmark core inflation indicator is both more rapid and more aggressive; the reaction implied by the standard Taylor rule is particularly dampened in relative terms (see Fig. 3, which refers to the case $\lambda = \mu = 0.25$ [12]).

There are, however, a number of systematic and relevant differences (which may be more or less pronounced, depending on the preference parameter combination one considers): the benchmark core inflation indicator implies a somewhat more aggressive policy than both exclusion core inflation measures; policy turning points are typically lagged with the latter; policy recommendations may diverge sharply (tightening vs. loosening of interest rates) in a few instances.

[FIGURE 3 APPROXIMATELY HERE]

Is the underperformance of the various core inflation indicators systematic? To answer that question, we follow the approach outlined in Monteforte and Siviero (2009) and perform a stochastic simulation exercise. The exercise consists of extracting 1000 replications from the set of estimated residuals and simulating the model, for each replication, under the various competing rules.[13]

[12] While different choices of the loss function weights may result in rather different impulse responses for the various rules, their relative features tend to remain relatively unchanged.

[13] Each replication includes 1500 realizations of the shocks for the six stochastic equations in the model, one realization per period. Only the last 1000 simulated values are used to evaluate the objective function, to prevent the results from being biased by the initial conditions.

[FIGURE 4 APPROXIMATELY HERE]

Figure 4 compares the performance of the rule relying on core inflation —as measured by headline inflation net of the energy and food components— with the performance of the rule relying on the benchmark core inflation measure. Specifically, it shows the percentage of replications in which the former rule underperforms with respect to the latter. The underperformance is found to be systematic, occurring in 95 to 100 per cent of all replications, for all values of λ and μ.

We conclude that the welfare loss associated with relying on the net-of-energy-and-food core inflation indicator is large and systematic only when the policymaker assigns no loss to instrument variability, but is relatively small and unsystematic otherwise.[14] By contrast, repeating the same testing procedure for the other core inflation indicators and for headline inflation results in significant performance differences with respect to the benchmark case.

These findings lead us to conclude that for the euro area the case for building and using popular core inflation indicators (in particular, inflation net of energy and food) depends on the weights assumed for the arguments in the policymaker's loss function and is at any rate weaker than for the US (see below).

All experiments have been repeated in a somewhat more realistic setting, in which the policymaker cannot react instantaneously to macroeconomic aggregates, the latter being assumed to be observed only with a one-period lag. The results are almost unchanged: specifically, the significant and systematic underperformance of inflation net of energy and food, particularly when inflation is the policymaker's overriding concern, is confirmed.

4.2.2 Results for the US

As in the euro area case, the US monetary policymaker's problem was solved for a range of values of λ and μ (both parameters assuming equally spaced values between 0 and 0.5), delivering the results shown in Table 5. The table reports the coefficients of the model-based rule and the associated performance, together with the corresponding information for the standard Taylor-type rule and for other core inflation indicators.

[TABLE 5 APPROXIMATELY HERE]
[FIGURE 5 APPROXIMATELY HERE]

[14] The test above results in an even sharper rebuttal of the other core inflation indicators considered.

Similarly to the euro area, the benchmark core inflation measure entails a muted response to both food and energy inflation (columns $\alpha - food$ and $\alpha - energy$),[15] while the weight assigned to the services and goods sectors (columns labelled $\alpha - services$ and $\alpha - goods$) far exceed those implied by the standard Taylor rule, in which the policymaker responds to headline inflation. Nevertheless, the underperformance of the standard Taylor rule is generally not very large (exceeding 10 percent only when both λ and μ are nil).

The resulting measure of core inflation is shown in Figure 5, together with actual aggregate inflation and other core inflation indicators. Once again, the benchmark measure is not much smoother than headline inflation itself, and tracks quite closely inflation excluding energy and food.

As in the euro area case, we consider three alternative core inflation measures and appraise their relative performance using the our benchmark. The results are shown in Table 5 and Figure 6.

[FIGURE 6 APPROXIMATELY HERE]

The only badly under-performing core inflation indicator is the Edgeworth measure and, for some parameter combinations, the core inflation measure excluding energy only. In all other cases, the under-performance of popular measures *vis-à-vis* the benchmark is small. These results are similar to the ones for the euro area, with the exception of the case in which the policymaker assigns zero weight to interest rate variability. However, differently from the euro area case, reacting to headline inflation according to the standard Taylor rule generally results in a relatively small increase in the loss function (the increase exceeds 10 per cent only for $\lambda = \mu = 0$).

The response of the interest rate to an inflation shock (uniform across all sectors) is rather similar for the benchmark, Taylor and inflation-excluding-energy-and-food rules, consistently with the finding that in the US case the performance of those rules tend to be similar (recall the results in Table 5). However, it still is the case that, as for the euro area, the Taylor rule is relatively less aggressive. All experiments have been repeated assuming that the policymaker cannot react instantaneously to macroeconomic aggregates. The main results are virtually unaffected.

[15] However, even in the extreme case of λ and μ, the weight on the food component remains non-nil.

5 Conclusions

It is common practice to build core inflation indicators relying on purely statistical criteria. Indeed, popular underlying inflation measures are typically computed with simple manipulations of the data aimed at removing or attenuating the most volatile components (e.g.: exclusion of some components; simple re-weighting schemes). While the precise way in which the various indicators are built differs from one case to another, they all tend to be significantly smoother than headline inflation itself, consistently with their being explicitly designed to isolate the trend component of inflation, as opposed to the transient, volatile components.

However, the usefulness of those measures when it comes to providing practical guidance to the monetary policy decision-making process has been often questioned in the literature.

We tackled the issue of building a core-inflation indicator useful for policy-making by adopting an altogether different selection criterion. Specifically, we required the indicator to be such that, by reacting to the information it provides, monetary policy-making is most effective when it comes to pursuing its macroeconomic stabilization objectives.

Our approach, which relies explicitly on a welfare optimization framework, was applied to euro area and US data; the resulting benchmark core inflation indicator was then used to appraise the performance of other, popular, widely used indicators.

According to our empirical results, core-inflation indicators do not perform equally well on both sides of the Atlantic and for all policymaker's preferences. For instance, in the US case, relying on the most popular exclusion core inflation indicator (inflation net of energy and food) does not hamper the effectiveness of monetary policy relative to the benchmark. By contrast, in the euro area this is not always the case, as the underperformance may be non trivial (when the policymaker assigns no weight to interest rate variability). However, the scope for relying on core inflation indicators in the US case is arguably limited, since reacting to headline inflation according to the standard Taylor rule does not result in a sizeable worsening of monetary policy effectiveness.

To conclude: our approach directly addressess a concern often raised in the literature; the empirical results, though model-dependent, are robust along a number of directions; they suggest that policy effectiveness and other core inflation selection criteria (smoothness, forecast ability) are not closely related, and that an indicator working satisfactorily in one case (the US) may not work as well in others (the euro area). All in all, we take these remarks to imply that, unless policy effectiveness is explicitly used as the main guiding principle in the choice of core inflation measures, there is no reason why such measures should be relied upon by a monetary policymaker.

Appendix : Data sources and description

Euro area

Sectoral inflation rates are given by the annualised seasonally adjusted quarterly rate of change of the appropriate component of the HICP (source: Eurostat); all series were seasonally adjusted using Tramo-Seats. The output gap is estimated as the cyclical component of (log) euro area GDP (source: Eurostat), using the asymmetric band-pass filter proposed by Christiano and Fitzgerald (2003).

US

Sectoral inflation rates are given by the annualised seasonally adjusted quarterly rate of change of the appropriate component of the CPI (source: Datastream, Thomson Financial). For potential output and the output gap: Congressional Budget Office estimates (as in Rudebusch and Svensson (1999)).

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Table 1

Modeling alternative core inflation indicators in a policy optimization framework

	Constraints to be imposed on the rule coefficients
Benchmark policy-effectiveness-based indicator	none
Headline inflation	$\gamma_{1j} = \omega_j \gamma_1$, for $j = G, S, F, E$, where ω_j = weight of j^{th} component of CPI
Inflation net of energy	$\gamma_{1E} = 0$, $\gamma_{1j} = \frac{\omega_j}{\omega_G + \omega_S + \omega_F} \gamma_1$, for $j = G, S, F$
Inflation net of energy and food	$\gamma_{1E} = \gamma_{1F} = 0$, $\gamma_{1j} = \frac{\omega_j}{\omega_G + \omega_S} \gamma_1$, for $j = G, S$
Edgeworth indicator	$\gamma_{1j} = \omega_j^{Ed} \gamma_1$, for $j = G, S, F, E$, where $\omega_j^{Ed} = \left(\frac{1}{\sigma_j^2} \right) \Big/ \sum_i \left(\frac{1}{\sigma_i^2} \right)$, and σ_k^2 = sample variance of inflation in sector k

Table 2
The estimated euro area model

	AD	ASservices	ASgoods	ASfood	ASenergy
y	*0.934 (0.045) ** [1]*	*0.255 (0.070) ** [1]*	*0.134 (0.077) * [1]*	*0.515 (0.245) ** [1]*	
i-4π	*-0.032 (0.016) ** [2]*				
$\pi_{services}$		*0.998 (0.006) ** [2]*	*0.300 (0.086) ** [1]*		
π_{goods}			*0.700 (0.086) ** [2]*		
π_{food}				*0.381 (0.099) ** [1]*	
π_{energy}		*0.002 (0.006) [1]*			*0.217 (0.117) * [1]* *0.293 (0.117) ** [3]*
Adj. R^2	*0.863*	*0.853*	*0.706*	*0.433*	*0.119*
σ	*0.254*	*0.402*	*0.44*	*1.297*	*7.013*

Notes: (1) Standard errors in round brackets. (2) * indicates significance at 10%, ** indicates significance at 5%; (3) Lags of the variable (row wise) included in each equation (column wise) are reported in square brackets.

Table 3
The estimated US model

	AD	ASservices	ASgoods	ASfood	ASenergy
y	*1.048 (0.038) ** [1]* *-0.170 (0.037) ** [4]*	*0.167 (0.064) ** [1]*	*0.173 (0.062) ** [1]*	*0.346 (0.128) ** [1]*	
i-4π	*-0.048 (0.023) ** [2]*				
$\pi_{services}$		*0.652 (0.062) ** [1]* *0.047 (0.071) [2]* *0.259 (0.062) ** [3]*			*0.579 (0.117) ** [1]*
π_{goods}			*0.655 (0.075) ** [1]* *0.096 (0.092) [2]* *0.230 (0.075) ** [3]*	*0.290 (0.087) ** [1]*	
π_{food}				*0.497 (0.080) ** [1]* *-0.085 (0.087) [2]* *0.298 (0.080) ** [3]*	
π_{energy}		*0.017 (0.010) * [1]* *0.025 (0.009) ** [2]*	*0.019 (0.010) ** [1]*		*0.299 (0.080) ** [1]* *-0.082 (0.083) [2]* *0.203 (0.081) ** [3]*
Adj. R^2	0.886	0.763	0.750	0.466	0.159
σ	0.710	1.572	1.567	2.888	12.414

Notes: (1) Standard errors in round brackets. (2) * indicates significance at 10%, ** indicates significance at 5%; (3) Lags of the variable (row wise) included in each equation (column wise) are reported in square brackets.

Table 4

Reaction function coefficients and losses for various rules, euro area

λ	μ	Approach	α−*services*	α−*goods*	α−*food*	α−*energy*	Loss
0.00	0.00	Benchmark	16.06	15.88	0.00	1.62	0.00
		Taylor	6.09	4.79	2.93	1.38	49.53
		Net energy&food	8.52	6.70	0.00	0.00	38.60
		Net energy	6.89	5.42	3.32	0.00	43.67
		Edgeworth	5.16	3.95	5.42	3.95	56.85
	0.25	Benchmark	2.30	2.28	0.20	0.07	0.00
		Taylor	2.08	1.64	1.00	0.47	22.67
		Net energy&food	2.48	1.95	0.00	0.00	7.61
		Net energy	2.33	1.84	1.12	0.00	9.81
		Edgeworth	2.09	1.60	2.19	1.60	20.25
	0.50	Benchmark	1.96	1.95	0.16	0.05	0.00
		Taylor	1.85	1.46	0.89	0.42	21.37
		Net energy&food	2.14	1.68	0.00	0.00	7.23
		Net energy	2.03	1.60	0.98	0.00	9.23
		Edgeworth	1.86	1.43	1.96	1.43	19.03
0.25	0.00	Benchmark	7.80	7.59	0.32	0.47	0.00
		Taylor	3.95	3.10	1.90	0.89	30.48
		Net energy&food	5.79	4.55	0.00	0.00	16.73
		Net energy	4.85	3.81	2.33	0.00	20.86
		Edgeworth	3.61	2.76	3.79	2.76	33.53
	0.25	Benchmark	2.11	2.10	0.14	0.06	0.00
		Taylor	1.89	1.49	0.91	0.43	20.82
		Net energy&food	2.27	1.78	0.00	0.00	7.20
		Net energy	2.14	1.68	1.03	0.00	9.22
		Edgeworth	1.90	1.46	2.00	1.46	18.85
	0.50	Benchmark	1.84	1.83	0.13	0.05	0.00
		Taylor	1.71	1.35	0.82	0.39	19.77
		Net energy&food	1.99	1.56	0.00	0.00	6.88
		Net energy	1.89	1.49	0.91	0.00	8.74
		Edgeworth	1.73	1.32	1.82	1.32	17.82
0.50	0.00	Benchmark	6.14	5.95	0.23	0.32	0.00
		Taylor	3.32	2.61	1.60	0.75	26.94
		Net energy&food	4.85	3.81	0.00	0.00	13.21
		Net energy	4.13	3.25	1.99	0.00	17.01
		Edgeworth	3.11	2.38	3.27	2.38	29.30
	0.25	Benchmark	1.99	1.98	0.14	0.06	0.00
		Taylor	1.77	1.39	0.85	0.40	19.50
		Net energy&food	2.12	1.67	0.00	0.00	6.91
		Net energy	2.00	1.58	0.96	0.00	8.81
		Edgeworth	1.78	1.37	1.87	1.37	17.85
	0.50	Benchmark	1.74	1.73	0.13	0.05	0.00
		Taylor	1.62	1.27	0.78	0.37	18.60
		Net energy&food	1.88	1.48	0.00	0.00	6.62
		Net energy	1.79	1.41	0.86	0.00	8.37
		Edgeworth	1.63	1.25	1.72	1.25	16.94

Table 5

Reaction function coefficients and losses for various rules, US

λ	μ	Approach	α–*services*	α–*goods*	α–*food*	α–*energy*	Loss
0.00	0.00	Benchmark	7.13	3.80	0.00	0.43	0.00
		Taylor	5.06	2.05	1.28	0.80	13.03
		Net energy&food	8.78	3.56	0.00	0.00	5.62
		Net energy	6.95	2.82	1.76	0.00	17.47
		Edgeworth	4.62	2.31	3.02	2.31	90.38
	0.25	Benchmark	2.50	1.20	0.11	0.15	0.00
		Taylor	2.06	0.83	0.52	0.32	6.94
		Net energy&food	2.83	1.15	0.00	0.00	4.20
		Net energy	2.47	1.00	0.63	0.00	9.05
		Edgeworth	1.90	0.95	1.25	0.95	46.96
	0.50	Benchmark	2.26	1.08	0.09	0.13	0.00
		Taylor	1.89	0.77	0.48	0.30	6.34
		Net energy&food	2.55	1.03	0.00	0.00	3.85
		Net energy	2.22	0.90	0.56	0.00	8.62
		Edgeworth	1.74	0.87	1.14	0.87	43.69
0.25	0.00	Benchmark	5.05	2.61	0.00	0.30	0.00
		Taylor	3.73	1.51	0.94	0.59	9.36
		Net energy&food	5.94	2.41	0.00	0.00	3.58
		Net energy	4.99	2.02	1.26	0.00	12.46
		Edgeworth	3.55	1.77	2.32	1.77	62.23
	0.25	Benchmark	2.34	1.10	0.10	0.13	0.00
		Taylor	1.92	0.78	0.49	0.30	6.76
		Net energy&food	2.62	1.06	0.00	0.00	3.53
		Net energy	2.31	0.94	0.59	0.00	8.35
		Edgeworth	1.80	0.90	1.18	0.90	42.84
	0.50	Benchmark	2.14	1.00	0.09	0.12	0.00
		Taylor	1.79	0.72	0.45	0.28	6.20
		Net energy&food	2.39	0.97	0.00	0.00	3.35
		Net energy	2.10	0.85	0.53	0.00	8.05
		Edgeworth	1.65	0.83	1.08	0.83	40.50
0.50	0.00	Benchmark	4.39	2.22	0.00	0.25	0.00
		Taylor	3.28	1.33	0.83	0.52	8.46
		Net energy&food	5.06	2.05	0.00	0.00	2.66
		Net energy	4.33	1.76	1.10	0.00	10.83
		Edgeworth	3.16	1.58	2.07	1.58	52.89
	0.25	Benchmark	2.24	1.03	0.10	0.12	0.00
		Taylor	1.83	0.74	0.46	0.29	6.67
		Net energy&food	2.48	1.01	0.00	0.00	3.07
		Net energy	2.20	0.89	0.56	0.00	7.86
		Edgeworth	1.73	0.86	1.13	0.86	39.94
	0.50	Benchmark	2.05	0.95	0.09	0.11	0.00
		Taylor	1.71	0.69	0.43	0.27	6.12
		Net energy&food	2.28	0.92	0.00	0.00	2.99
		Net energy	2.02	0.82	0.51	0.00	7.63
		Edgeworth	1.59	0.80	1.04	0.80	38.13

Figure 1

Euro area - Benchmark core inflation indicator, inflation excluding energy and food and overall inflation

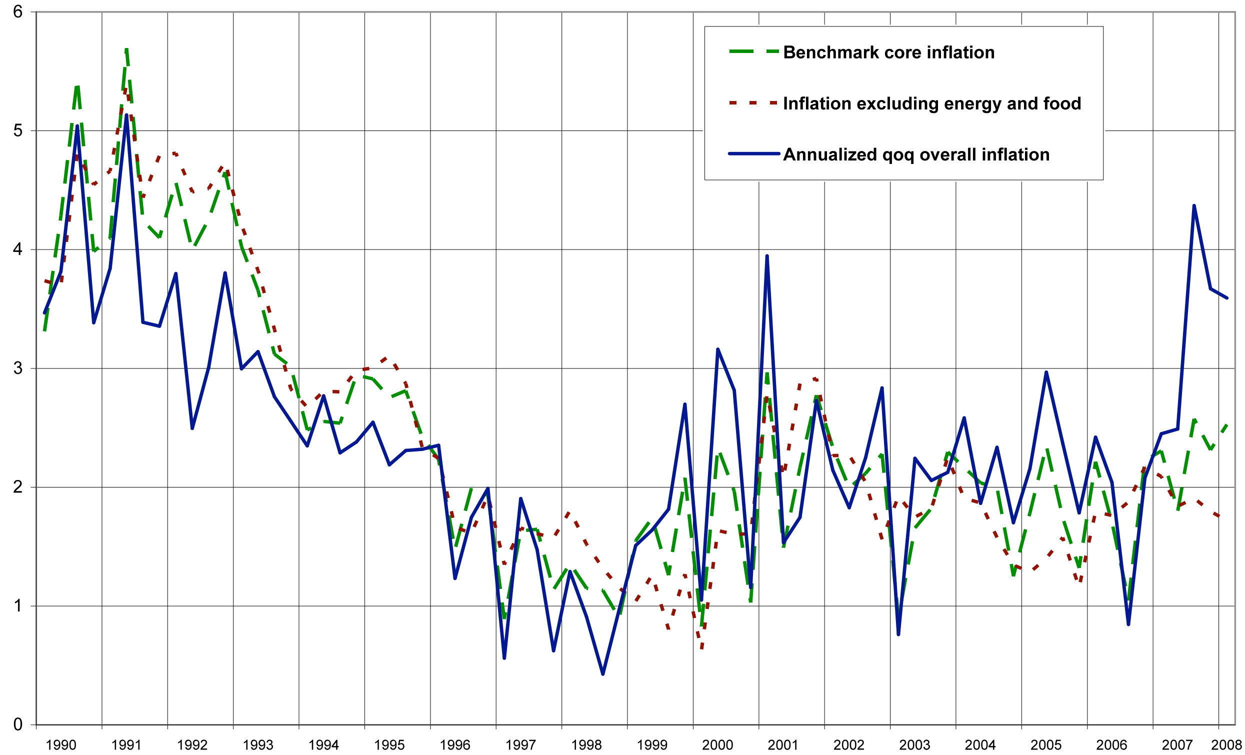


Fig. 2

Euro area – Percentage worsening in the monetary policymaker's loss function, rule relying on core-inflation net of energy and food vs. benchmark-core-inflation-based rule

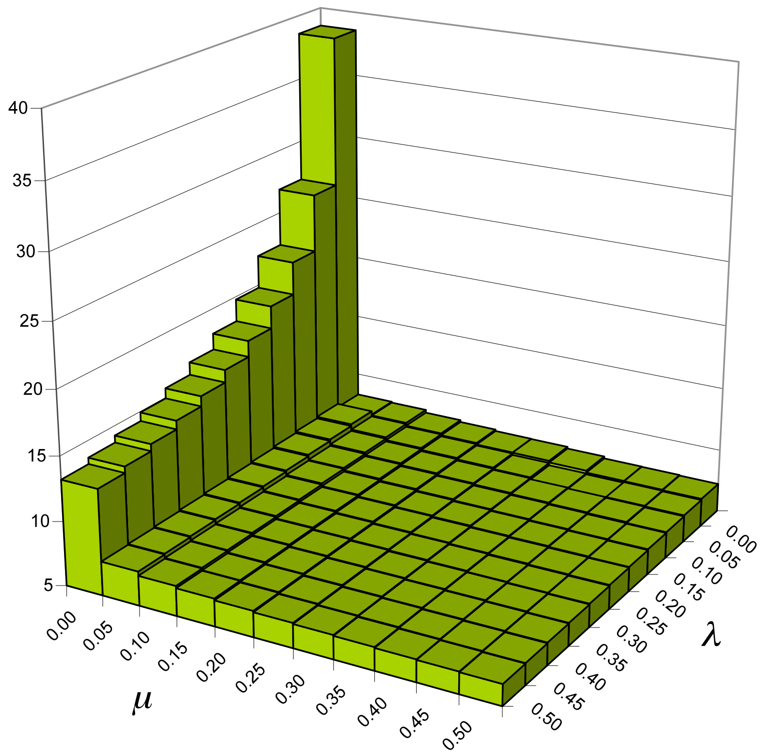


Fig. 3

Euro area - Nominal interest rate: Impulse response function to a +1pp inflation shock (uniform across all sectors)

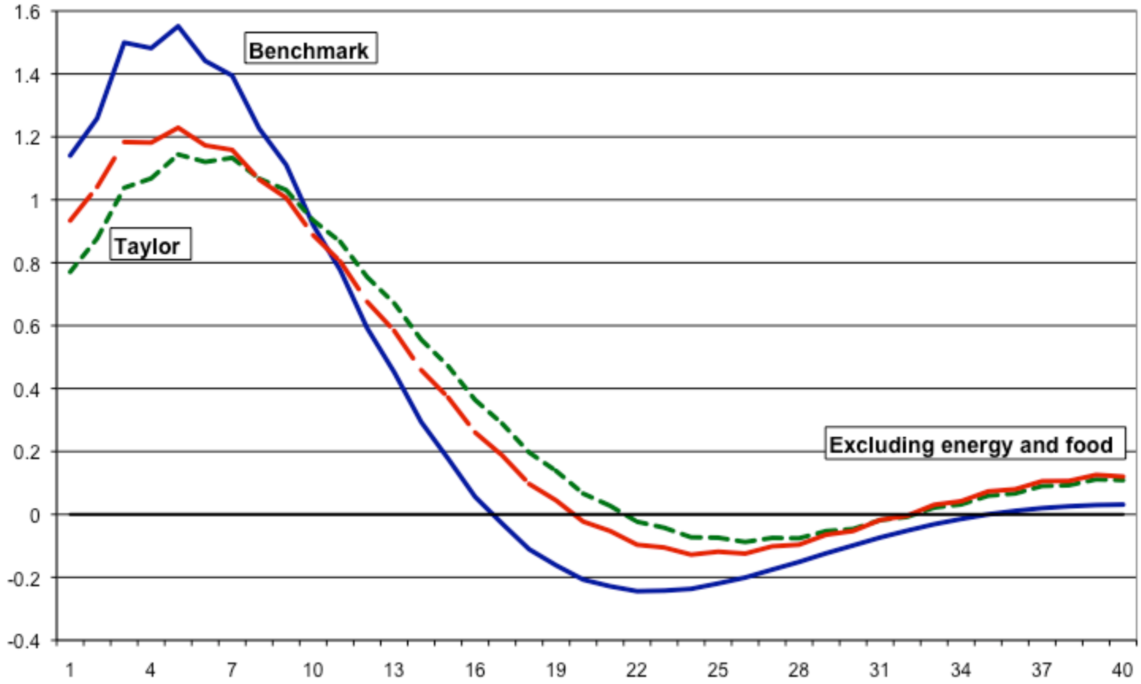
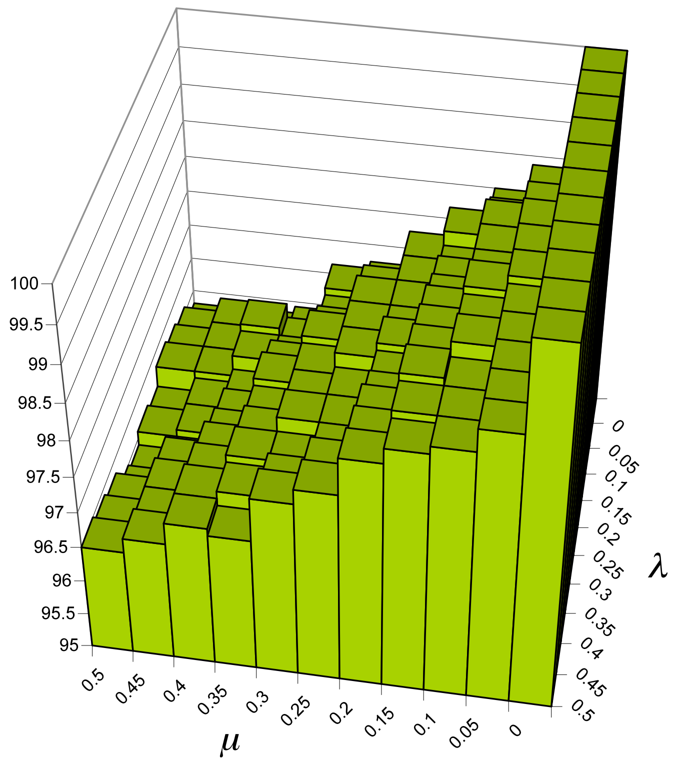


Fig. 4

Euro area - Random drawings from distribution of estimation residuals, core-inflation-net-of-energy-and-food-based-rule vs. benchmark rule



Note: Percentage of cases in which the core-inflation-net-of-energy-and-food-based-rule is outperformed by the benchmark-core-inflation-based rule

Fig. 5

US – Benchmark core inflation indicator, inflation excluding energy and food and overall inflation

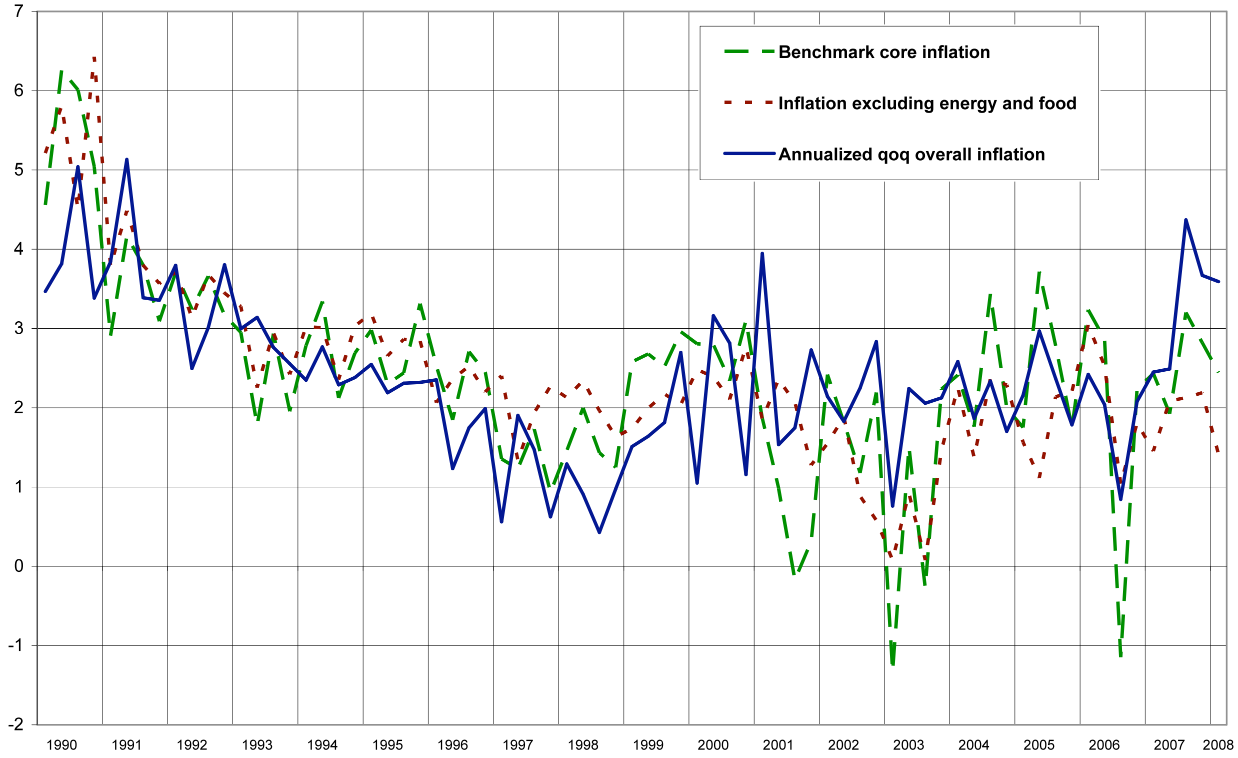


Fig. 6

US – Percentage worsening in the monetary policymaker's loss function, rule relying on core-inflation net of energy and food vs. benchmark-core-inflation-based rule