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Content

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Editor's note[1]

Pedro Duarte Neves

April 2023

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1. This issue of the Banco de Portugal *Economic Studies* contains three studies. The first presents the macroeconomic model for the Portuguese economy which has been one of the core pieces in the production of the Banco de Portugal's projections since the early 2000s. The second reviews recent price behaviour in Portugal, by using a new inflation indicator and developing a methodology to identify contagion effects across the different components of the Harmonised Index of Consumer Prices (HICP). The third is a monetary policy synopsis.

2. The opening study of this issue, by Castro and Duarte, presents a macroeconomic model – the M model – for the Portuguese economy. As is the case for most central banks, the M model is a semi-structural model, reflecting a balanced compromise between theoretical foundations and the required flexibility to address the analytical challenges posed by a changing economic environment. Given the detailed representation of the economy provided by the M model and the set of technical assumptions on the relevant exogenous variables, the forecasts produced by the model provide an informative narrative on the most likely evolution of the Portuguese economy.

The study describes the empirical properties of the M model by presenting the impact of selected economic "shocks" on key macroeconomic variables (GDP, private consumption deflator, employment, and the trade balance): two demand "shocks" of a real nature (increase in real exports and in real consumption expenditure), one supply shock (increase in oil prices), and two "shocks" of a nominal nature (appreciation of the euro and increase in short and long-term interest rates). All the results are plausible and inform on the quantitative effects of such events.

3. The origin of macroeconomic modelling goes back to a keynote address to the annual meeting of the Dutch Association for Economics and Statistics, delivered by

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1. The analyses, opinions and conclusions expressed in this editorial are entirely those of the editor and do not necessarily coincide with those of Banco de Portugal or the Eurosystem.

Jan Tinbergen in October 1936.[2] Tinbergen[3] possibly developed the first comprehensive national macroeconomic model[4] – seeking to obtain a quantitative answer to the following question: should the Dutch guilder be devalued, and would that affect the Dutch economy? – characterised by an empirical, dynamic, policy-oriented, and macroeconomic representation of an open economy.

Central banks started to face much more regular and demanding forecasting needs over the last 30 years or so, when they started to release regular quarterly macroeconomic forecasts with a focus on price and real developments. Central banks progressively adapted a forecasting approach based on the use of a suite of economic models offering complementary economic perspectives when developing a forecast.[5]

Semi-structural models constitute the main forecasting econometric tool for four important reasons. First, they provide – most of the time – a convincing narrative of economic developments. Second, they are flexible enough to incorporate new features on a varying economic environment. Third, they are useful for policy analysis, through the development of scenario analysis and counterfactual experiments. Finally, they provide relevant and reliable quantitative assessments of policy decisions.

Semi-structural models have proven to be superior to the existing alternatives,[6] although they are quite often complemented by other analytical approaches like the Dynamic Stochastic General Equilibrium (DSGE) model, time-series models (including Vector Autoregressive and factor models) and a range of short-term forecasting models.[7] Semi-structural models provide – compared to the alternatives – a broader description of the economy, a more detailed mapping into national accounts, and considerably higher

2. For more qualified opinions on the origins of macro-econometric modelling, the reader is invited to read "When it all began: The 1936 Tinbergen model revisited", Geert Dhaene and Anton P. Barten, (1989), Economic Modelling, Volume 6, Issue 2, April 1989, pages 203-219, and "A Short History of Macro-econometric Modelling", David F. Hendry, (2020), Nuffield College, University of Oxford, UK, 20 January 2020.

3. Jan Tinbergen was awarded the first Nobel Memorial Prize in Economic Sciences in 1969, shared with Ragnar Frisch. Jan Tinbergen is considered one of the founding fathers of econometrics.

4. There are very few textbooks on macroeconometric model building. One notable exception is Barten, A. P., (1981), "Methodological aspects of macroeconomic model construction", U.C.L./K.U.L., CABAY, Libraire-Editeur S.A., Louvain-la-Neuve/Leuven, Belgium.

5. See for instance "The Bank of England's forecasting platform: COMPASS, MAPS, EASE and the suite of models", Stephen Burgess, Emilio Fernandez-Corugedo, Charlotta Growth, Richard Harrison, Francesca Monti, Konstantinos Theodoridis and Matt Waldron, Bank of England, Working Paper No 471, May 2013.

6. Semi-structural models have proven to be much more useful than DSGE models for forecasting purposes. On this, Hendry (2020) – see again footnote 2 – states the following: "Dynamic stochastic general equilibrium models (DSGEs) began life at those [1970a] oil crisis implementing rational expectations and real-business cycle ideas and should have ended with forecast failures during the Great Recession but are currently in denial about their problems".

7. On this the reader is invited to browse the piece "Review of macroeconomic modelling in the Eurosystem: current practices and scope for improvement", ECB Strategy Review, (2021), Occasional Paper Series No 267, September 2021, ECB.

empirical flexibility.

There are areas where macroeconomic modelling needs significant progress. For that purpose – and bearing in mind the varied nature of the required improvements – an approach based on the use of a range of economic models by far dominates any single-model approach.

The following examples constitute, in the opinion of the editor, the most decisive ones:[8]

- Reinforcing the incorporation of heterogeneity in macroeconometric modelling and, in general, being more informative on distributional aspects related to consumer spending, sectoral production, labour market, housing equity, liquidity constraints on firms and households, and possibly also on expectations;
- Developing the interlinkages between the real economy and the financial sector (banking and non-banking), accounting for the changing characteristics of the business cycles with the degree of financial intensity (indebtedness), nonlinearities associated with episodes of financial instability, and international spillovers;
- Reinforcing the modelling of the interactions between monetary, fiscal, and macro-prudential policies, aiming for a better understanding of the transmission channels of these policies;
- Improving the modelling of the labour market – the relationship between inflation, wages, participation, and the real economy – and accounting for possible structural changes;
- Incorporating the relevant medium and long-term trends in the functioning of the economy (such as demographics, automation, digitalisation, remote work, energy patterns, and composition of the world trade);
- Developing a consistent analytical framework linking climate change to macroeconomic outcomes, including their geographic and sectoral dimensions, as well as global (real and financial) interlinkages.

It is fundamental that central banks are able to identify and explain the effects – direct effects and side effects – of their policy decisions, as well as to provide a deeper understanding of the functioning of the economy. Further improving macroeconomic modelling is a decisive step forward reinforcing central banks' accountability.

4. The second study in this Banco de Portugal Economic Studies, by Quelhas and Serra, is an analytical contribution to explaining price behaviour in Portugal. First, the

8. On this see for instance: Constâncio, V. (2017), "Developing models for policy analysis in central banks", speech at the Annual Research Conference, Frankfurt am Main, 25-26 September 2017; "Review of macroeconomic modelling in the Eurosystem: current practices and scope for improvement", ECB Strategy Review, (2021), Occasional Paper Series No 267, September 2021, ECB; Neves, P. D. (2022), "Summing up", in the Proceedings of the Conference Rebuilding Social Capital: the Role of Central Banks, for the occasion of the 175th anniversary of the Banco de Portugal, 1 April 2022.

authors replicate a methodology presented this year by economists[9] at the Bank for International Settlements (BIS) to identify contagion effects on price developments: i.e. how the prices of the main aggregate components of the price index are affected by shocks in the remaining components. The authors conclude that these contagion effects have increased in the latest period, 2020-22, compared to the historical period 2011-19.

Second, the authors present a new inflation indicator – based on a 2020 paper by a Federal Reserve Board economist[10] – called "common inflation", this measure seeks to capture price movements that are common to the different components of the price index, in contrast to the specific (or idiosyncratic) components of individual components. This indicator trends very close to the HICP for the period 2002-22, also increasing sharply as of the end of 2021 (to around 8% at the end of 2022). In visual terms, it behaves more smoothly than the HICP, with a small incidence of erratic disturbances – associated with the irregular behaviour of some price index components – which are far more evident and frequent in the HICP.

The authors provide a joint reading of these two analytical instruments. At an initial phase as of July 2021, the increase in inflation reflected the effects of supply-side constraints, worsened by developments in energy and food prices as a direct consequence of the onset of the Russian invasion of Ukraine. Subsequently, contagion effects became more significant in the transmission of pressures to price index components and thus to price behaviour.

5. Understanding recent price behaviour in most advanced economies represents a major challenge for economic analysis, in particular to assess the most temporary or most persistent nature of inflation. The behaviour of specific price index classes can make it difficult to understand the determinant features of an inflationary process.

In a recent article, the well-known financial analyst John Authers[11] – when analysing price index developments in the United States in August – presented a chart under the suggestive title: "*Inflation Excluding Everything: Still Rising, A measure designed to exclude all transitory rising prices is at a new peak*", and then concluded: "*In another sad echo of the "transitory" debate, the Bureau of Labor Statistics last year started publishing a measure of CPI excluding food, shelter, energy and used cars and trucks. (. . .). Sadly, even this Stepford measure*

9. Borio, Claudio, Marco Lombardi, James Yetman and Egon Zakrajšek (2023). "The two-regime view of inflation." Working Paper 133, Bank of International Settlements.

10. Luciani, Matteo (2020), "Common and Idiosyncratic Inflation", Finance and Economics Discussion Series (FEDS).

11. John Authers spent nearly three decades with the Financial Times and is now a senior editor at Bloomberg. Quotes in this editorial are from his newsletter of 14 September 2022, "Inflation's Terrible, Horrible, No Good, Very Bad Day", available on the Bloomberg website, where he commented on developments in the US consumer price index for August 2022, released the day before (13 September).

of inflation has hit a new high."

There are several inflation trend indicators that essentially aim to distinguish between temporary and permanent changes in price level or, in other words, try to identify the general trend in price developments by isolating the "noise" created by one-off and temporary disturbances in some price developments:

- Indicators that exclude specific components from the CPI, notably the core inflation indicator, which excludes unprocessed food and energy;
- Indicators of "limited influence" – such as the trimmed mean or weighted median – which are measures of the central location of price changes, and which tend to be less affected by extreme changes than the change in the HICP (which is a weighted average);
- Indicators that are reweightings of CPI weights, assigning alternative weights that seek to capture the information content of each of the index components (for example by assigning weights that are inversely proportional to price volatility);
- Indicators based on the main components (especially the first main component) that seek, through this statistical approach, to obtain a measure for overall price developments;
- Indicators that seek to breakdown each elementary price index into an idiosyncratic and a common component, as is the case of common inflation, presented for the first time for Portugal in this issue of the Banco de Portugal Economic Studies.

Assessing the contribution of each of these types of indicators to understand price behaviour is a key and relatively unexplored issue in the central banking community. Probably the most comprehensive summary of the features that are valuable in an inflation indicator is that of Wynne,[12] in a 1999 ECB Working Paper, which presents the following six criteria for selecting a trend inflation measure: (1) be computable in real time, (2) be forward-looking, (3) have a positive experience of describing inflation developments in the past, (4) be understandable by the public, (5) be definitive, in the sense that past values do not change when new observations become available, and (6) have some theoretical foundation.

How to assess the use of such a wide range of trend inflation indicators? How can we assess the added value of each of these indicators, in terms of the overall understanding of price developments? What assessment can be made on the informative contribution of this new joint inflation indicator when analysing inflation developments?

Current price behaviour – with inflation in most advanced economies hitting a record high for the past (approximately) 40 years – is certainly a unique occasion to

12. Wynne, M.A., (1999), "Core inflation: a review of some conceptual issues", European Central Bank, Working Paper No 5.

evaluate the information contained in the various indicators. It is therefore expected that a comparative analysis of the of these various indicators' behaviour will be done in the near future – in Portugal and also for other economies – and, in particular, which of these measures were most informative in the transition phase from price stability to the current inflation episode.

6. Freitas and Teles present an overview of monetary policy in the current inflation episode. Three topical arguments stand out in this overview. The first one highlights the weak empirical and theoretical support of active monetary policy rules, based on Taylor's principle that the intervention interest rate should respond more than one-to-one to deviations of inflation from the price stability target. The second points out that in a scenario of large relative price changes and some nominal rigidities (wages and prices), higher inflation may favour a more efficient adjustment in productive resources. Finally, the third contribution illustrates how the unanticipated nature of current inflation leads to a reduction, as a percentage of GDP, in public debt and in some public expenditure components (as wages and pensions).

This synopsis also calls for a better understanding of the relationship between monetary policy – in interaction with fiscal and other policies – and inflation behaviour, thereby reiterating what was said in point 3 of this editorial.

Non-technical summary

April 2023

The *M* Model: a macroeconomic model for the Portuguese economy

Gabriela Castro and Cláudia Duarte

Models are a simplified representation of reality, contributing to economic analysis and to the interpretation of the behaviour of households, firms and governments. This article presents a macroeconomic quarterly model for the Portuguese economy—*M* model—that is one of the key elements of the Banco de Portugal's toolkit used for projection exercises and scenario analyses. This model, with an initial version from the early 2000's, has been regularly developed ever since.

The *M* model results from a compromise between theoretical foundations and a flexible approach to better fit the behaviour of the Portuguese economy. The complex entanglement of economic relations is represented through linkages between the several blocks of the model, which include demand, supply, wages, prices, employment, financial and fiscal variables. In spite of having a structure close to the ones developed by other central banks and international institutions, the *M* model captures important specificities of the Portuguese case, such as being an economy integrated in the euro area.

This article illustrates the dynamic properties of the *M* model in the short and medium term through a "what if" analysis—what would happen if there is a shock to one input of the model, while all the others remain unchanged? In this context, five shocks and their impacts on 12 variables are presented. Figure 1 shows a summary of the results for a set of variables (GDP, private consumption deflator, employment and trade balance). The magnitudes of the shocks are not directly comparable, so the relative impact for a given variable is not informative.

An increase in foreign demand for Portuguese goods and services triggers an increase in exports, domestic demand, GDP, employment and in the trade balance (yellow bars in Figure 1). The increase in demand leads to a rise in prices, measured by the private consumption deflator. An increase in real public consumption has also a positive impact on economic activity, leading to a reduction in the trade balance (blue bars). This evolution reflects the combination of higher imports, driven by domestic demand, and lower exports due to a loss in competitiveness.

In addition to these two shocks to the real side of the economy, the article also includes three nominal shocks—an appreciation of the euro against all other currencies (red bars), an increase in oil prices in international markets in US dollars (green bars) and

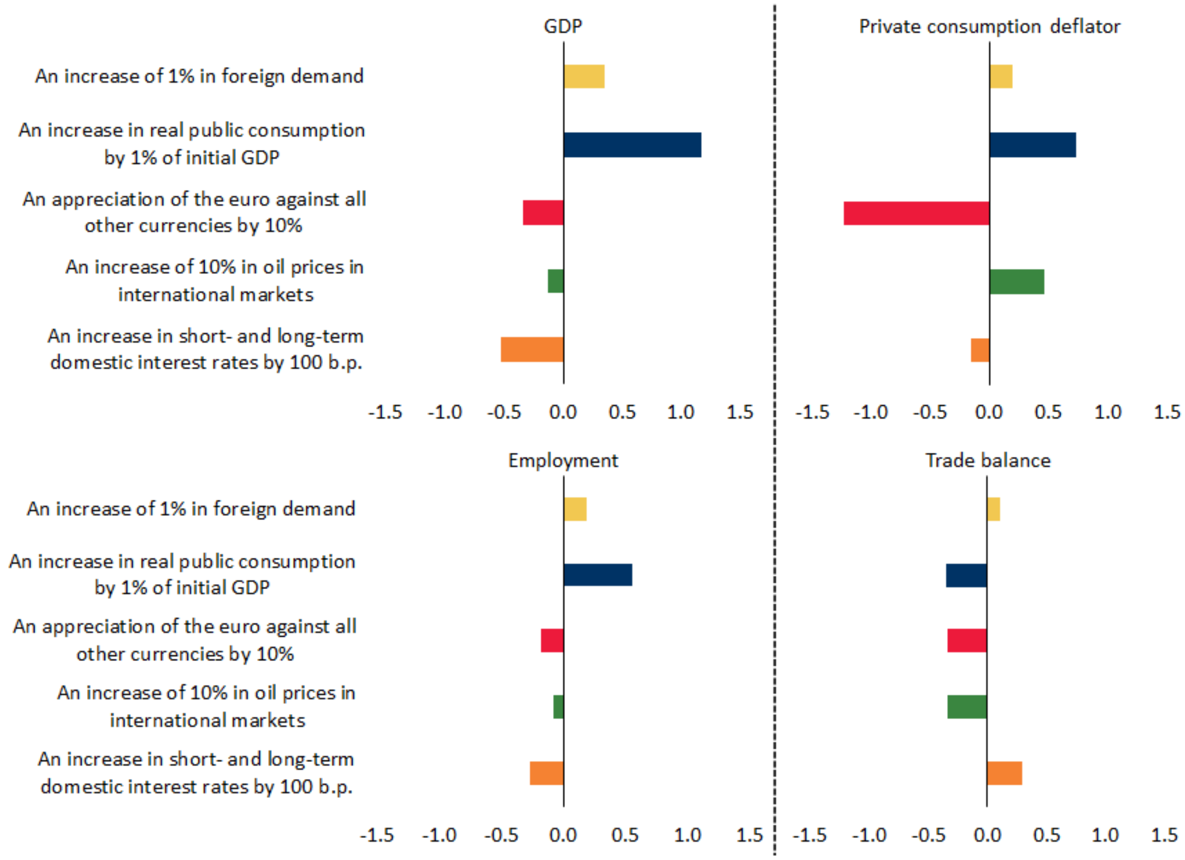

FIGURE 1: Summary of illustrative simulations using the *M* model | Impact on a set of variables in the third year of the simulation horizon

Notes: b.p. - basis points. The figure presents the difference in percentages (for GDP, private consumption deflator and employment) or percentage points (for the trade balance) between the levels of a variable in the shocked and the baseline scenarios, in the third year of the simulation horizon. The magnitudes of the shocks are not directly comparable, so the relative impact for a given variable is not informative.

an increase in short- and long-term domestic interest rates (orange bars). These shocks trigger a negative impact on GDP and employment. When the euro appreciates and interest rates rise, lower activity translates also into lower domestic prices (green bars). In turn, higher oil prices naturally lead to higher consumer prices (red bars). Looking to the external accounts, the trade balance declines in the exchange rate and oil price shocks, while in the case of the interest rates shock lower domestic demand and imports lead to an improvement in the trade balance.

The results presented are conditioned by the modelling strategy, reinforcing the need to continue to develop the *M* model. Additionally, the use of this model by the Banco de Portugal must continue to be framed within a broad set of complementary analytical tools—models and indicators—in order to reinforce the ability to project and analyse the Portuguese economy.

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The *M* Model: a macroeconomic model for the Portuguese economy

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April 2023

Abstract
Macroeconomic models offer valuable insights to improve economic reasoning and to help interpreting agents' behaviour, albeit being an imperfect representation of reality. This article presents a general description of the current version of the *M* model, a macroeconomic quarterly model for the Portuguese economy, which has been developed at the Economics and Research Department of Banco de Portugal since the early 2000's. This semi-structural model embodies a compromise between theoretical foundations, anchored on the so-called neoclassical synthesis, and a more flexible approach to better fit the data. This type of models remains a common and useful tool, due to its pragmatic approach to the changing economic reality. The interconnectedness of economic relations is considered through linkages between the several blocks of the model, which include demand, supply, wages, prices, labour market, financial and fiscal variables. The *M* model is used for different purposes and is part of the toolkit for projection exercises and scenario analyses. An illustration of its dynamic properties in the short and medium term is provided through the simulation of five shocks: foreign demand, public consumption, exchange rate, oil price and interest rate. (JEL: C32, C53, E17)

1. Introduction

This article presents a general description of the key features of the *M* model, a macroeconomic quarterly model for the Portuguese economy. This model has been developed at the Economics and Research Department of Banco de Portugal and its initial version dates back to the early 2000's. The *M* model is a semi-structural model, which embodies the so-called neoclassical synthesis. Its structure builds on the experiences of other central banks and international institutions with macroeconometric models, although some specificities of the Portuguese economy are explicitly accounted for, such as the participation in the euro area.

Acknowledgements: The authors are grateful for the discussion with participants in a seminar at the Economics and Research Department and the comments made by Nuno Alves, João Amador, António Antunes, Cláudia Braz, Paulo Júlio, José R. Maria, Pedro Duarte Neves and Ana Sequeira. The analyses, opinions and conclusions expressed herein are the sole responsibility of the authors and do not necessarily reflect the opinions of Banco de Portugal or the Eurosystem.

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The model is one of the tools used in the projection exercises published in Banco de Portugal's Economic Bulletin. There are four projection exercises in each year—March, June, October and December. The June and December projections are produced within the Eurosystem framework, with the collaboration of the European Central Bank (ECB) and the National Central Banks, as described in ECB (2016). The projection horizon varies across exercises, covering between two to three years ahead of the current year.

In addition to medium-term projections, the *M* model is also used for scenario analyses. These analyses can include the assessment of risks, for instance the stress testing of the financial sector, as well as economic policy simulations. The *M* model also underlies a tool called Basic Model Elasticities (BME), which provides mechanical impacts of shocks on the economy, such as changes in the exogenous assumptions underlying the projection exercises. This tool has been used in several sensitivity analyses, such as Banco de Portugal (2019, 2022a,b).

Given the variety of utilisations, the *M* model is a flexible, though quite detailed, tool that is focused on both short- and medium-term purposes. The model incorporates the interdependencies of a broad set of variables, which includes aggregate demand, international trade, potential output, wage and price formation, labour market developments, financial and fiscal variables.

The model design also accounts for the need to track recent developments in macroeconomic data. This requires a compromise between theoretical foundations, which anchor the supply block, and a more flexible specification of the demand block, to better fit the data. Moreover, the model is fitted to the data through a combination of econometric estimation, based on error-correction equations, and calibration.

This type of macroeconomic models remains a common and useful tool for macroeconomic analyses and projections, as well as for assessing policy interventions (Pareja *et al.* 2017; Bulligan *et al.* 2017; Berben *et al.* 2018). Flexibility is one of the key factors for its longevity, which facilitates a pragmatic approach to the changing economic environment. The *M* model has undergone several changes over time and is regularly re-estimated, as new data for the Portuguese economy becomes available (e.g. new National Accounts series).

The remainder of this article is organised as follows. Section 2 provides an overview of the model. Section 3 explains key details about the model's blocks—supply, demand, prices and wages, labour market, financial sector and public sector. In Section 4 the dynamic properties of the model are illustrated with some simulation results. Section 5 concludes.

2. A bird's eye view of the model

The *M* model is a medium-sized semi-structural model, with almost 30 behavioural equations. The basic theoretical elements are fairly standard and are in line with the ECB's Area-Wide Model, presented in Fagan *et al.* (2001) and Fagan *et al.* (2005), and the country blocks of the European System of Central Banks's Multi-Country Model, such as Villetelle and Boissay (2005) and Warmedinger and Vetlov (2006). The theoretical foundation of the behavioural equations combines both neoclassical and Keynesian elements. The time dimension plays a crucial role in this synthetic approach.

The supply block is the anchor for the long-run properties of the model, which essentially correspond to the basic framework of neoclassical economic theory. In particular, aggregate supply is determined by available resources and technological progress, through a production function. Firms' decisions on prices and production factors are derived from a profit maximization problem, assuming perfect competition in input markets and monopolistic competition in output markets, where producers set a markup over the marginal cost. In the long run, the aggregate supply curve is vertical, so that prices do not matter for the supply level. Inflation is, therefore, a nominal phenomenon.

A key concept of the supply block is potential output, which corresponds to the maximum level of production, with full employment that does not trigger excessive inflationary pressures (Okun 1962). The concept of full employment is linked to the Non-Accelerating Wage Rate of Unemployment (NAWRU), i.e. the unobserved unemployment rate that does not trigger excessive wage pressures. Both these elements are exogenous to the model. In the long run, actual production equals potential output, i.e., the output gap is nil, which implies full capacity utilisation. In the labour market, the actual unemployment rate equals the NAWRU in the long run, i.e., the unemployment gap is nil. Long-run potential output growth reflects exogenous assumptions on technology and population developments and all real variables must grow at this rate.

In the short run, prices and wages are sluggish to adjust, reflecting, for instance, the existence of contracts and transaction costs. In this context, output is determined by demand and, therefore, mismatches between potential and actual output can arise. The over-utilisation (underutilisation) of production capacities translates into positive (negative) output gaps in the product market and into negative (positive) unemployment gaps in the labour market. These mismatches on product and labour markets are key factors in the price setting by firms and wage setting through bargaining, in a framework akin to price and wage Phillips curves. Deviations of aggregate demand from potential supply trigger wage and price adjustments, which contribute to move the economy towards the equilibrium.

The *M* model explicitly accounts for the fact that the Portuguese economy participates in the euro area. Consistent with this framework, all variables describing the world economic conditions, such as commodity prices, market interest rates and nominal exchange rates, are treated as exogenous variables, and are included in the set of common external assumptions within the Eurosystem projection exercises (Figure 1). This set of assumptions also includes foreign demand and competitors' prices. The Portuguese economy is sufficiently small for domestic shocks to have no effect on the rest of the world and for domestic conditions to have no influence on international prices and output. In the long run, the domestic inflation rate is driven by the exogenous growth rate of foreign prices, and all prices must grow at this rate.

The expectation formation process of agents is assumed to be backward looking, i.e. adaptive. The use of backward-looking expectations in semi-structural models is quite common, as in, for example, Banca d'Italia econometric model (Bulligan *et al.* 2017) and De Nederlandsche Bank macroeconomic policy model (Berben *et al.* 2018). In this context, equations may include lagged terms to proxy expected variables. Moreover, lags may also signal that agents take some time to react. As a consequence, product and labour markets mismatches may persist for long periods of time.

2.1. Data and estimation strategy

The dataset used to estimate the M model spans the period from $1999Q1$ to $2019Q4$ and mainly covers the Quarterly National Accounts released by Statistics Portugal. Whenever needed, this information set is complemented by the quarterly historical series presented in Cardoso and Sequeira (2015), which are regularly updated. In projection exercises, observed data is prolonged with short-term projections for the current quarter and one quarter ahead. These short-term projections draw heavily on a set of bridge models, which use a comprehensive dataset of high-frequency indicators, as described in Esteves and Rua (2012).

The specification of the behavioural equations follows an error-correction model. This type of specification preserves structural links between variables that share common trends, due to embodied cointegrating relationships, to which they converge in the long run. In this framework, both short- and long-run features of economic agents' behaviour are taken into account. Developments of a given variable depend in the long run on the levels of its determinants (i.e., the cointegration relationship), but are influenced by changes in variables included in the short-term dynamics. Equation (1) presents a generic and simplified version of this model:

$$\Delta y_t = A(L)\Delta y_{t-1} + B(L)\Delta x_t + C(L)\Delta z_t + \lambda(y_{t-1} - C - \varphi x_{t-1}), \tag{1}$$

where y_t is the variable of interest, x_t is the determinant in the long run, z_t influences the short-run dynamics, C is a constant, $A(L), B(L)$ and $C(L)$ are lag polynomials, Δ denotes first differences and lower-case variables denote logarithms, i.e. $y_t = \log(Y_t)$ and, conversely, $Y_t = \exp(y_t)$. Extended versions of this specification can include more than one variable in the long-run relationship and in the short-run dynamics. The coefficient λ is the error-correction coefficient, which reflects the speed of convergence back to the long-run relationship. Cointegration exists if this coefficient is significantly different from zero and negative. In some cases, deterministic terms, such as step dummies or trends, must be included in the long-run relationship in order to obtain a stationary error-correction term. Moreover, dummy variables may be added to the estimated equations to account for outliers. These deterministic terms play an in-sample role, because they contribute to improve the statistical fit of the model. However, they remain constant in the last figure of the estimation sample over the projection horizon. For the sake of simplicity, deterministic variables are not presented in this article.

The equations are estimated separately with ordinary least squares, using the two-step procedure proposed by Engle and Granger (1987). The first step consists in estimating the long-run, co-integrated relationships. In the second step, the dynamic equations are estimated in the error-correction format.

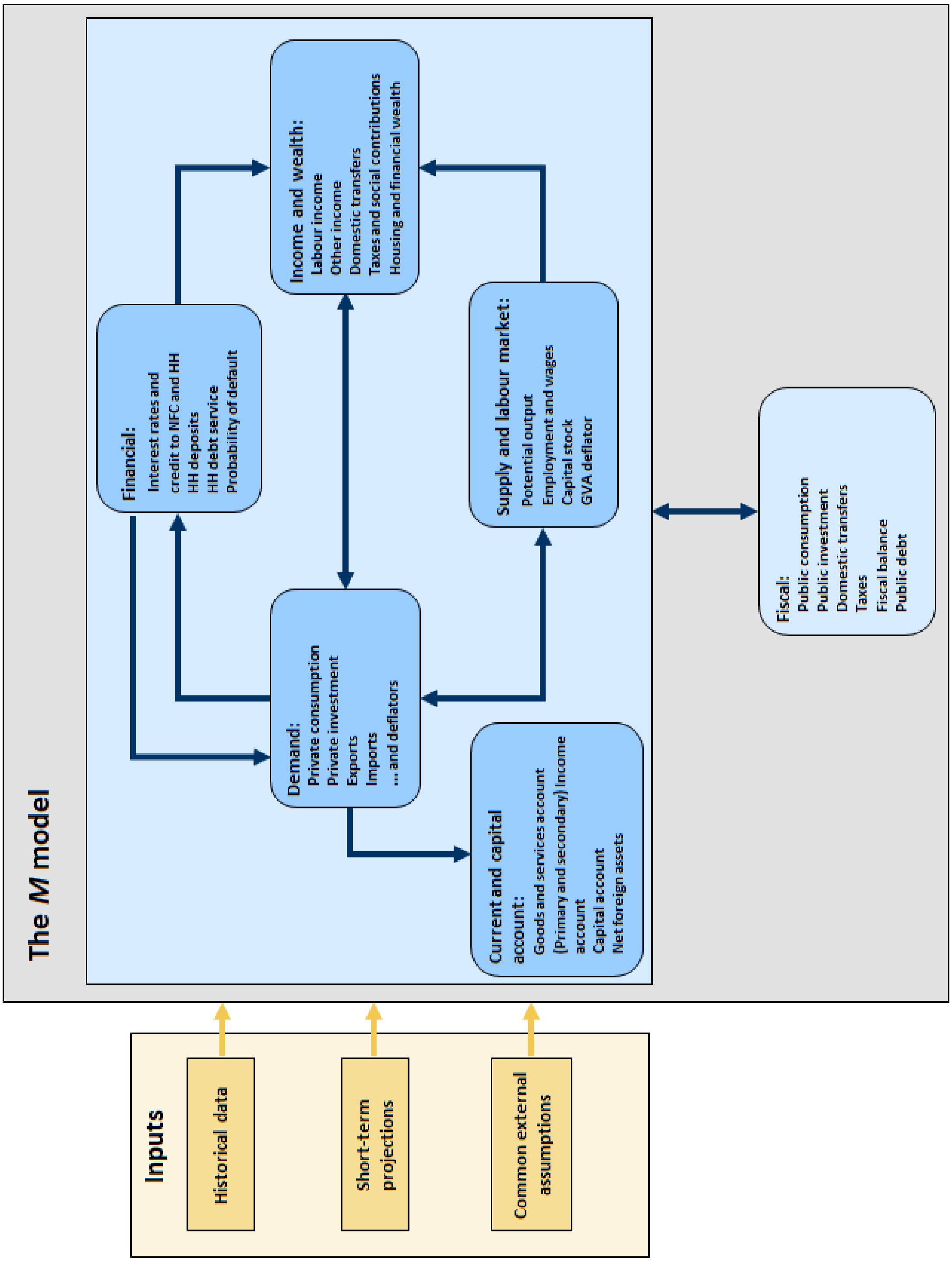

FIGURE 1: Summary of *M* model's structure

Source: The authors.

Notes: GVA - Gross value added. HH - Households. NFC - Non-financial corporations.

The short-term dynamics is estimated more freely and is not heavily conditioned by theory. Initially, all relevant variables and lags are included, but only those that are statistically significant remain in the final specification. The duration of short-term effects, as well as the speed of adjustment to the long-run equilibrium, depends exclusively on the estimation outcome.

The extent of short-term effects and the coefficients in the long-run relationship result from a mix of estimation and calibration. The criteria for calibration involve theoretical restrictions and assumptions that yield more plausible projections. Theoretical restrictions mainly result from the need to impose that the model converges to a stable solution in the long run, i.e. a balanced-growth path (static homogeneity) and that the static and dynamic equilibrium solutions of the model coincide (dynamic homogeneity). When the data clearly reject this restriction, dynamic homogeneity is imposed in its simplest form, which involves adding a short-term constant that guarantees consistency between static and dynamic steady-state growth rates for the dependant variable (Stoevsky and Consolo 2016). For the sake of brevity, these constants are omitted from the equations.

3. Properties of the main equations

This section presents the most important equations grouped according to the main blocks in the model. It also provides information on the most relevant parameters of interest. A comprehensive listing of variable names and corresponding description is provided in the Online Appendix A. The Online Appendix B contains the full set of equations. In addition to the estimated equations, the model also includes a large set of identities, which reflect the national accounts framework, and definitions, such as bottom-up aggregation procedures in order to obtain broader concepts from more detailed elements.

3.1. *Supply*

The M model splits the economy into three sectors, namely (i) private non-housing, (ii) housing and (iii) public sector. Potential gross value added (GVA) in the private non-housing sector ($yftp_t$) features a Cobb-Douglas production function with potential labour supply ($lntp_t$) and capital stock ($ksrp_t$) as production factors, as well as trend total factor productivity (tft_t), formulated as Hicks-neutral technical progress:

$$yftp_t = tft_t + \alpha \cdot lntp_t + (1 - \alpha) \cdot ksrp_t, \tag{2}$$

where the parameter α represents the elasticity of $yftp_t$ with respect to $lntp_t$ and lower-case variables denote logarithms. This elasticity is proxied by the share of labour compensation on GVA. Currently, the α parameter is calibrated to around 60%, corresponding to the average share of labour compensation over 1999-2019.

Potential private sector labour supply is exogenous to the model, and is calculated by multiplying actual labour force by the NAWRU estimates, obtained using the methodology described in Duarte *et al.* (2020), and subtracting public sector employment. Over the projection horizon, labour force projections take on board the demographic projections released by the Eurostat and Statistics Portugal, while the NAWRU follows a random walk process, i.e., remains constant in the last quarter of the estimation sample. The capital stock is obtained through the standard capital accumulation equation, in which the depreciation rate is exogenous to the model (see equation B.3 in the Online Appendix B). Trend total factor productivity is calculated by applying the Hoddrick-Prescott filter to the Solow residual, obtained by applying equation (2) to actual GVA and employment in the private non-housing sector (equation B.4). Over the projection horizon, tft_t is assumed to follow the steady-state growth path.

The supply side anchors the long run of the model. Thus, long-run relationships for the capital stock ($ksrp_t^*$), price level ($yfdp_t^*$) and real wages ($wrnp_t^*$) follow from the first-order conditions of profit maximising producers, in combination with exogenous labour supply, technology and capital financing costs ($RCCP_t$). In particular,

$$wrnp_t^* = \log(\alpha) + yftp_t - lntp_t \tag{3}$$

$$yfdp_t^* = wunp_t + lntp_t - yftp_t - log(\alpha) \tag{4}$$

$$ksrp_t^* = \alpha \cdot \log\left(\frac{1-\alpha}{\alpha}\right) + \alpha \cdot (wunp_t - ccp_t) + yftp_t - tft_t, \tag{5}$$

where $wunp_t$ denotes the nominal wage and $ccp_t = yfdp_t + \log(RCCP_t)$.

The M model considers a simplified approach to account for housing and public sectors. Output of the housing sector corresponds to imputed and actual rents ($pcrr_t$), which are also included in the households' disposable income account (see Subsection 3.2 for more details). The public sector output ($yerg_t$) corresponds to compensation to public employees plus gross operating surplus and received subsidies on production (see Subsection 3.6 for more details). The housing stock ($ksrh_t$) and the public capital stock ($ksrg_t$) are obtained through standard capital accumulation equations.

3.2. *Demand*

The production function framework holds in the long run only. In the short run, output is determined by aggregate demand, which results from combining the main components of gross domestic product (GDP, YER_t) on the expenditure side—private consumption (PCR_t), public consumption (GCR_t, see Subsection 3.6 for more details), gross fixed capital formation (ITR_t), changes in inventories (SCR_t), exports (XTR_t) and imports (MTR_t).

$$YER_t = PCR_t + GCR_t + ITR_t + SCR_t + XTR_t - MTR_t \tag{6}$$

In the M model, the specification of private consumption is influenced by the life-cycle and permanent income hypotheses. Households try to smooth the path of consumption over time based on their expected lifetime income with a more persistent nature. In the long run, consumption depends on both adjusted real disposable income ($pyra_t$) and real (financial fwr_t and housing hwr_t) wealth.

Private consumption is disaggregated into four components, namely housing services (i.e., imputed and actual rents), durables, fuels, and other goods and services. The latter component is the most important in terms of spending and has the following equation:

$$\begin{aligned}\Delta pcro_t =&\beta^{pcro} \cdot \Delta pyra\_mm_t + \gamma^{pcro} \cdot \Delta URX_t + \varphi^{pcro} \cdot \Delta STR^D_{t-3} + \lambda^{pcro}(pcro_{t-1} - \\ &C^{pcro} - \psi^{pcro} \cdot pyra_{t-1} - \zeta^{pcro} \cdot fwr_{t-1} - (1 - \psi^{pcro} - \zeta^{pcro}) \cdot hwr_{t-1}),\end{aligned} \tag{7}$$

where $pyra_t$ comprises net compensation of labour, transfers and other income, which is adjusted by the debt servicing, housing rents and financial intermediation services indirectly measured. Income and wealth in real terms are obtained by deflating the nominal aggregates with the private consumption deflator (see Subsection 3.3). Nominal housing wealth is computed as the real housing stock valued at current house prices (equations B.20 and B.31).

The long-run parameter ψ^{pcro} represents the marginal propensity to consume out of income, while ζ^{pcro} and $(1 - \psi^{pcro} - \zeta^{pcro})$ are the marginal propensities to consume out of financial and housing wealth, respectively. These parameters add up to one in order to impose the static homogeneity condition. This specification is also compatible with the assumption that there are two types of households in the economy—those who have liquidity constraints (consuming a fraction of their current disposable income) and those who have not (consuming a fraction of their wealth).

The short-run dynamics is influenced by developments in the real interest rate of deposits (STR^D_t), which proxies an opportunity cost, and the unemployment rate (URX_t), as a measure of households' uncertainty, both with a negative impact on $pcro_t$, in line with economic theory. Moreover, a moving average of the adjusted real disposable income ($pyra\_mm_t$) is also included, which allows to smooth the reaction to transitory shocks in income. This formulation contributes to a procyclical savings rate, in line with historical patterns (Alves and Cardoso 2010).

The consumption of durable goods comprises the adjusted real disposable income and financial wealth, as well as STR^D_t and URX_t in the long-run relationship, while the short run is governed by $\Delta pyra_t$ (equation B.12). Thus, the consumption of durable goods shows a more cyclical pattern, in accordance with historical evidence. Consumption of housing services and of fuels evolve according to simple rules, the former taking into account the housing stock.

Regarding gross fixed capital formation, the model considers a breakdown by institutional sector—private non-housing (ipr_t), housing (ihr_t) and public investment (see Subsection 3.6 for more details). In the long run, private non-housing investment is pinned down by the capital stock derived from the first-order conditions of the profit maximising producers ($ksrp^*_t$ in equation 5). Thus, the actual capital stock converges to its equilibrium level and ipr_t matches capital depreciation adjusted for the exogenous assumptions on technology and population growth, so that the investment to capital stock ratio is constant.

The short-run dynamics of ipr_t is influenced by fluctuations in private GDP ($yerpr_t$) and some inertia. Additionally, investment decisions also depend (negatively) on financing conditions and on entrepreneurs' assessment of the economic outlook and its uncertainty. Uncertainty is proxied by the composite indicator of financial stress ($ICSF_t$), introduced by Braga *et al.* (2014):

$$\Delta ipr_t = \beta^{ipr} \cdot \Delta yerpr_t + (1 - \beta^{ipr}) \cdot \Delta ipr_{t-1} + \gamma^{ipr} \cdot \Delta STR^B_{t-4} + \varphi^{ipr} \cdot ICSF_{t-2} + \lambda^{ipr}(ipr_{t-1} - ksrp^*_{t-1} - \log\left(\frac{g+\delta}{1+g}\right)), \tag{8}$$

where δ is the exogenous depreciation rate of the capital stock in the private non-housing sector and g denotes the exogenous assumption on technology and population growth, both in the steady state. Parameters β^{ipr} and $(1 - \beta^{ipr})$ add up to one in order to impose the dynamic homogeneity condition. Moreover, the estimated value of β^{ipr} is above one, in line with the investment accelerator effect.

Housing investment mainly reflects demand conditions from domestic households, which are similar to those that determine private consumption. The long-run level of ihr_t is influenced by the adjusted real disposable income and the unemployment rate. The short-run dynamics depends on developments in real disposable income, in the real interest rate of housing mortgages, in the unemployment rate and in Tobin's q for housing investment. As discussed in Mankiw (2002), Tobin's q compares the market price of housing (ihx_t) with its replacement cost (proxied by the housing gross fixed capital formation deflator, ihd_t). In addition to housing demand by households who plan to live in it, this variable tries to capture the incentives to invest in housing, as a non-financial asset:

$$\Delta ihr_t = \beta^{ihr} \cdot \Delta pyra\_mm_t + \gamma^{ihr} \cdot \Delta URX_{t-2} + \varphi^{ihr} \cdot \Delta STR^H_t + \xi^{ihr} \cdot \Delta(ihx_{t-2} - ihd_{t-2}) + \lambda^{ihr}(ihr_{t-1} - C^{ihr} - pyra_{t-1} - \psi^{ihr} \cdot URX_{t-1}), \tag{9}$$

where γ^{ihr} and φ^{ihr} have negative values.

The observed data for changes in inventories are extremely volatile and do not seem to be correlated with demand, supply or financial conditions. Thus, a simplifying technical assumption is used—the evolution of changes in inventories, as well as the statistical discrepancy associated with chain-linked data, is assumed to be neutral in terms of its impact on real GDP growth.

Turning to external flows, exports (xtr_t) and imports (mtr_t) are modelled in a standard way, where market shares—computed in relation to aggregate foreign demand and final demand, respectively—are a function of a price competitiveness indicator, which compares domestic and foreign prices. Exports and imports of goods excluding fuels, of fuels and of services are modelled separately. In the latter case, the model also accounts for a further disaggregation of exports into tourism and other services.

Exports of goods excluding fuels ($xtro_t$) are largely determined by a foreign demand indicator (wdr_t), which is a trade-weighted average of imports by trading partners (Hubrich and Karlsson 2010). In the long run, the equation also accounts for a price competitiveness indicator, which compares developments in GDP deflators of main trading partners (yed_t^F) with the domestic value-added deflator ($yfdp_t$). The parameters associated with wdr_t are set to one, due to the static and dynamic homogeneity restrictions.

$$\Delta xtro_t = \Delta wdr_t + \lambda^{xtro}(xtro_{t-1} - C^{xtro} - wdr_{t-1} - \psi^{xtro}(yed_{t-1}^F - yfdp_{t-1})) \tag{10}$$

The equation for tourism exports ($xtrt_t$) is quite similar, with specific tourism-related foreign demand and price competitiveness indicators (equation B.16). Simple rules are used for exports of fuels ($xtre_t$), depending on foreign demand developments, and for exports of other services ($xtrs_t$), considering an average of developments in exports and imports of goods excluding fuels and exports of tourism. This weighted average tries to capture insurance and transportation services, which represent a significant share of $xtrs_t$.

Imports of goods excluding fuels ($mtro_t$) depend on the weighted final demand indicator, excluding fuels (wer_t) and on a price competitiveness indicator, which compares imports deflator ($mtdo_t$) with the deflator of domestically produced goods in the private sector ($yfdpr_t$). This specification assumes (imperfect) substitutability between imported and domestically produced goods. The wer_t indicator is calculated as a weighted average of final demand components taking into account their import content, which is calculated following the methodology in Cardoso and Rua (2021).

$$\begin{aligned}\Delta mtro_t =& \beta^{mtro} \cdot \Delta wer_t + (1 - \beta^{mtro}) \cdot \Delta wer_{t-1} + \\ & \lambda^{mtro}(mtro_{t-1} - C^{mtro} - wer_{t-1} - \psi^{mtro}(mtdo_{t-1} - yfdpr_{t-1}))\end{aligned} \tag{11}$$

Imports of fuels ($mtre_t$) are modelled in a similar way to $mtro_t$, depending on a weighted final demand for fuels and import prices of fuels in real terms (equation B.18). The long-run parameter on relative prices is smaller than in equation (11), reflecting a less elastic demand for imports of fuels. Finally, imports of services ($mtrs_t$) are driven by exports and imports of goods excluding fuels. This simple rule tries to capture the need for financing, insurance and transportation services.

The trade balance is computed by combining real developments for exports and imports with their respective prices (see Subsection 3.3). This balance is an important element of the current and capital account, which reflects the net lending/borrowing position of the economy. The other elements are the (primary and secondary) income and capital accounts. These accounts are modelled as a mix between simple rules for the interest-bearing and -paying items, including public debt, and exogenous information (e.g. related with EU transfers, with the exception of taxes paid and the national contribution for the EU budget). Current and capital account balances cumulatively change the net international investment position. Every year the net flow is added to the previous year stock of assets, ignoring changes in valuation.

3.3. *Prices and wages*

The two main equations in this block refer to the GVA deflator ($yfdp_t$) and nominal wages ($wunp_t$) in the private non-housing sector. Starting with the GVA deflator, the long-run relationship ($yfdp^*_t$) is derived from the supply block (see Subsection 3.1 for more details), while the short-run dynamics is driven by the deviation between actual demand and potential supply in the product market, i.e., the output gap ($ygat_t$), and by developments in trend unit labour costs ($ultp_t$), with some lags:

$$\Delta yfdp_t = \beta^{yfdp} \cdot ygat_t + \Sigma_{i=1}^{4} \gamma_i^{yfdp} \cdot \Delta ultp_{t-i} + \lambda^{yfdp}(yfdp_{t-1} - yfdp^*_{t-1}) \tag{12}$$

where $\Sigma_{i=1}^{4} \gamma_i^{yfdp} = 1$ in order to ensure dynamic homogeneity. The GDP deflator is obtained through the accounting identities linking market prices to basic prices.

Long-run nominal wages are also derived from the supply block, using the GVA deflator and real wages ($wrnp^*_t$). The short-run dynamics includes deviations of the unemployment rate from the NAWRU, i.e., the unemployment gap (UGA_t) and current and lagged developments in output per worker ($yerp_t - lnnp_t$). Moreover, expected inflation is also included, measured by lags of changes in the private consumption deflator (pcd_t):

$$\begin{aligned}\Delta wunp_t =& \beta^{wunp} \cdot UGA_{t-1} + \Sigma_{i=0}^{3} \gamma_i^{wunp} \cdot \Delta(yerp_{t-i} - lnnp_{t-i}) + \Sigma_{i=0}^{2} \varphi_i^{wunp} \cdot \Delta pcd_{t-i} + \\ & \lambda^{wunp}(wunp_{t-1} - yfdp_{t-1} - wrnp^*_{t-1}),\end{aligned} \tag{13}$$

where $\Sigma_{i=0}^{3} \gamma_i^{wunp} = 1$ and $\Sigma_{i=0}^{2} \varphi_i^{wunp} = 1$ in order to ensure dynamic homogeneity.

Prices and wages are crucial for the model to move towards the long-run equilibrium. Positive (negative) pressures in the output and labour markets are associated with a positive (negative) output gap and a negative (positive) unemployment gap, which translate into positive (negative) price and wage pressures (with a positive β^{yfdp} and a negative β^{wunp}) until the long-run equilibrium is again achieved. Moreover, the so-called "output per worker gap" represents an additional implicit channel connecting demand-driven pressures to inflation—the equation for $yfdp_t$ considers trend output per worker, while the equation for $wrnp_t$ includes actual output per worker.

Given that private domestic demand combines domestic inputs with imports, its deflators—following the same breakdown as in Subsection 3.2—result from a combination of the GVA deflator with the imports deflator. In the long run, the shares of these two components are calibrated according to the specific import content (Cardoso and Rua 2021). The dynamic equations include the same variables as in the long run, extended with lags of the dependent variable whenever deemed necessary, coupled with the restriction that dynamic homogeneity holds (equations B.24 to B.27).

The three exceptions to the standard formulation of domestic demand deflators are the consumption of housing services, the consumption of fuels and changes in inventories. In the first case, a simple rule is used. In the second case, oil prices and specific taxes are taken into account. Lastly, the deflator of changes in inventories is such that the national accounts aggregation condition for GDP in nominal terms holds.

Regarding external deflators, the M model assumes that the Portuguese economy is a price taker in international markets. Thus, export and import deflators—with the same breakdown as in Subsection 3.2—mainly follow competitors' prices on the export and import side in the long run, which are taken from the set of common assumptions underlying Eurosystem's projection exercises. The short run captures the pass-through dynamics of a shock in foreign prices, which may reflect, for instance, time and contractual lags or composition effects (equations B.28 and B.30). In the case of fuels, export and import deflators are linked to developments in oil prices. The deflators of exports of other services and of imports of services use simple rules. The exception to the price-taker framework is the deflator of exports of tourism, which is determined by domestic consumer prices (equation B.29).

3.4. *Labour*

In the labour block, the main equation refers to employment in the private non-housing sector, measured in full-time equivalents. In the long run, the level of employment is determined by the exogenous labour supply ($lntp_t$). Employment growth in the short run depends on developments in real wages and output, both adjusted for trend total factor productivity.

$$\begin{aligned}\Delta lnnp_t =& \beta^{lnnp} \cdot \Delta(wunp_t - yfdp_t - (tft_t/alpha)) + \Sigma_{i=0}^{1}\gamma_i^{lnnp} \cdot \Delta(yerp_{t-i} - \\ & (tft_{t-i}/alpha)) + \Sigma_{i=1}^{3}\varphi_i^{lnnp} \cdot \Delta lnnp_{t-i} + \lambda^{lnnp}(lnnp_{t-1} - lntp_{t-1})\end{aligned} \tag{14}$$

As expected from theory, employment growth is negatively related to real wage growth ($\beta^{lnnp} < 0$). The short-run elasticity of employment growth with respect to real output is about 0.4, split over two quarters ($\Sigma_{i=0}^{1}\gamma_i^{lnnp} \simeq 0.4$). The equation also includes lags of the growth rate of the dependent variable, to mimic employment inertia.

By assumption, no employment is considered in the housing sector, while employment developments are exogenous in the public sector (see Subsection 3.6 for more details).

3.5. *Financial sector*

The financial block accounts for interactions between the real economy and the financial sector in a stylised way. Under normal financing conditions and complete markets, interest rates clear the market for any credit demand level and, therefore, credit to the private sector can be obtained from the demand curve, under the assumption of a perfectly elastic credit supply. Changes in interest rates affect (i) the cost of capital and capital formation by firms, (ii) the housing market, both through real investment and house prices, and (iii) the intertemporal substitution underlying consumption decisions. Moreover, households' consumption and investment decisions are also influenced by income and wealth effects triggered by developments in the financial markets.

This block includes equations for bank lending rates and outstanding credit to the private sector in three different segments: non-financial corporations, mortgage lending to households and consumer credit. Households' debt service can be obtained by combining households' credit and lending rates.

The specification for bank lending rates is very similar across the different segments. Previous work on this topic can be found in Castro and Santos (2010). The long-run relationship is determined by the reference interbank interest rate (the 3-month EURIBOR, $EURIBOR_t$) and by an aggregate default probability indicator (PD_t). In the short run, developments in the lending rates reflect the evolution of $EURIBOR_t$, an assessment of the uncertainty outlook, proxied by changes in URX_t, and some inertia:

$$\begin{aligned}\Delta STN^k_t =& \beta^{STN^k} \cdot \Delta STN^k_{t-1} + \Sigma^1_{i=0} \gamma^{STN^k}_i \cdot \Delta EURIBOR_{t-i} + \varphi^{STN^k} \cdot \Delta URX_{t-1} + \\ & \lambda^{STN^k} (STN^k_{t-1} - C^{STN^k} - \psi^{STN^k} . EURIBOR_{t-1} - \zeta^{STN^k} \cdot PD_{t-1}),\end{aligned} \quad (15)$$

where $k = \{B, C, H\}$ denotes the segment, namely non-financial corporations, consumer credit and mortgage lending to households, respectively, and $\varphi^{STN^H} = 0$. The pass-through of $EURIBOR_t$ to financing costs is complete in the long run, except in consumer credit ($\psi^{STN^B} = \psi^{STN^H} = 1$ and $\psi^{STN^C} < 1$).

The default probability indicator mimics the financial accelerator effect discussed in Bernanke *et al.* (1996), through which credit market conditions contribute to amplify the effects of real or monetary shocks. In an adverse shock financial markets are also negatively hit and it becomes harder and more expensive to borrow money. In turn, this leads to further decreases in investment and spending, amplifying the slowdown in the economy. The default probability is modelled in a simple way, evolving with real GDP growth and an average nominal lending rate (STN^A_t), with some inertia in the short run (equation B.39).

Turning to outstanding amounts, credit to non-financial corporations (cre^B_t) depends positively on the nominal private non-housing capital stock ($ksnp_t$) and negatively on the financing costs, in the long run. The short-run dynamics is governed by fluctuations in STN^B_t, URX_t and in the underlying type of financed expenditure—nominal private non-housing gross fixed capital formation (ipn_t)—in addition to some inertia:

$$\begin{aligned}\Delta cre^B_t =& \beta^{cre^B} \cdot \Delta cre^B_{t-1} + (1 - \beta^{cre^B}) \cdot \Delta ipn_t + \gamma^{cre^B} \cdot \Delta STN^B_{t-1} + \varphi^{cre^B} \Delta URX_{t-2} + \\ & \lambda^{cre^B} (cre^B_{t-1} - C^{cre^B} - ksnp_{t-1} - \psi^{cre^B} \cdot STN^B_{t-1} - \zeta^{cre^B} \cdot EURIBOR_{t-1}),\end{aligned} \quad (16)$$

where static and dynamic homogeneity restrictions are assumed to hold. The equations for credit to households for housing acquisition (cre^H_t) and for consumption (cre^C_t) have similar specifications, where the underlying expenditures and financing costs are replaced by the relevant ones (equations B.41 and B.42).

Households' deposits and the fixed-term deposit rate are also included in the model. The fixed-term deposit rate is determined by $EURIBOR_t$ in the long run, while its developments in the short run are a function of banks' financing costs, proxied by changes in $EURIBOR_t$ and a simple average of bank lending rates (equation B.36).

The households' fixed-term deposit stock depends on households adjusted nominal disposable income and on the fixed-term deposit rate (equation B.43). Demand deposits use a simple rule involving adjusted nominal disposable income.

3.6. Public sector

The fiscal block describes public revenues and expenditures—for the general government sector as a whole, according to national accounts—and public debt. The macro-fiscal linkages contribute to enrich the M model and allow for a better understanding of (i) the reaction of fiscal aggregates to changes in the macroeconomic scenario and, conversely, of (ii) the reaction of the macroeconomic environment to changes in fiscal policies. For example, fiscal and demand blocks are linked through the impact of social transfers and households' income taxes on disposable income.

This block offers a quite extensive disaggregation of revenues and expenditures. Although many variables are modelled endogenously, there are some exogenous elements, especially on the expenditure side, given its more discretionary nature. For the current year, these exogenous elements are based on information included in official documents, such as the State Budget.

The revenue side includes a myriad of tax and non-tax revenues. In general, tax revenues evolve in line with the underlying tax base, acting in many cases as automatic stabilisers. According to Eurosystem's rules, tax rates are assumed to remain unchanged over the projection horizon, unless changes to statutory taxes or to taxation schemes have been approved or have been specified with enough detail and are likely to pass the legislative process.

The expenditure side is also quite detailed. Public consumption (gcr_t) results from a bottom-up approach, aggregating several variables. Its main items are compensation to public employees plus intermediate consumption and social payments in kind, to which the proceeds from the sale of goods and services are subtracted. Real compensation to public employees evolves in line with the exogenous dynamics of public employment. The evolution of the other components is mostly linked to activity, while in some cases, particularly for the current year, they may follow an exogenous path.

Developments in social transfers in cash depend on demographic and labour market developments, as well as on legislation in force, which includes, among other things, the pensions update formula. Social transfers also include the unemployment benefits, which act as an automatic stabiliser and mainly reflect the evolution of the unemployment rate. Public investment (gir_t) is either set exogenously, on the basis of information included in official documents, or evolves in line with GDP. Its profile also takes into account the expected absorption of European Union funds.

In general, prices and wages in the fiscal block take into account inflation developments. The main exception is the public gross fixed capital formation deflator (gid_t), with a specification close to those of private domestic demand deflators (equation B.44). Moreover, in the short term, the evolution of public wages takes into account the approved updates of the wage scale plus a wage drift due to promotions and progressions in careers. When relevant, composition effects related with the change in the wage structure are also taken on board.

Interest payments are calculated using the structure of public debt stock and the evolution of short- and long-term yields. Public debt results from a standard debt accumulation condition—debt in previous period plus fiscal balance (i.e., difference between total revenues and total expenditures) and any exogenous deficit-debt adjustment. No fiscal rule is incorporated over the projection horizon. With the exception of approved or well specified policies, the projection follows a no-policy-change scenario.

4. Simulations

This section reports the results of some key simulations to illustrate the main properties of the model in the short and medium run. The simulations compare a baseline scenario with an alternative scenario in which all exogenous assumptions are kept unchanged except one, the variable that is shocked. Thus, the simulations use a stylised approach to calculate, *ceteris paribus*, the mechanical impact of shocks.

The article presents simulations of five standard shocks, namely a foreign demand shock, a public consumption shock, an exchange rate shock, an oil price shock and an interest rate shock. The shocks are implemented in the variable level, starting in $2022Q1$ and lasting over a horizon of six years (i.e., 24 quarters). Note that the timing of the shock may affect the results, in particular because the baseline scenario is conditional on the shares of demand aggregates, which may change over time. For example, *ceteris paribus*, the impact of a foreign demand shock depends on the share of exports in GDP. These shares are constant only in the steady state. Moreover, it is important to bear in mind that this type of models may take some years to reach the steady state, as their speed of convergence tends to be low (Fagan *et al.* 2005; Berben *et al.* 2018).

The charts present the difference in percentages or percentage points (for the trade and current plus capital accounts) between the level of a variable in the shocked and the baseline scenarios, in each quarter.

4.1. Foreign demand

This shock corresponds to an increase of 1% in foreign demand for Portuguese goods and services. In response to this shock, Portuguese exports increase by 1% in the short run, implying a rise of 0.3% in GDP by the end of the first year (Figure 2).

Higher exports translate into demand pressures, boosting the demand for capital and labour services, and this triggers an increase in investment and employment, and a decline in the unemployment rate. In response to higher output per worker and to labour market tightness, wages increase. Households' purchasing power and, thus, private consumption rise as a result. The impact of higher exports in GDP is attenuated by the increase in imports, due to the high import content of exports.

In the medium run, positive spillovers to domestic demand increase and by year four GDP is 0.4% above the baseline. However, demand pressures implies an increase

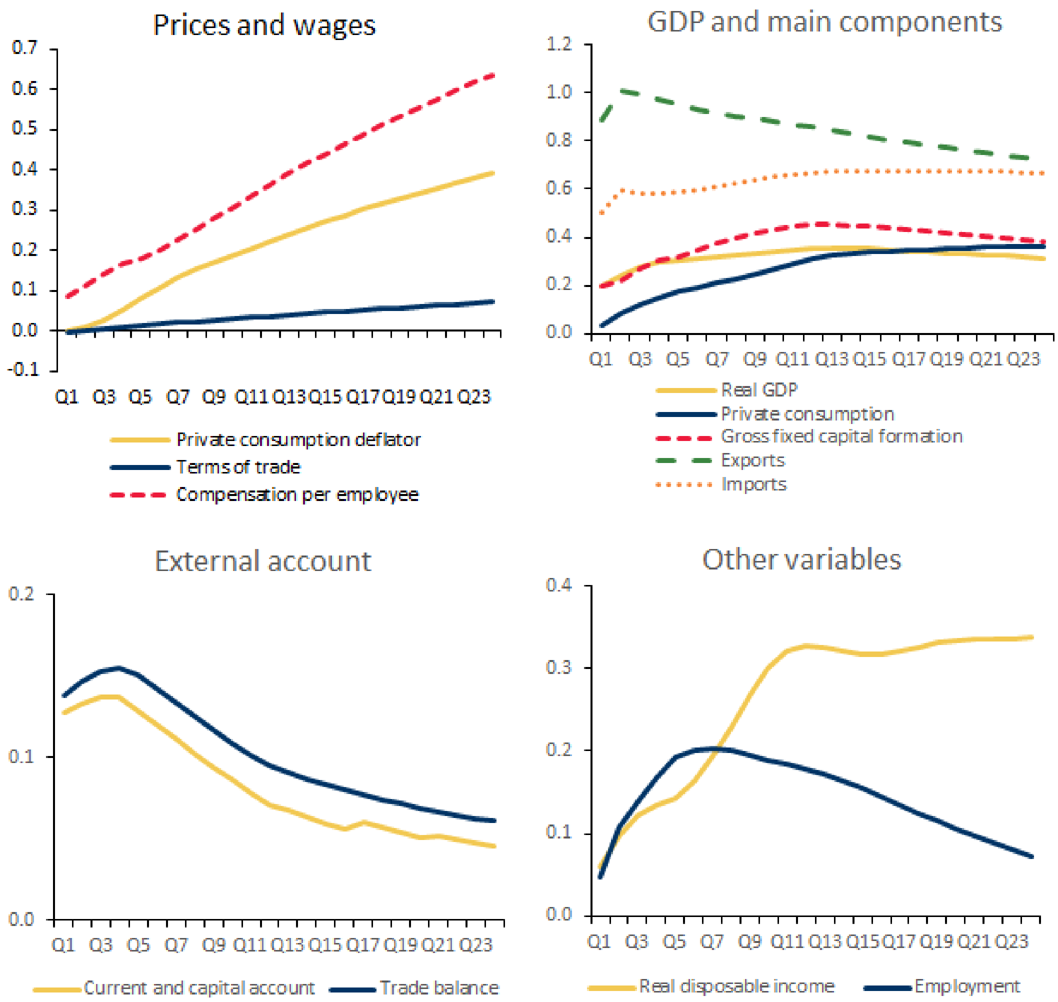

FIGURE 2: Effects of an increase of foreign demand by 1% | In percentage differences from baseline

Source: Authors' calculations.

in prices leading to a loss competitiveness, which attenuates the initial boost in exports. Over the horizon, exports slow down, standing at 0.7% above the baseline in the sixth year. Trade and current and capital account balances improve in the medium term due to higher exports and marginal gains in the terms of trade. The positive developments in domestic activity lead to higher tax revenues and lower unemployment benefits, which have a positive effect on the fiscal balance.

4.2. *Public consumption*

This shock corresponds to an increase in real public consumption by 1% of initial GDP driven by a change to real purchases of goods and services. The immediate and positive effect on GDP is amplified by the increase in business investment and private consumption (Figure 3). The former reflects the accelerator effect, while the latter derives from higher employment and real wages. Due to higher aggregate demand and a tighter labour market, wages and production costs rise, placing upward pressure

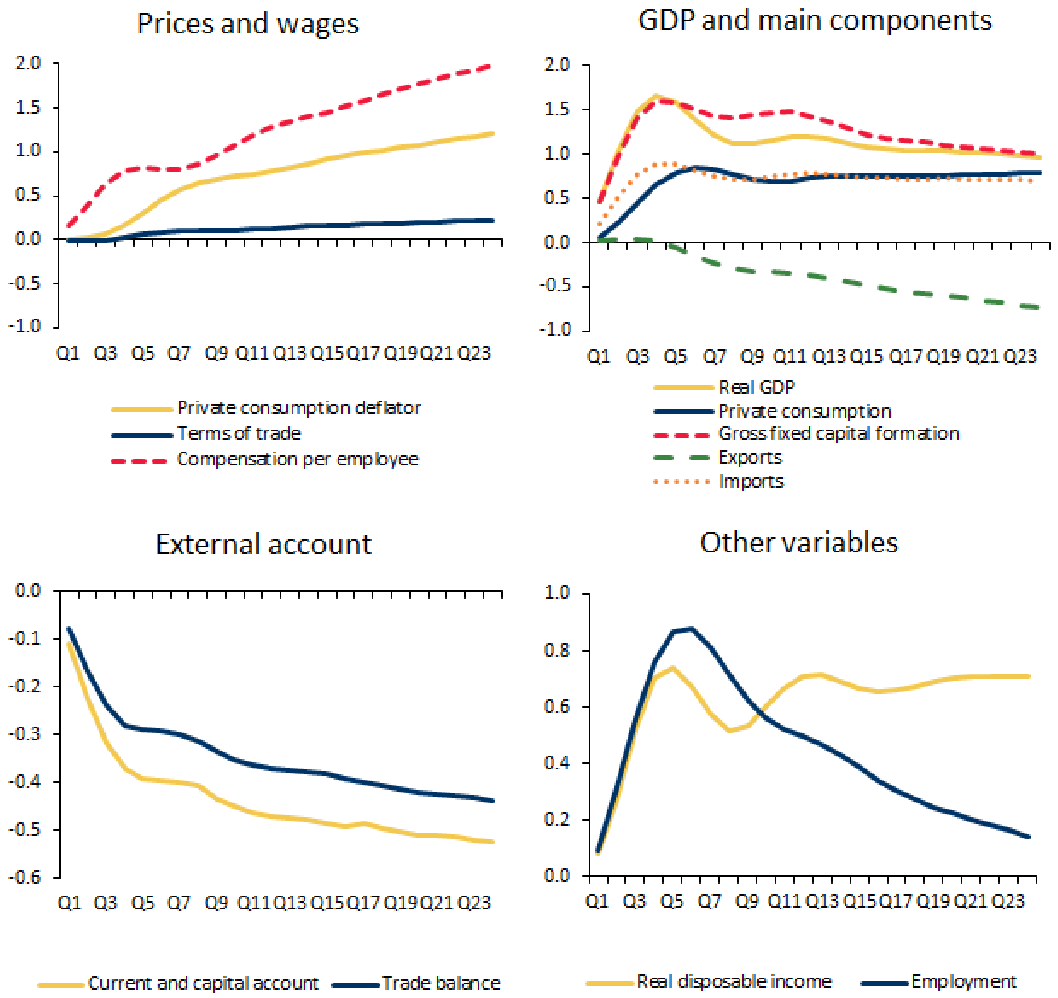

FIGURE 3: Effects of an increase in public consumption by 1% of initial GDP | In percentage differences from baseline

Source: Authors' calculations.

on consumer prices. Since nominal rates are kept unchanged, the rise in inflation results in a fall of real interest rates, amplifying the positive effect on consumption and investment. Higher prices also trigger a competitiveness loss and, thus, a decline in exports. The trade balance steadily deteriorates, reflecting the increase in imports, driven by higher domestic demand, and the competitiveness loss, triggered by the increase in domestic prices. Lower exports and the fading of the initial accelerator effect in business investment lead to a gradual downward adjustment in GDP.

4.3. *Nominal exchange rate*

This shock corresponds to an appreciation of the euro against all other currencies by 10%. This shock propagates through the model mainly *via* its effect on price competitiveness of exports and imports. Additionally, there is also an important channel *via* the impact on oil prices, since oil is traded on international markets in US dollars.

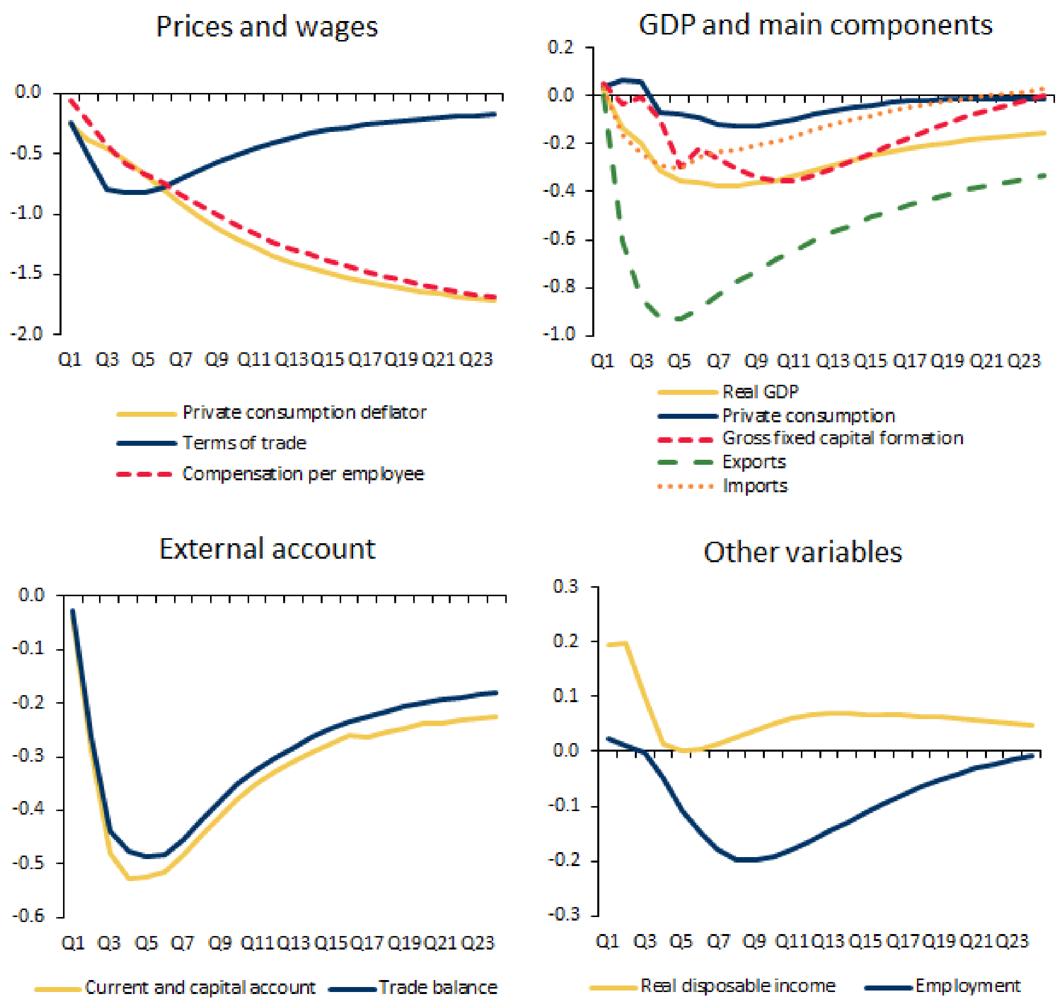

FIGURE 4: Effects of an appreciation of euro nominal exchange rate by 1% | In percentage differences from baseline

Source: Authors' calculations.

The pass-through effect on import and export prices is almost complete after six years. The appreciation of the euro makes Portuguese exports more expensive to consumers and firms outside the euro area. This translates into a reduction of exports and consequently of GDP, implying also a decline in imports due to lower demand (Figure 4). By the end of the first year GDP is 0.3% below the baseline level. The negative impact on imports is partially offset by the substitution of domestic production by imports, which are now cheaper. Lower demand triggers less investment and lower employment, implying an increase in the economy's slack. As wages and prices decrease, and real interest rate and unemployment increase, private consumption adjusts downwards. The lagged effect of a higher real interest rate leads to some volatility in the second year of the investment profile.

The adverse economic developments lead to lower tax revenues and higher unemployment benefits, both having a negative effect on the fiscal balance. The nominal trade balance deteriorates slightly, reflecting the volume effect that offsets the nominal impact of euro appreciation.

Over the medium term, the negative effect on exports due to the price competitiveness loss is gradually attenuated and after six years GDP is 0.2% below the baseline. This effect reflects the decline in domestic deflators, reinforced as lower import prices pass-through the production chain.

4.4. *Oil prices*

This shock corresponds to an increase of 10% in oil prices in international markets, in US dollars. The simulation assumes that the oil price is about 85 dollars per barrel in the baseline scenario. An increase in the price of imported oil products leads immediately to higher consumer prices, implying also an increase in wages and domestic production costs (Figure 5). Notwithstanding the increase in nominal wages, real wages decline, implying a reduction in real disposable income and, hence, in private consumption.

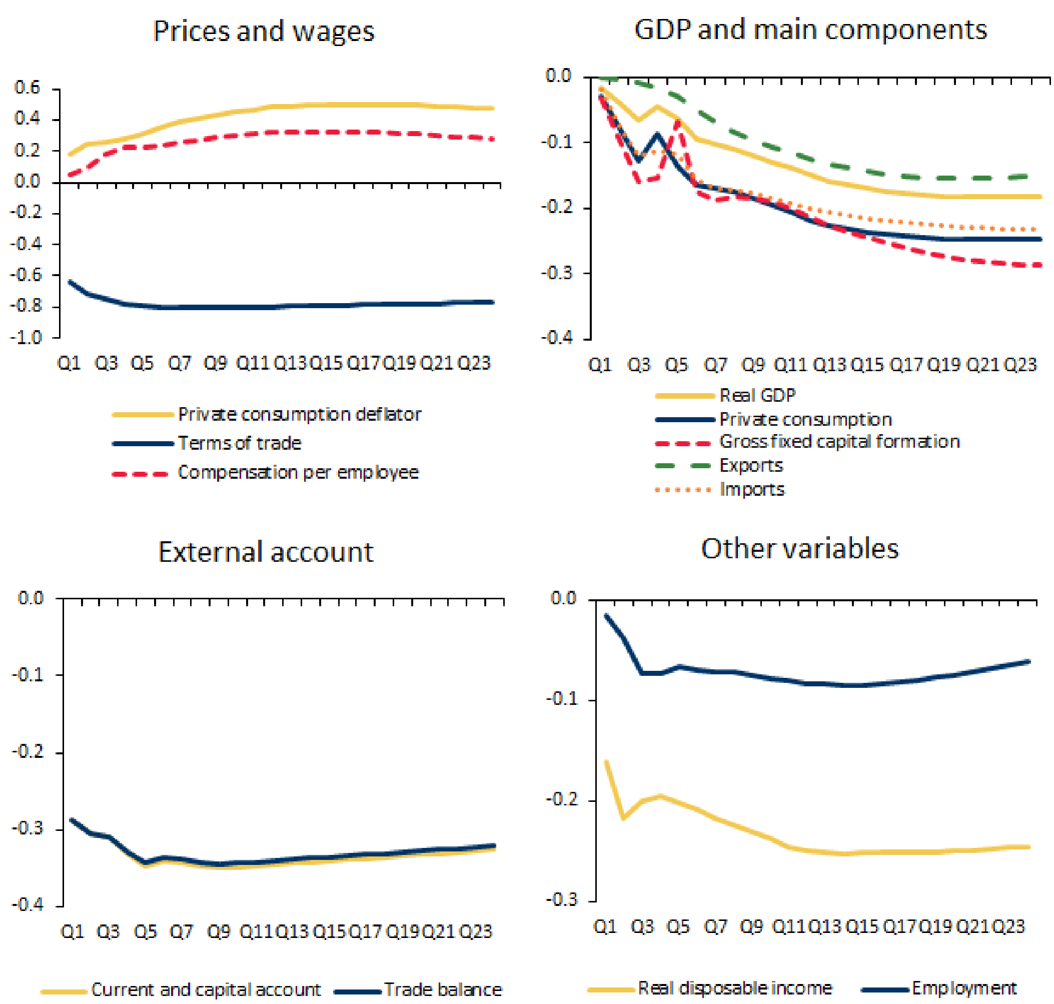

FIGURE 5: Effects of an increase in oil prices by 10% | In percentage differences from baseline
Source: Authors' calculations.

The increase in the production costs causes a decline in competitiveness and, therefore, exports fall. Less production leads to lower input demand, which affects negatively investment and employment. There is some volatility in the second year of the investment profile, which is linked to the lagged effect of the decrease in the real interest rate. In this context, terms of trade and the trade balance deteriorate. The fiscal balance also deteriorates, reflecting lower production and employment, which lead to lower tax revenues and higher unemployment benefits.

4.5. *Interest rates*

This shock corresponds to an increase in short- and long-term domestic interest rates by 100 basis points. Higher interest rates affect the economy through various channels and have a negative impact on the activity of firms, households, and the government. The borrowing costs of firms increase, affecting the cost of capital and the optimal capital stock. Lower demand for capital goods implies lower production and lower business investment and employment (Figure 6).

Real wages also decline due to lower productivity, since employment adjusts more slowly than activity. These developments result in lower real disposable income and consumption. Households' debt service increases following the interest rate hike, which contributes to a further decline in private consumption. Additionally, higher interest rates increase the opportunity cost of consuming, favouring a delay in spending and an increase in savings. The increase in interest rates also translates into lower demand for housing, placing a downward pressure on house prices and triggering a negative wealth effect that reinforces the reduction in private consumption. In turn, the negative impact on activity translates into lower domestic prices, implying marginal gains in competitiveness, which favours exports and contributes to slightly attenuate the negative impact on activity.

The trade balance steadily improves, mainly reflecting the decrease in imports, driven by lower domestic demand, especially investment and private consumption. Overall, the adverse impact on activity and labour market implies lower tax revenues and higher unemployment benefits, reducing the fiscal balance and increasing public debt. The increase in interest rates also implies a larger interest bill on public debt.

5. Final remarks

Models should be seen as a valuable tool to improve our reasoning and to help interpreting agents' behaviour. The *M* model has been a useful tool for empirical purposes over the years, especially in the context of projection and simulation exercises.

However, three important points underlying its utilisation must be stressed. Firstly, all models are probabilistic in nature, i.e. they generate results with some degree of uncertainty. This arises partly from uncertainty about estimated parameters and partly from the structure of the model itself. Therefore, the *M* model is one tool within an eclectic framework that includes other models and indicators, all contributing to inform the projection and simulation exercises. This broader set of tools includes large-scale models, such as the PESSOA model (Júlio and Maria 2017), and satellite models addressing specific topics, such as short-term developments (Lourenço and Rua 2021), inflationary pressures (Serra 2018) and potential output (Duarte *et al.* 2020).

Secondly, the information plugged into the model is also subject to uncertainty, especially the exogenous set of assumptions. The M model should not be seen as a tool for obtaining the best prediction of future developments, but rather as a way of building consistent projections, if a set of exogenous assumptions follows a certain path.

Finally, the M model has been extended and adjusted over the years, and will continue to be developed and improved, in order to better respond to the challenges of an ever-changing reality.

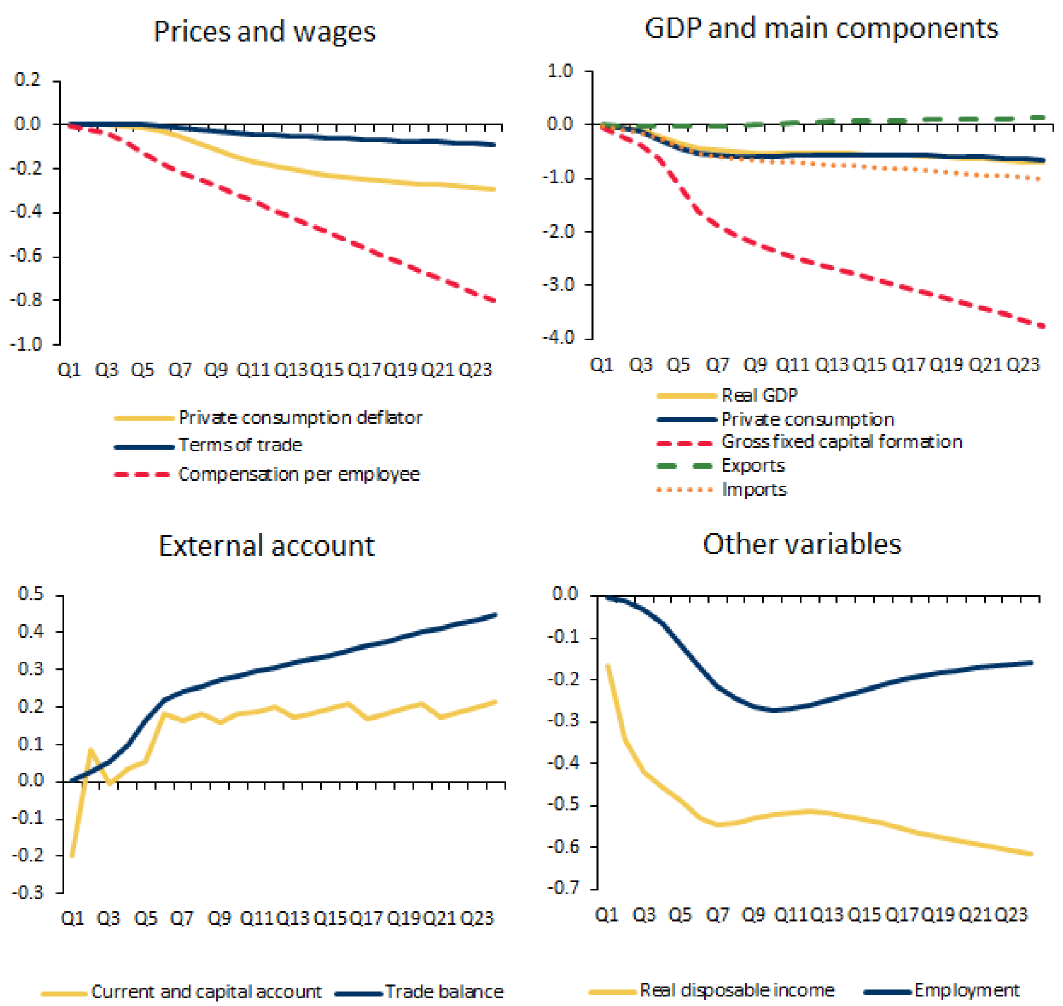

FIGURE 6: Effects of an increase in short-term and long-term interest rates by 100 basis points | In percentage differences from baseline

Source: Authors' calculations.

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Non-technical summary

April 2023

The inflation process in Portugal: the role of price spillovers

João Quelhas and Sara Serra

In 2022, similarly to what happened in most advanced economies, inflation in Portugal recorded high levels (8.1% on average in 2022, as measured by the Harmonized Index of Consumer Prices - HICP). The increase in inflation in Portugal was particularly significant from July 2021 onward, reflecting, to a large extent, the impact of supply side bottlenecks, accentuated by developments in energy and food prices following the invasion of Ukraine by Russia. In addition, these effects propagated through the production chain to the prices of the remaining goods and services. The article analyses the role of price spillovers — defined as the extent to which the price of each of the main HICP aggregates is affected by shocks in the remaining components — in recent developments of prices in Portugal.

To assess price spillovers, a Bayesian Vector Autoregression model was estimated for the five main components of HICP, drawing on the work developed by Borio *et al.* (2023). The measure of spillover effects corresponds to the contribution of a shock in the price index of each component to the forecast error variance of the remaining. For the identification of spillovers, two HICP samples were considered, 2011-2019 and 2011-2022, to distinguish the impact of the recent inflation period on the results.

The article concludes that around 25% of HICP developments between 2011 and 2019 is explained by spillovers, a percentage that increases to 30% when the sample is extended until the end of 2022. This increase mainly reflects the fact that spillover effects become more prolonged in time, i.e., the impact of a shock in the price of an aggregate percolates over more months to the price of the remaining.

The most significant change when we compare the two sample periods comes from the processed food component, that has higher indirect effects on the others, as can be observed in Figure 1. This shows the role of each aggregate as the source of spillover effects in each sample, i.e., the share of price volatility of the remaining aggregates that is explained by each component, over a 12-month horizon. One can conclude that between 2011 and 2019 the effects coming from the processed food component explained only 5% of the overall variance of prices, while over the extended period, this figure rose to 45%.

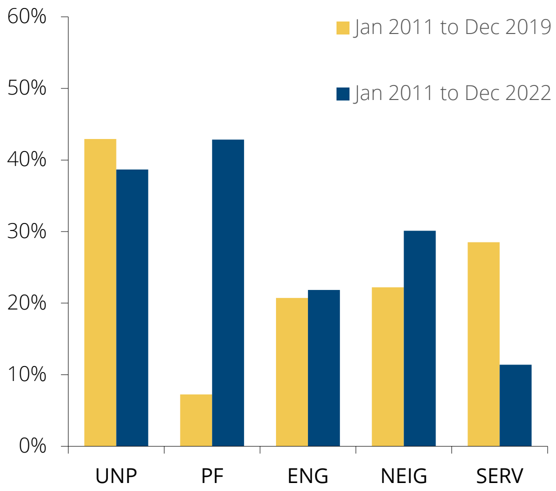

FIGURE 1: Sources of spillover effects from inflationary pressures by component | Percentage

Notes: UNP - Unprocessed Food, PF - Processed Food; ENG - Energy goods; NEIG - Non-energy industrial goods; SERV - Services. The effect of each component as a source of spillovers corresponds to the percentage of the price volatility of the other aggregates that it explains, over a 12-month horizon. Two sample periods were considered: 2010 M1 to 2019 M12 and 2010 M1 to 2022 M12.

Then, the article develops an inflation indicator, designated as *common inflation*, that aims at capturing changes in prices that are broad-based, as opposed to changes that are specific to individual items or due to measurement errors. This *common inflation* indicator was estimated on the basis of a dynamic factor model, in line with the one in Luciani (2020). According to Smets *et al.* (2018), the increasing impact of spillovers should be reflected in this common component of inflation. In the case of Portugal, headline and *common inflation* have evolved in a broadly similar way over the past 20 years. In the end of 2022, the two surged above 8%, suggesting that the common component explains a larger share of the recent variability in individual price changes.

Since the start of the war in Ukraine, the increase in *common inflation* has been mainly due to a rise in food prices. These dynamics have later propagated to the remaining components, as at the end of 2022 almost half of the increase in *common inflation* was due to the less volatile components, i.e., non-energy industrial goods and services, possibly reflecting stronger spillovers, a result in line with the first part of the article.

Given that the direct effects of recent external shocks, initially reflected in only a few HICP items, have spread to many other prices, as is apparent from an increase in spillover effects, their impact in inflation has become more broad-based, translating into widespread inflation pressures.

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The inflation process in Portugal: the role of price spillovers

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April 2023

Abstract
The recent rise in inflation was initially driven by external shocks and restricted to some items, becoming increasingly entrenched over 2022. In this article, the role of price spillovers in the generalization of inflationary pressures is analysed. Spillover effects rose in the post-pandemic period and are more important for a longer period due to a higher transmission across sectors. This suggests that relative price changes are more likely to propagate to underlying inflation as they echo more into other components. The measure of *common inflation* built confirms this trend as it shows that co-movement across a large number of prices has been the main driver of headline inflation. **Keywords**: inflation, spillover effects, Bayesian VAR (JEL: C11, C38, E31)

1. Introduction

Inflation in Portugal has surged significantly since July 2021, attaining levels not seen in the preceding thirty years (8.1% on average in 2022). After nearly a decade of inflation consistently below 2%, the shift in the inflationary process happened remarkably fast, similarly to what occurred in most advanced economies. The recent upward trend is the outcome of different, but interconnected and mutually reinforcing factors. The economy's reopening following the pandemic, aided by economic policies supporting activity, prompted a quick and intense recovery characterized by high demand for goods that the supply chains were unable to adequately fulfill. Additionally, the invasion of Ukraine by Russia led to an increase in import prices for energy and food items, exacerbating supply-side bottlenecks. The higher costs of these commodities were translated directly into higher consumer prices. In addition, they may have propagated through the production chain due to spillovers of inflationary pressures across sectors,

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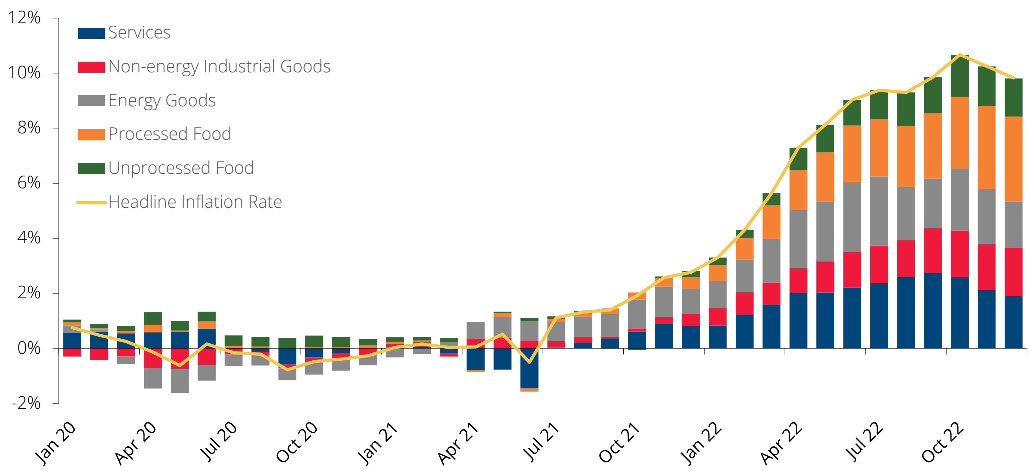

FIGURE 1: Year-on-year HICP inflation rate and its decomposition | Percentage

Sources: Eurostat and authors' calculations.

turning into a broad-based inflation.

Initially, the hike in prices was restricted to a limited number of items. In December 2021, the share of items of the Harmonized Index of Consumer Prices (HICP) with a year-on-year rate of change higher than 6% was around 10%.[1] The relative price changes resulting from supply and demand imbalances took place on items with comparatively flexible prices, such as oil, which boosted fuel prices. These seemed, at the beginning, short-lived and reversible movements in the inflation rate. However, with the invasion of Ukraine, food items were abruptly impacted and, to a smaller extent, services and non-energy industrial goods as well, as reported in Figure 1. The share of items in the consumption basket with prices growing at a pace faster than 6% grew to 49% in December 2022. The generalization of inflationary pressures suggests that the greater dynamism of the prices of more volatile goods, affected by the large shocks, was extended to the typically more stable components, which is currently visible in an increase of the underlying inflation measures.

There is evidence in the literature that a high inflation environment is characterized by higher price spillovers across sectors because it amplifies the transmission of both economy-wide and idiosyncratic shocks to all prices (BIS (2022)). One consequence of this is that relative price changes are more likely to propagate to underlying inflation as they echo more into other components. Therefore, it is important to better understand how price spillovers are currently shaping the growth of prices in Portugal and how they are associated with broad-based inflation. In this article, these topics are explored on the basis of HICP data by employing two complementary and empirical approaches.

To begin, the spillover effects of inflationary pressures across the main HICP components are measured and their relevance to the variation of prices over time is assessed. This entails the estimation of a Bayesian Vector Autoregression (BVAR) model,

1. The data considered includes 126 items with a 4-digit level of disaggregation, under the Classification of Individual Consumption by Purpose (COICOP).

drawing on the work developed by Borio *et al.* (2023). The estimates from the model are used to compute generalized impulse response functions (GIRF) and the respective matrices of generalized forecast error variance decomposition (GFEVD) for different horizons. The off-diagonal elements of such matrices express the fraction of the variance in each component's inflation rate that results from changes in other components, controlling for the macroeconomic factors driving prices. A conclusion of this analysis is that price spillovers rose in the post pandemic period, meaning that idiosyncratic shocks in each component are transmitted more intensely across sectors. The most significant change in the sources of effects when comparing the period from 2011 until 2019 with the one that includes data until 2022 stems from processed food items. The rise in spillovers between the two sub-samples is not due to a higher contemporaneous correlation of idiosyncratic shocks but rather to the transmission of those through the lag structure of the model, with the effects remaining relevant for longer periods. Finally, when the analysis is extended by including producer price indices (PPI) in the model to examine the dynamics of spillover effects along the production value chain, the results for HICP still hold but the index of total spillovers more than doubles.

Next, this article aims to validate the result of a recent increase in spillovers with a totally diverse approach. A measure of *common inflation* is constructed to assess whether hikes in prices have been driven by common or idiosyncratic shocks and confirm the generalization of the inflationary pressures in the post-pandemic period. This measure is a statistical instrument that captures co-movement across a panel of disaggregated HICP items using a dynamic factor model (DFM) in line with the one developed by Luciani (2020). The inflation rate of each item is decomposed into two components: a common component, which corresponds to price changes that are attributable to economy-wide factors, and an idiosyncratic part that captures fluctuations over time specific to that item or a small group of them and measurement errors. According to Smets *et al.* (2018), the impact of spillovers should be reflected in this common component, which is found to increase substantially over 2022. Additionally, the instabilities and unusual co-movement across many prices resulting from the Ukraine invasion by Russia are accounted for as their impact on parameter estimation in February 2022 is analyzed. The model suggests that headline and *common inflation* have generally been synchronized over the past 20 years. In the end of 2022, the two surged above 8%, as the common component explains a larger share of the total variability of individual price changes.

One could expect that once the external shocks began to subside, inflation would decay. However, since the most affected items have moved jointly with many others, the impact caused by those has been converted into broad-based inflationary pressures. Their magnitude, aligned with the higher connectedness of prices, have contributed to recent broad-based inflation wave.

Related literature. This article draws on two main streams of the empirical literature on inflation. The first part of the article follows closely on the work by Borio *et al.* (2023) and its application in BIS (2022), in which they measure the spillovers of prices across sectors and how they have changed over time. This study resorts to a BVAR model to study the relationships across different categories of the U.S. Personal

Consumption Expenditures (PCE) deflator, controlling for macroeconomic variables like economic slack or commodity prices, that account for the common drivers of several PCE components. Borio *et al.* (2023) find evidence of stronger spillovers in the high inflation regime that preceded the Great Moderation. Gasoline and food items stand out as the main origins of spillovers. This analysis is extended in BIS (2022) by adding producer prices to the model, which leads to the conclusion that spillovers are higher across PPI components and that they are stronger in the direction from PPIs to PCEs rather than otherwise. The methodology used in this article and in Borio *et al.* (2023) comes from the seminal work for the literature on financial volatility and international business cycle spillovers by Diebold and Yilmaz (2009). This was extended in Diebold and Yilmaz (2012) by setting aside the need for a Cholesky-type structural identification scheme, which makes results dependent on the order of variables in the VAR.

Borio *et al.* (2023) present a two-regime view of inflation. While inflation tends to be selfstabilising in the low-inflation regime, it is especially sensitive to relative price increases in the high-inflation one. Fiore *et al.* (2022) argue that an increase in sectoral price spillovers can signal a transition from a low to a high inflation regime. Corsello and Tagliabracci (2023) focus on the transmission of energy price shocks to other inflation components, on the basis of a Structural VAR for the euro area and Italian data. They find a sizable pass-through to food inflation, but a more limited transmission to core inflation. Even though this methodology is used in the current study to estimate inflation connectedness within the Portuguese economy, this method has also been used to analyse spillovers between countries (Álvarez *et al.* (2019) and Hałka and Szafranek (2016), for example). The results in these studies suggest that spillovers to core components are weaker than to more volatile ones.

Price spillovers are found to increase when the sample is extended to include data up to 2022. The fact that spillovers increase in a period of high inflation is in line with the literature on non-linear transmission of shocks to inflation and non-linearities in the output-inflation nexus (see Dupasquier and Ricketts (1998) for a review). Bäurle *et al.* (2021) analyse the transmission of external shocks to Swiss inflation, concluding that a part of the impact is likely mechanical (direct), but general equilibrium effects (spillovers) are important as well. The importance of spillovers effects also seems to vary with the underlying shocks, with energy playing a prominent role. Bobeica *et al.* (2019) find shock-dependent pass-through effects of labor costs to prices, which are systematically lower in periods of low inflation as compared to periods of high inflation. Forbes *et al.* (2021) find that the Phillips curve is linear and steep in periods of high inflation, which is consistent with evidence of downward nominal wage and price rigidity, but flat otherwise. Ball and Mankiw (1994) show that in a staggered price setting environment with the presence of menu costs large shifts in relative prices correspond to adverse supply shocks and that this effect is asymmetric, given that when shock raises some firms' desired prices and lowers others', the desired increases trigger greater price adjustment than the desired decreases.

If the post-pandemic period involves a stronger transmission of relative price changes across HICP components, an idiosyncratic shock to a component can become more easily a broad-based movement in the headline inflation rate. BIS (2022) argue that a period of low inflation is characterized by lower inflation volatility, and this decrease happens because the covariance between individual prices changes. Thus, spillovers are expected to increase their role as drivers of overall HICP in the recent inflationary period. To assess this, each item of the consumption basket is decomposed into an idiosyncratic component and a common component. This common component tries to capture a broad-based and sustained increase in prices and is estimated on the basis of a DFM, drawing closely on Luciani (2020). Smets *et al.* (2018) conclude, on the basis of the results of a multi–sector dynamic stochastic general equilibrium model, that the impact of spillovers tends to be included in the common component of a DFM. Moreover, they conclude, resorting to US PPI and PCE data for 1970-2007, that, due to price stickiness along the supply chain, pipeline pressures are an important source of inflation persistence and volatility.

Several articles analyse inflation developments by separating broad-based movements from idiosyncratic ones (Boivin *et al.* (2009), Kaufmann and Lein (2013), De Graeve and Walentin (2015), Dixon *et al.* (2014), Cristadoro *et al.* (2005), Amstad *et al.* (2017), etc.). Some of them resemble the current article more because they restrict the dataset of analysis to consumer prices at a detailed level (Borio *et al.* (2021), Maćkowiak *et al.* (2009), Conflitti (2020)). The measure that most resembles the approach adopted in this article is the one of Reis and Watson (2010), which try to quantify "pure" inflation from a dataset of disaggregated U.S. inflation items. This measure differs from the *common inflation* indicator computed in this article due to additional technical constraints imposed on the estimation. In addition, in this article the overall *common inflation* measure is constructed by aggregating the common component of each detailed consumer price item with the original HICP weights, thus preserving the original structure. In the same vein, Bańbura and Bobeica (2020) use a generalized dynamic factor model based on data across 12 euro area countries to construct the Persistent and Common Component of Inflation index. This measure excludes from the common component cycles with a length shorter than three years. Some of these studies analyse the properties of the underlying inflation indicators obtained, namely their forecasting ability of the headline. This analysis is beyond the scope of this article.

An extension of Luciani (2020) assesses the impact of the Covid-19 pandemic on prices. This is achieved with a counterfactual built by estimating the model up to the beginning of the pandemic and comparing the common component obtained with the result from the full sample estimation. Potjagailo *et al.* (2022) apply this methodology to U.K. inflation and extend it by considering the impact of the Ukraine invasion by Russia from February 2022 onward, finding similar results to the ones presented here.

Roadmap. The rest of the article is organized as follows. Section 2 presents the measures of spillovers across HICP components for the time frames considered. Section 3 focus on the construction of the *common inflation* indicator and the role of price spillovers on the recent generalization of inflationary pressures. Section 4 concludes with final remarks.

2. Price Spillovers

This section measures price spillovers across the five main components of the HICP. For that purpose, a BVAR model is estimated in line with the one in Borio *et al.* (2023), to analyse how year-on-year rates of change of the price index of the components are affected by a specific shock in each of the other ones over time, when accounting for the developments in the main macroeconomic drivers of inflation as exogenous variables.

2.1. *Model Specification*

The infinite moving average representation of the BVAR model allows to compute generalized impulse response functions (GIRF) for different horizons and then to construct static spillover measures, as shown in the work by Diebold and Yilmaz (2009, 2012). While the traditional impulse response function answers the question of an impact hitting the system if no other shocks happen, the GIRF considers the situation of a multivariate model with contemporaneous correlated shocks by adjusting for them on the basis of the estimated parameters of the variance-covariance matrix (Koop *et al.* (1996)). In the application of this article, the restrictions imposed by a recursive ordering of the endogenous variables entering the BVAR would be difficult to justify from a theoretical perspective. The approach followed in this article does not require the orthogonalization of the shocks and thus is invariant to the ordering of the system. Furthermore, it fully accounts for the historical patterns of correlations across errors, which is not true in a Structural VAR. Assuming the property of Gaussianity, the GIRF for a shock to a variable j at horizon h is given by:

$$\gamma_j\left(h\right) = \ E_{t-1}\left(x_{t+h} \middle|\ \varepsilon_{j,t} = 1\right) - E_{t-1}\left(x_{t+h}\right) = {\sigma_{jj}}^{-\frac{1}{2}} A_h \Sigma e_j, \tag{1}$$

where e_j is a selection vector with unit values in the j^{th} position and zeros elsewhere. It is possible to extract each entry from the vector of GIRFs, so that $\gamma_{ij}\left(h\right)$ corresponds to the response of the variable i to a shock to the variable j for the horizon h.

Then, GIRFs can be used to construct the matrix with the general forecast error variance decomposition at h-horizon with each element calculated as:

$$\lambda_{ij}(h) = \frac{\sum_{l=0}^{h} \gamma_{ij}(h)^2}{\sum_{j=1}^{N}\sum_{l=0}^{h} \gamma_{ij}(h)^2}. \tag{2}$$

Given that shocks are not orthogonal, the sum of contributions to the forecast error variance do not necessarily sum to unit and the following normalization, suggested by Diebold and Yilmaz (2012), is imposed:

$$\widetilde{\lambda}_{ij}\left(h\right) = \frac{\lambda_{ij}\left(h\right)}{\sum_{l=1}^{N} \lambda_{il}\left(h\right)}. \tag{3}$$

The main diagonal of the matrix $\widetilde{\lambda}_{ij}(h)$ defines own variance shares, i.e. the fraction of the h-step-ahead forecast error variance of variable i explained by shocks to x_i, while the remaining entries $\widetilde{\lambda}_{ij,i\neq j}(h)$ are cross variance shares, defined as spillover effects. These correspond to the fractions of the h-step ahead error variances in forecasting the variable i due to shocks to a variable j, when $i \neq j$. Each column of the matrix $\widetilde{\lambda}_{ij}(h)$ shows the spillover effects from variable x_j to all variables $x_{i,i\neq j}$, in the role of x_j as an origin of spillovers. Each row of the matrix $\widetilde{\lambda}_{ij}(h)$ defines the spillovers received by variable x_i from shocks to all variables $x_{j,i\neq j}$, in the role of x_i as a destination of spillovers. Finally, an index of total spillovers is constructed in order to capture the sum of spillover effects across variables relative to the total forecast error variation:

$$S_t(h) = 100 \frac{\sum_{i,j=1,i\neq j}^{N} \widetilde{\lambda}_{ij}(h)}{\sum_{i,j=1}^{N} \widetilde{\lambda}_{ij}(h)}. \tag{4}$$

2.2. *Data and Estimation*

The data used is the HICP at the two-digit level of disaggregation of the Classification of Individual Consumption by Purpose (COICOP): unprocessed food (UNP), processed food (PF), energy goods (ENG), non-energy industrial goods (NEIG) and services (SERV).[2] Log changes were considered as they allow to extract the decomposition of the shocks directly from the model, without retrieving the deterministic trend that tends to dominate the results with data in levels.[3] Although more disaggregated versions of the model have been estimated, results over different sub-samples proved more stable at this level of aggregation. This is also the most common level of analysis of HICP developments for euro area countries. As an extension, upstream price spillovers are also investigated by including producer price indices in the model. A level of aggregation of PPI items similar to the one of the HICP is considered for consistency of the analysis.

Seasonally and calendar adjusted HICP monthly data was provided by the European Central Bank (ECB). The BVAR was estimated over two sub-samples: the first starts in January 2011 and ends in December 2019 while the second is extended up to December 2022. The selection of time frames was chosen based on two key considerations. Firstly, it's well-established that spillover effects may vary over time. Given the data availability for the PPI series that starts in 2011, for coherence the results for the two versions of the model were estimated with the same time window. Nevertheless, Figure **??** of the Appendix reports the results obtained with different sample starting dates. The main results still hold for the time frames tested, providing further confidence in the validity of the conclusions here presented. Moreover, to ensure a sufficient number of degrees of freedom, the last years of the sample are not isolated from the period before.

The model includes six lags of the endogenous variables. It comprises also a set of exogenous variables to capture the macroeconomic shocks that potentially affect all

2. Note that the statistical production, in particular price collection, were affected by restrictions imposed during the pandemic. Some prices had to be collected using alternative sources and others were imputed (check Statistics Portugal press release of the April 2020 CPI). It is not possible to infer how this may have affected the results presented, but its impact is expected to be limited, given that the share of expenditure in the HICP affected by imputation quickly became negligible after the initial months of the pandemic.

3. For further detail on the Bayesian VAR estimation in rates of changes, check Ferroni and Canova (2021).

HICP components at the same time. The endogenous part of the BVAR thus models the remaining drivers of prices: idiosyncratic shocks that may be transmitted across HICP components. The exogenous variables considered include the short-term interest rate, oil prices in euros and the import deflator excluding energy goods, the year-on-year growth rate of hourly compensation per employee and the amount of slack in the economy as measured by the unemployment gap.[4] [5] The last two were included with a three-month lag and interpolated to monthly frequency using the Litterman method (Litterman (1983)). Dummies were included to account for Value Added Tax rate changes that took place in January and November 2011 and March 2012 and that did not affect all items uniformly. For the estimation of the BVAR, a Litterman/Minnesota prior was considered, along with with the following parameterization: $\lambda_1 = 0.1$, $\lambda_2 = 0.99$, $\lambda_3 = 1$, $\lambda_4 = \infty$, $\lambda_5 = \infty$, 500 iterations and a burn-in percentage of 10%.

2.3. *Main Results*

Figure 2 shows the estimated 12-month horizon forecast error variance decomposition for the two sub-samples in the form of matrices, where the darkest color denotes higher spillover effects from the source component (in columns) towards the destination component (in rows). Each element reports the share of the variance of the year-on-year rate of change in the price of each aggregate that is explained by a shock in each of the remaining ones, controlling for common and generalized drivers of inflation.

Price spillovers rose in the post-pandemic period, meaning that idiosyncratic shocks in each component are transmitted more intensely through the production chain and have a greater impact on the price volatility of the others. Even though the own variance shares (the main diagonal of the matrix) explain the majority of the total variance of forecasting errors, this shift may be relevant for the inflation dynamics. In the shorter sub-sample, it is worth noting the effects of idiosyncratic changes to unprocessed food prices on processed food items (21%), as the former is an essential input for the production of the latter, and in both energy and non-energy industrial goods aggregates, with magnitudes of about 8% and 9%, respectively. Besides these, one must highlight the inflationary pressures originated from non-energy industrial goods towards processed food prices, summing up to 8,5%.

With the extension of the sample period until the end of 2022, not only the bilateral spillover effects became more intense, but also new channels of transmission emerged. The increased connectedness in periods of higher inflation is also found in the work by Borio *et al.* (2023). In this case, the role of processed food as a source of effects gains relevance. A shock to this component now generates substantial price spillovers for unprocessed food, non-energy industrial and energy goods, in a descending order of magnitude. Changes in the prices of energy goods also show a stricter co-movement

4. Unemployment gap is measured as the difference between observed and trend unemployment rates. For further details on the methodology to compute the trend unemployment rate, see Duarte *et al.* (2020).

5. Data points for 2022 Q4 for the import deflator excluding energy goods and hourly compensation per employee correspond to projections published in Economic Bulletin of Banco de Portugal December 2022.

with the prices of food items as a whole, summing to 18,5% in total. These two results corroborate with the ongoing impact of the invasion of Ukraine on food and energy. Furthermore, the NEIGs stand out as the origin of spillover effects, i.e. through contagion of the remaining categories, mainly influencing processed food prices, possibly because of their return to growth in 2021 after several years of decline.

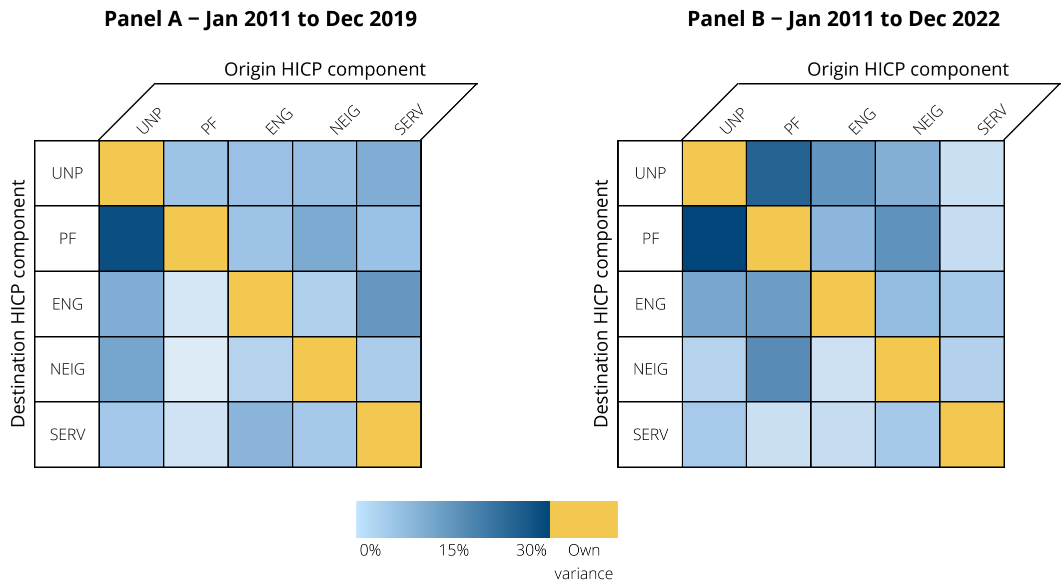

FIGURE 2: Spillover effects across HICP components for a 12-month horizon | Percentage

Sources: ECB, Statistics Portugal and authors' calculations. Notes: UN – Unprocessed Food; PF - Processed Food; EN - Energy Goods; NEIG - Non-energy Industrial Goods; SERV – Services. The spillover effect is assessed by the proportion of the variance of the year-on-year rate of change in the price of each aggregate that is explained by a one standard-deviation shock in each of the remaining HICP components, controlling for common and generalized variations in the economy. The reading of the matrix is as follows: each element represents the percentage of the variance of the year-on-year rate of change of the price of the component in the respective row explained by a one standard deviation shock to the year-on-year rate of change of the price of the component in the respective column. The goal is to analyse the spillover effects across categories, so the diagonal elements, which are based on GIRFs of a category to impulses on itself, are omitted (in yellow). The darkest the blue color the higher is the magnitude of the spillover effects. Given the normalization presented above, the sum of contributions to the forecast error variance of each variable, presented in each line, sums to unit. The same is not necessarily true when summing the contributions from each variable, given by each column. The respective percentage values for each element of the two matrices are shown in Table A.1 of the Online Appendix.

The analysis of the aggregate effect of each component as destination or source of effects confirms the rise in the intensity of spillover effects. For this assessment, the following measures were calculated for a 12-month horizon: sum of the percentage change in the price of each component that is explained by a shock in each price of the remaining components (destinations), and sum of the percentage change of the other categories' price volatility explained by a shock in each component (sources).

Figure 3 compares the directional spillovers across the two sub-samples. Prior to the pandemic, processed food items were the most affected by pressures stemming from the other components, which explain more than 40% of its forecasting variance unrelated to exogenous variables. The categories of unprocessed food and energy goods also were the destination of a considerable level of indirect effects. Conversely, the main source of spillover effects to other goods and services was the unprocessed food aggregate, being responsible for almost 43% of their total variance, mainly due to its impact on the processed food component. The degree of spillovers increases when the sample is extended to 2022. Processed food remains as the most affected, but now unprocessed food is very close with indirect effects accounting for 39,4% of its variation. On the sources side, the most significant change stems from the processed food component, which becomes the main origin of spillovers (42,9%). The relevance of the indirect effects triggered by energy goods (21,8%) and NEIG (30,1%) also goes up.

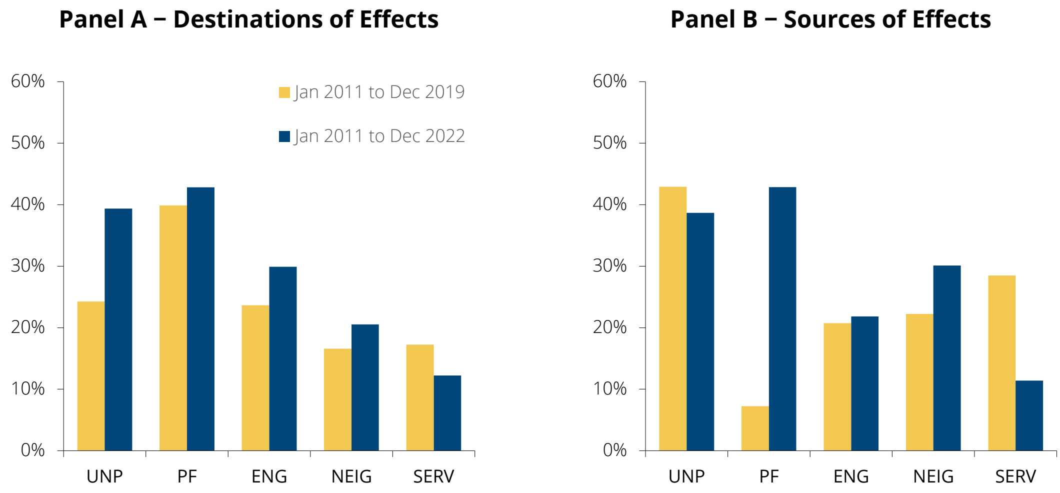

FIGURE 3: Destination and sources of spillover effects by HICP component | Percentage

Sources: ECB, Statistics Portugal and authors' calculations. Notes: Destinations of effects are calculated by summing the non-diagonal elements of each row of the matrix in Figure 2 (Panel A). Sources of effects are calculated by summing the non-diagonal elements of each column of the matrix in Figure 2 (Panel B).

In order to ascertain the reliability of these findings, an alternative specification based on a structural identification of the model was tested, using a Cholesky decomposition, keeping in mind the mentioned limitations to this application. Results, shown in Figures A.2 and A.3 of the Online Appendix, are qualitatively similar to those presented here. The choice of exogenous variables to include in the model was also tested. Two proxies for the impact of supply bottlenecks on the global value chains that were prevalent over 2021 were considered: an indicator of the goods cost of shipping, the Baltic Dry index, and the manufacturing PMI delivery time indicator in the euro area, with no significant changes to results. An alternative version was estimated by replacing non-energy import prices by an aggregate of euro area farm gate prices, alongside the remaining goods deflator and the services deflator.[6] Given that food prices played an important role in recent inflationary pressures, the transmission of shocks for these items may have been different than for overall import prices. Results, available upon request, are qualitatively similar to those above described, with an increase in spillovers when the sample is extended to 2022 that takes place mostly trough food items. The main difference is that source effects increase with the extended sample for all components and become closer among core ones.

6. Data available at https://agriculture.ec.europa.eu/international/agricultural-trade.

To understand the importance of price spillovers over time, the analysis is extended by adding a time dimension. Figure 4 illustrates the importance of spillover effects on each category total variance after a shock in all components, computed using different horizons for the h-step-ahead forecasts. It should be noted that, in the first sub-sample, the importance of inflationary pressures is most pronounced in the first 9 months, with visible quarterly increases, while after the first year the weights become relatively stable. There is a clear difference when looking at the sample that includes the period with higher inflation. The steepening of the bars presented reflects not only stronger indirect effects across components but also a higher importance of price spillovers over time as the transmission of inflationary pressures is still relevant after 12 months. This result is extensive to most components, specially in the most affected: unprocessed and processed food and non-energy industrial goods. The aggregate of energy goods reports high increases in the first 6 months but then slows down. The exception is the category of services, which is the one that suffers less from inflationary pressures coming from the others, as, in reality, the weight of indirect effects decreases after the first year.

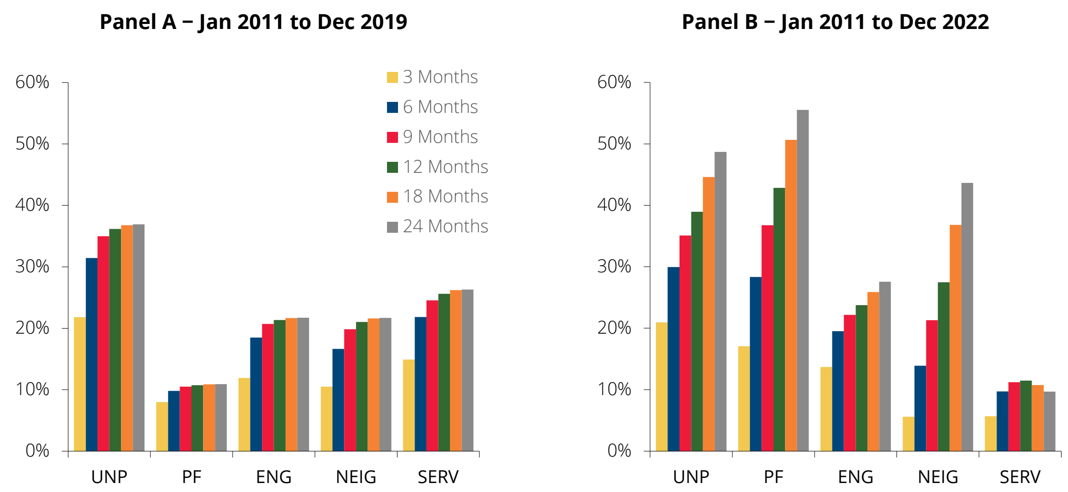

FIGURE 4: Importance of spillover effects on each component's variance | Percentage

Sources: ECB, Statistics Portugal and authors' calculations. Notes: The importance of spillover effects on the variance of each component is defined as the weight of spillover effects from that component in the total variance (sum of all elements of each line of the matrix in Figure 2). The measure is computed with GIRFs of different horizons: 3, 6, 9, 12, 18 and 24 months.

Finally, the index of total spillovers is computed for different horizons, as shown in Figure 5. It expresses the importance of spillovers on the overall variance of the forecast errors. The addition of the most recent observations leads to 5% and 13% increases in the weight of spillover effects in the first 12 and 24 months, respectively, while remaining constant at shorter horizons. This steepening shows again that spillovers are more important for a longer period, meaning that the rise in spillovers between the two sub-samples is not due to a higher contemporaneous correlation of relative price changes but rather to the transmission of those through the lag structure of the BVAR.

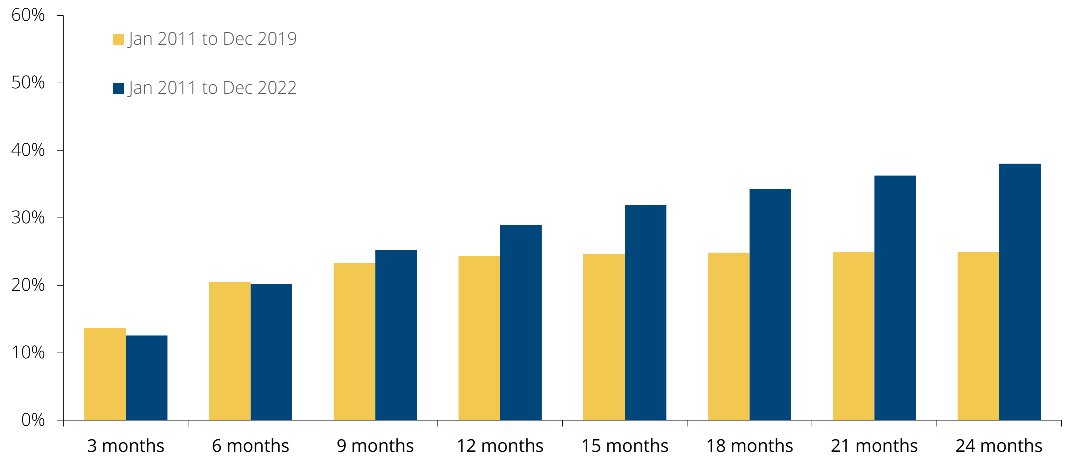

FIGURE 5: Index of total spillover effects over time | Percentage

Source: authors' calculations. Notes: The index of total spillover effects is the ratio between the sum of spillover effects and sum of all elements of the matrix in Figure 2.

2.4. *Upstream Spillovers*

As an extension, upstream price spillovers are investigated by including in the model the PPI, to assess the transmission of effects along the production value chain. Data pertaining to some subsectors is unavailable for the whole sample, as such it was replaced with the weighted average of the PPI of the remaining subsectors on the same aggregate. There are data availability issues as the sample of year-on-year rates of change starts only in Jan 2011.[7] Within the aggregate of consumer goods, the PPIs cover more directly the production of processed food and NEIG.[8] The aggregates considered in the model include: food, beverages and tobacco (PPI_PF), remaining consumption goods (PPI_CXPF), investment goods (PPI_INV), intermediate goods (PPI_INT) and energy goods (PPI_ENG). This order for the inclusion of variables in the model is an attempt to order them (increasingly) based on the average distance to final use, like in BIS (2022) and Antràs *et al.* (2012). Thus, consumption goods are the least upstream while energy goods are the most upstream, in the sense that energy is required to produce every other good. The exogenous variables are the same as in the previous subsection.

First, a model similar to the one described above was estimated with the PPI components alone. The results, available upon request, show that total spillovers have a magnitude close to the one obtained for the HICP model above. Price spillovers are reinforced for all items, except for non-food consumption goods, when considering the extended sample. In addition, HICP and PPI data were combined into a single BVAR model, using otherwise the same specifications of the previous subsection. Because of the limitations to degrees of freedom in estimation imposed by such a large number of

7. Price index data to construct the PPI related to food, beverages and tobacco is only available after 2010.

8. For a closer correspondence with consumer prices, consumption goods were separated into a food, beverages and tobacco aggregate and the remaining consumer goods, using detailed sector data and conversion tables available in the EU Commission Regulation No. 2020/1197 of 30 July 2020.

regressors, the lags of endogenous variables were reduced to three in this case. Some interesting results emerge as shown in Figure 6. In this model, total spillovers more than double when compared to those in the HICP or in the PPI models considered separately: around 25% for each of the individual models and 57% in the joint HICP-PPI model. Indirect effects coming from PPI components are in general stronger when compared to those of the HICP aggregates. The strongest and most pervasive effects steam from the processed food and intermediate goods PPIs (Appendix A.4). As regards HICP components, for the model estimated up to 2019, services have the strongest price spillovers, a large part of which due to effects on PPI components, possibly an indirect effect reflecting transportation costs, that was not possible to capture in the model with HICP categories only. When the sample period is extended to 2022, total spillovers increase from 57% to 63%. This reflects stronger transmission effects stemming from the majority of HICP components, in line with results from the previous subsection.

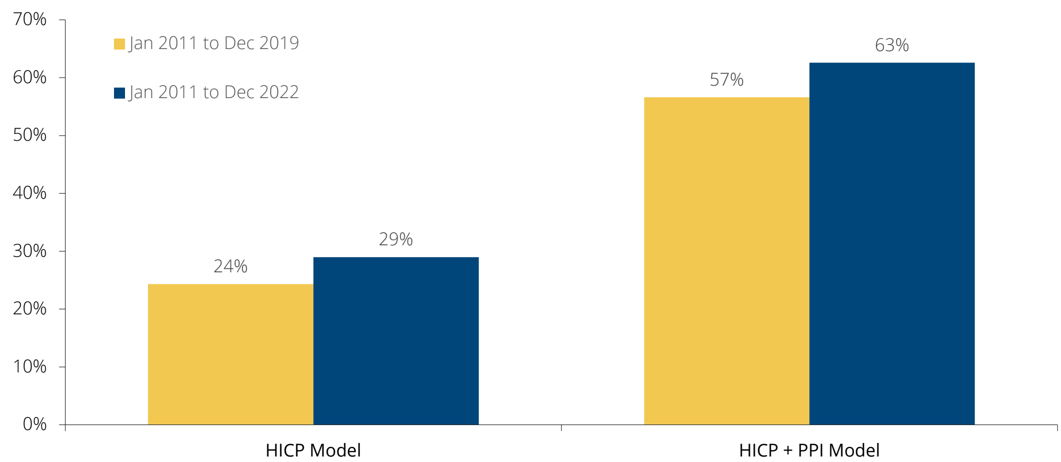

FIGURE 6: Index of total spillover effects for the HICP and HICP + PPI models | Percentage

Source: authors' calculations. Notes: The index of total spillover effects is the ratio between the sum of spillover effects and sum of all elements of the matrix in Figure 2.

3. Common Inflation

Now, the role of price spillovers on the recent generalization of inflationary pressures is analysed by estimating a dynamic factor model, similar to the one shown in Luciani (2020), and applying it to a detailed breakdown of HICP time series. This statistical model allows the identification of co-movements across a large number of prices, capturing the low-frequency component of inflation, defined as *common inflation*. This measure enables the distinction between the extent to which a change in prices is caused by shocks that affect a large share of items, as opposed to changes that are specific to individual items or errors in measurement.

3.1. *Model Specification*

Each month-on-month inflation rate in the dataset is decomposed into a common part χ_{it} and an idiosyncratic part ξ_{it}. Formally, if π_{it} is the month-on-month inflation rate, the following equality applies:

$$\pi_{it} = \chi_{it} + \xi_{it}. \tag{5}$$

Consider a panel of n disaggregated prices $\{\pi_t = (\pi_{1t}...\pi_{nt})' : t = 1, ..., T\}$, then:

$$\chi_{it} = \sum_{k=0}^{s} \lambda_{ik} f_{t-k}, \tag{6}$$

$$f_t = \sum_{l=1}^{p} \mathcal{A}_l f_{t-l} + u_t, \qquad u_t \overset{i.i.d.}{\sim} \mathcal{N}(0, Q), \tag{7}$$

$$\xi_{it} = \sum_{j=1}^{d_i} \rho_{ij} \xi_{it-j} + e_{it}, \qquad e_t \overset{i.i.d.}{\sim} \mathcal{N}(0, \Gamma), \tag{8}$$

where $f_t = (f_{1t}...f_{qt})'$ are the q common latent factors capturing co-movements across series and across time; $\lambda_{ik} = (\lambda_{i1k}...\lambda_{iqk})$ are the loadings for price i at lag k; $s \geq 0$ and $p \geq 1$ are finite integers; Q is a $q \times q$ positive definitive covariance matrix with full rank; the roots of $\mathcal{A}(L) = \sum_{p}^{l=1} \mathcal{A}_l$ and of $\rho_i(L) = \sum_{j=1}^{d_1}$ lie all outside the unit circle; and Γ is a $n \times n$ positive definitive covariance matrix with full rank. It must be noted that the common u_t and the idiosyncratic shocks e_t are assumed to be independent at all leads and lags.[9]

As in Luciani (2020), the proposed model is estimated using the Quasi-Maximum Likelihood method implemented through the Expectation-Maximization (EM) algorithm.[10] A measure of *common inflation* is computed using the estimated common components for each disaggregated price (χ_{it}) and the corresponding weight on the overall HICP (w_{it}). It is calculated as:

$$\pi_t^C = \sum_{i}^{N} w_{it} \chi_{it}. \tag{9}$$

3.2. *Data and Estimation*

The dataset includes data on 97 HICP subindices and corresponding weights, in accordance with the 4-digit COICOP classification. Those sub-indices not available since 2001 or that have been discontinued were replaced with the respective upper-level index. This resulted in a total of 75 items in the dataset. The raw monthly data, which covers the time period from 2001 to 2022, was obtained from Eurostat. Data was seasonally and calendar adjusted with X13 ARIMA procedures in Jdemetra+.[11] For the

9. For a rigorous treatment of this model, see Luciani (2020) and Barigozzi and Luciani (2019).

10. Further details on use of the EM algorithm in Dynamic Factor Models in Barigozzi and Luciani (2019).

11. This is the software for seasonal and calendar adjustment officially recommended by the European Commission to the members of the European Statistical System and the European System of Central Banks.

estimation, the number of factors q was set to 1 and the number of lags s in factors was set to 2. The same tests as in Luciani (2020) were performed. The Hallin-Liska information criterion was the method chosen for selecting the number of factors. The criterion is based on the behavior of the eigenvalues of the spectral density matrix of the factor loadings, which are a measure of the amount of variance explained by each factor in the model. In addition, the number of lags in the factor loadings, represented by s, was chosen such that the variance explained by the first r principal components of the covariance matrix of π_t is similar to the variance explained by the q principal components of the spectral density matrix of π_t (averaged over all frequencies).[12] All in all, the specification includes one common factor and each individual price can load the common factor in a time window of three months.

3.3. *Main Results*

Figure 7 shows the year-on-year percent change in the total HICP index, shown by the yellow line. The blue line represents the measure of *common inflation*, which is the year-on-year rate of change of the index obtained by aggregating the common component across all HICP items. It quantifies what total inflation at each month would be if idiosyncratic price shocks were absent over the previous 12 months.

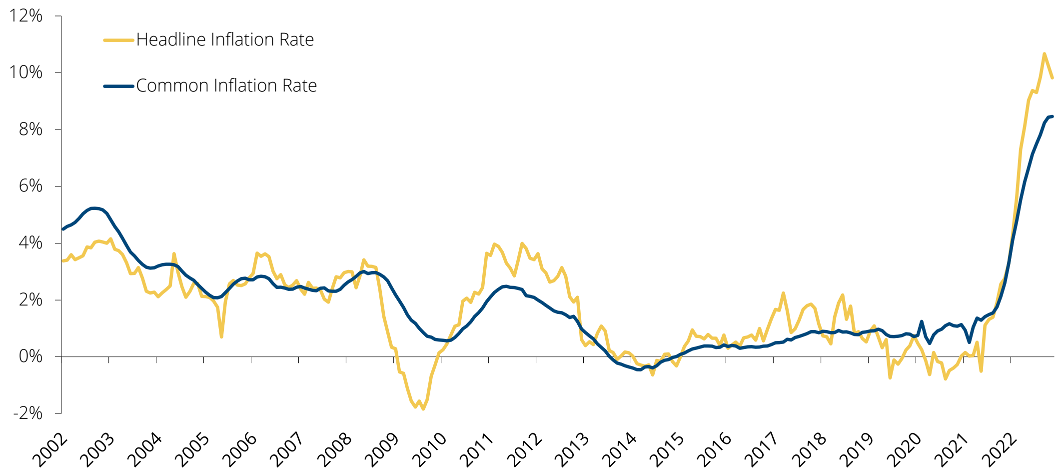

FIGURE 7: Headline and common HICP year-on-year rate of change | Percentage

Sources: Eurostat and authors' calculations.

The model suggests that headline and *common inflation* have generally moved in tandem over the past 20 years, with the exception of the period between 2008 and 2013. During this time, the Portuguese economy experienced significant macroeconomic shocks due to the Great Recession and the Sovereign Debt Crisis, which led to unique idiosyncratic dynamics. Prior to 2008, *common inflation* was around the inflation target of 2% set by the ECB, but after 2013, it remained closer to 0%. In an environment of low inflation, price changes in individual items are less transmitted to the remaining and thus to the aggregate price indices. In these periods, small and brief fluctuations in prices

12. This method builds on the work of D'Agostino and Giannone (2012).

occur around a relatively stable *common inflation*. This is in stark contrast to 2021 and 2022, during which both headline and *common inflation* surged above 8%, suggesting that a broad range of prices have increased simultaneously over this period. When inflation is high, increases in prices tend to be more aligned as the common component explains a larger share of the total variability of individual prices. Similar results were reported for the U.S. economy by Luciani (2020). The evolution of the computed *common inflation* measure compares reasonably well with other indicators of underlying inflation that belong to the toolkit of central banks (Appendix A.5). Even though all the measures aim to estimate the evolution of the (unobservable) persistent component of headline inflation, the *common inflation* helps to better understand the role of price spillovers on the recent generalization of inflationary pressures. Econometric techniques were used to filter out the transitory components of inflation by analyzing cross-sectional information across prices. Thus, this approach has the advantage of including the impact of medium-term shocks on food and energy, while excluding idiosyncratic fluctuations specific to core items.

To better understand the broad-based rise in prices, the exposure of HICP aggregates to common shocks in the recent years is investigated. For that, the common component of all sub-indices included in each of the main HICP components is combined, using the respective weights on the overall index. Figure 8 shows the contribution of each aggregate to the *common inflation* rate. The conclusion obtained is that the recent large external shocks caused soaring energy and food prices and the relative price changes in these components were transmitted to the remaining.

In the beginning of 2021, services were the highest contributors to *common inflation*, followed by food and energy goods. While the latter are more volatile, the former have historically been more affected by economy-wide fluctuations in prices. From mid-2021 onward, food and energy items have gained relevance in the dynamics of the *common inflation* and the two combined accounted for half of the broad-based variation of prices in January of 2022. After the beginning of the war, the bulk of the increase in *common*

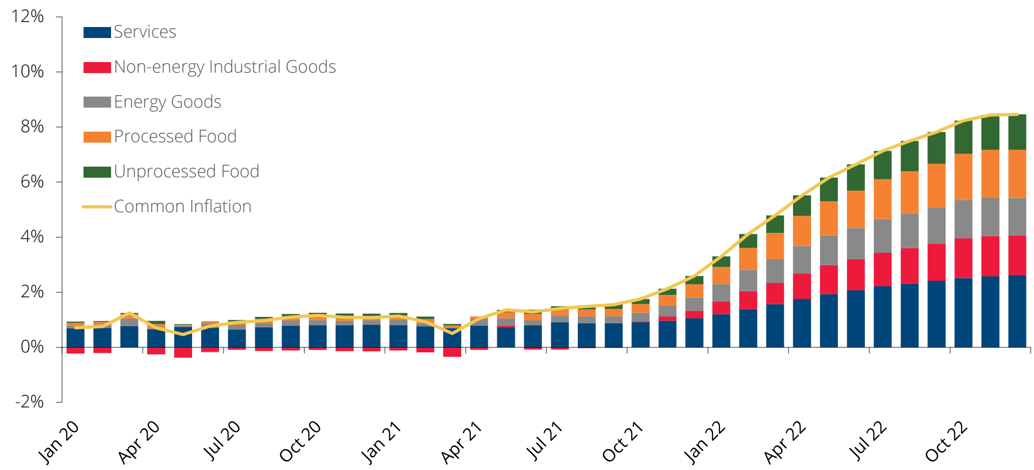

FIGURE 8: Contributions by HICP component to the *common inflation* rate | Percentage

Sources: Eurostat and authors' calculations.

inflation has been due to a broad-based rise in food prices, combing unprocessed and processed items, suggesting that they have increasingly co-moved with other prices. More than one-third of the overall increase of 8,5% is explained by the variation in the common component of the food (3%) and energy (1,3%) items. Currently, almost half of the increase in broad-based inflation is due to core items, that are more persistent and structural drivers of inflation. For example, NEIG prices, which in the past had very small contributions, picked up and since mid-2022 account for 1,4% of the total variation. This evidence suggests that the mentioned shocks may have induced stronger linkages across sectors and led to increased co-movement among prices, which is in line with the increase in price spillovers shown.

Comparing Figures 1 and 8, is it visible that over 2022, energy and food components have higher contributions to the headline HICP than to *common inflation*. This is in line with the fact that these components are the most volatile of the HICP. On the other hand, the contribution of services to *common inflation* is higher than in the headline up to 2022 and similar from them onward, possibly reflecting idiosyncratic demand impacts of the pandemic on services involving social interaction. Over 2022, the contribution of services to headline and *common inflation* is very similar.

Finally, the computation of the *common inflation* measure also has the advantage of allowing to approximate the impact of the large shock caused by the invasion of Ukraine by Russia on the co-movement of prices. To understand the impact that this event had on the inflation dynamics, its effects on *common inflation* were quantified on the basis of the methodology presented by Luciani (2020). The final estimate of *common inflation* after the shock is compared with the quasi-final estimate obtained by estimating the parameters before the shock. Doing that, the instabilities and unusual co-movements across individual prices that emerged with the shock are isolated. Let:

$$UkW_t^C = \chi_{t,Fin}^C - \chi_{t,Q-Fin}^C, \tag{10}$$

if $t \geq$ February 2022, otherwise is 0. $\chi_{t,Fin}^C$ corresponds to the *common inflation* indicator estimated with the full sample, while $\chi_{t,Q-Fin}^C$ corresponds to the quasi-final estimate of *common inflation*, obtained by estimating the parameters up to January 2022 and running the Kalman Smoother until December 2022. Figure 9 shows the evolution of *common inflation* in yellow and its decomposition between what *common inflation* would be if the parameters were kept unchanged after February 2022 and the increase in inflation due to the external shock caused by the invasion of Ukraine by Russia.

Since February 2022, the effects from the Ukraine Invasion have increasingly boosted *common inflation*, reaching a contribution of 3% in December. A detailed analysis of the contributions per component shows that food and energy were the most affected by the invasion of Ukraine. On the other hand, this shock had little impact on the rise of the common components of the the less volatile aggregates, i.e. NEIG and services.

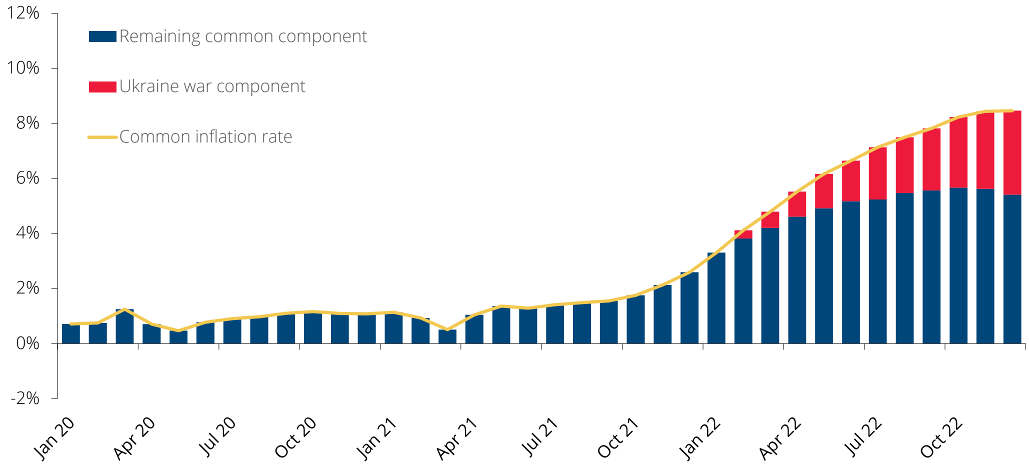

FIGURE 9: *Common inflation* and the impact of the war in Ukraine shock | Percentage

Sources: Eurostat and authors' calculations.

4. Final Remarks

Headline inflation has increased sharply in Portugal since mid-2021. Food and energy goods played a key role as drivers of the inflationary pressures but the great dynamism of their prices in the recent period was extended to the typically more stable categories. In this article, the role of price spillovers on the generalization of price increases is examined. First, a BVAR model with aggregate HICP data for Portugal is estimated to compute spillover measures, as in Borio *et al.* (2023), and compare a period with a low-inflation environment against the last years with the large price hikes. Price spillovers rose in the most recent period, meaning that idiosyncratic shocks in each component are transmitted more intensely through the production chain and have a greater impact on the price volatility of the others. The initial rise in raw material prices may have caused inflation of costs in the early stages of production, which then led to higher prices for goods and services throughout the production process. The higher magnitude and persistence of these effects suggest that relative price shocks are more likely to propagate to underlying inflation as they echo more into other components. For this reason, a measure of *common inflation* is constructed, as in Luciani (2020), which identifies co-movements across a large number of prices. As the most affected items have moved jointly with many others, the impact caused by the large external shocks has been converted into broad-based inflationary pressures.

Further avenues for research include analyzing more formally the properties of the common component of inflation as an underlying inflation indicator, in particular its forecasting performance and its behavior within a Phillips curve.

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Non-technical summary

April 2023

Economic Synopsis
Monetary policy and the recent inflation surge

Bruno Freitas and Pedro Teles

After a long period of an apparent inability of monetary policy in the euro area, and also in the US, to raise inflation back to target, we are now observing inflation far exceeding the objective of 2% in both economies. Inflation in the euro area started to deviate from target in July 2021 and was 8.5% in February 2023. In the US, PCE inflation surpassed 2% since March 2021, and was 5.0% in February 2023.

What was the response of monetary policy to the inflation surge? The increase in policy rates following the substantial rise in inflation was considerable. However, as we argue in this note, interest rate policy in the euro area was passive, inertial and slow in its response. It was passive, and not active, because it did not follow the Taylor principle according to which the policy rate ought to respond more than one-to-one to deviations of inflation from target. It was inertial, because the fit with an interest rate rule with built-in gradualism is remarkable. It was slow to respond, because it took longer to adjust than what the inertial rule would have prescribed. Overall, rather than tightening to fight the surge in inflation, monetary policy took a loose stance, possibly also contributing to the inflationary process. The underlying quantity of money is also consistent with high inflation, even considerably higher than the one observed.

We discuss three possible justifications for the moderate response of interest rates to inflation. The first is the weak theoretical support to the belief that interest rates ought to respond in an aggressive manner to deviations of inflation from target.

Even with no theoretical support, active rules appear to work in practice. The disinflation of the 1970s and 1980s in the US and in Germany is often seen as proof of the success of monetary policy that follows the Taylor principle in taming inflation. The case of Japan is a useful comparison. Japan virtually did not respond to the surge in inflation, inflation was a lot higher than in the US or Germany, but it was short-lived. While realised real rates during the inflation surge in the 1980s were positive in the US and Germany (reaching around 5% and 8%, respectively), they were considerably negative in Japan in the 1970s (as negative as around -18%). The possible deviation of real interest rates from their natural levels (either above or below) did not occur without costs. We also explore the case of current day Turkey, which is an extreme case of non-responsive policy, with added risks that we also discuss.

One normative justification for relatively high inflation is that, in a world where some prices, possibly wages, are downward rigid, it is optimal to allow for an inflation bias that can be very large if relative price movements are also very large.

Another normative justification for high inflation is the optimal policy response to a large negative fiscal shock, such as the one that occurred during and in the aftermath of the COVID-19 pandemic. The surge in inflation has allowed for substantial debt depletion, dispensing tax hikes. Teles and Tristani (2021) make the case for an optimal response of inflation in the euro area to the large fiscal shock that is of a similar order of magnitude to the observed inflation. The surprise inflation also has a large effect on the wages of civil servants and pensions measured in real terms.

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Economic Synopsis
Monetary policy and the recent inflation surge

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April 2023

Abstract
Monetary policy in the euro area responded to the recent inflation surge in a passive, gradual and slow manner, possibly even contributing to the inflationary process by employing an expansionary stance. We discuss three justifications for the moderate response of monetary policy: (1) The weak theoretical support of active feedback rules in the conduct of monetary policy; (2) an optimal inflationary bias when there are large relative price movements and prices are downward rigid; (3) optimal debt depletion in response to a large negative fiscal shock, such as the one observed after the outbreak of the COVID-19 pandemic. (JEL: E12; E4; E5; E62)

Introduction

After a long period of an apparent inability of monetary policy in the euro area, and also in the US, to raise inflation back to target, we are now observing inflation far exceeding the objective of 2% in both economies. As can be seen in Figure 1, HICP inflation in the euro area started to deviate from target in July 2021 and was 8.5% in February 2023. In the US, PCE inflation has noticeably surpassed 2% since March 2021, and was 5.0% in February 2023.

What was the response of monetary policy to the inflation surge? As seen in Figure 1, policy rates were raised in response to the substantial rise in inflation. However, as we argue in this note, interest rate policy in the euro area was passive, inertial and slow in its response. It was passive, and not active, because it did not follow the Taylor principle according to which the policy rate ought to respond more than one-to-one to deviations of inflation from target. It was inertial because the fit with an interest rate rule with built-in gradualism is remarkable. It was slow to respond because it took longer to adjust than what the inertial rule would have prescribed. Overall, rather than tightening to fight the surge in inflation, monetary policy took a loose stance, possibly also contributing to the inflationary process. The stance was loose, and not tight, because the resulting real rate

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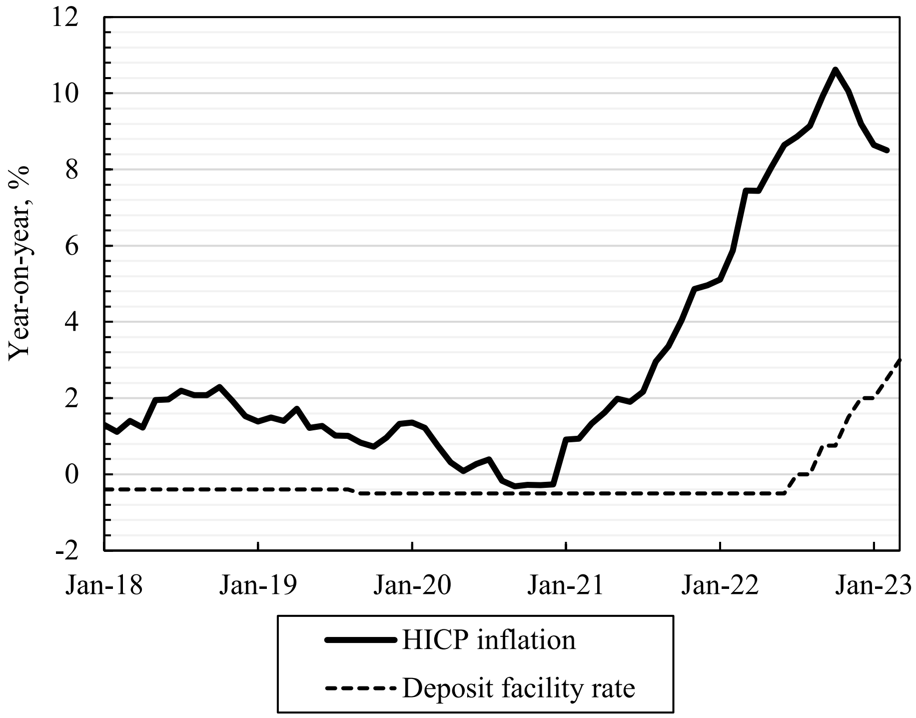
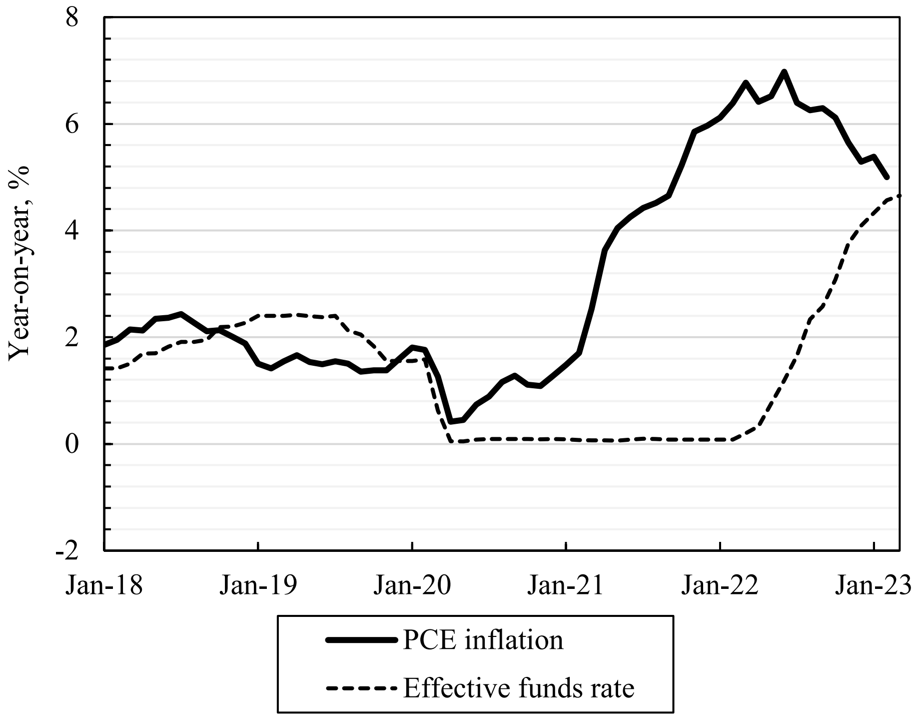


(A) Euro area. Notes: End-of-month deposit facility rate, until Mar-23. Data for HICP inflation until Feb-23.



(B) United States. Notes: Monthly averages of daily data for the effective funds rate, until 31 March 2023. Data for PCE inflation until Feb-23.

FIGURE 1: Inflation and policy rates.

Sources: Eurostat, Refinitiv and authors' calculations.

is lower than an estimated natural/neutral rate. The underlying quantity of money is also consistent with high inflation, even considerably higher than the one observed.

We discuss three justifications for the moderate response of monetary policy. We do not perform a quantitative evaluation of monetary policy. We simply discuss three arguments why it may be admissible or even desirable to allow for a deviation of inflation from target in the current conditions in the euro area, as well as in the US.

The first justification for a moderate response of policy is the weak theoretical support to the belief that interest rates ought to respond in an aggressive manner to deviations of inflation from target. The theoretical support is based on a local determinacy argument. Indeed, an interest rate policy that follows the Taylor principle and responds more than one-to-one to deviations of inflation from target is able to achieve local determinacy. Yet, that is all it achieves. While there is a single equilibrium in the neighbourhood of a particular steady state, there is an infinite number of other equilibria. Some of those converge to the zero bound steady state. The alternative is a passive interest rate policy that responds less than one-to-one to deviations of inflation from target, giving rise to local indeterminacy. While this is the case under rational expectations, recent work by Angeletos and Lian (2021) shows that, with a small departure from rational expectations, equilibria are determinate.

Even with no theoretical support, active rules appear to work in practice. The disinflation of the 1970s and 1980s in the US and in Germany is often seen as proof of the success of monetary policy that follows the Taylor principle in taming inflation. The case of Japan is a useful comparison. Japan virtually did not respond to the surge in inflation, inflation was a lot higher than in the US or Germany, but it was short-lived. While realised real rates during the inflation surge in the 1980s were positive in the US and Germany (reaching around 5% and 8%, respectively), they were considerably negative in Japan in the 1970s (as negative as around -18%). The possible deviation of real interest rates from their natural levels (either above or below) did not occur without costs. We also explore the case of current day Turkey, which is an even more extreme case of non-responsive policy, with added risks that we also discuss.

The second justification for relatively high inflation is that, in a world where some prices, possibly wages, are downward rigid, it is optimal to allow for an inflation bias that can be very large if relative price movements are also very large.[1,2]

Another normative justification for high inflation is the optimal policy response to a large negative fiscal shock, such as the one that occurred during and in the aftermath of the COVID-19 pandemic. The surge in inflation has allowed for substantial debt depletion, dispensing tax hikes. Teles and Tristani (2021) make the case for an optimal response of inflation in the euro area to the large fiscal shock that is of a similar order

1. The inflation bias, resulting in a departure of inflation from target, happens here under full commitment. It is not the result of discretionary policy.

2. Inflation also reduces the minimum wage in real terms. Minimum wages are one of the reasons for downward wage rigidity in response to shocks. The reduction of the real value of the minimum wage through surprise inflation penalizes those receiving the minimum wage but benefits those that can be formally employed at a lower minimum wage.

of magnitude to the observed inflation. The surprise inflation also has a large effect on the wages of civil servants and pensions measured in real terms. This can be welfare improving given the downward rigidity of both wages in the public sector and pensions.

In what follows we first describe the conduct of monetary policy in response to the surge in inflation. We proceed to discuss the three justifications for the timid response.

Interest rate policy and the surge in inflation

How should monetary policy respond to positive deviations of inflation from target? The conventional view is to follow the Taylor principle, which calls for an increase of interest rates more than one-to-one to a rise in inflation in order to ensure local price determinacy. The question thus arises of what policy rates would have been consistent with the Taylor principle in the euro area during the recent inflation surge. To tackle this issue, we consider the following policy rule, where the policy rate reacts positively to deviations of the natural rate (r_t) – the real interest rate in response to shocks that would prevail in an economy without nominal rigidities – from its long-term levels (r^*) and to deviations of inflation (π_t) from target (π^*) with a given coefficient ($\rho > 1$ to be consistent with the Taylor principle):

$$i_t - i^* = r_t - r^* + \rho(\pi_t - \pi^*) \tag{1}$$

Since $i^* = r^* + \pi^*$, equation (1) becomes:

$$i_t = r_t + \pi^* + \rho(\pi_t - \pi^*) \tag{2}$$

To estimate the natural rate in response to shocks, we consider the DSGE-model based estimates of the Federal Reserve Bank of New York for the US. We calculate the corresponding rate for the euro area assuming covered interest rate parity. We use the forward discount and forecast nominal and real exchange rates assuming they follow a random walk. Our estimates yield that, in the last quarter of 2022, the natural rate in the euro area was approximately 0.3%.[3] Given that $\pi_{2022Q4} = 10\%$ and $\pi^* = 2\%$, it directly follows from equation (2) that the policy rate in the euro area consistent with the Taylor principle in the last quarter of 2022 would have been at least 10%, approximately (as shown in equation (3)). The actual average policy rate was 1.4%.

$$i_{2022Q4} \approx 0.3\% + 2\% + 1.01(10\% - 2\%) = 10.4\% \tag{3}$$

In practice, central banks appear to follow rules with built-in gradualism.[4] To show this, we consider the following Taylor rule with built-in gradualism for the US while

3. See Appendix A for a detailed breakdown of this estimation.

4. Bernanke (2004) argues for a gradualist approach to monetary policy, highlighting policymakers' uncertainty, a greater influence over the long-term interest rate, and reduced risks to financial stability.

removing any direct considerations of the unemployment gap ($u_t - u_t^*$) for the euro area to reflect the fact that the ECB does not follow a dual mandate:[5]

$$i_t = 0.85 i_{t-1} + 0.15 \left(r_t^* + \pi^* + 1.5 \left(\pi_t - \pi^*\right) - 2 \left(u_t - u_t^*\right)\right) \tag{4}$$

As shown in Figure 2, the prescriptions from the above inertial rule have closely followed the actions of both the Fed and the ECB. During the recent high inflation episode, there were negative deviations in both economies, showing a slow response of policy even taking gradualism into account.

Overall, the stance of monetary policy in the euro area was expansionary, possibly contributing to the inflationary process. In order to assess the monetary policy stance, we need to compute the real rate using inflation expectations. Atkeson *et al.* (2001) show that a naive forecast of one-year-ahead inflation that uses the inflation rate over the previous year is at least as accurate as NAIRU Philips curve-based inflation forecasts. Thus, in the assessment of the monetary policy stance in the last quarter of 2022, we can consider $\pi_t^e = 8.4\%$, which is the annual HICP change in 2022 for the euro area. The policy stance is very expansionary:

$$r_{2022Q4} = i_{2022Q4} - \pi_{2022Q4}^e = 1.4\% - 8.4\% = -7\% < 0.3\% \tag{5}$$

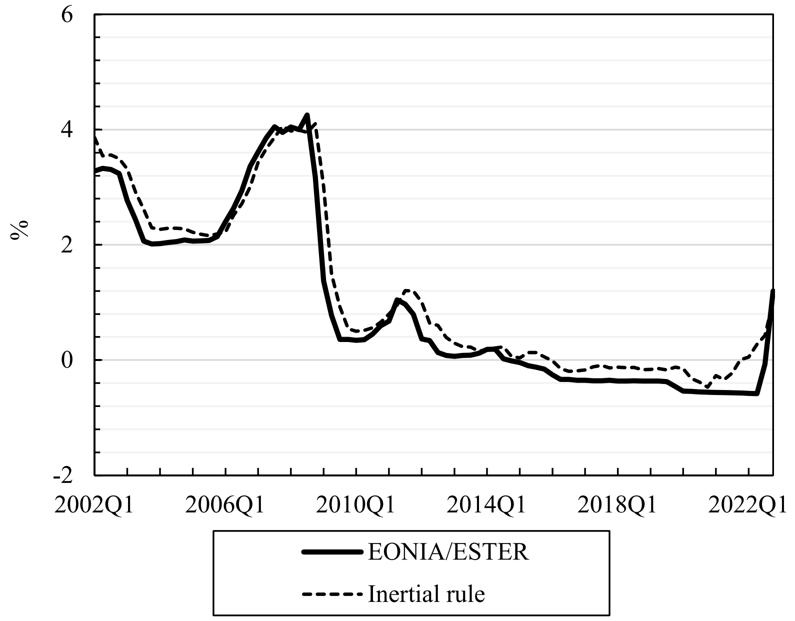
The special nature of the shocks, with the end of the pandemic and the outbreak of the war in Ukraine in February 2022, may justify using other forecasts, possibly with more judgement. Using the December 2022 ECB projections for the inflation rate in the euro area in 2024, $\pi_t^e = 3.4\%$, the stance is less expansionary:

$$r_{2022Q4} = i_{2022Q4} - \pi_{2022Q4}^e = 1.4\% - 3.4\% = -2\% < 0.3\% \tag{6}$$

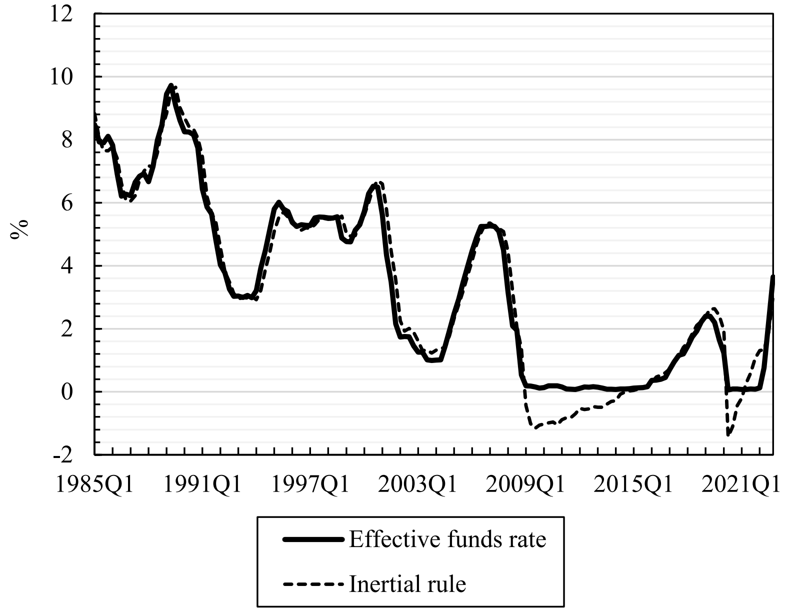
Alternatively, we can consider the expected inflation rate in the euro area for 2024 in the Survey of Professional Forecasters of the last quarter of 2022, $\pi_t^e = 2.4\%$, which yields broadly similar results:

$$r_{2022Q4} = i_{2022Q4} - \pi_{2022Q4}^e = 1.4\% - 2.4\% = -1\% < 0.3\% \tag{7}$$

5. See Appendix B for a detailed analysis with other illustrative practical policy rules.



(A) Euro area. Notes: We employ EONIA until 2019Q4 and ESTER thereafter (quarterly averages of daily data). We consider HICP excluding food and energy, and 2% as the inflation target. Data until 2022Q4.



(B) United States. Notes: Quarterly averages of daily data for the effective funds rate. We consider PCE inflation excluding food and energy, and 2% as the inflation target. We consider the Congressional Budget Office estimates of the noncyclical rate of unemployment as a measure of u*. Data until 2022Q4.

FIGURE 2: Inertial rule prescriptions.

Sources: Congressional Budget Office, ECB, Eurostat, Federal Reserve Bank of New York, Federal Reserve Economic Data (FRED), Refinitiv and authors' calculations. Notes: The natural interest rate is estimated from the Holston, Laubach and Williams (HLW) model. The New York Fed suspended the publication of the HLW estimates of the natural interest rate after releasing estimates for the second quarter of 2020. Beyond this period, we follow the procedure of the Federal Reserve Bank of Atlanta and assume that the HLW estimates remain at their last published values.

Monetary aggregates and inflation

How much of the inflation surge can be explained by an expansion of monetary aggregates? What implications does that have for policy? Since the financial crisis of 2008 and through the sovereign debt crisis in Europe, money supply has expanded considerably without that translating into noticeably higher inflation. Figure 3 shows the ratio of the monetary aggregate M2 to GDP for the US and the euro area since the first quarter of 2002. The reason why such an expansion of the money supply did not translate into high inflation is that interest rates on nominal assets such as government bonds paid interest rates that were actually lower than the zero interest paid on money. As shown in Figure 4, short-term risk-free interest rates remained close to 0% since 2011 in the euro area and for a large period of time since 2008 in the US.

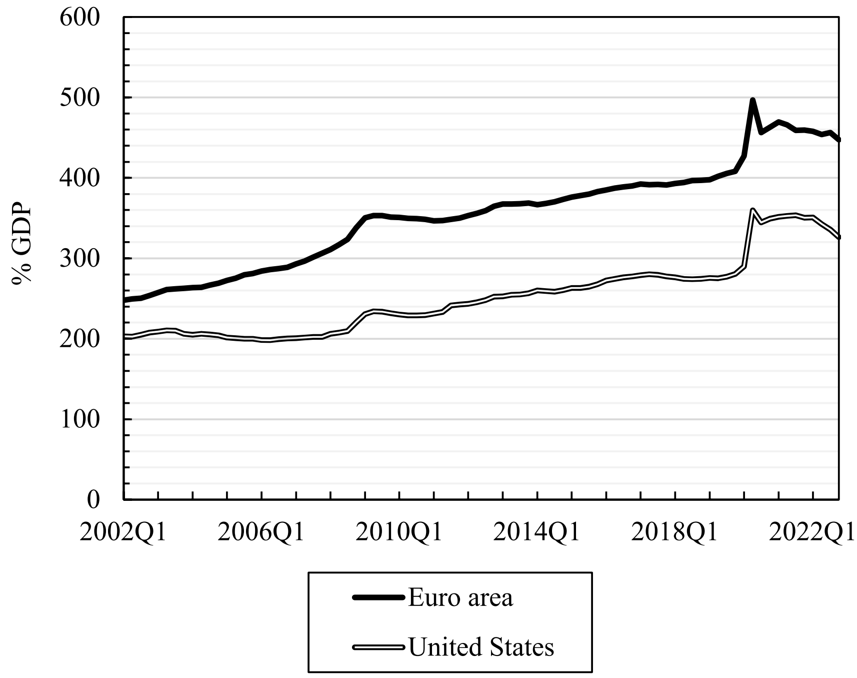


FIGURE 3: Monetary aggregate M2.

Source: ECB, Eurostat, Federal Reserve Economic Data (FRED) and authors' calculations. Notes: Quarterly averages of monthly data. Data until 2022Q4. Monetary aggregate M2 was chosen due to a structural break in M1 for the US after Apr-20 and a discontinuation of Money Zero Maturity (MZM) for the US in Feb-21.

When interest rates are at the zero bound, there is no reason for the quantity theory equation, $MV = PY$, to hold with equality. In that condition, M is some monetary aggregate, V is a measure of velocity for that monetary aggregate, P is the price level and Y is a measure of transactions in real terms, possibly GDP. When money is not dominated in rate of return, in the sense that the interest rate on alternative assets is less than or equal to the rate of interest on money, then people are willing to hold more money than the one they want to use for transactions so that the quantity condition holds with inequality, $MV \geq PY$. In that case, an increase in the monetary aggregate does not necessarily translate into an increase in prices, or output for that matter.

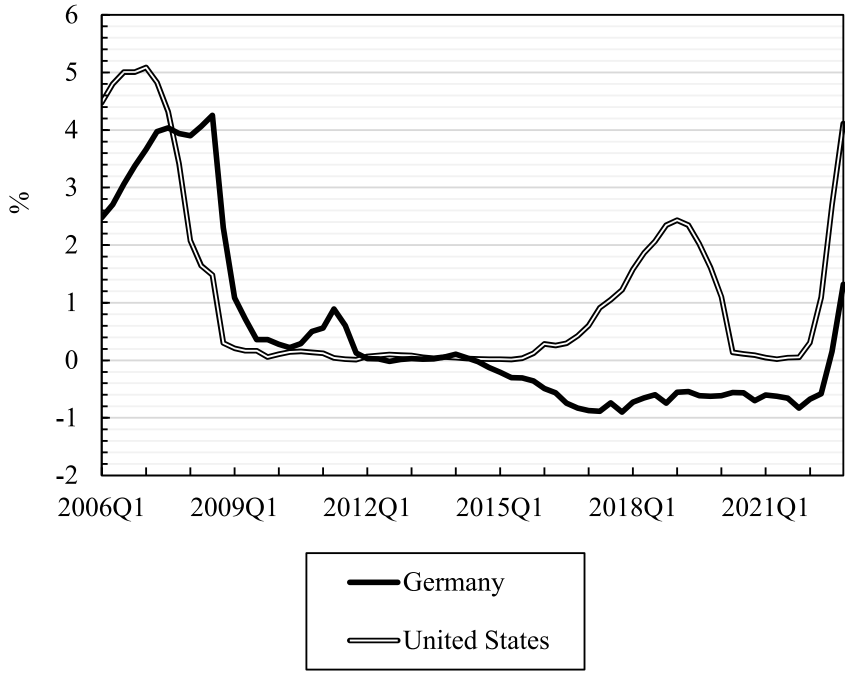


FIGURE 4: 3-month sovereign bond yields.

Source: Refinitiv and authors' calculations. Notes: Quarterly averages of daily data. Data until 2022Q4. We employ Germany as the risk-free benchmark for the euro area.

Once interest rates have risen to levels way above zero, then it is no longer the case that the money demand is indeterminate as when interest rates are at the zero bound. In order to understand how the growth rate of money balances can translate to inflation outside the zero bound, we can turn to Lucas (2000), where the following theoretical equilibrium relationship between real money demand $\left(\frac{M_t}{P_t}\right)$, a nominal interest rate (i_t) as a measure of the opportunity cost of money, and real output (Y_t) is derived,

$$\frac{M_t}{P_t} = \alpha Y_t i_t^{-\gamma} \tag{8}$$

Using data from 1900 through 1994 and the monetary aggregate M1 as the measure of money, Lucas (2000) reports an interest elasticity for the US, γ, of 0.5. Using Money Zero Maturity (MZM) as an alternative monetary aggregate to account for regulatory reforms and innovation in electronic payments in the US since the early 1980s, Teles and Zhou (2005) propose an interest elasticity of 0.2 for the period 1980-2003. For simplicity, we avoid the need to estimate γ by calculating the implied growth rate of prices between two periods where the interest rate was roughly identical. Formally, from equation (8):

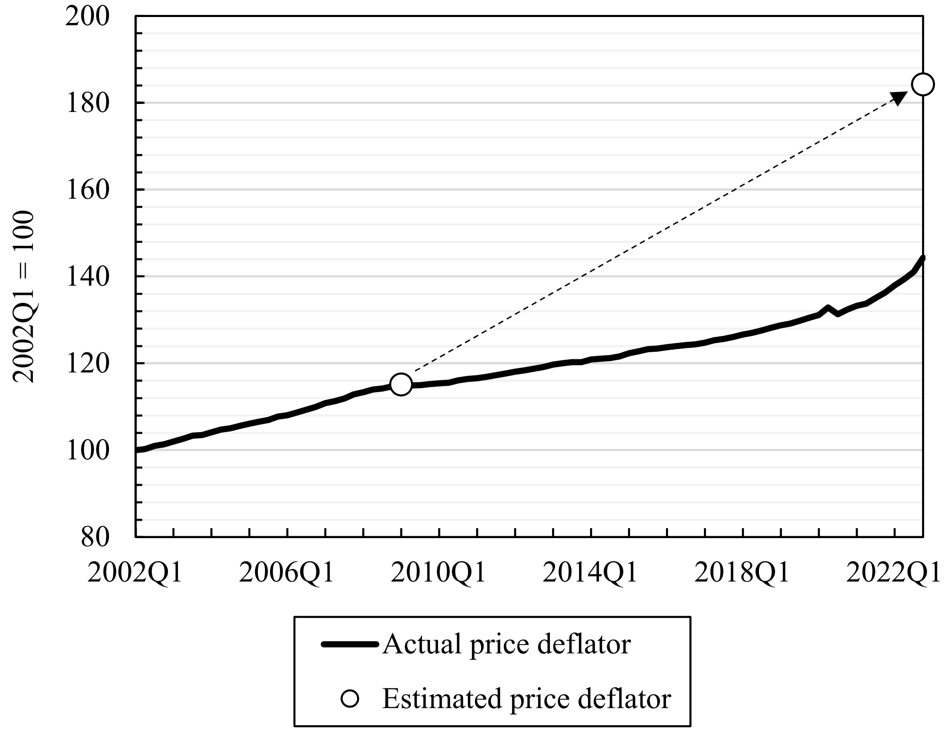
$$\frac{\hat{M}}{\hat{P}} = \hat{Y}\hat{i}^{-\gamma} \Leftrightarrow \frac{\hat{M}}{\hat{P}} = \hat{Y} \cdot 1 \Leftrightarrow \hat{P} = \frac{\hat{M}}{\hat{Y}} \tag{9}$$

The periods chosen for the euro area were the first quarter of 2009 and the fourth quarter of 2022, where the German 3-month sovereign yield was 1.1% and 1.3%, respectively.[6] For the US, we chose the third quarter of 2007 and the fourth quarter of 2022, where the 3-month sovereign yield was 4.3% and 4.1%, respectively. We consider the monetary aggregate M2 for both economies. The growth rate of the price deflator that would be consistent with equation (9) is 60% for the euro area and 125% for the US, as Figure 5 illustrates. The high money supply is certainly consistent with an elevated price level in both economies, substantially higher than the one that has been observed. While part of the extra money demand may be explained by bad data,[7] it is too large to be that. The excessive money demand is an embarrassment for the simple money demand theory implicit in these calculations.

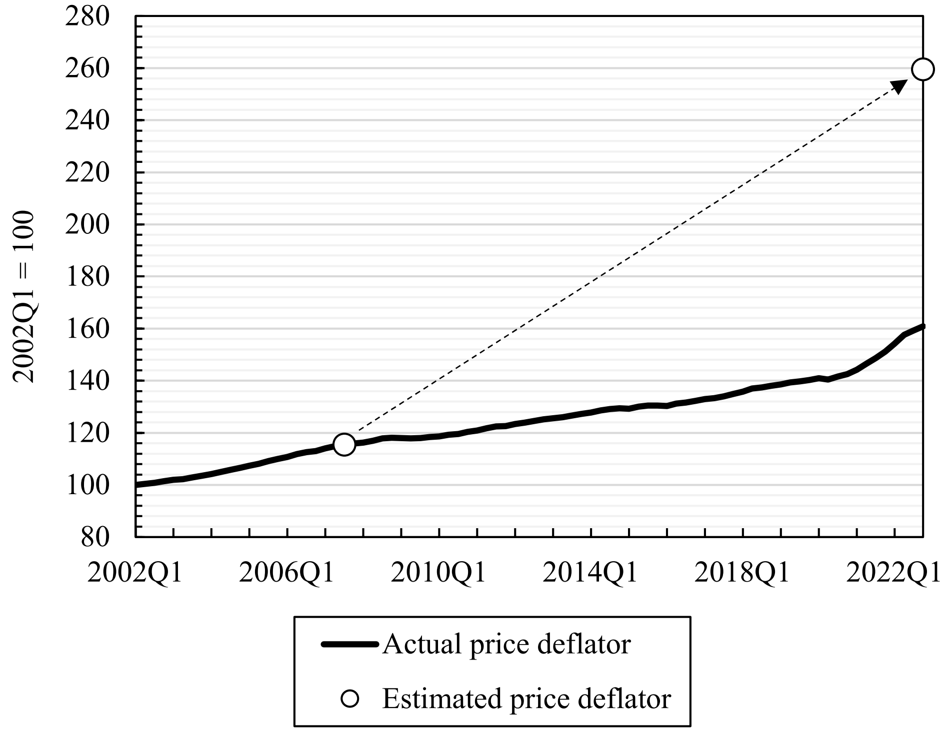
The inquiry into the underlying quantity of money in explaining the high inflation is of theoretical interest, but of no practical interest. In a context of an enlarged balance sheet with interest-bearing reserves, central banks are not able to control the quantity of money. They can control total liabilities but not the way they are distributed across the different monetary aggregates and interest-bearing reserves.

6. We use German sovereign yields to eliminate default risk premia.

7. We are using a measure for money that aggregates many different assets with different liquidity characteristics and different returns. We are also using a rough measure for the opportunity cost of money.



(A) Euro area.



(B) United States.

FIGURE 5: Price levels consistent with the money demand equation derived in Lucas (2000).

Sources: ECB, Eurostat, Federal Reserve Economic Data (FRED), Refinitiv and authors' calculations. Notes: We consider the GDP deflator as the price deflator.

Inflation and the Taylor principle

The theoretical support for monetary policy to follow the Taylor principle is to ensure local price determinacy. However, as shown in Benhabib *et al.* (2001), active interest rate feedback rules lead to global indeterminacy. We illustrate this source of multiplicity using a simple flexible price model. In that model, the real interest rate, r_t, does not depend on the nominal rate, i_t, or inflation, π_t. The following approximated dynamic equations must hold: the Fisher equation (equation (10)) and a policy rule (equation (11)),

$$i_t = r_t + \pi_{t+1} \tag{10}$$

$$i_t - i^* = r_t - r^* + \rho(\pi_t - \pi^*) \tag{11}$$

where

$$i^* = r^* + \pi^* \tag{12}$$

with the superscript * denoting the long run values.

These equations together imply that:

$$\pi_{t+1} - \pi^* = \rho(\pi_t - \pi^*) \tag{13}$$

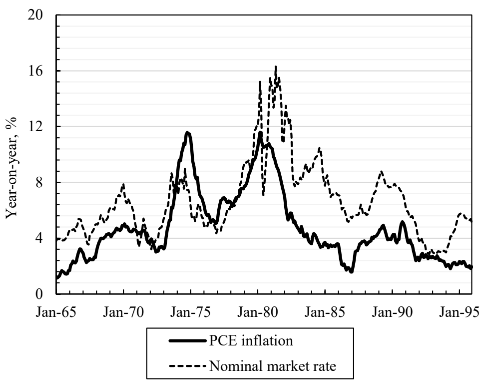
One solution to this dynamic equation is $\pi_t = \pi^*$. But, if monetary policy follows the Taylor principle ($\rho > 1$), there is also a continuum of explosive solutions and a continuum of solutions converging to the zero bound. If, instead, policy does not follow the Taylor principle ($\rho < 1$), there is a continuum of solutions converging to target. In this model with rational expectations, the convergence to target is gained at the expense of local indeterminacy. Yet, as shown in Angeletos and Lian (2021), the introduction of a friction in social memory to a baseline New Keynesian model may remove local price indeterminacy, yielding a unique equilibrium regardless of monetary policy.

Even if there is no theoretical support for active rules that follow the Taylor principle, there appears to be some empirical support. They seem to work in practice. The disinflation of the 1970s and 1980s in the US and in Germany is often seen as proof of the success of monetary policy that follows the Taylor principle in taming inflation. For example, Clarida *et al.* (2000) show how US monetary policy changed from passive in the pre-1979 period to active after 1979, which coincided with the beginning of the disinflation process, as shown in Figure 6. In Germany, the surge in inflation was also met with a strong interest rate response, and inflation did go down. The case of Japan in the 1970s is an interesting contrasting case. The response of interest rate policy to inflation in Japan was basically non-existent. Inflation was a lot higher in Japan but it was short-lived and returned fast to target.

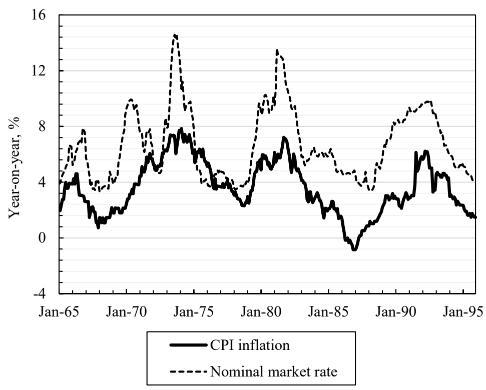
Current day Turkey is an even more extreme case of non responsive policy with very large inflation, which has recently started to come down. As shown in Figure 7, the Central Bank of the Republic of Turkey (CBRT) has kept policy rates low or even decreased them despite very high inflation and a huge depreciation of the lira. In a related recent paper, Gürkaynak *et al.* (2022) argue that the current high inflation in Turkey is a case study example of the use of a passive interest rate rule, which does not follow the Taylor principle. But the case of Turkey has more than meets the eye.

As shown in Figure 8, the commercial loans rate in Turkey started to diverge significantly from the policy rate at the beginning of 2022, suggesting that the policy rate was no longer reflecting market equilibrium conditions. In this context, the CBRT imposed strict bank lending requirements. This was followed by a convergence of the two rates. The case of Turkey is impressively well explained by the analysis in Bassetto and Phelan (2015). They show that there can be equilibria with high inflation and low nominal rates as long as there are quantity restrictions on credit, which they interpret as financial repression. When real rates are that low, as low as -70%, the demand for central banking lending is basically unbounded so quantity restrictions have to be imposed. Rather than a textbook case of a passive interest rate rule, the case of Turkey seems to be a case study of these types of equilibria.

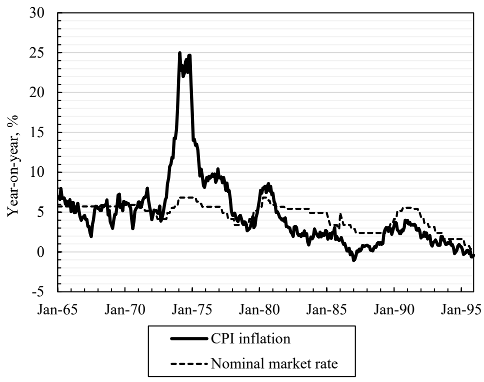
Both the case of Japan in the 1970s and current Turkey are important to keep in mind as possible risks of non-responsive policies.



(A) United States. Notes: We consider 3-month sovereign yields as the market rate.



(B) Germany. Notes: We consider 3-month interbank rates as the market rate.



(C) Japan. Notes: We consider 13-week treasury bill rates as the market rate.

FIGURE 6: Market rates and inflation in the 1970s and 1980s.

Sources: Federal Reserve Economic Data (FRED), Refinitiv and authors' calculations.

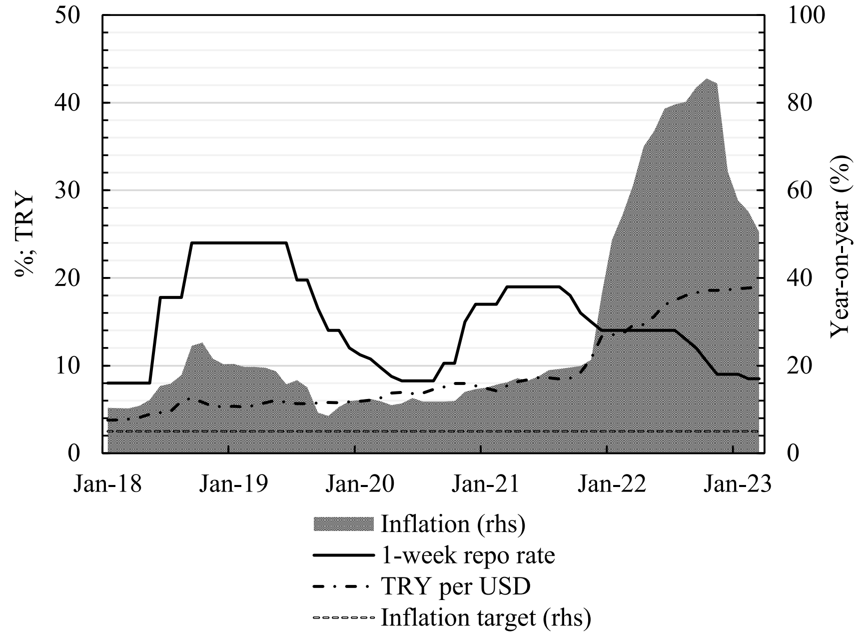


FIGURE 7: Inflationary developments in Turkey.

Sources: CBRT, Refinitiv and authors' calculations. Notes: End-of-month 1-week repo rate. The inflation target is a 5% year-on-year change in the CPI as of year-end. Data until Mar-23.

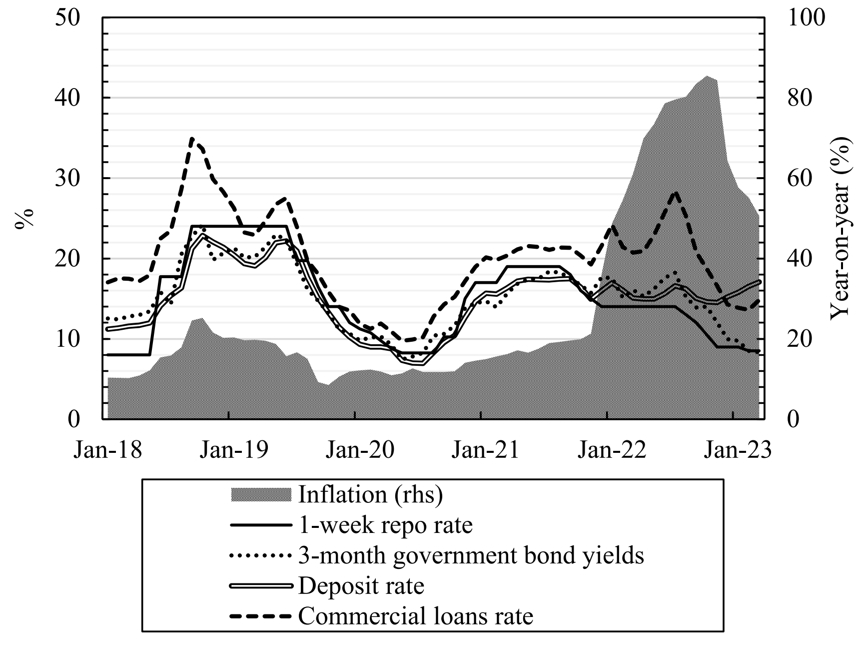


FIGURE 8: Interest rates in Turkey.

Sources: CBRT, Refinitiv and authors' calculations. Notes: End-of-month 1-week repo rate. The deposit rate is the weighted average of new, up to one-month lira deposits. The commercial loans rate is the weighted average of new commercial loans denominated in liras. In Aug-22, the CBRT introduced requirements for banks to hold securities as collateral equal to 20% of commercial loans extended with an interest rate 1.4x the CBRT reference rate, with the requirement rising to 90% of commercial loans with an interest rate more than 1.8x the reference rate. Data until Mar-23.

Inflation and structural shocks

Some of the public health measures during the COVID-19 pandemic, followed by the war in the Ukraine, caused significant supply and demand disruptions that have translated into large movements in relative prices. Figure 9 shows the extent of those price movements in the euro area by comparing total HICP inflation with a measure of core inflation, which excludes energy and food prices. Relative price movements were also significant within core inflation, as shown in Figure 10. How should monetary policy deal with inflation that is so unequally distributed across sectors? Should it aim at stabilising total inflation by inducing deflation in the sectors where relative prices are falling? Should it allow for relatively high total inflation by stabilising prices in the sectors with decreasing relative prices?

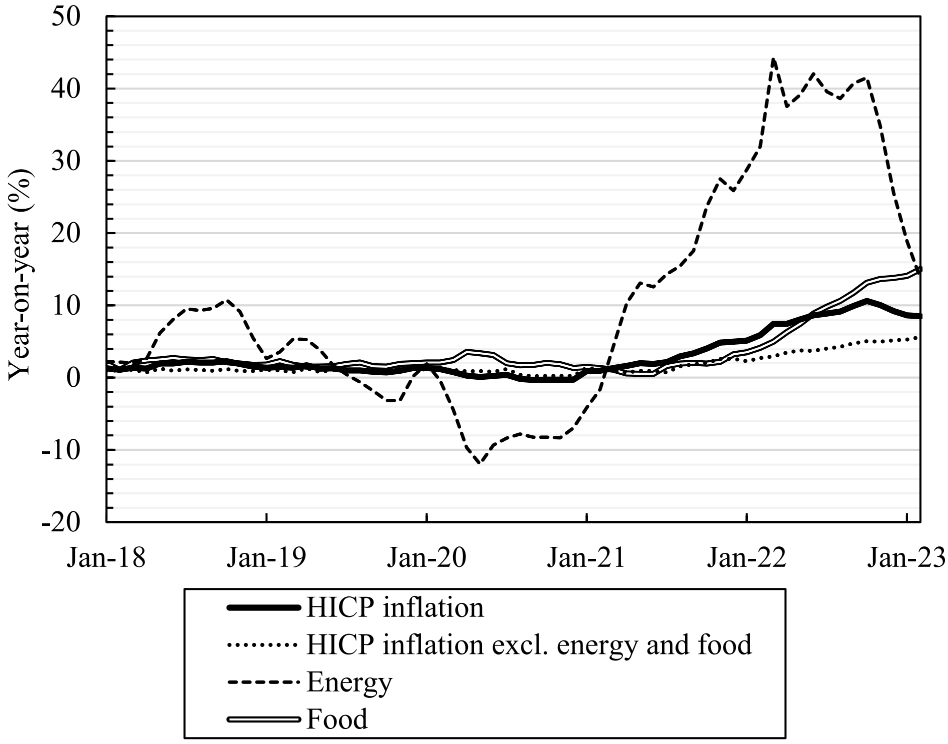
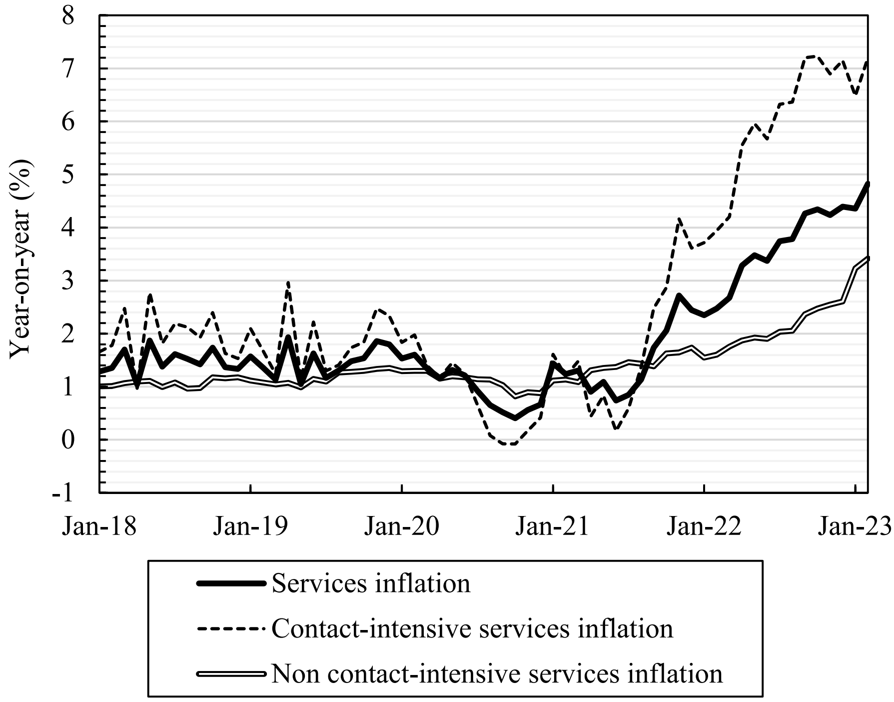


FIGURE 9: Euro area HICP inflation.

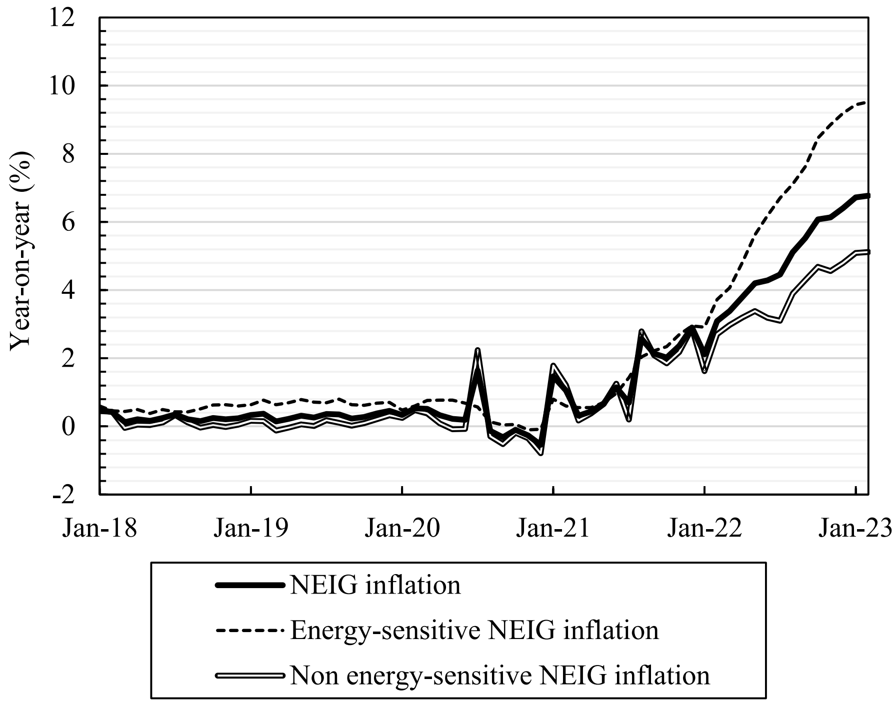
Source: Eurostat. Notes: Data until Feb-23.

A good benchmark to tackle these questions is to consider the premise that the goal of monetary policy is to implement the allocations that would take place without nominal rigidities. Under this premise, simple arguments from a model with downward wage rigidities suggest that stabilising total inflation is not the right goal for policy. Furthermore, allowing for some inflation in the sectors with decreasing relative prices may also be desirable. The allocations under flexible prices and wages may not be the second best optimum, but they should be close to it.

To discuss these arguments, let us consider a world with two sectors, A and B. Suppose that, under flexible prices and wages, real wages in sector A measured in



(A) Euro area services inflation. Notes: Contact-intensive services identified by the ECB. These items had a 39% weight on the HICP basket of services in 2022. Data until Feb-23.



(B) Euro area non-energy industrial goods (NEIG) inflation. Notes: Energy-sensitive goods identified by the ECB. These items have a share of energy in total costs (direct and indirect) above the average energy cost share across all NEIG items, and had a 37% weight on the HICP basket of NEIG in 2022. Data until Feb-23.

FIGURE 10: Euro area core inflation.

Sources: ECB, Eurostat and authors' calculations.

units of good A would decrease (possibly because of supply chain disruptions) and the relative price of good B would increase (possibly because of shifting demand). That is,

$$\frac{W_A}{P_A}\downarrow \ , \quad \frac{P_B}{P_A}\uparrow$$

In order to implement this allocation in an alternative world with downward wage rigidities, it is necessary to have inflation in sector A and even higher inflation in sector B. Illustratively,

$$\frac{\overline{W_A}}{P_A\uparrow}\downarrow \ , \quad \frac{P_B\uparrow\uparrow}{P_A\uparrow}\uparrow$$

Under this implementation, the nominal wage does not have to go down, but the real wage in units of A goods decreases and the real wage in units of B goods decreases even further. Optimality in such a world introduces an inflation bias. Both the need for an adjustment in real wages and relative price movements give rise to an inflation bias that could be large when those adjustments are also large.

The argument is not very different from the one that is normally used to justify that central banks pay attention to core inflation. The reason to exclude food and energy prices in core inflation is that those prices are very volatile. Monetary policy aims at stabilising prices in sectors where nominal rigidities are present, precisely because those sectors are the ones where price volatility is costly.[8] The difference with the argument above is that targeting core inflation does not necessarily generate an inflation bias, as total inflation under the optimal policy would deviate down from target when food and energy prices are relatively cheaper and would go above target when those goods are relatively more expensive. Instead, if the main source of inefficiency is downward wage rigidities, as illustrated above, optimal monetary policy will include an inflation bias that can be very large in response to large asymmetric shocks.

The issue of optimal monetary policy in a two-sector model with downward wage rigidities is also explored in a recent paper by Guerrieri *et al.* (2021). Under this framework, policy can address labour reallocation inefficiencies following a sectoral preference shock by allowing inflation to temporarily run above target, supporting stronger real wage growth in the labour-constrained sector, which sends the right price incentive for workers to move. The fact that real wages in the euro area in contact-intensive sectors such as the aggregate of wholesale and retail trade, repair of motor vehicles and motorcycles, transportation and storage and accommodation and food service activities has not decreased as much as in other sectors, as shown in Figure 11, supports this framework in thinking through the recent inflationary process.

8. See Aoki (2001) for a seminal analysis of optimal monetary policy in a two-sector dynamic general equilibrium model with a flexible-price sector and a sticky-price sector.

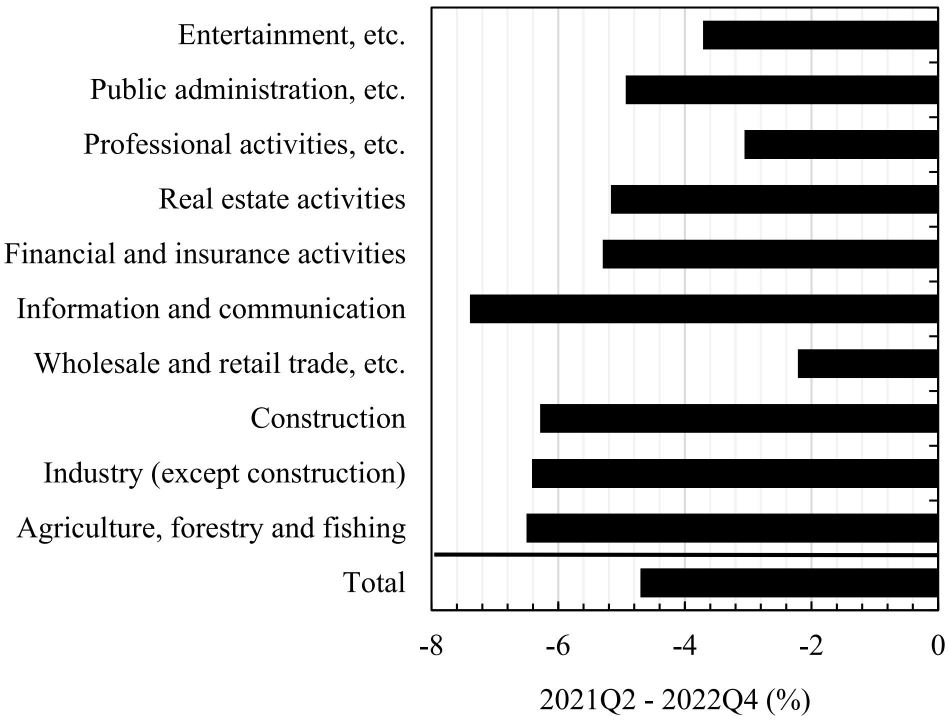


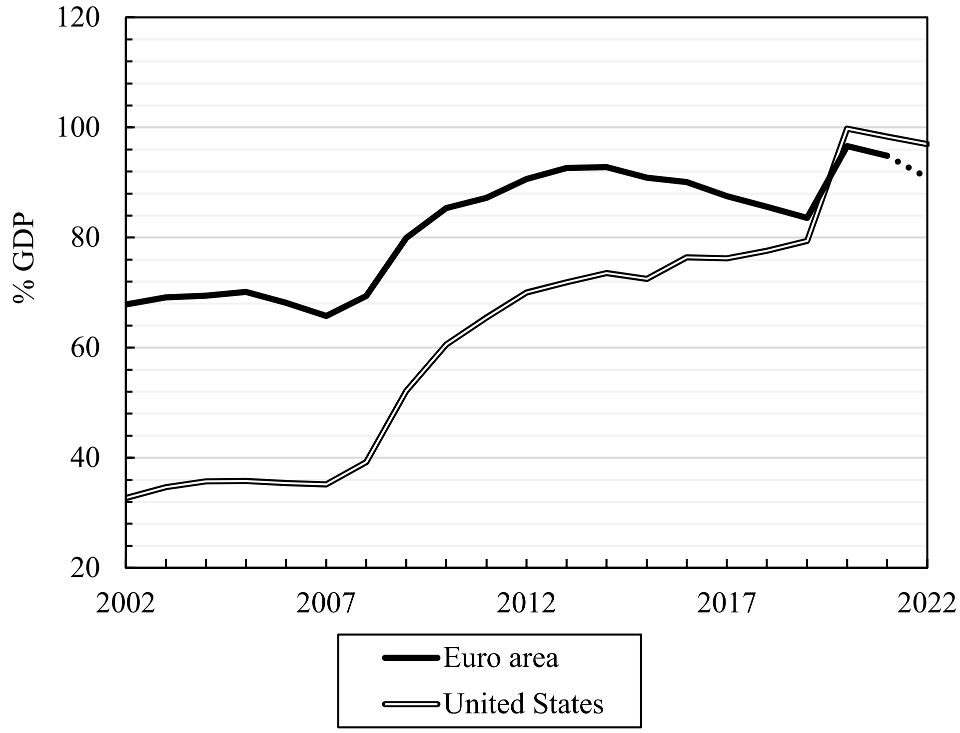
FIGURE 11: Euro area real compensation per employee.

Sources: ECB and authors' calculations. Notes: Nominal compensation per employee deflated by headline HICP. Seasonally adjusted data. Entertainment, etc. - Arts, entertainment and recreation; other service activities; activities of household and extra-territorial organizations and bodies. Public administration, etc. - Public administration, defence, education, human health and social work activities. Professional activities, etc. - Professional, scientific and technical activities; administrative and support service activities. Wholesale and retail trade, etc. - Wholesale and retail trade; repair of motor vehicles and motorcycles; transportation and storage; accommodation and food service activities.

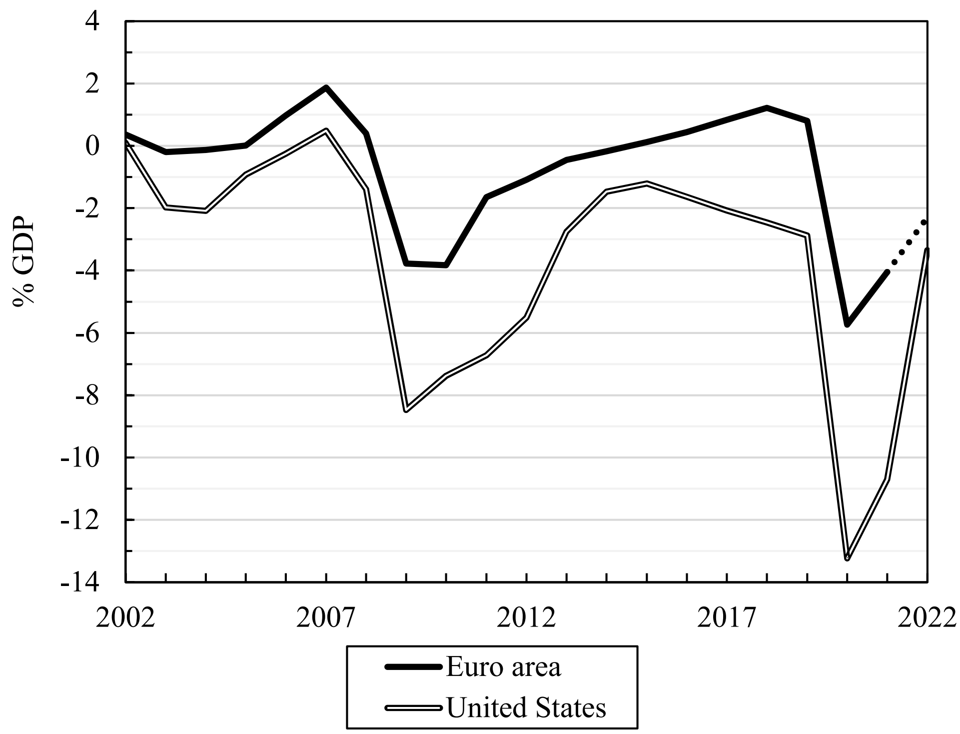
Inflation and debt depletion

The policy response to the pandemic included a significant expansion of public spending, both health and non-health related, including transfers. Both in the euro area and in the US, this translated into a large increase in debt levels, especially when measured as a share of a depressed GDP. As shown in Figure 12, the level of debt as a percentage of GDP increased in both economies by roughly twenty percentage points at the outbreak of the pandemic. Since then, and in spite of large fiscal deficits (as shown in Figure 12), debt as a share of GDP has decreased in both economies. A large part of this is explained by the nominal appreciation of GDP due to inflation.

The contribution of inflation to debt financing is not limited to the real depletion of the debt. The wages of civil servants are a large part of government spending, as are pensions. The depletion of the real value of those obligations through surprise inflation also amounts to a large cut in public spending. Figure 13 shows the evolution of real wages in the public administration in the euro area as well as in Portugal, one example where those wages are downward rigid. In the euro area, the fall in real wages through the pandemic is the largest since its inception; in Portugal, it is the largest cut in a decade.



(A) Debt. Notes: For the United States, we consider federal debt held by the public. For the euro area, we consider consolidated gross debt. Projected data for 2022 for the euro area.



(B) Primary balance. Notes: Projected data for 2022 for the euro area.

FIGURE 12: General government finance.

Sources: Congressional Budget Office and IMF.

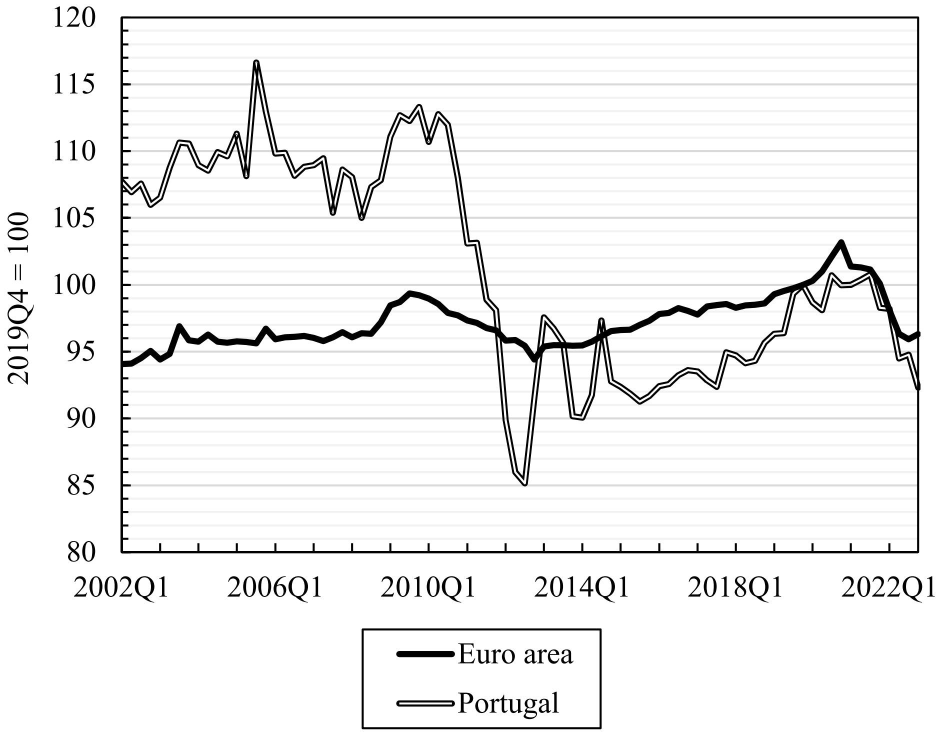


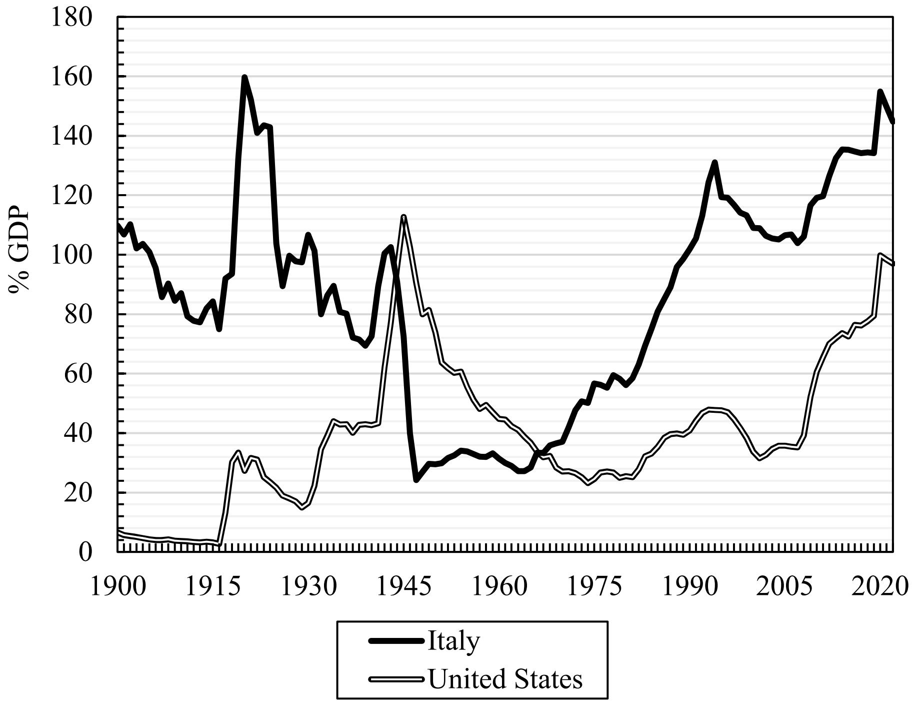
FIGURE 13: Real compensation per employee in the public sector.

Sources: ECB and authors' calculations. Notes: Compensation per employee of public administration, defence, education, human health and social work activities deflated by headline HICP. Data until 2022Q4.

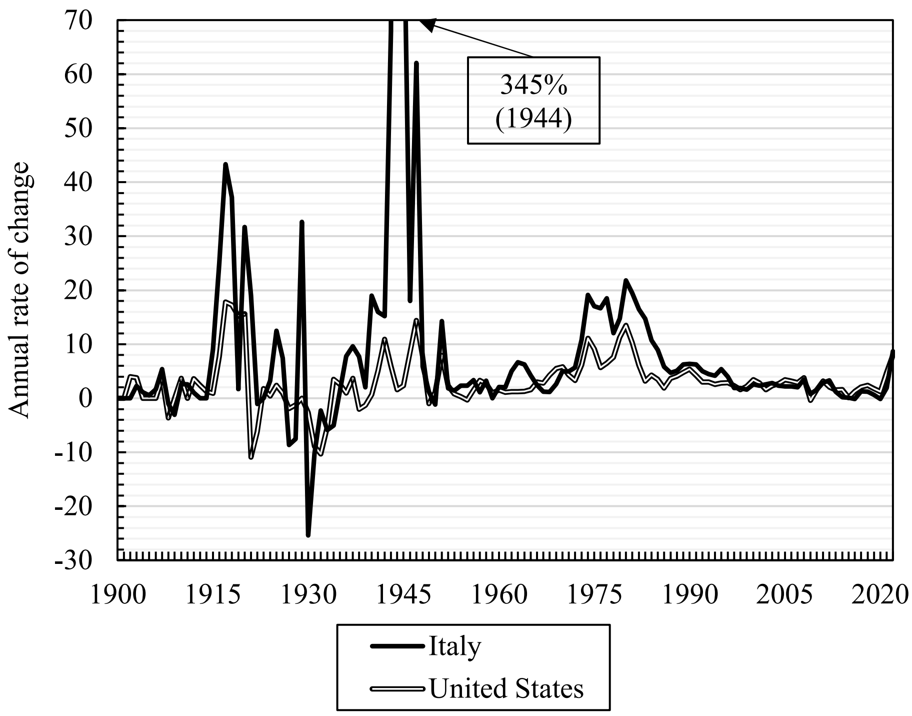
The use of inflation to deplete debt in response to a large fiscal shock is certainly not new. Hall and Sargent (2022) show that the US federal government financed its wartime expenditures during WWI and WWII primarily by issuing debt and printing money, rather than explicit taxation. Both during and after the wars, price levels rose significantly, eroding the real value of debt as creditors suffered large real losses. In the case of Italy, a key European player in both world wars, the stylized facts are broadly similar, as shown in Figure 14.

Is it optimal for policy to let inflation run high to deplete elevated nominal debt, rather than impose higher taxes? Under Calvo price setting, as is standard in the literature, the answer is no. Regardless of the maturity of the debt, which may smooth down inflation over time, the Calvo sticky price friction generates too much price dispersion. However, as shown in Teles and Tristani (2021), under alternative price setting assumptions such as sticky information as in Mankiw and Reis (2002), a significant inflation response is desirable if the maturity of debt is sufficiently long. The optimal response of inflation calibrated to the debt levels and maturity structure of the euro area is very close to the one that has been observed.

Interestingly, the war on COVID-19 and the two world wars of the 20th century share in common not only a large increase in the level of debt, which may be optimally depleted with surprise inflation, but also large structural shocks, giving rise to relative price movements that should be accommodated with higher than usual inflation.



(A) Debt. Notes: For the United States, we consider federal debt held by the public. For Italy, we consider consolidated gross debt.



(B) Inflation.

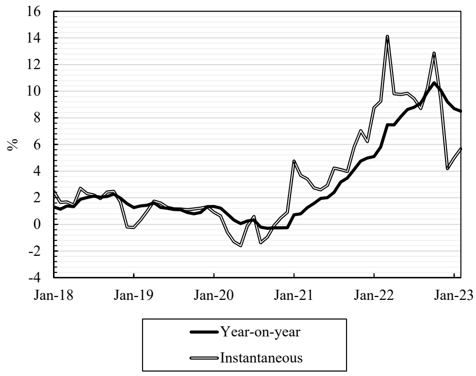
FIGURE 14: Historical evolution of debt and inflation.

Source: Congressional Budget Office, Eurostat, Federal Reserve Bank of Minneapolis, IMF, Reinhart and Rogoff (2011) and authors' calculations. Notes: We do not consider other European key players, such as Germany and France, due to data constraints. Data until 2022.

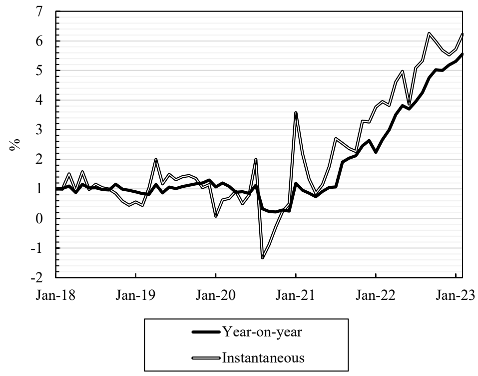
Concluding remarks

In this synopsis, we discuss reasons for current inflation to be tolerated. Large structural shocks and relative price movements with downward wage rigidity induce an inflationary bias that may be quite large given the size of the shocks. Furthermore, the large accumulation of debt during the pandemic could be more efficiently financed with surprise inflation than with higher taxes.

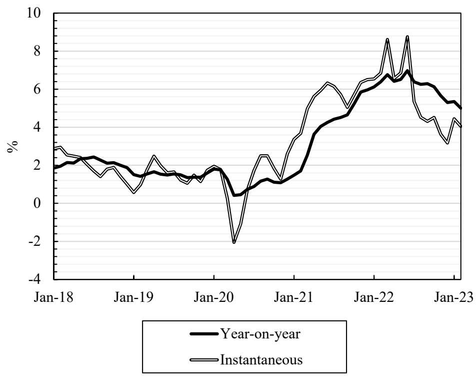
The risks of allowing for some inflation is that you may get a lot of it. Could this surge in inflation not be short lived, but rather have induced a very persistent deviation of inflation from target? In a recent work, Eeckhout (2023) highlights that when inflation is either going up or down, the annual average inflation rate can hide this information, since it implicitly uses equal weights for inflation within the year. He proposes a measure of instantaneous inflation that gives a higher weight to more recent data as a more adequate measure of the price changes. Employing such measure, headline inflation in the euro area and in the US appears to be closer to target, as shown in Figure 15. However, if we consider core inflation, the signs of a sustained disinflation process are less evident in both economies.



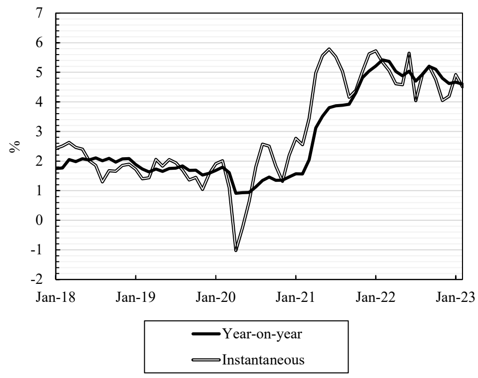
(A) Euro area - Headline HICP inflation.



(B) Euro area - Core HICP inflation.



(C) United States - Headline PCE inflation.



(D) United States - Core PCE inflation.

FIGURE 15: Instantaneous inflation.

Sources: ECB, Refinitiv and authors' calculations. Notes: Data until Feb-23.

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Appendix A: Estimation of the natural rate in the euro area

To estimate the natural rate in response to shocks, we consider the Federal Reserve Bank of New York estimates for the US and calculate the corresponding rate for the euro area.

From:

$$\frac{1+r^{e}_{t+1}}{1+r^{*e}_{t+1}} \approx \frac{\frac{1+i_t}{P^{e}_{t+1}/P_t}}{\frac{1+i^{*}_t}{P^{*e}_{t+1}/P^{*}_t}}$$

where P is the price level and the superscript e denotes the expectation, we get:

$$\frac{1+r^{e}_{t+1}}{1+r^{*e}_{t+1}} \approx \left[\frac{1+i_t}{1+i^{*}_t}\cdot\frac{F_{t,t+1}}{E_t}\right]\cdot\left[\frac{E^{e}_{t+1}}{F_{t,t+1}}\right]\cdot\left[\frac{\frac{E_t\cdot P_t}{P^{*}_t}}{\frac{E^{e}_{t+1}\cdot P^{e}_{t+1}}{P^{*e}_{t+1}}}\right]$$

Given the covered interest parity condition, $\frac{1+i_t}{1+i^{*}_t}\cdot\frac{F_{t,t+1}}{E_t}=1$, where E is the nominal exchange rate and F is the forward exchange rate, and assuming that the nominal exchange rate follows a random walk, $E^{e}_{t+1}=E_t$, we have

$$\frac{1+r^{e}_{t+1}}{1+r^{*e}_{t+1}} \approx \frac{E_t}{F_{t,t+1}}\cdot\frac{e_t}{e^{e}_{t+1}}$$

or

$$r^{e}_{t+1} \approx r^{*e}_{t+1} + i_t - i^{*}_t + \ln e_t - \ln e^{e}_{t+1}$$

Assuming that the real exchange rates also follow a random walk,

$$r^{e}_{t+1} \approx r^{*e}_{t+1} + i_t - i^{*}_t$$

The Federal Reserve Bank of New York estimates for the US natural rate in the last quarter of 2022 was 2.6%. Given that the policy rates in the euro area and in the US in the third quarter of 2022 were, on average, -0.1% and 2.2%, respectively, it follows that the natural rate in the last quarter of 2022 in the euro area was approximately 0.3%, on average, as shown below:

$$r^{e}_{2022Q4} \approx 2.6\% - 0.1\% - 2.2\% = 0.3\%$$

Appendix B: Other illustrative practical policy rules

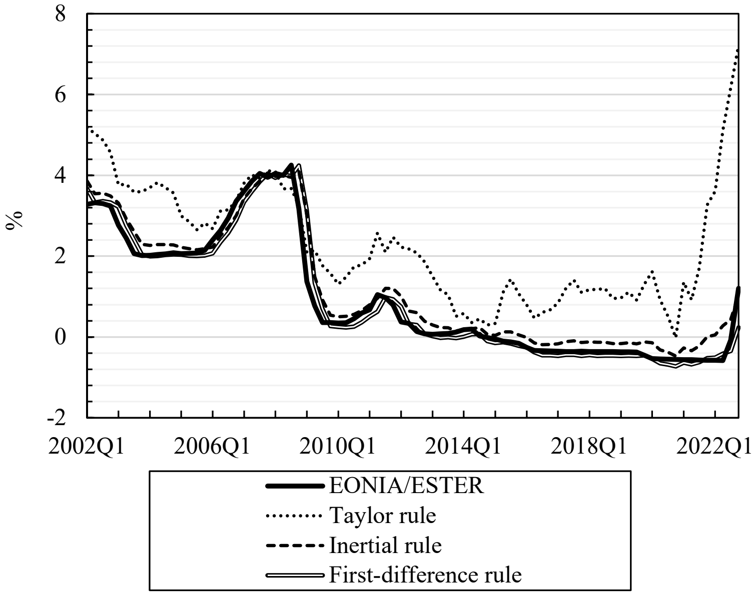
In this section, we consider four illustrative practical policy rules similar to those presented and extensively discussed in the Federal Reserve Board website, with minor modifications:[9]

9. See https://www.federalreserve.gov/monetarypolicy/policy-rules-and-how-policymakers-use-them.htm. We do not consider the ELB-adjusted rule due to the large uncertainty regarding where this bound lies, especially in the euro area.

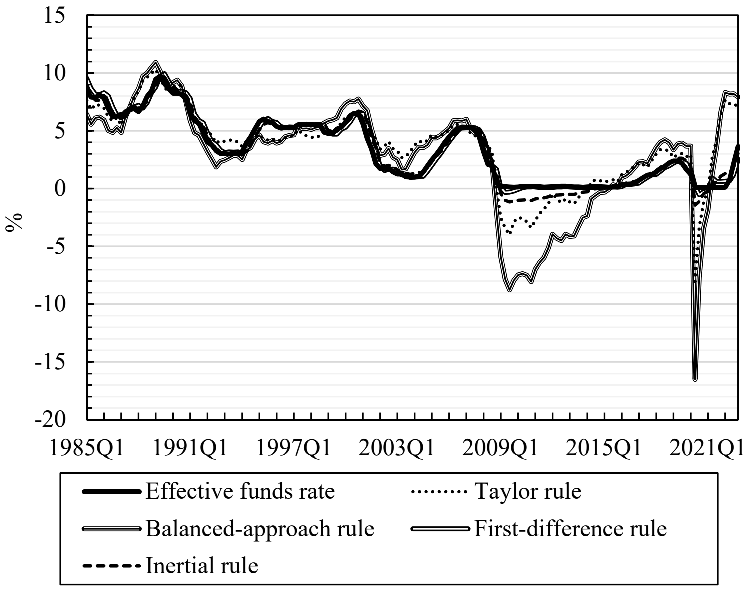
$$
\begin{array}{cc}
\text{Taylor rule:} & i_t^T = r_t^* + \pi^* + 1.5\,(\pi_t - \pi^*) - (u_t - u_t^*) \\
\text{Balanced-approach rule:} & i_t^{BT} = r_t^* + \pi^* + 1.5\,(\pi_t - \pi^*) - 2\,(u_t - u_t^*) \\
\text{Inertial rule:} & i_t^I = 0.85 i_{t-1} + 0.15 i^{BT} \\
\text{First-difference rule:} & \Delta i_t^{FD} = 0.1\,(\pi_t - \pi^*) - 0.1\,(u_t - u_{t-4})
\end{array}
$$

For the euro area, we remove any direct considerations of the unemployment gap to reflect the fact that the ECB does not follow a dual mandate, which effectively eliminates the distinction between the Taylor rule and the Balanced-approach rule.

As shown in Figure B.1, the prescriptions from the Taylor rules with built-in gradualism, such as the inertial rule and the first-difference rule, have closely followed the actions of both the Fed and the ECB. During the recent high inflation episode, there were negative deviations from the inertial rule in the euro area and from both gradualist rules in the US, showing a slow response of policy even taking gradualism into account.



(A) Euro area. Notes: We employ EONIA until 2019Q4 and ESTER thereafter (quarterly averages of daily data). We consider HICP excluding food and energy, and 2% as the inflation target. Data until 2022Q4.



(B) United States. Notes: Quarterly averages of daily data for the effective funds rate. We consider PCE inflation excluding food and energy, and 2% as the inflation target. We consider the Congressional Budget Office estimates of the noncyclical rate of unemployment as a measure of u*. Data until 2022Q4.

FIGURE B.1: Rules prescriptions.

Sources: Congressional Budget Office, ECB, Eurostat, Federal Reserve Bank of New York, Federal Reserve Economic Data (FRED), Refinitiv and authors' calculations. Notes: The natural real interest rate is estimated from the Holston, Laubach and Williams (HLW) model. The New York Fed suspended the publication of the HLW estimates of the natural real interest rate after releasing estimates for the second quarter of 2020. Beyond this period, we follow the procedure of the Federal Reserve Bank of Atlanta and assume that the HLW estimates remain at their last published values.

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