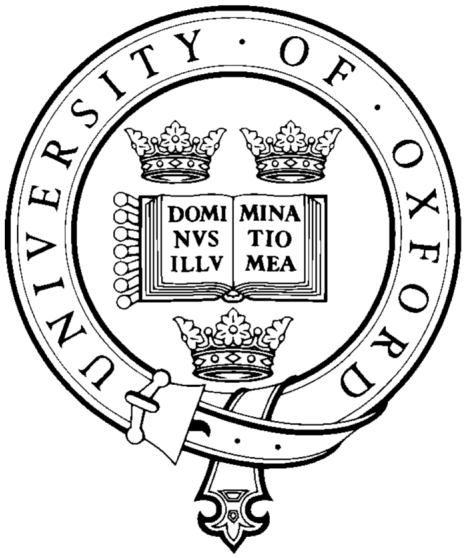
Essays in Macroeconomics



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Abstract

This thesis consists of three standalone essays in macroeconomics that study distinct but related questions in inflation dynamics, fiscal policy, and monetary policy.

Chapter 1 examines the distributional consequences of supply-driven energy shocks. Using household-level expenditure data for the United States, the chapter shows that energy price increases lead to significantly larger consumption declines for low-income households than for high-income households. To analyse policy responses, the chapter develops a two-agent New Keynesian model with non-homothetic preferences. The model shows that targeted fiscal transfers can mitigate rising consumption inequality, but only at the cost of higher inflation and interest rates, giving rise to an inflation–inequality dilemma.

Chapter 2 studies the transmission of exogenous energy supply shocks to inflation in the euro area. While energy shocks generate sharp but transitory movements in headline inflation, pass-through into core inflation is more persistent. Allowing for state dependence reveals important nonlinearities, showing that energy shocks can materially affect underlying inflation when inflationary pressures are elevated or energy price increases are large. As a result, linear estimates can be misleading, and the relevance of energy shocks for underlying inflation in the medium run depends critically on the macroeconomic environment.

Finally, *Chapter 3* explores the relationship between automatic indexation of government spending and the cyclicality of fiscal policy. The chapter introduces a novel panel dataset on indexation practices for public wages, social security, and social assistance programmes covering over 100 countries from 2002 to 2023, along with a weighted index capturing indexation intensity. On average, indexation is not significantly associated with fiscal cyclicality, but the relationship is nuanced across country groups. In advanced economies, indexation tends to be associated with weaker fiscal countercyclicality by constraining discretion, while in emerging markets it is linked to lower procyclicality through a commitment channel.

Taken together, the essays provide new evidence on how inflation shocks and policy responses interact with heterogeneity across households, countries, and macroeconomic states, carrying important implications for policy design and evaluation.

Supervisors

The thesis was supervised by Sergio de Ferra (primary supervisor) and Andrea Ferrero (secondary supervisor), both from the University of Oxford.

Statement of Authorship

The thesis was completed as part of my DPhil at the University of Oxford and has not been submitted, in whole or in part, for any other degree. Chapter 1 is joint work with Momo Komatsu (then DPhil student at Oxford, now at the Federal Reserve Board of Governors). Chapter 2 is single-authored. Chapter 3 was conducted in collaboration with Vybhavi Balasundharam, Arika Kayastha, and Alexandra Solovyeva from the International Monetary Fund, where part of the research was conducted during a visit in 2023.

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This thesis contains approximately 65,000 words.

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As I write these acknowledgements in the beautiful Bodleian Library, I cannot help but think back to the first time I came to Oxford some 15 years ago. My mother and I were visiting London, and I insisted on a day trip to Oxford. *'My daughter is interested in academia and wants to visit one of the oldest universities in the world?'* She was so proud of me - that is, until we stepped off the Oxford Tube and she realised my actual motive was to visit the Harry Potter filming locations. Nonetheless, as I was in awe of the city, the university, and its environment, something clicked, and back home, I spent hours reading about different degrees at Oxford, dreaming

[1] While it may be odd to point it out, I feel very fortunate to have been part of a macro cohort with almost equal gender representation - which is still quite rare in the field, but makes the experience so much better.

about studying here, so that I sometimes have to pinch myself that this is where I spent the last few years.

Much of my research was motivated by my personal experience working as a macroeconomic researcher in the private sector, forecasting inflation in 2021 at the start of the surge. I would often hear, *'It's just food and energy; it will pass quickly'*, yet month after month, this turned out to be wrong. This sparked questions that ultimately set me on my DPhil journey and shows that asking questions is always the first step.

Rosi D. Chankova
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List of Abbreviations

2SLS Two-stage least squares

AE Advanced economies

AMECO Annual Macro-Economic Database

AR(1) First-order autoregressive process

BEA Bureau of Economic Analysis

BLS Bureau of Labor Statistics

Brent Brent crude oil

CES Consumer Expenditure Survey

Covid-19 Coronavirus disease 2019

CPI Consumer price index

DSGE Dynamic stochastic general equilibrium

EA-20 Euro area (20 countries)

EC European Commission

ECB European Central Bank

EM Emerging markets

EMDE Emerging markets and developing economies

FAD IMF Fiscal Affairs Department

FRED Federal Reserve Economic Data

GDP Gross domestic product

GMM Generalised method of moments

HANK Heterogeneous-agent New Keynesian

HICP Harmonised index of consumer prices

HP Hodrick-Prescott filter

i.i.d. Independent and identically distributed

ILO International Labor Organization

IPW Inverse probability weighting

IRF Impulse response function

ISSA International Social Security Association

IV Instrumental variables

LIDC Low-income developing countries

LM Lagrange multiplier

LOWESS Locally weighted scatterplot smoothing

LP Local projection

LP-IV Local projections with instrumental variables

MPC Marginal propensity to consume

NAWRU Non-accelerating wage rate of unemployment

NEIG Non-energy industrial goods

OECD Organisation for Economic Co-operation and Development

OLS Ordinary least squares

OPEC Organization of the Petroleum Exporting Countries

PCE Personal consumption expenditures

Q Quarter (e.g., 1990-Q1, 2023-Q1)

SPL-AT Social Protection and Labor Toolkit (IMF Database)

TANK Two-agent New Keynesian

U.S. United States

US SSA United States Social Security Administration

WEO World Economic Outlook

WISI Weighted index of spending indexation

Introduction

After several decades of low and stable inflation, the global economy experienced a sharp resurgence of inflation in 2021/22, bringing inflation back to the centre of macroeconomic research and policy debates. In advanced economies, inflation reached levels not seen since the 1980s, prompting rapid monetary tightening and renewed attention to the interaction between monetary policy, fiscal policy, and distributional outcomes. The inflation surge followed an extraordinary sequence of shocks, including the Covid-19 pandemic, large-scale fiscal and monetary interventions, supply-chain disruptions, and the war in Ukraine.

This episode exposed important gaps in our understanding of how inflationary shocks propagate through the economy and how policy frameworks shape their consequences. In particular, inflation turned out to be more persistent than initially anticipated and its distributional effects became increasingly salient. Relative-price shocks originating in energy markets spilled over into broader inflation dynamics, while institutional features such as fiscal rules and indexation mechanisms influenced both the speed of adjustment and the allocation of inflation risk across households and governments. As a result, policymakers faced difficult trade-offs - how aggressively to respond to inflation driven by sector-specific shocks, how to protect vulnerable households without reinforcing inflationary pressures, and how to balance the discipline provided by fiscal institutions with the flexibility needed to operate under sustained price instability.

This thesis contributes to these questions by studying different aspects of inflation dynamics across three chapters. Chapters 1 and 2 form a first block that analyses the macroeconomic consequences of energy price shocks, focusing on distributional outcomes and the pass-through of energy prices into underlying inflation, respectively. Chapter 3 forms a second block that examines how inflation interacts with fiscal institutions, studying the implications of government spending indexation

for fiscal cyclicality. Together, the chapters provide a unified perspective on how inflation shocks affect households, prices, and policy frameworks, and on why heterogeneity, nonlinearity, and institutional context are central to understanding inflation dynamics in practice.

Chapter 1:
Energy Shocks, Consumption Disparities, and the Inflation-Inequality Dilemma
Chapter 1 studies the distributional consequences of supply-driven energy shocks on household consumption and examines the implications for fiscal policy design. The motivation stems from the observation that energy price shocks disproportionately affect low-income households. Specifically, as energy expenditures constitute a larger share of the consumption basket for poorer households, sharp energy price increases translate into higher effective inflation rates and tighter real budget constraints. While the literature extensively documents the effects of energy shocks on aggregate inflation and output, less is known about their impact on distributional outcomes and consumption inequality.

The chapter makes three main contributions. First, it provides new empirical evidence on how exogenous energy price shocks affect consumption across the income distribution. Second, it documents that these heterogeneous responses lead to a persistent widening of consumption inequality. Third, it quantifies the trade-offs faced by fiscal policy in responding to energy shocks, highlighting tensions between inequality mitigation and inflation stabilization.

Empirically, the analysis combines household-level expenditure data from the U.S. Consumer Expenditure Survey with an instrumental-variables local projection framework. Exogenous energy price movements are identified using oil supply news shocks derived from OPEC announcements, following Känzig (2021). Income-decile-specific measures of real consumption and inflation are constructed using detailed expenditure weights, enabling a direct assessment of heterogeneous inflation exposure.

The results show that energy price shocks lead to significant declines in consumption for low-income households, while consumption among high-income households remains broadly unaffected. These effects extend beyond energy expenditures to non-energy consumption, resulting in an increase in consumption inequality that lasts several quarters.

To interpret these findings and evaluate policy responses, the chapter develops a two-agent New Keynesian model with non-homothetic preferences and energy as a necessity good. The model replicates the empirical patterns of heterogeneous consumption responses and rising inequality. Counterfactual policy exercises show that fiscal transfers targeted at low-income households substantially reduce the inequality effects of energy shocks, but come at the cost of higher aggregate inflation and a stronger monetary policy response. These results emphasise the *inflation–inequality dilemma* policymakers face in the presence of supply-driven energy shocks.

Chapter 2:
Look-Through or Look Closer? Energy Shocks and Underlying Inflation in the Euro Area

Chapter 2 examines the transmission of exogenous energy supply shocks into underlying inflation in the euro area. While energy prices have been a major driver of headline inflation in recent years, existing empirical evidence suggests that pass-through to core inflation is, on average, limited. However, much less is known about how this transmission varies across macroeconomic environments, core inflation components, and countries within the euro area.

To address these questions, the analysis combines externally identified energy supply shocks from Känzig (2021) with local projection methods that allow for flexible dynamics and explicit nonlinear state dependence.

The results yield three main findings. First, energy supply shocks generate a sharp but short-lived increase in energy and food inflation, which passes through quickly to headline inflation and largely dissipates within one year. By contrast, pass-through into core inflation only materialises with a substantial delay, peaks after roughly two years, and is considerably more persistent. This distinction reflects the difference between direct compositional effects in the overall consumption basket and indirect effects operating through wages, expectations, and pricing decisions.

Second, pass-through into core inflation is heterogeneous across components and countries. Non-energy industrial goods account for a disproportionate share of the response, while services inflation reacts more slowly and less strongly. Across countries, responses vary markedly, with particularly strong and persistent effects in Germany, consistent with differences in production structures and exposure to energy-intensive manufacturing.

Third, and most importantly, the pass-through from energy shocks to core inflation is highly nonlinear and state dependent. When inflationary pressures are elevated, as reflected in high wage growth, unanchored inflation expectations, or high headline inflation, energy shocks transmit into core inflation faster and with substantially larger peak effects. Large energy price movements further amplify pass-through relative to moderate shocks. In contrast, when inflationary pressures are subdued, energy shocks have little or no effect on core inflation. Linear estimates therefore mask economically meaningful variation across macroeconomic regimes and may provide misleading guidance for policy.

Overall, the results support a *conditional* interpretation of the "look-through" view. On average, pass-through from energy shocks to core inflation is modest, suggesting that central banks can often abstract from energy price fluctuations. However, the strong state dependence documented in the nonlinear analysis fundamentally qualifies this conclusion, underscoring the importance of nonlinear transmission mechanisms in models of inflation.

Chapter 3:
Indexation and Cyclicality of Fiscal Policy: Evidence from a Panel Data Analysis
Chapter 3 shifts focus from the transmission of inflation shocks to the role of fiscal institutions, examining how the indexation of government spending affects fiscal cyclicality. Inflation indexation mechanisms, such as automatic adjustments of public wages, pensions, or social transfers to inflation, are often designed to preserve the purchasing power of households. However, their macroeconomic implications, particularly for fiscal stabilization, remain poorly understood.

The chapter makes three main contributions. First, it constructs a novel cross-country dataset on indexation practices for major government spending categories, covering more than 100 countries over two decades. Second, it develops a weighted index of spending indexation that captures the overall intensity of automatic indexation in government expenditure. Third, it provides the first systematic empirical assessment of how indexation affects the cyclical behaviour of fiscal policy across countries and institutional settings.

Using panel regressions with country and time fixed effects, the chapter estimates the cyclicality of government spending and fiscal balances and examines how this cyclicality varies with the degree of indexation. To address endogeneity concerns, the analysis employs an instrumental-variables strategy based on indexation

practices in neighbouring countries. The results show that indexation has heterogeneous effects. In advanced economies, higher indexation is associated with weaker countercyclicality, reflecting reduced fiscal flexibility. In contrast, in emerging and developing economies, indexation is associated with lower procyclicality and stronger countercyclicality, suggesting that it can act as a commitment device in environments with weak fiscal institutions.

These findings highlight that inflation-related fiscal institutions play an important role in shaping macroeconomic outcomes, particularly during periods of elevated inflation. Chapter 3 complements the first two chapters by showing that the consequences of inflation depend not only on the shocks themselves but also on the institutional frameworks through which policies operate.

Chapter 1

Energy Shocks, Consumption Disparities, and the Inflation-Inequality Dilemma*

Abstract The 2021/22 inflation surge, driven primarily by rising energy prices, disproportionately affected low-income households due to their higher budget share spent on necessities. This study examines how supply-driven energy price shocks impact consumption behaviour across income groups in the United States, with a focus on the implications for consumption inequality. Using household expenditure data, this paper finds that low-income households experience significantly larger consumption declines than high-income households, with larger adjustments occurring via energy than non-energy consumption. To explore consumption inequality and macroeconomic outcomes under alternative policy scenarios, a two-agent New Keynesian model with non-homothetic preferences is introduced. This paper shows that targeted fiscal transfers can help mitigate the deepening of consumption inequality, albeit at the cost of higher inflation and interest rates, pointing to an *inflation-inequality dilemma*.

Keywords: Energy Shocks, Inflation Heterogeneity, Inequality, Households.
JEL: D31, E21, E31, E52, E62.

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1.1 Introduction

Sharp increases in energy prices pose distinct macroeconomic and distributional challenges. While the aggregate effects of energy shocks on inflation and output have been studied extensively, the recent surge in energy prices highlights the importance of understanding the heterogeneous effects of relative price shocks on households. Accordingly, this paper addresses two key questions: (i) how do energy price shocks affect consumption patterns across the income distribution, and (ii) how do consumption inequality and other macroeconomic outcomes differ, depending on whether fiscal support is targeted toward vulnerable households?

The distributional relevance of energy shocks arises from three stylised facts. First, energy goods make up a disproportionately large share of low-income household expenditure. As a result, asymmetric energy price shocks resemble a regressive consumption tax, unlike a broad-based inflation increase, as lower-income households face a higher effective inflation rate (Chan et al., 2024; Erosa & Ventura, 2002).[1] Second, because energy demand is relatively inelastic (Andreyeva et al., 2010; Labandeira et al., 2017), households are forced to absorb price increases, and low-income households in particular have limited margins of substitution.[2] Third, liquidity constraints limit the ability of poorer households to smooth consumption through saving or borrowing in response to price spikes (Battistini et al., 2022). Together, these features imply that energy price shocks can produce substantial heterogeneity in household inflation experiences and cause consumption inequality to rise.

Governments frequently respond to such shocks with short-term fiscal measures designed to sustain the purchasing power of households. These include tax rebates and credits (e.g., the 2008 *Economic Stimulus Act*), temporary suspensions of gasoline taxes (as implemented in Maryland and Georgia in 2022), or direct transfers and subsidies (e.g., the 2020-21 *Economic Impact Payments* - commonly referred to as 'stimulus checks', the federal *Low Income Home Energy Assistance Program*, and the *California Alternate Rates for Energy* discount program for low-income households).[3] In line with the "three T's" principle of fiscal design (see Elmendorf and Furman, 2008), these measures were generally *timely* and *temporary*, but not always *targeted*. This paper examines the implications of that distinction, asking how interventions targeted at vulnerable households versus untargeted (i.e., universally extended) ones shape the distributional and aggregate macroeconomic effects of energy price shocks.

To address these research questions, this paper proceeds in two steps. First, using household-level microdata from the U.S. Consumer Expenditure Survey (CES), decile-specific inflation rates and real consumption series are constructed.[4] An instrumental variables local projec-

[1] This relates to a larger literature which shows households with lower income to experience higher inflation rates than those with higher income (see Hobijn et al., 2009; Jaravel, 2019; Kaplan and Schulhofer-Wohl, 2017; Neyer and Stempel, 2025).

[2] Low-income households have fewer substitution options, because they are more likely to already consume the least expensive variety within each category of goods and services.

[3] While the 2008 *Economic Stimulus Act* and 2020 *Economic Impact Payments* were part of broader recovery packages aimed at mitigating wider economic downturns, they were in part also responding to rising energy and living costs following the energy price surges of 2007 and 2021.

[4] This study focuses on consumption inequality because it is a more welfare-relevant measure than income inequality.

tion approach à la Jordà et al. (2015) is then applied to estimate the effects of exogenous energy price shocks on consumption patterns across income groups. Energy shocks are measured using the OPEC-based supply shock series from Känzig (2021), which captures oil price movements independent of domestic demand. Second, the paper introduces a two-agent New Keynesian model with non-homothetic preferences that captures the heterogeneity between constrained (low-income) and unconstrained (high-income) households. This framework provides a structural lens through which to assess the distributional and macroeconomic implications of targeted fiscal transfers under supply-driven energy shocks.

This study documents four main findings. First, in response to an energy price shock, consumption falls more sharply for lower-income households than for higher-income households, with responses declining (nearly monotonically) across income deciles. Second, the resulting rise in consumption inequality is persistent, lasting up to a year after the initial shock. Third, the contraction in energy consumption is deeper and more persistent than that of non-energy consumption. Fourth, policy design strongly influences outcomes: fiscal transfers targeted at constrained (low-income) households can substantially mitigate the rise in consumption inequality, albeit at the cost of higher inflation, giving rise to the *inflation-inequality dilemma* the paper points to.

Thus, the analysis contributes to the literature in two ways. Empirically, the paper quantifies the heterogeneous consumption effects of supply-driven energy shocks across the income distribution and characterises their impact on consumption inequality. Theoretically, this paper makes a novel contribution by introducing a framework that highlights the trade-off policymakers face between stabilising inflation and mitigating consumption inequality in response to supply-driven energy price shocks, a dimension largely unexplored in prior research.

The remainder of the paper is structured as follows. Section 1.2 gives an overview of the relevant literature. Section 1.3 presents the household survey data and descriptive results that motivate the study. Section 1.4 details the econometric framework and discusses insights from the empirical estimates. Section 1.5 introduces a theoretical DSGE model, and Section 1.6 discusses the baseline model impulse responses and counterfactual policy interventions. Finally, Section 1.7 concludes with key insights and directions for future research.

1.2 Literature Review

This paper relates to three strands of literature: (i) the macroeconomic effects of energy price shocks, (ii) the distributional consequences of inflation, and (iii) the role of household heterogeneity in macroeconomic transmission.

Although the recent increase in energy prices is striking in scale, sharp fluctuations in these prices are not uncommon given the inherent volatility of these markets (e.g., Parker, 2017). A substantial body of literature examines the macroeconomic impacts of energy price shocks, especially oil prices, and finds mixed results regarding their effects on aggregate consumption and output, with outcomes varying by country and sample period (see Hoang et al., 2019, for a review of previous studies). Kilian (2008) shows that the economic consequences of energy price shocks depend crucially on their underlying source: supply-driven increases in energy prices exert more pronounced adverse effects on output and inflation

than demand-driven shocks. While some studies suggest that the aggregate impacts of these shocks have lessened over time in advanced economies,[5] the disproportionate burden on lower-income households is less well understood at the micro level.

Lower-income households are particularly vulnerable to inflationary pressures due to their limited savings and tendency to hold assets in cash or low-interest accounts that do not protect against inflation (see Bettarelli et al., 2023, for a comprehensive review). Galli and van der Hoeven (2001) and Doepke and Schneider (2006) show that inflation can exacerbate income inequality, and Easterly and Fischer (2001) argue that low-income workers are less able to adjust for rising prices given their limited wage bargaining power. Moreover, energy price shocks have been shown to drive significant labour reallocation across sectors (Loungani, 1986). A closely related contribution is Bettarelli et al. (2023), which examines energy inflation in a panel of countries and finds a significant increase in aggregate consumption inequality measures (e.g., the consumption Gini coefficient), particularly in economies with weaker financial systems and monetary policy frameworks. This paper contributes by adopting a 'ground-up' view of inequality, leveraging detailed U.S. microdata to uncover the mechanisms of consumption adjustment and to evaluate counterfactual policy interventions, rather than considering inequality in aggregate terms.

The literature on consumption inequality highlights both cyclical and structural determinants of disparities across income groups. Foundational contributions include Coibion et al. (2012), Krueger and Perri (2006), and Meyer and Sullivan (2013), who document how business cycles, credit constraints, and risk-sharing mechanisms shape the distribution of consumption. The study contributes to the literature by emphasising energy price shocks as a cyclical source of inequality, with potential implications for the secular rise in consumption inequality. Using household-level data from the Bureau of Labor Statistics' Consumer Expenditure Survey, it examines how energy price shocks disproportionately affect lower-income households. This approach provides new evidence on the interaction between sectoral price volatility and consumption inequality. A growing body of work examines fiscal policy responses to mitigate the distributional effects of energy price shocks (Kharroubi & Smets, 2024; Kröger et al., 2023; Meyimdjui & Combes, 2021; Zhang et al., 2014). Jaravel and Olivi (2019) analyse optimal tax policy in the presence of heterogeneous inflation, offering insights relevant to inflationary pressures driven by energy costs. More generally, fiscal measures such as targeted subsidies, cash transfers, and progressive taxation have been shown to ease the burden on low-income households (Bonifacio et al., 2021).

Finally, recent advances in the heterogeneous agent literature underscore the importance of accounting for income, wealth, and consumption preference differences in understanding the effects of economic shocks (Auclert, 2019; Bilbiie, 2008, 2017; Broer et al., 2020; Debortoli & Galí, 2017; Dolado et al., 2021; Kaplan et al., 2018; Komatsu, Forthcoming). Non-homothetic preferences capture differences in the exposure and response of low- and high-income households to price changes in essential goods, as lower-income households allocate a larger share of their income to necessities (Boppart, 2014). By focusing on consumption basket heterogeneity in a two-agent New Keynesian framework, the paper extends this literature, exploring the analytical channels through which differences in

[5] Blanchard and Galí (2007), Choi et al. (2018), and Hooker (1996) attribute the muted impact of energy shocks in later periods to improvements in monetary policy frameworks and greater diversification of energy supplies

spending patterns impact consumption inequality following relative price shocks.

By integrating insights from these strands of literature, this analysis provides a comprehensive understanding of the cyclical effects of energy price shocks on consumption inequality and draws policy-relevant implications for designing fiscal interventions aimed at protecting vulnerable households.

1.3 Data and Empirical Background

1.3.1 Consumer Expenditure Survey and Other Data

To study heterogeneous consumption behaviour across households, this paper uses microdata from the "Interview Survey" component of the quarterly U.S. Consumer Expenditure Survey (CES).[6] The Interview Survey is designed to capture regular and recurring expenditures and follows households for up to four consecutive quarters, allowing for a rich characterisation of consumption patterns over time.

The CES is widely used in empirical macroeconomics and public finance (see Aguiar and Bils, 2015; Argente and Lee, 2021; Cravino et al., 2020; Garner et al., 1999; Hobijn and Lagakos, 2005; Hobijn et al., 2009; Jaravel, 2019) and constitutes the primary data source underlying the construction of expenditure weights in the U.S. Consumer Price Index (CPI). Its detailed structure provides information on household income, demographic characteristics, and disaggregated expenditures across more than 1000 consumption categories, including a fine breakdown of food and energy items. This level of granularity is particularly well suited to studying the distributional consequences of sector-specific price shocks.

Relative to alternative household surveys, the CES offers two key advantages for the purposes of this paper. First, it provides detailed household-level information on consumption expenditures across a large number of narrowly defined categories, allowing consumption baskets to vary systematically across households. Second, the CES combines a long historical coverage beginning in the mid-1980s with a relatively high frequency, as households are interviewed on a quarterly basis. Together, these features make it possible to exploit the micro-level structure of the CES to trace how supply-driven energy price shocks translate into heterogeneous consumption adjustments across the income distribution, rather than focusing solely on aggregate measures of inequality.

The analysis uses CES Interview Survey data spanning from 1990-Q1 to 2023-Q1, comprising approximately 5,000 to 7,000 household responses per quarter. After applying standard consistency checks (e.g., excluding observations with zero reported expenditures in key categories), the final sample contains roughly 860,000 household-quarter observations, providing both substantial statistical power and a high degree of granularity.

A limitation of the CES is its rotating panel structure, under which households are observed for a maximum of four consecutive quarters and new households enter the sample each period. To address this feature, the analysis constructs a pseudo-panel by grouping

[6] This study focuses on the U.S. due to the public availability of granular household-level data, which enables a more detailed analysis. Extending the framework to Europe is a natural next step for future research, especially as the 2021/22 inflation surge there was more strongly driven by energy supply shocks.

households into income percentiles each quarter and tracking cohort-level means over time, following the approach of Deaton (1985), Moffitt (1993), and Verbeek and Nijman (1992).[7] This approach allows the evolution of consumption responses across the income distribution to be studied even as individual households enter and exit the sample, and as households move across income percentiles over time. By averaging outcomes within income groups, the pseudo-panel reduces idiosyncratic measurement error in household-level expenditure data. Despite this aggregation, percentile-level expenditure series remain relatively noisy, so that a four-quarter moving average smoothing is applied to the expenditure series.[8]

Additional data used in the analysis include headline, core, food, and energy inflation rates from the Personal Consumption Expenditures (PCE) Price Index, obtained from the Bureau of Economic Analysis. Section 1.4 further employs the Känzig (2021) shock to isolate exogenous, supply-driven variation in energy inflation. The empirical specifications also control for real interest rates, the unemployment gap, and real output growth. Summary statistics for key variables are reported in Table A.1.

1.3.2 Descriptive Evidence

Household income plays a decisive role in shaping consumption patterns. Consistent with previous studies (including seminal work by Michael, 1979, and Hagemann, 1982), CES data show that households' consumption baskets differ systematically across income. Figure 1.1 illustrates energy expenditure shares and shows that lower-income households allocate a substantially larger fraction of their budget to energy than higher-income households. Specifically, households in the lowest decile spend more than 12 percent of total expenditure on energy, compared with only about 5 percent among the highest decile. Even when considering potential sampling noise and measurement error around the tails of the distribution, the graph reveals a clear, nearly linear, negative link between income and the energy-expenditure share.[9] This relationship remains largely stable over time, with only minor fluctuations (see Figure A.1).[10]

Combining the differences in the expenditure shares for energy with relative price shocks in these prices, such as those observed in the 2021/22 inflation episode, rather than a broad-based increase in prices, yields significant variation in the inflation impacts between income groups. To measure the variation, this study calculates distinct inflation rates for

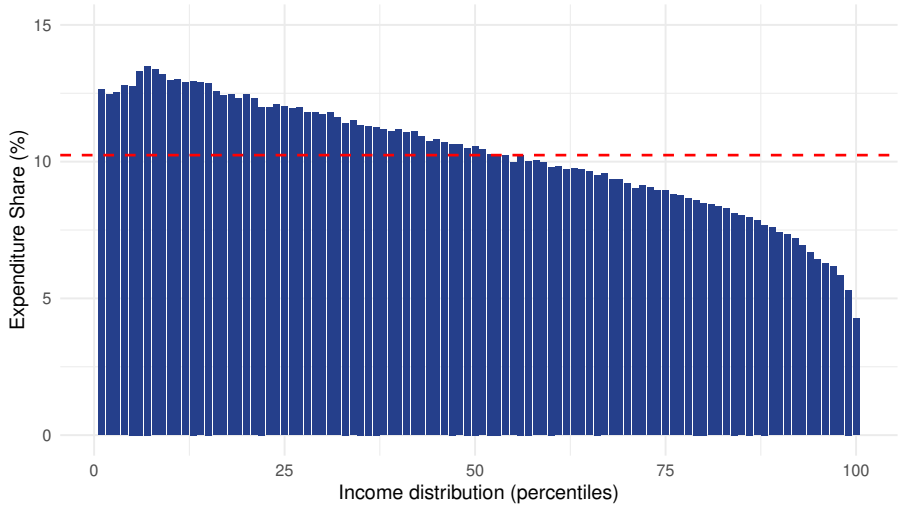
[7] The income variable used is defined as "income received from salary or wages before deduction" (coded: fsalaryx; U.S. Bureau of Labor Statistics, 2018). Results are robust to alternative income measures.

[8] Household survey data are known to be noisy as they are inherently subject to both sampling and non-sampling errors (e.g., misreporting, recall bias, and interviewer effects), which can introduce substantial volatility into micro consumption series (see Kalton, 1983; Salant and Dillman, 1995)

[9] The study also explored whether other household characteristics (including age, gender, region, urbanisation, and housing tenure) create such distinct differences in expenditure shares. These factors were found to have relatively minor impacts, highlighting income as the primary dimension driving heterogeneous consumption baskets.

[10] Figure A.1 shows the time series of energy expenditure shares by income decile. The series exhibit low within-decile volatility and move closely together over time. Periods of sharp increases in energy prices (e.g., 2007, 2011, and 2021) are associated with temporary increases in energy expenditure shares across all deciles, consistent with energy being a necessity good with relatively inelastic demand.

Figure 1.1. Energy expenditure shares across the income distribution



Note: Red-dotted line shows the full-sample mean expenditure share across the income distribution (10.23 percent). Bars report average expenditure shares by income percentile. Data sources: CES/ BLS.

income-deciles, $i = \{1, 2, ..., 10\}$, as:

$$\pi_{it} = \sum_{k=1}^{K} \omega_{kit} \pi_{kt} \tag{1.1}$$

where

$$\omega_{kit} = \frac{E_{kit}}{\sum_{k=1}^{K} E_{kit}} \geq 0$$

is the decile-specific i and time-varying t expenditure weight for good k, π_{kt} denotes the Personal Consumption Expenditures (PCE) inflation for good k, and E_{kit} is the decile's average spending on good k.[11] For tractability, $k = \{\text{energy}, \text{food}, \text{core}\}$, where 'core' denotes goods and services excluding food and energy, following the standard definition in the literature.[12]

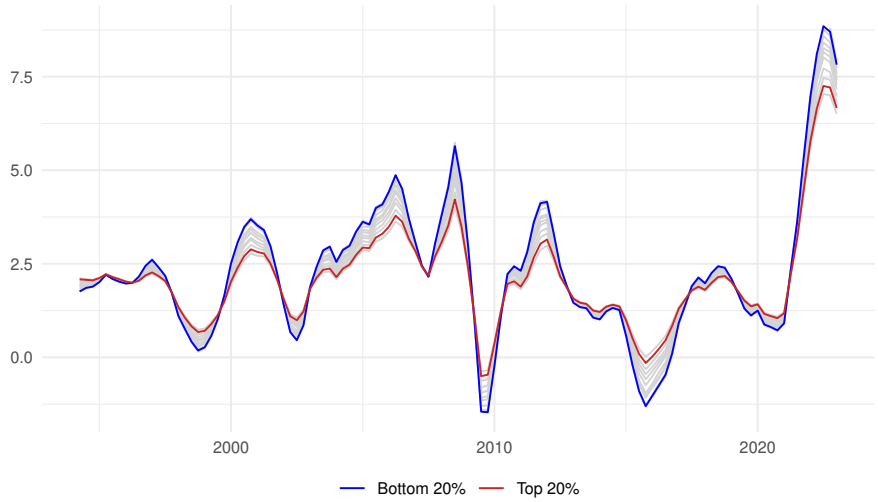
Figure 1.2 plots the resulting inflation rates for different deciles of the income distribution, where two patterns stand out. First, decile-specific inflation rates comove closely. Second, the extent to which decile-specific inflation rates rise or fall differs across the income distribution as they differ in amplitudes, so that, at times, notable gaps emerge between low-

[11] Deciles are constructed by aggregating percentiles using unweighted ('democratic') averages. It is important to note that the decile-specific inflation measure, π_{it}, does not capture within-category substitution. Given data limitations, the construction assumes a common category-level inflation rate π_{kt} across income deciles, whereas in reality inflation is likely to be decile-specific within categories (i.e., π_{ikt}). The inability to account for household's substitution within product categories implies that the true inflation gap across income groups is likely understated. High-income households can substitute toward cheaper varieties when prices rise, whereas low-income households (who are more likely to already consume the lowest-priced options) have more limited scope for such substitution, resulting in higher effective inflation rates.

[12] Accordingly, the expenditure shares satisfy $\sum_{k=1}^{K} \omega_{kit} = 1 \, \forall \, i, t$.

and high-income households' inflation rates. Specifically, inflation for poorer households is more volatile, with sharper declines in disinflationary periods and steeper increases during inflationary episodes. During the recent inflation surge in 2021/22, this has translated into a sizable gap with inflation for the top income quintile peaking at about 7 percent, while being roughly 1.5 percentage points higher for the bottom quintile. Because π_{kt} is assumed common across income groups in this calculation, all cross-decile variation in π_{it} is mechanically driven by differences in expenditure weights ω_{kit} across i. This highlights that heterogeneous exposure (rather than differential price changes) is the key source of dispersion in measured inflation rates.

Figure 1.2. Inflation rates across low- and high income households



Note: Gray lines show inflation rates across income deciles, while the red and blue lines highlight the top and bottom income quintiles for visualisation purposes. Data sources: CES/BLS, BEA.

Next, let $\bar{i} \equiv 11 - i$ denote the income decile symmetric to i. Then, the *inflation gap* is defined as

$$\pi^{\text{gap}}_{i,t} \equiv \pi_{i,t} - \pi_{\bar{i},t}, \quad i = 1, \ldots, 5$$

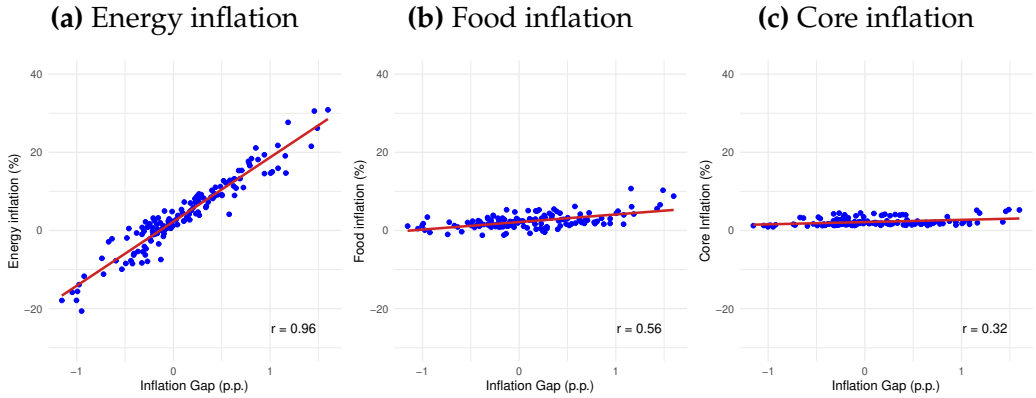
where $\pi^{gap}_{it} > 0$ indicates that the bottom-income decile faces higher inflation than the corresponding top decile.[13] These fluctuations are key for understanding heterogeneous consumption responses. To explore the sources of the gap, unconditional correlations between inflation components and the inflation gap are shown in Figure 1.3. Energy inflation exhibits the strongest correlation, followed by food inflation, whereas the correlation with core inflation is relatively weak. Despite accounting for only 10.23 percent of total household expenditure on average (see Figure 1.1), energy price movements generate a disproportionate share of cross-decile inflation heterogeneity due to their high volatility.[14] This underscores the importance of zooming in on energy price shocks when analysing

[13] Figure A.2 illustrates the inflation gap, showing that while the average gap over the full sample is small, it exhibits notable fluctuations.

[14] See Table A.1 for standard deviations and other summary statistics.

consumption inequality.[15]

Figure 1.3. Correlations between the inflation gap and PCE components



Note: Full sample period. Inflation gap refers to top/bottom 20 percent of income earners. Pearson correlation included. Data sources: CES/BLS, BEA.

Taken together, household consumption patterns differ sharply across the income distribution, with lower-income households allocating a larger share of their budget to energy and consequently facing higher and more volatile effective inflation, particularly during episodes such as the 2021/22 surge. These differences, driven primarily by energy price movements, create substantial heterogeneity in inflation exposure. This motivates the subsequent analysis: first, an empirical investigation using decile-level local projections to quantify the dynamic response of consumption and inequality to exogenous energy price shocks, and second, a structural two-agent New Keynesian model to explore counterfactual fiscal policies and assess how targeted interventions can mitigate the unequal impacts of such shocks. Together, these approaches allow the paper to connect observed expenditure heterogeneity to causal consumption responses and policy-relevant outcomes.

1.4 Empirical Analysis

1.4.1 Econometric Framework

To examine how supply-driven energy price shocks influence consumption patterns and inequality, this paper estimates local projections with instrumental variables (LP-IV) using a two-stage procedure. Originally introduced by Jordà et al. (2015), this approach has become widely used in empirical macroeconomics (e.g., Afrouzi et al., 2024; Drossidis et al., 2024; Stock and Watson, 2018). Identification relies on isolating exogenous movements in energy prices that are orthogonal to contemporaneous macroeconomic conditions and household

[15]The paper also examines the correlation between inflation heterogeneity and consumption inequality (as the ratio of real consumption expenditure between the top and bottom income deciles where nominal expenditures have been deflated with decile-specific inflation rates) which points to an asymmetric relationship (Figure A.3). Specifically, when the inflation gap is positive, the consumption inequality rises sharply. Instead, when the inflation gap is negative, the corresponding reduction in consumption inequality is modest. This asymmetry suggests that inflation heterogeneity may contribute to a structural increase in consumption inequality over time, and offers interesting extensions for future research.

demand. By instrumenting energy inflation with oil supply "news shocks", the LP-IV framework disentangles the effects of supply-driven energy price changes from broader macroeconomic fluctuations.

First Stage: Instrumenting Energy Inflation
In the first stage, contemporaneous PCE energy inflation is instrumented using exogenous oil supply news shocks constructed from high-frequency movements in oil futures prices around OPEC production announcements, following Känzig (2021). These shocks capture unexpected revisions to global oil supply expectations within a narrow announcement window and have been shown to generate plausibly exogenous variation in energy prices that is orthogonal to domestic demand conditions and macroeconomic developments.[16]

Formally, the first-stage regression is given by:

$$\pi_t^E = \delta + \theta Z_t + \sum_{k=1}^{K} \kappa_k' W_{t-k} + u_t \tag{1.2}$$

where π_t^E denotes PCE energy inflation, Z_t is the exogenous Känzig (2021) shock, and W_t is a vector of aggregate macroeconomic controls, including the unemployment gap and the real interest rate.

Second Stage: Estimating Decile-Specific Consumption Responses
In the second stage, local projections are estimated to trace the dynamic responses of household consumption across income deciles and expenditure categories to exogenous energy price shocks. For each horizon h and income group d, the second-stage regression takes the form:

$$\widetilde{c_{t+h}}^{\,d} = \alpha^d + \beta_h^d \widehat{\pi}_t^E + \sum_{j=1}^{J} \gamma_{h,j}^{\prime d} X_{t-j}^d + \sum_{k=1}^{K} \phi_{h,k}^{\prime d} W_{t-k} + \epsilon_{t+h}^d \tag{1.3}$$

where $\widetilde{c_{t+h}}^{\,d}$ is the h-period-ahead log-detrended real consumption of households in income decile d. The regressor $\widehat{\pi}_t^E$ denotes the fitted value of energy inflation obtained from the first stage. The vector X_t^d contains decile-specific controls, including lagged consumption $\widetilde{c}_t^d$, decile-specific inflation π_t^d (defined in Equation (1.1)), and real income growth y_t^d. Aggregate macroeconomic controls W_t are included as in Equation (1.2).

Decile-specific inflation and income are excluded from the first stage, as they are not expected to directly respond to global oil supply news beyond their impact through domestic energy prices. Equation (1.3) is estimated both at the aggregate household level and separately by income decile and expenditure category, allowing for heterogeneous dynamic responses to energy price shocks.

In the baseline specification, $J = K = 3$, and impulse responses are estimated for horizons $h = 1, \ldots, 8$ quarters over the sample period 1990-Q1 to 2023-Q1. Standard errors are computed using heteroskedasticity- and autocorrelation-consistent estimators with horizon-specific bandwidths to account for serial correlation induced by overlapping observations.[17]

[16] Recent applications of these shocks include Afrouzi et al. (2024), Drossidis et al. (2024), Gomes et al. (2025), Sardar and Qureshi (2024), and Zhu et al. (2025).

[17] The first-stage regression is estimated separately for each horizon h. Across all horizons, the F-statistics on the excluded instrument exceed the Staiger-Stock threshold of 10, indicating that the instrument is sufficiently strong.

1.4.2 Empirical Results

This section presents the empirical results on how supply-driven energy price shocks affect household consumption. The analysis focuses first on aggregate consumption responses, then examines heterogeneity across income groups and consumption categories. These results provide the foundation for later structural exercises, where counterfactual policy interventions are evaluated in a model framework.

Figure 1.4 reports the response of total consumption at both the aggregate level and across income groups. At the aggregate level (Figure 1.4a), total consumption declines by approximately 0.3 percentage points on impact following a shock to PCE energy inflation. The effect is found to be relatively persistent and remains significant at the 10 percent confidence level for roughly five quarters. It is worth noting that the magnitude of the aggregate response appears larger than some estimates reported in the literature (e.g., Känzig, 2021). This discrepancy likely reflects a known limitation of the CES, namely its underrepresentation of the upper tail of the income distribution. Sabelhaus et al. (2015) provide evidence that response rates decline at the top of the income distribution, contributing to under-measurement of aggregate expenditures. Similarly, Bee et al. (2015) document both under-representation and under-reporting among top-income households. Consequently, the estimates may be attenuated relative to their true population-level responses, implying that comparisons with aggregate-based studies should be interpreted with caution.

When disaggregating by income groups (Figure 1.4b), substantial heterogeneity in consumption responses emerges. Households in the bottom decile experience a sharp and persistent contraction, with peak responses close to twice the magnitude of the aggregate effect in the short run. By contrast, the change in consumption for the top decile remains close to zero at all horizons and is not statistically distinguishable from no response.[18]

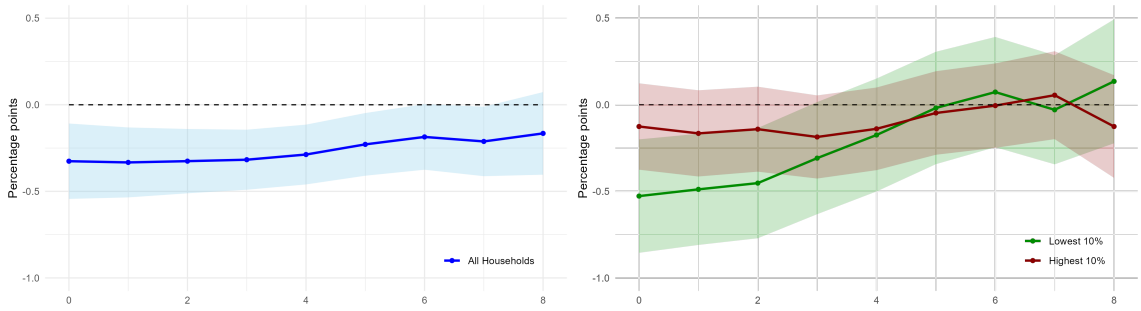
This pronounced asymmetry indicates that the adjustment to higher energy prices is borne disproportionately by low-income households. Two features are likely to underpin this pattern. First, energy expenditures account for a substantially larger share of total consumption at the bottom of the income distribution, mechanically amplifying the impact of energy price shocks on real purchasing power. Second, lower-income households face tighter liquidity constraints and therefore exhibit limited scope for intertemporal smoothing, translating relative price increases into immediate consumption reductions. In contrast, the muted response among high-income households is consistent with a lower marginal propensity to consume out of transitory income shocks and a smaller exposure to energy costs in their overall expenditure basket. Taken together, these results suggest that energy price shocks propagate through consumption via distributional channels rather than uniform aggregate effects.

The analysis further examines heterogeneity beyond the extremes of the income distribution. Figure 1.5 summarises the contemporaneous (impact-period) responses to an energy price

[18] Section 1.5.7 follows standard calibration from the literature, setting the fraction of constrained households to $\lambda = 0.2$. Interpreting constrained households as low-income households (see Section 1.5.1), Figure A.5 plots the response of total consumption to an energy shock for the lowest 20 percent versus the highest 80 percent income earners, allowing for a clearer comparison between the empirical and model impulse responses. Robustness checks include alternative lag structures, additional control variables, and different sample periods. The main findings remain qualitatively unchanged (see Figure A.6).

Figure 1.4. Total consumption response to energy inflation shock

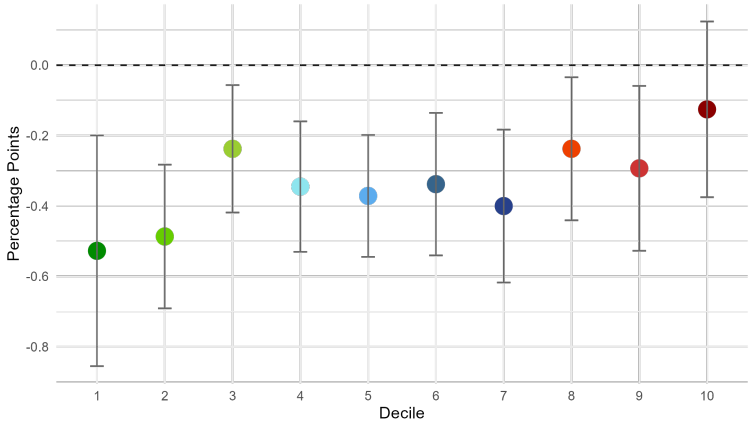
(a) Aggregate consumption response **(b)** Decile-level responses



Note: Responses show percentage point deviations from the log-linear trend after a one percentage point shock. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: CES/BLS, BEA, FRED, Känzig (2021).

shock across deciles.[19] The estimates reveal a clear and almost monotonic gradient in consumption responses as the contraction is largest among the lowest-income households and steadily attenuates moving up the income distribution. This pattern corroborates that the burden of energy price shocks is not evenly distributed but declines systematically with household income.

Figure 1.5. Contemporaneous impact of total consumption



Note: Responses show percentage point deviations from the log-linear trend at $h = 0$. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: CES/BLS, BEA, FRED, Känzig (2021).

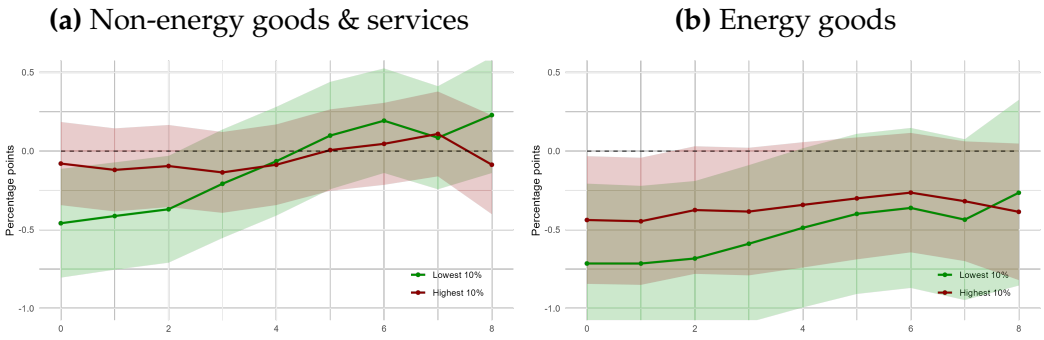
Next, the total consumption response is decomposed into energy and non-energy components to shed light on the underlying adjustment margins (Figure 1.6). Non-energy consumption closely tracks the dynamics of total consumption, reflecting its dominant

[19] Figure 1.5 reports impact-period estimates only, as overlaying dynamic responses for all deciles reduces readability. Nonetheless, the full set of decile-specific impulse responses is included in Figure A.4 for completeness.

share in household expenditure. Among low-income households, non-energy spending contracts sharply (though less persistently than total consumption in Figure 1.4b) following an energy price shock, whereas the response of high-income households remains small and statistically insignificant.

Energy consumption itself also exhibits pronounced heterogeneity. Low-income households reduce energy expenditures sharply (by roughly 0.75 percentage points on impact) with effects persisting for about one year. High-income households also exhibit a decline, but the response is markedly smaller and shorter-lived, indicating a greater ability to absorb higher energy prices without substantially adjusting quantities consumed.

Figure 1.6. Consumption responses across components



Note: Responses show percentage point deviations from the log-linear trend after a one percentage point shock in energy inflation. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: CES/BLS, BEA, Känzig (2021), FRED.

Taken together, the results highlight systematic differences in households' responses to supply-driven energy price shocks that lead to an increase in consumption inequality. Two factors account for the observed gradient in the consumption responses. First, lower-income households spend a larger share of their budgets on energy and related necessities, so identical price increases reduce their real purchasing power more sharply. Second, liquidity constraints and limited access to smoothing instruments limit low-income households' ability to offset temporary shocks, whereas higher-income households face lower exposure and adjust less. As a result, energy price shocks compress consumption more among households with fewer resources, contributing to short-run increases in consumption inequality. The decomposition across categories further shows that most of the aggregate consumption adjustment occurs through non-energy spending, while energy consumption is an important source of heterogeneity across income groups.

These patterns underscore the role of differential exposure and limited smoothing capacity among low-income households, and motivate the structural model in Section 1.5, which is used to explore the channels and evaluate counterfactual policy interventions. These patterns are consistent with models featuring non-homothetic preferences and borrowing constraints, in which necessities such as energy weigh more heavily in low-income households' budgets. As a result, supply-driven energy price shocks exacerbate consumption inequality by disproportionately compressing spending among households least able to smooth temporary price increases.

1.5 TANK Model

The empirical results on the differential impact of shocks to energy inflation on consumption across income groups motivate a model to understand the underlying mechanisms and conduct counterfactual policy analysis. To this end, the paper introduces a two-agent New Keynesian (TANK) model featuring two sectors and non-homothetic preferences.

The model considers a closed economy inhabited by two types of households, two firm sectors, a monetary authority, and a fiscal authority. Households consume and supply labour, and are either constrained or unconstrained on the financial market. Both households consume two types of goods, energy goods and other goods, and have non-homothetic preferences such that energy is a necessity good. The two firm sectors correspond to the two consumption goods. There is monopolistic competition in both sectors with a different degree of price rigidity. Both sectors use labour as a production input, and the other goods sector also uses energy as a production input. The monetary authority sets interest rates and the fiscal authority is responsible for the distribution of taxed profits from firms and other transfers, and for the issuing of one-period risk-free bonds. Appendix A.2 provides a detailed overview of the model and characterises the steady state (Appendix A.2.4).

1.5.1 Households

To account for heterogeneity between income groups, households are denoted by superscripts $k \in \{c, u\}$, representing constrained and unconstrained types.[20] Constrained households, comprising a share $\lambda \in (0, 1)$ of the population, face borrowing constraints and are fully excluded from financial markets. Their consumption choices are therefore more sensitive to income fluctuations and price changes. Unconstrained households, representing a share $1 - \lambda$, have full access to financial markets and can smooth consumption over time, making their consumption decisions less influenced by short-term price movements and income variations. As such, constrained households in the model approximate the behaviour of low-income households in the data, and analogously, unconstrained agents that of high-income households.

1.5.1.1 Preferences

The preferences are identical for the two types of households: both derive utility from energy goods, c^k_{Et}, and other goods, c^k_{Ot}. Since the preferences are non-homothetic, the allocation of expenditure between the two goods depend on the total nominal spending of the household:

$$S^k_t = P_{Et} c^k_{Et} + P_{Ot} c^k_{Ot} \tag{1.4}$$

[20] Introducing a TANK model with constrained and unconstrained households is a simplification of the continuous income distribution given by the data. Debortoli and Galí (2017) show that the simpler structure of TANK models with constrained and unconstrained households can still replicate the essential dynamics of heterogeneous agent New Keynesian (HANK) models. Given the tractability of TANK over HANK models, the full income distribution is not modelled.

where P_{Et} and P_{Ot} are price of energy and other goods, respectively. The indirect utility function introduced by Boppart (2014) is employed for the preferences:[21]

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{\varepsilon_1} \left[\left(\frac{S_t^k}{P_{Ot}} \right)^{\varepsilon_1} - 1 \right] - \frac{\gamma}{\varepsilon_2} \left[\left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2} - 1 \right] \right\} \tag{1.5}$$

where β is the discount factor and $\gamma > 0$ gives the share of energy consumption in steady state. ε_1 determines the expenditure elasticity of demand while ε_2 governs the elasticity of substitution between energy and other goods, as shown in equations (1.6) and (1.7).[22]

Using Roy's Identity, the relative demand between the two types of goods is obtained:

$$c_{Ot}^k = \frac{(1 - \gamma \omega_t^k)}{\gamma \omega_t^k} \frac{P_{Et}}{P_{Ot}} c_{Et}^k \tag{1.6}$$

where

$$\omega_t^k = \left(\frac{P_{Ot}}{S_t^k} \right)^{\varepsilon_1} \left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2} \tag{1.7}$$

is the energy expenditure share wedge, which reflects the non-homotheticity of the preferences. The share households spend on energy goods increases when the relative price of energy increases, controlled by ε_2, but decreases when the relative total expenditure increases (i.e., when the households have more income to spend), controlled by ε_1. This reflects stylised facts previously discussed. With $\varepsilon_1 = \varepsilon_2 = 0$, the standard Cobb-Douglas case is recovered, with relative demand $c_{Ot}^k = \frac{1-\gamma}{\gamma} \frac{P_{Et}}{P_{Ot}} c_{Et}^k$. In this scenario, both types of goods have an expenditure elasticity equal to one.

1.5.1.2 Intertemporal Choice

The constrained households have a simple budget constraint, since they do not have access to the financial market:

$$S_t^c = P_{Et} c_{Et}^c + P_{Ot} c_{Ot}^c = W_t n_t^c + P_t \tau_t^c + P_t T_t^c \tag{1.8}$$

where W_t is nominal wages and n_t^c labour effort. τ_t^c and T_t^c are fiscal transfers discussed in Section 1.5.4. P_t is the aggregate price index given by $P_t = (P_{Et})^{\gamma} (P_{Ot})^{1-\gamma}$.

Unconstrained households have access to one-period, risk-free bonds B_t with interest rate R_t. Hence, their budget constraint is the following:

$$S_t^u = P_{Et} c_{Et}^u + P_{Ot} c_{Ot}^u = W_t n_t^u + \frac{1-\delta}{1-\lambda} P_t D_t + R_{t-1} B_t - B_t + P_t \tau_t^u + P_t T_t^u \tag{1.9}$$

[21] An indirect utility function $v(p, S)$ represents the highest level of utility a household can achieve given a specific price vector p for goods and a set expenditure amount S. Typically, there is no corresponding direct utility function that can be used to derive this same indirect utility in all cases.

[22] When $\varepsilon_1 > 0$, energy demand is less responsive to changes in income (with an elasticity below one), while the demand for other goods is more responsive (with an elasticity above one). This implies that as total nominal expenditure, or income for consumption, falls, demand for energy declines less than proportionally to income, whereas demand for other goods falls more than proportionally.

where n_t^u is the labour effort. D_t is the firms' profits and δ their tax rate. So, unconstrained households enjoy the untaxed part of the firms' profits as an extra income, which creates a permanent income difference between constrained and unconstrained households, in line with their interpretation as high- and low-income households. τ_t^u and T_t^u are fiscal transfers.

Taking the first-order conditions, the Euler equation is derived:

$$\mathbb{E}_t \left(\frac{S_{t+1}^{u,rel}}{S_t^{u,rel}} \right)^{1-\varepsilon_1} = \beta R_t \mathbb{E}_t \left(\frac{1}{\Pi_{O,t+1}} \right)^{1-\varepsilon_1} \tag{1.10}$$

where $S_t^{rel} = S_t / P_{Ot}$ is the total nominal expenditure relative to the price of other goods and $\Pi_{Ot} = P_{Ot} / P_{O,t-1}$ is gross inflation of other goods. Labour supply is inelastic under these preferences with $n_t^c = \bar{n}^c$ and $n_t^u = \bar{n}^u$, but workers can move between sectors.

1.5.2 Firms

The economy features two sectors of firms, indexed by $j \in \{E, O\}$, producing energy and other goods, respectively.[23] A continuum of intermediate firms $i \in [0, 1]$ populate both sectors, competing under monopolistic competition. A final goods producer in each sector bundles the different varieties of goods in that sector produced by the intermediate firms and sells the bundled final good to the households. The two sectors are identical, except for the degree of price rigidity as discussed in the Section 1.5.7.

1.5.2.1 Final Goods Producers

The final good firm in each sector produces the final consumption good, energy or other, Y_{jt}, using intermediate goods from that sector, $Y_{jt}(i)$, according to:

$$Y_{jt} = \left[\int_0^1 Y_{jt}(i)^{(1-\epsilon)/\epsilon} di \right]^{\epsilon/(1-\epsilon)} \tag{1.11}$$

where $Y_{jt}(i)$ is the output of the intermediate firm i and ϵ the elasticity of substitution between different varieties of the intermediate good. The firms produce in a competitive market and maximise profits given by $P_{jt} Y_{jt} - \int_0^1 P_{jt}(i) Y_{jt}(i) di$. The first-order condition to the maximization problem gives the demand function of the intermediate good i:

$$Y_{jt}(i) = \left(\frac{P_{jt}(i)}{P_{jt}} \right)^{-\epsilon} Y_{jt} \tag{1.12}$$

and the price of the final good Y_{jt}:

$$P_{jt} = \left[\int_0^1 P_{jt}(i)^{-(1-\epsilon)} \right]^{1-\epsilon} \tag{1.13}$$

where $P_{jt}(i)$ is the price of the intermediate good i.

[23] Energy is modelled as domestically produced rather than imported, since the share of net energy imports in the U.S. have represented less than 15 percent of total energy use since 2013 and have been negative since 2019 (World Bank Group Data, 2025).

1.5.2.2 Intermediate Goods Producers

Energy Producers The intermediate firms i in the energy sector $j = E$ compete under monopolistic competition, using labour N_{Et} as input for production. The total factor productivity, A_{Et}, follows an AR(1) shock process $A_{Et} = \rho^E A_{E,t-1} + \epsilon_{Et,a}$ with $\epsilon_t^j \sim$ i.i.d. $\mathcal{N}(0, \sigma_v^2)$. The firms face adjustment costs à la Rotemberg (1982).[24] The profit maximization problem of the representative firm in sector j is:

$$\max_{P_{Et}(i), N_{Et}(i)} \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{t+1} \left[\frac{P_{Et}(i)}{P_{Et}} Y_{Et}(i) - \frac{W_t}{P_{Et}} N_{Et}(i) - Y_{Et} FC_{Et} \right] \tag{1.14}$$

$$\text{s.t. production function} \quad Y_{Et}(i) = A_{Et} N_{Et}(i) \tag{1.15}$$

$$\text{demand curve} \quad Y_{Et}(i) = \left(\frac{P_{Et}(i)}{P_{Et}} \right)^{-\epsilon} Y_{Et} \tag{1.16}$$

$$\text{price adjustment costs} \quad FC_{Et}(i) = \frac{\xi_E}{2} \left(\frac{P_{Et}(i)}{P_{E,t-1}(i)} - 1 \right)^2 \tag{1.17}$$

where $\Lambda_{t+1} = \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma}$ is the stochastic discount factor and $N_{Et}(i) = \lambda n_{Et}^c(i) + (1 - \lambda) n_{Et}^u(i)$ aggregate labour demand per firm. The first-order condition with respect to $P_{Et}(i)$ yields the standard New Keynesian Phillips Curve. Given that all intermediate goods are identical, we have $P_{Et}(i) = P_{Et}$ and $N_{Et}(i) = N_{Et}$. Aggregate firm profits are therefore expressed as $D_{Et} = Y_{Et} (1 - FC_{Et}) - \frac{W_t}{P_{Et}} N_{Et}$.

Other Goods Producers The intermediate goods i in the other goods sector $j = O$ compete and produce analogously to firms in the energy sector, but also use energy as a production input. Hence, the production function is a Constant Elasticity of Substitution (CES) aggregator:

$$Y_{Ot}(i) = A_{Ot} \left[\left(\gamma^f \right)^{1/\theta^f} \left(E_t^f(i) \right)^{(\theta^f - 1)/\theta^f} + \left(1 - \alpha^f \right)^{1/\theta^f} \left(N_{Ot}(i) \right)^{(\theta^f - 1)/\theta^f} \right]^{\theta^f/(\theta^f - 1)} \tag{1.18}$$

where γ^f is the fraction of energy used in the firms' production and θ^f is the elasticity of substitution between energy and labour. $E_t^f(i)$ is the energy used in the production of other goods. The aggregate profits of the firms producing other goods are:

$$D_{Ot} = Y_{Ot} (1 - FC_{Ot}) - \frac{W_t}{P_{Ot}} N_{Ot} - \frac{P_{Et}}{P_{Ot}} E_t^f \tag{1.19}$$

1.5.3 Monetary Policy

The central bank implements a standard Taylor rule, setting the nominal interest rate R_t in response to deviations of overall inflation and output deviations from steady state, in line with the Federal Reserve's dual mandate:

$$R_t = \frac{1}{\beta} \left(\frac{\Pi_t}{\bar{\Pi}} \right)^{\phi_\pi} \left(\frac{Y_t}{Y_t^n} \right)^{\phi_y} \exp(\nu_t) \tag{1.20}$$

[24] Note that Calvo (1983) and Rotemberg (1982) pricing setups are equivalent up to first order approximation.

where Π_t is aggregate gross inflation, given by:

$$\Pi_t = (\Pi_{Et})^{\gamma}(\Pi_{Ot})^{1-\gamma} \tag{1.21}$$

and Y_t is aggregate output, given by:

$$Y_t = Y_{Et} + Y_{Ot} \tag{1.22}$$

ϕ_π and ϕ_y are the Taylor coefficients of inflation and output. ν_t is a monetary policy shock that follows an AR(1) process.

1.5.4 Fiscal Policy

The fiscal authority conducts two types of fiscal policy. First, they redistribute taxed firms' profits δD_t as in Debortoli and Galí (2017) by allocating the total taxed profits between constrained and unconstrained households according to:

$$\tau_t^c = (1-\tau_0)\delta D_t \tag{1.23}$$

$$\tau_t^u = \left(1 + \frac{\tau_0 \lambda}{1-\lambda}\right)\delta D_t \tag{1.24}$$

such that $\lambda\tau_t^c + (1-\lambda)\tau_t^u = \delta D_t$. The parameter τ_0 determines the fraction of the taxed profits are redistributed to the constrained households. Second, the fiscal authority collects lump-sum taxes to issue targeted transfers. The taxes and transfers are designed such that the unconstrained households' lump-sum taxes finance the transfers targeted at constrained households:

$$(1-\lambda)T_t^u = -\lambda T_t^c \tag{1.25}$$

The targeted transfers are absent unless otherwise specified. Both types of fiscal policy imply a balanced budget for the government.

1.5.5 Equilibrium and Market Clearing

The equilibrium in this economy is characterised by a sequence of prices $\{W_t, P_{Et}, P_{Ot}\}$ and allocations $\{c_{Et}^c, c_{Et}^u, c_{Ot}^c, c_{Ot}^u, n_t^c, n_t^u\}$ such that the goods market is cleared for both energy and other goods and the labour market is cleared. The full list of equilibrium conditions are in Appendix A.2.3.

Goods market clearing conditions specify that the output of energy good, Y_{Et}, equals the total consumption demand from constrained and unconstrained households, weighted by their population shares, and from the demand from firms that use energy as an intermediate good. The output of other goods, Y_{Ot}, must meet the aggregate demand from both household types and account for adjustment costs associated with price changes in the production of other goods:

$$Y_{Et} = \lambda c_{Et}^c + (1-\lambda)c_{Et}^u + E_t^f + Y_{Et}\frac{\xi_E}{2}(\Pi_{Et}-1)^2 \tag{1.26}$$

$$Y_{Ot} = \lambda c_{Ot}^c + (1-\lambda)c_{Ot}^u + Y_{Ot}\frac{\xi_O}{2}(\Pi_{Ot}-1)^2 \tag{1.27}$$

Moreover, the labour market clears when total labour demand, N_t, equals the sum of labour demands in the energy sector (N_{Et}) and the core sector (N_{Ot}). Additionally, total labour

supply is split between constrained and unconstrained households, with the weighted sum equal to total labour.

$$N_t = N_{Et} + N_{Ot} \tag{1.28}$$
$$N_t = \lambda n_t^c + (1-\lambda) n_t^u \tag{1.29}$$

1.5.6 Inequality

In measuring consumption inequality, the model follows Debortoli and Galí (2017) and introduces ω_t, which represents the relative consumption gap between constrained and unconstrained households:

$$\omega_t = 1 - \frac{c_t^c}{c_t^u} \tag{1.30}$$

1.5.7 Calibration

In calibrating the model, the fraction of constrained households is set to 0.2, representing the bottom 20 percent of households in the income distribution, as analysed in the empirical section. The average energy share in the consumption basket is set to 0.10, matching the mean expenditure share observed in the CES data (Figure 1.1). The non-homotheticity parameters are set to unity to better match the decile-specific energy share in the consumption basket. The tax rate on firm profits is set to $\delta = 0.266$, based on OECD (2020) data.

The share of energy used in production, γ^f, is calibrated to 0.06 such that the production sector uses about 30 percent of total energy production in steady state (U.S. Energy Information Administration, 2025). The elasticity of substitution between energy and labour, θ^f, is set to 0.2 following Bachmann et al. (2024) and Bayer et al. (2023). The transfer parameter τ_0 is set to unity, implying that all taxed profits are rebated to unconstrained households.

The persistence of the energy-sector technology shock, ρ_{α_E}, is set to 0.8 to match the empirical persistence of the energy shock in the data. All remaining parameters are calibrated to standard values commonly used in the literature. In the baseline calibration, energy goods are modelled as necessities and exhibit higher price volatility than other goods, consistent with the empirical evidence.[25] Table 1.1 summarises the full set of calibrated parameters.

[25]The current version of the model is calibrated using standard parameter values from the literature and moments from the data. Future extensions will strengthen the link between the empirical analysis in Section 1.4.2 and the structural results in Section 1.6 through impulse-response matching between empirical and theoretical responses.

Table 1.1. Overview of model parameters and their calibration

Parameter	*Description*	*Value*
Households		
λ	Fraction of constrained households	0.2
γ	Energy share in consumption basket	0.1
ε_1	Non-homotheticity parameter	1
ε_2	Non-homotheticity parameter	1
β	Discount factor	0.99
ϵ	Elasticity of substitution within goods	9
Firms		
θ_p^O	Calvo parameter price stickiness, other goods sector	0.75
θ_p^E	Calvo parameter price stickiness, energy sector	0.5
γ^f	Share of energy in production	0.06
θ^f	Elasticity of substitution between energy and labour	0.2
ρ_{a_E}	Technology shock persistence, energy sector	0.8
Monetary policy		
ϕ_π	Taylor-coefficient on inflation	1.5
ϕ_y	Taylor-coefficient on output	0.125
Fiscal policy		
δ	Tax rate on firms' profits	0.266
τ_0	Share of taxed profits for unconstrained households	1

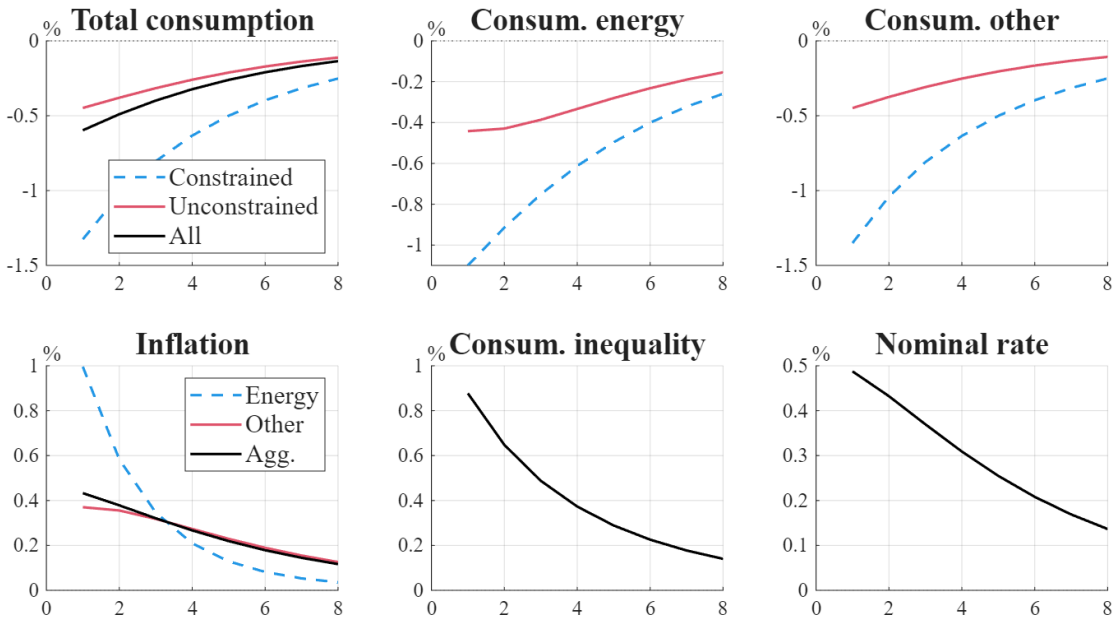
1.6 Analysis of Impulse Responses

1.6.1 Model Dynamics

This section presents impulse response functions to a negative supply shock in the energy sector, in the absence of targeted transfers (Figure 1.7). The shock is calibrated to generate a one percentage point increase in energy inflation on impact. The rise in energy prices leads to a contraction in aggregate consumption, reflecting the increase in the cost of an essential input and the resulting decline in households' real purchasing power.

Despite originating in the energy sector, the adjustment in consumption is not confined to energy goods. While energy consumption declines, the contraction in other goods consumption is larger. This pattern reflects the role of non-homothetic preferences: as energy is a necessity good with limited scope for substitution, households primarily adjust by cutting back on discretionary, other goods expenditures. As a result, the aggregate consumption response is driven mainly by reductions in other goods spending rather than by energy consumption itself.

Figure 1.7. Negative energy supply shock



Note: IRFs show percentage point deviations from steady state.

The responses differ markedly across household types. Constrained households experience substantially larger declines in total consumption than unconstrained households. This asymmetry mirrors the empirical results in Section 1.4.2 and reflects two reinforcing mechanisms. First, constrained households devote a larger share of expenditure to energy, so higher energy prices translate into a larger effective loss in real income. Second, limited access to financial markets restricts their ability to smooth consumption intertemporally, forcing a sharper contemporaneous adjustment. Unconstrained households, by contrast, face lower exposure to energy prices and can partially absorb the shock through greater access to financial markets, resulting in a more muted consumption response.

These heterogeneous adjustments generate a pronounced increase in consumption inequality following the shock. As constrained households reduce consumption by more than unconstrained households, the dispersion in consumption widens on impact and remains elevated until the end of the two-year horizon. The inequality response closely tracks the differential consumption dynamics, highlighting that distributional effects of essential goods price shocks arise endogenously from differences in exposure and smoothing capacity rather than from explicit redistribution mechanisms.

On the nominal side, the supply shock produces a sharp increase in energy inflation and a more gradual rise in non-energy inflation through pass-through effects. In reaction to rising inflation, nominal interest rates adjust upward as monetary policy responds to stabilise prices and manage inflation expectations. In the closed-economy setting of the model, the contraction in consumption translates directly into a decline in output.

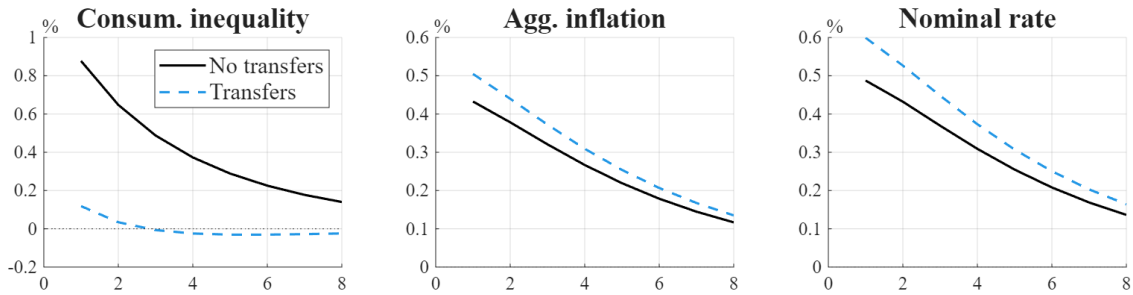
Overall, the model captures how energy supply shocks generate both aggregate and distributional consequences. While the shock affects all households, its impact is unevenly distributed, with constrained households bearing a disproportionate share of the adjustment. These dynamics provide a disciplined framework for the counterfactual policy

experiments considered in the next section, where targeted transfers are introduced to assess their ability to mitigate the distributional costs of energy price shocks.

1.6.2 Targeted Transfers and the Inflation–Inequality Dilemma

The counterfactual fiscal policy analysis explores the impact of cash transfers targeted at constrained households in response to their real income decline. The unconstrained households pay taxes for these transfers targeted at constrained households. The results are in Figure 1.8. Targeted transfers are calibrated such that the response of consumption inequality is close to zero.

Figure 1.8. 'Targeted transfers' vs. 'No transfers'



Note: Impulse responses show percentage point deviations from steady state.

In the baseline case without transfers, consumption inequality increases as constrained households reduce consumption more sharply than unconstrained households. In the case of transfers, they are designed such that on impact the consumption inequality remains broadly unchanged. In the later periods consumption inequality declines as the fall in consumption for constrained households is smaller than for unconstrained households. This result highlights the effectiveness of targeted transfers in alleviating the adverse consumption effects on more vulnerable households, though it does not entirely equalise consumption outcomes across groups.

The relative increase in consumption among constrained households under targeted transfers, who have higher marginal propensity to consume (MPC), raises overall demand in the economy, leading to greater inflationary pressure, particularly within core sectors. The stronger inflationary response can be attributed to constrained households spending a larger share of their income on other goods, thus amplifying demand-driven price increases. This finding emphasises the inflationary side effects of redistributive fiscal policies that target liquidity-constrained households, as their increased spending can quickly translate into higher prices, especially in sectors with limited flexibility in supply.

In response to the heightened inflation, the central bank adopts a more aggressive stance by raising nominal interest rates beyond the level observed in the baseline case. The stronger monetary tightening aims to counteract the inflationary pressures resulting from the fiscal intervention. This response underscores the trade-off inherent in fiscal policies that prioritise consumption support for constrained households: while cash transfers to high-MPC households reduce consumption inequality, they also increase inflation, prompting a stronger reaction from monetary authorities. This mechanism is what introduces the *inflation-inequality dilemma*.

In summary, the cash transfers targeted at constrained households reduce consumption inequality relative to the baseline. However, this policy approach introduces higher inflationary pressures, leading to a more pronounced tightening by the central bank. This counterfactual highlights the balancing act between supporting household consumption and maintaining price stability, underscoring the complex interactions between fiscal and monetary policies in the context of targeted income support.

1.7 Conclusion

This paper studies how supply-driven energy price shocks affect household consumption and consumption inequality in the United States, combining evidence from micro-level empirical analysis with a structural model. Using instrumental variable local projections, the empirical results show that such shocks disproportionately reduce the consumption of low-income households, while consumption responses at the top of the income distribution remain largely unaffected. This differential impact leads to a rise in consumption inequality, highlighting how relative price shocks can have uneven distributional consequences across households.

The analysis highlights two central mechanisms behind this heterogeneity. Lower-income households are more exposed to energy price fluctuations due to their higher expenditure shares on energy and related necessities, and they face tighter liquidity constraints that limit their ability to smooth consumption. In contrast, higher-income households benefit from more diversified consumption and greater access to financial markets, allowing them to absorb transitory price increases with limited adjustment in consumption. A two-agent New Keynesian model with non-homothetic preferences reproduces these empirical patterns, showing that negative supply shocks reduce output and real wages, disproportionately depress consumption for constrained households, and raise consumption inequality. These results underscore that the bulk of consumption adjustments occur through non-energy consumption, while constrained households' higher exposure amplifies the inequality effects.

The counterfactual fiscal policy analysis demonstrates that targeted transfers to constrained households can attenuate the consumption losses at the bottom of the income distribution and dampen the rise in inequality. However, these gains come at the cost of higher inflationary pressures, particularly in non-energy sectors, prompting a stronger monetary policy response. This finding therefore underscores the balancing act policymakers face and points to a novel trade-off: measures that protect vulnerable households from adverse supply shocks can alleviate distributional consequences but may exacerbate aggregate inflation dynamics, necessitating careful coordination between fiscal and monetary policy.

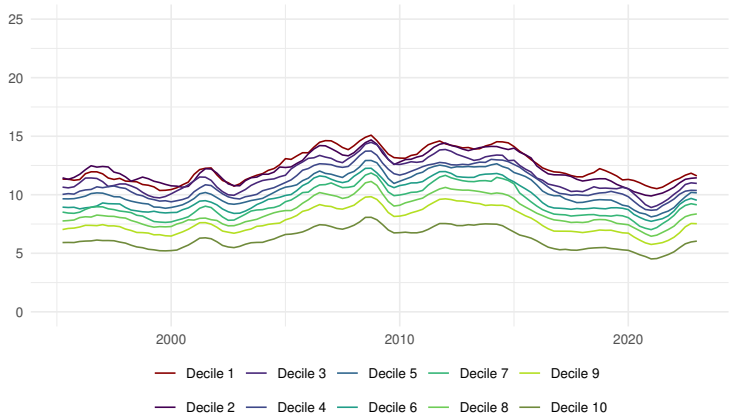
Taken together, the findings shed light on the mechanisms through which supply-driven energy shocks propagate unevenly across households and highlight the complex policy trade-offs in addressing consumption inequality. By jointly quantifying consumption responses and inequality effects, this paper contributes to the growing literature on the distributional consequences of inflationary shocks. Future work will strengthen the empirical–theoretical link by disciplining the model more tightly using impulse response matching and additional distributional moments, further improving its ability to evaluate policy interventions in the presence of supply-driven inflation.

Appendix A

Appendix of Chapter 1

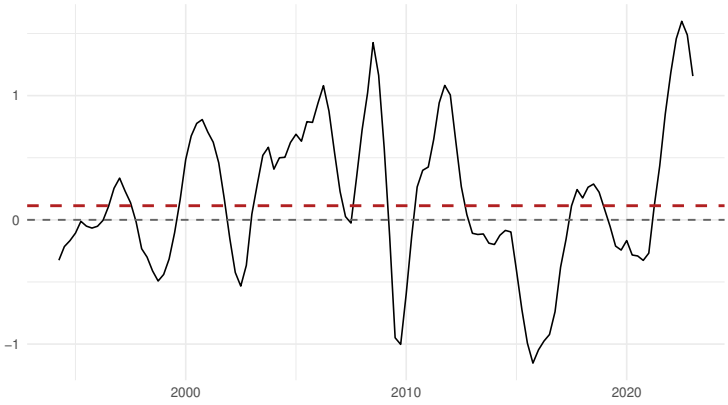
A.1 Supplementary Figures and Data Overview

Figure A.1. Energy expenditure shares across income deciles



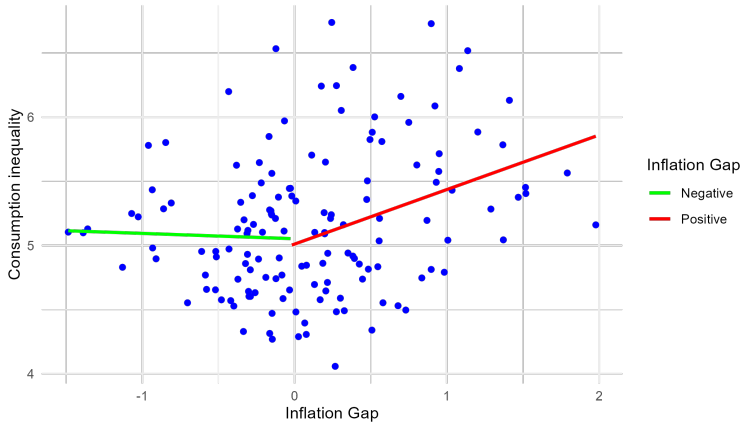
Data sources: CES/BLS.

Figure A.2. Time series of the inflation gap measure



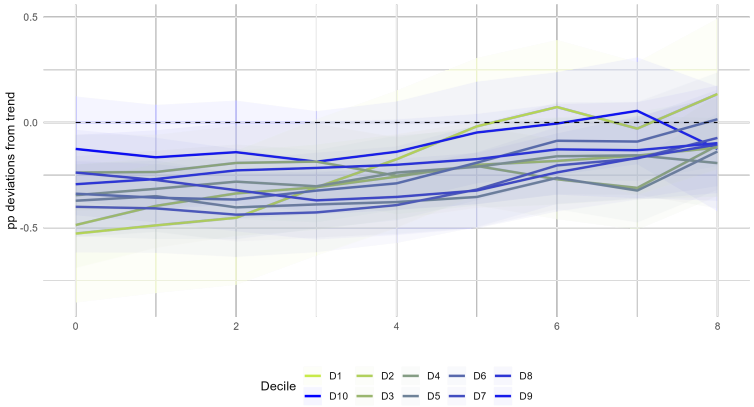
Note: Red-dashed line shows the sample average of the inflation gap. Data sources: CES/BLS, BEA.

Figure A.3. Correlations between the inflation gap and consumption inequality



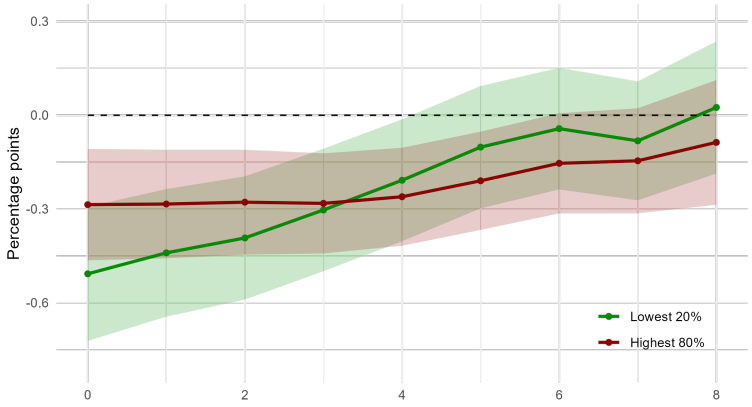
Note: Inflation gap and consumption inequality shown refer to the top/bottom quintile for more robustness away from the tails of the income distribution. Data sources: CES/BLS, BEA, FRED.

Figure A.4. Total consumption responses across deciles



Note: Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: CES/BLS, BEA, Känzig (2021), FRED.

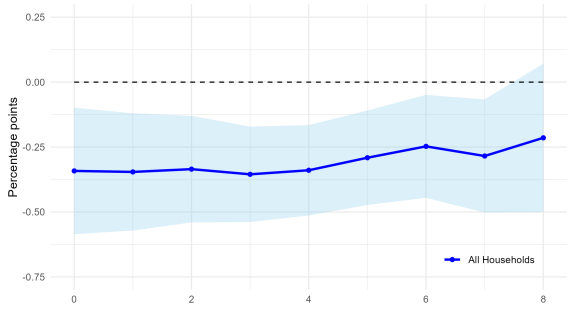
Figure A.5. Total consumption responses across 80/20 percent split



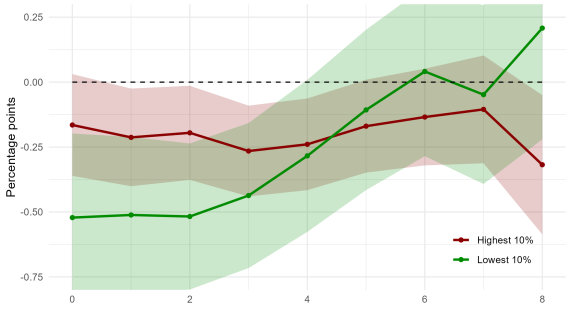
Note: Responses show percentage point deviations from the log-linear trend after a one percentage point shock. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: CES/BLS, BEA, Känzig (2021), FRED.

Figure A.6. Robustness of main consumption responses

(a) Aggregate consumption response



(b) Decile-level responses



Note: Sample size shortened to 2022-Q1. Responses show percentage point deviations from the log-linear trend after a one percentage point shock. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: CES/BLS, BEA, Känzig (2021).

Table A.1. Summary statistics of key variables

Variable	Mean	Median	Min	Max	SD	IQR
Core inflation (PCE)	2.1	1.8	0.7	5.5	1.0	0.7
Energy inflation (PCE)	4.2	2.6	-26.3	36.8	11.8	12.8
Food inflation (PCE)	2.4	1.8	-1.8	11.9	2.3	2.0
Headline inflation (PCE)	2.2	2.0	-1.2	6.9	1.3	1.2
Income growth: Decile 1	1.7	1.4	-19.4	23.0	8.4	10.2
Income growth: Decile 2	2.2	2.1	-23.2	27.3	9.8	15.8
Income growth: Decile 9	3.4	4.1	-9.3	10.4	3.4	3.4
Income growth: Decile 10	4.2	4.1	-5.8	15.7	4.5	5.2
Inflation: Decile 1	2.4	2.2	-1.5	8.9	1.9	2.1
Inflation: Decile 2	2.4	2.2	-1.4	8.8	1.8	2.1
Inflation: Decile 9	2.3	2.2	-0.6	7.5	1.4	1.4
Inflation: Decile 10	2.3	2.1	-0.4	7.0	1.3	1.3
LD real exp. (core): Decile 1	0.0	0.0	-0.1	0.2	0.1	0.1
LD real exp. (core): Decile 2	0.0	0.0	-0.2	0.2	0.1	0.1
LD real exp. (core): Decile 9	0.0	0.0	-0.1	0.1	0.1	0.1
LD real exp. (core): Decile 10	0.0	0.0	-0.1	0.1	0.1	0.1
LD real exp. (energy): Decile 1	0.0	0.0	-0.1	0.2	0.1	0.2
LD real exp. (energy): Decile 2	0.0	0.0	-0.1	0.2	0.1	0.1
LD real exp. (energy): Decile 9	0.0	0.0	-0.1	0.2	0.1	0.1
LD real exp. (energy): Decile 10	0.0	0.0	-0.1	0.2	0.1	0.1
LD real exp. (food): Decile 1	0.0	0.0	-0.1	0.1	0.1	0.1
LD real exp. (food): Decile 2	0.0	0.0	-0.1	0.1	0.0	0.1
LD real exp. (food): Decile 9	0.0	0.0	-0.1	0.1	0.0	0.1
LD real exp. (food): Decile 10	0.0	0.0	-0.1	0.1	0.0	0.1
LD real exp. (total): Decile 1	0.0	0.0	-0.1	0.1	0.1	0.1
LD real exp. (total): Decile 2	0.0	0.0	-0.1	0.1	0.0	0.1
LD real exp. (total): Decile 9	0.0	0.0	-0.1	0.1	0.0	0.1
LD real exp. (total): Decile 10	0.0	0.0	-0.1	0.1	0.0	0.1
Känzig shock	0.0	0.0	-1.4	1.1	0.3	0.4
Real GDP growth	2.5	2.6	-7.4	12.4	2.1	1.8
Real interest rate	2.7	2.2	0.1	8.2	2.4	4.9
Unemployment rate	5.8	5.5	3.5	13.0	1.7	2.3

LD: Log detrended, PCE: Personal Consumption Expenditure Price Index, SD: Standard Deviation, IQR: Interquartile Range.

A.2 Model Details

A.2.1 Households

Indirect utility function with non-homothetic preferences following Boppart (2014):

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{\varepsilon_1} \left[\left(\frac{S_t^k}{P_{Ot}} \right)^{\varepsilon_1} - 1 \right] - \frac{\gamma}{\varepsilon_2} \left[\left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2} - 1 \right] \right\} \tag{B.1}$$

where $0 \leq \varepsilon_1 \leq \varepsilon_2 < 1$ and $\gamma > 0$. Superscript $k \in \{c, u\}$ for constrained and unconstrained households. Constrained households are share $\lambda \in (0, 1)$ of the population, whereas unconstrained households are share $1 - \lambda$. Households supply labor inelastically. The per-period utility takes the form $v = \frac{1}{\varepsilon_1} \left[\left(\frac{S_t}{P_{Ot}} \right)^{\varepsilon_1} - 1 \right] - \frac{\gamma}{\varepsilon_2} \left[\left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2} - 1 \right]$.

Intratemporal choice Marshallian demand functions obtained with Roy's identity:

$$c_{Et}^k = -\frac{\partial v / \partial P_{Et}}{\partial v / \partial S_t^k} = \frac{\gamma \left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2 - 1}}{\left(\frac{S_t^k}{P_{Ot}} \right)^{\varepsilon_1 - 1}} \tag{B.2}$$

$$c_{Ot}^k = -\frac{\partial v / \partial P_{Ot}}{\partial v / \partial S_t^k} = \frac{\left(\frac{S_t^k}{P_{Ot}} \right)^{\varepsilon_1} - \gamma \left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2}}{\left(\frac{S_t^k}{P_{Ot}} \right)^{\varepsilon_1 - 1}} \tag{B.3}$$

Rearrange to express c_{Ot}^k in terms of c_{Et}^k to get relative demand[1]:

$$c_{Ot}^k = \frac{\left[1 - \gamma \omega_t^k \right]}{\gamma \omega_t^k} \frac{P_{Et}}{P_{Ot}} c_{Et}^k \tag{B.4}$$

where

$$\omega_t^k = \left(\frac{P_{Ot}}{S_t^k} \right)^{\varepsilon_1} \left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2} \tag{B.5}$$

is the energy expenditure share wedge. If $\varepsilon_1 = \varepsilon_2 = 0$ (Cobb-Douglas case), then $c_{Ot}^k = \frac{1-\gamma}{\gamma} \frac{P_{Et}}{P_{Ot}} c_{Et}^k$. Expenditure is defined as $S_t^k = P_{Et} c_{Et}^k + P_{Ot} c_{Ot}^k$. Hence, define:

$$S_t^{k,rel} \equiv \frac{S_t^k}{P_{Ot}} = \frac{P_{Et}}{P_{Ot}} c_{Et}^k + c_{Ot}^k \tag{B.6}$$

Intertemporal choice and labor supply Nominal budget constraint of constrained households:

$$S_t^c = P_{Et} c_{Et}^c + P_{Ot} c_{Ot}^c = W_t n_t^c + P_t \tau_t^c + P_t T_t^c \tag{B.7}$$

Constrained households supply labor n_t^c and consume their per-period income according to their preferences.

[1] See the Appendix in Komatsu (Forthcoming) to see an alternative way to rearrange relative demand.

Nominal budget constraint of unconstrained households:

$$S_t^u = P_{Et}c_{Et}^u + P_{Ot}c_{Ot}^u = W_t n_t^u + \frac{1-\delta}{1-\lambda}P_t D_t + R_{t-1}B_t - B_{t+1} + P_t\tau_t^u + P_t T_t^u \tag{B.8}$$

Unconstrained households supply labor n_t^u and have access to the financial market. They smooth consumption according to the Euler equation:

$$\mathbb{E}_t\left(\frac{S_{t+1}^{u,rel}}{S_t^{u,rel}}\right)^{1-\varepsilon_1} = \beta R_t \mathbb{E}_t\left(\frac{1}{\Pi_{O,t+1}}\right)^{1-\varepsilon_1} \tag{B.9}$$

A.2.2 Firms

Intermediate energy and other goods firms, $j \in \{E, O\}$ face monopolistic competition with firms within the same sector. They face adjustment costs à la Rotemberg. For both types of firms, the first order condition with respect to $P_{jt}(i)$ is:[2]

$$\begin{aligned}&(1-\epsilon)\left(\frac{P_{jt}(i)}{P_{jt}}\right)^{-\epsilon}\frac{1}{P_{jt}}Y_{jt} - \xi_j\left(\frac{P_{jt}(i)}{P_{j,t-1}(i)} - 1\right)\frac{1}{P_{j,t-1}(i)}Y_{jt}\\ &+ \mu_{jt}\epsilon P_{jt}(i)^{-\epsilon-1}\left(\frac{1}{P_{jt}}\right)^{-\epsilon}Y_{jt} + \mathbb{E}_t\left[\Lambda_{t+1}\xi_j\left(\frac{P_{j,t+1}(i)}{P_{jt}(i)} - 1\right)Y_{F.t+1}\left(\frac{P_{j,t+1}(i)}{P_{jt}(i)^2}\right)\right] = 0\end{aligned} \tag{B.10}$$

which leads to the New Keynesian Philips Curve (NKPC) after imposing the symmetry conditions $P_{jt}(i) = P_{jt}$ and $Y_{jt}(i) = Y_{jt}$. For the energy firms, the first order condition with respect to N_{Et} is:

$$\frac{W_t}{P_{Et}} = \mu_{Et}(i)A_{Et} \tag{B.11}$$

For the other goods firms, the first order conditions with respect to N_{Ot} and E_t^f are:

$$\frac{W_t}{P_{Ot}} = \left(1-\gamma^f\right)^{1/\theta^f}\mu_{Ot}(i)\left(\frac{Y_{Ot}(i)}{N_{Ot}(i)}\right)^{1/\theta^f}A_t^{(\theta^f-1)/\theta^f} \tag{B.12}$$

$$\frac{P_{Et}}{P_{Ot}} = \left(\gamma^f\right)^{1/\theta^f}\mu_{Ot}\left(\frac{Y_{Ot}(i)}{E_t^f(i)}\right)^{1/\theta^f}A_t^{(\theta^f-1)/\theta^f} \tag{B.13}$$

[2]The Lagrange multiplier on the production function μ_{jt} is the marginal cost.

A.2.3 Summary of Model Equations

Households

$$c_{Ot}^{c} = \frac{[1-\gamma\omega_t^c]}{\gamma\omega_t^c}\frac{P_{Et}}{P_{Ot}}c_{Et}^{c} \tag{B.14}$$

$$c_{Ot}^{u} = \frac{[1-\gamma\omega_t^u]}{\gamma\omega_t^u}\frac{P_{Et}}{P_{Ot}}c_{Et}^{u} \tag{B.15}$$

$$\omega_t^c = \left(S_t^{c,rel}\right)^{-\varepsilon_1}\left(\frac{P_{Et}}{P_{Ot}}\right)^{\varepsilon_2} \tag{B.16}$$

$$\omega_t^u = \left(S_t^{u,rel}\right)^{-\varepsilon_1}\left(\frac{P_{Et}}{P_{Ot}}\right)^{\varepsilon_2} \tag{B.17}$$

$$S_t^{c,rel} = \frac{P_{Et}}{P_{Ot}}c_{Et}^{c} + c_{Ot}^{c} \tag{B.18}$$

$$S_t^{u,rel} = \frac{P_{Et}}{P_{Ot}}c_{Et}^{u} + c_{Ot}^{u} \tag{B.19}$$

$$S_t^{c,rel} = \frac{W_t}{P_t}\frac{P_t}{P_{Ot}}n_t^c + \frac{P_t}{P_{Ot}}\tau_t^c + \frac{P_t}{P_{Ot}}T_t^c \tag{B.20}$$

$$\mathbb{E}_t\left(\frac{e_{t+1}^{u,rel}}{S_t^{u,rel}}\right)^{1-\varepsilon_1} = \beta R_t \mathbb{E}_t\left(\frac{1}{\Pi_{O,t+1}}\right)^{1-\varepsilon_1} \tag{B.21}$$

$$\omega_t = \frac{c_t^u}{c_t^c} \tag{B.22}$$

Firms

$$Y_{Et} = A_{Et} N_{Et} \tag{B.23}$$

$$Y_{Ot}(i) = A_{Ot} \left[\left(\gamma^f\right)^{1/\theta^f} \left(E_t^f(i)\right)^{(\theta^f-1)/\theta^f} + \left(1-\alpha^f\right)^{1/\theta^f} \left(N_{Ot}(i)\right)^{(\theta^f-1)/\theta^f} \right]^{\theta^f/(\theta^f-1)} \tag{B.24}$$

$$(\Pi_{Et}-1)\,\Pi_{Et} = \frac{\epsilon}{\xi}(\mu_{Et}-\bar{\mu}) + \beta \mathbb{E}_t \left[(\Pi_{E,t+1}-1)\,\Pi_{E,t+1} \frac{Y_{E,t+1}}{Y_{Et}} \right] \tag{B.25}$$

$$(\Pi_{Ot}-1)\,\Pi_{Ot} = \frac{\epsilon}{\xi}(\mu_{Ot}-\bar{\mu}) + \beta \mathbb{E}_t \left[(\Pi_{O,t+1}-1)\,\Pi_{O,t+1} \frac{Y_{O,t+1}}{Y_{Ot}} \right] \tag{B.26}$$

$$D_{Et} = Y_{Et} \left[1 - \frac{\xi_E}{2} \left(\frac{P_{Et}}{P_{E,t-1}} - 1 \right)^2 \right] - \frac{W_{Et}}{P_{Et}} N_{Et} \tag{B.27}$$

$$D_{Ot} = Y_{Ot} \left[1 - \frac{\xi_E}{2} \left(\frac{P_{Ot}}{P_{O,t-1}} - 1 \right)^2 \right] - \frac{W_t}{P_{Ot}} N_{Ot} - \frac{P_{Et}}{P_{Ot}} E_t^f \tag{B.28}$$

$$D_t = D_{Et} + D_{Ot} \tag{B.29}$$

$$\frac{W_t}{P_t}\frac{P_t}{P_{Et}} = \mu_{Et} A_{Et} \tag{B.30}$$

$$\frac{W_t}{P_t}\frac{P_t}{P_{Ot}} = \left(1-\gamma^f\right)^{1/\theta^f} \mu_{Ot} \left(\frac{Y_{Ot}}{N_{Ot}} \right)^{1/\theta^f} A_t^{(\theta^f-1)/\theta^f} \tag{B.31}$$

$$\frac{P_{Et}}{P_{Ot}} = \left(\gamma^f\right)^{1/\theta^f} \mu_{Ot} \left(\frac{Y_{Ot}}{E_t^f} \right)^{1/\theta^f} A_t^{(\theta^f-1)/\theta^f} \tag{B.32}$$

Monetary and fiscal policy

$$R_t = \frac{1}{\beta} \left(\frac{\Pi_t}{\bar{\Pi}} \right)^{\phi_\pi} \left(\frac{Y_t}{Y_t^n} \right)^{\phi_y} \exp(\nu_t) \tag{B.33}$$

$$\Pi_t = (\Pi_{Et})^{\gamma} (\Pi_{Ot})^{1-\gamma} \tag{B.34}$$

$$\tau_t^c = (1-\tau)\delta D_t \tag{B.35}$$

$$(1-\lambda) T_t^u = -\lambda T_t^c \tag{B.36}$$

Aggregation and market clearing

$$n_t^c = \bar{n}^c \tag{B.37}$$

$$n_t^u = \bar{n}^u \tag{B.38}$$

$$N_{Et} + N_{Ot} = \lambda n_t^c + (1-\lambda) n_t^u \tag{B.39}$$

$$c_t^c = c_{Et}^c + c_{Ot}^c \tag{B.40}$$

$$c_t^u = c_{Et}^u + c_{Ot}^u \tag{B.41}$$

$$C_t = \lambda c_t^c + (1-\lambda) c_t^u \tag{B.42}$$

$$Y_{Et} = \lambda c_{Et}^c + (1-\lambda) c_{Et}^u \tag{B.43}$$

$$Y_{Ot} = \lambda c_{Ot}^c + (1-\lambda) c_{Ot}^u + Y_{Ot} \frac{\xi}{2} (\Pi_{Ot}-1)^2 \tag{B.44}$$

$$Y_t = Y_{Et} + Y_{Ot} \tag{B.45}$$

A.2.4 Steady State

Prices. Assume that prices of both goods are unity in steady state:

$$\bar{P}_E = \bar{P}_O = 1 \tag{B.46}$$

Hence, we get that the relative price of energy and other goods, $P_t^{rel,EO} \equiv \frac{P_{Et}}{P_{Ot}}$, in steady state is also equal to unity:

$$\bar{P}^{rel,EO} = 1 \tag{B.47}$$

Demand side. The Marshallian demands in steady state are:

$$\bar{c}_E^c = \gamma \frac{\bar{S}^c}{\bar{P}_E} \left(\frac{\bar{P}_O}{\bar{S}^c}\right)^{\varepsilon_1} \left(\bar{P}^{rel,EO}\right)^{\varepsilon_2} = \gamma \left(\bar{S}^c\right)^{1-\varepsilon_1} = \gamma \left(\bar{S}^{c,rel}\right)^{1-\varepsilon_1} \tag{B.48}$$

$$\bar{c}_E^u = \gamma \frac{\bar{S}^u}{\bar{P}_E} \left(\frac{\bar{P}_O}{\bar{S}^u}\right)^{\varepsilon_1} \left(\bar{P}^{rel,EO}\right)^{\varepsilon_2} = \gamma \left(\bar{S}^u\right)^{1-\varepsilon_1} = \gamma \left(\bar{S}^{u,rel}\right)^{1-\varepsilon_1} \tag{B.49}$$

$$\bar{c}_O^c = \frac{\bar{S}^c}{\bar{P}_O} \left[1 - \gamma \left(\frac{\bar{P}_O}{\bar{S}^c}\right)^{\varepsilon_1} \left(\bar{P}^{rel,EO}\right)^{\varepsilon_2}\right] = \bar{S}^c - \gamma \left(\bar{S}^c\right)^{1-\varepsilon_1} = \bar{S}^{c,rel} - \gamma \left(\bar{S}^{c,rel}\right)^{1-\varepsilon_1} \tag{B.50}$$

$$\bar{c}_O^u = \frac{\bar{S}^u}{\bar{P}_O} \left[1 - \gamma \left(\frac{\bar{P}_O}{\bar{S}^u}\right)^{\varepsilon_1} \left(\bar{P}^{rel,EO}\right)^{\varepsilon_2}\right] = \bar{S}^u - \gamma \left(\bar{S}^u\right)^{1-\varepsilon_1} = \bar{S}^{u,rel} - \gamma \left(\bar{S}^{u,rel}\right)^{1-\varepsilon_1} \tag{B.51}$$

Then the energy expenditure share wedge $\varpi_t^k = \left(\frac{P_{Ot}}{S_t^k}\right)^{\varepsilon_1} \left(\frac{P_{Et}}{P_{Ot}}\right)^{\varepsilon_2}$ in steady state is:

$$\bar{\varpi}^c = \left(\bar{S}^{c,rel}\right)^{-\varepsilon_1} \tag{B.52}$$

$$\bar{\varpi}^u = \left(\bar{S}^{u,rel}\right)^{-\varepsilon_1} \tag{B.53}$$

Market clearing. Goods market clearing gives:

$$\bar{Y}_E = \lambda \bar{c}_E^c + (1-\lambda)\bar{c}_E^u + \bar{E}_f \tag{B.54}$$

$$\bar{Y}_O = \lambda \bar{c}_O^c + (1-\lambda)\bar{c}_O^u \tag{B.55}$$

Labor market clearing gives:

$$\bar{N}_E + \bar{N}_O = \lambda \bar{n}^c + (1-\lambda)\bar{n}^u \tag{B.56}$$

$$\bar{N} = \bar{N}_E + \bar{N}_O \tag{B.57}$$

Supply side. Technology is unity in steady state in both sectors:

$$\bar{A}_E = \bar{A}_O = 1 \tag{B.58}$$

Taking the first-order condition of the the intermediate firm (B.10) and (B.11) in steady state, we obtain:

$$\bar{\mu} = \frac{\epsilon - 1}{\epsilon} \tag{B.59}$$

$$\bar{W}_E^{real} = \bar{W}_O^{real} = \bar{\mu} \tag{B.60}$$

Aggregating the firms' profits gives:

$$\bar{D} = \bar{D}_E + \bar{D}_O \tag{B.61}$$
$$= \bar{Y}_E - \frac{\bar{W}_E}{\bar{P}_E}\bar{N}_E + \bar{Y}_O - \frac{\bar{W}_O}{\bar{P}_O}\bar{N}_O - \frac{\bar{P}_E}{\bar{P}_O}\bar{E}^f \tag{B.62}$$
$$= \bar{Y}_E - \bar{\mu}\bar{Y}_E + \bar{Y}_O - \bar{\mu}\bar{Y}_O - \bar{E}_f \tag{B.63}$$
$$= (\bar{Y}_E + \bar{Y}_O)(1 - \bar{\mu}) - \bar{E}_f \tag{B.64}$$

The demand for energy from firms producing other goods gives:

$$\bar{E}^f = \gamma^f \bar{\mu}\bar{Y}_{Ot}\left(\frac{\bar{P}_O}{\bar{P}_E}\right)^{\theta^f} \tag{B.65}$$
$$= \gamma^f \bar{\mu}\bar{Y}_{Ot} \tag{B.66}$$

Use the supply-side steady-state values in the households' nominal budget constraint to get their relative expenditure in steady state:

$$\bar{S}^{c,rel} = \bar{W}^{real}\bar{n}^c \tag{B.67}$$
$$= \bar{\mu}\bar{n}^c + \bar{\tau}^c + \bar{T}^c \tag{B.68}$$
$$\bar{S}^{u,rel} = \bar{W}^{real}\bar{n}^u + \frac{1}{1-\lambda}\bar{D} \tag{B.69}$$
$$= \bar{\mu}\bar{n}^u + \frac{1}{1-\lambda}\bar{D} \tag{B.70}$$
$$= \bar{\mu}\bar{n}^u + \frac{1}{1-\lambda}\bar{D} + \bar{\tau}^u + \bar{T}^u \tag{B.71}$$

Chapter 2

Look-Through or Look Closer? Energy Shocks and Underlying Inflation in the Euro Area*

Abstract This paper studies the transmission of exogenous energy supply shocks to underlying inflation in the euro area. Using externally identified energy supply shocks and local projection methods, it examines whether and under which conditions energy price movements propagate beyond headline inflation into core inflation. The results show that energy shocks generate sharp but short-lived increases in energy and headline inflation, while pass-through to core inflation is delayed, persistent, and concentrated in non-energy industrial goods. Crucially, this pass-through is highly state dependent. When wage growth, inflation expectations, or headline inflation are elevated, or when energy price increases are large, energy shocks transmit into core inflation faster and more strongly. In low-inflation environments, pass-through is negligible. These findings imply that linear estimates mask important nonlinearities and that the appropriateness of "looking-through" energy shocks depends critically on prevailing macroeconomic conditions.

Keywords: Energy Shocks, Core Inflation, Local Projections, State-Dependent Pass-Through.
JEL: C53, E31, E32, E52, Q43.

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2.1 Introduction

The post-pandemic episode of high inflation confronted central banks with a classic but consequential challenge: distinguishing transitory from persistent inflationary pressures in real time. In the euro area, headline inflation rose sharply from early 2021 and peaked at about 10.6 percent in October 2022. Much of the early rise was concentrated in food and energy prices, while common measures of underlying (core) inflation remained comparatively muted.[1] This pattern motivated repeated claims in policy circles and many forecasts that the initial inflation jump was largely transitory (ECB, 2021a, 2021b), such that monetary policy could "look-through" energy-driven fluctuations. Yet inflation subsequently proved more persistent than many anticipated and broadened into services and wage dynamics, reopening the question of whether and when energy shocks feed into underlying inflation.

The focus of this paper on core inflation is grounded in both policy practice and theory. Central banks typically define their objectives in terms of headline inflation but routinely rely on measures of underlying inflation (and on theoretical arguments that map the economy into "flexible-price" and "sticky-price" sectors) when designing and communicating policy.[2] Stabilizing inflation in the sticky-price sector is welfare-optimal in canonical New Keynesian frameworks (Aoki, 2001; Benigno, 2004; Woodford, 2003). If shocks to energy prices remain isolated to the flexible sector, the "look-through" doctrine is appropriate. If, however, they spill over materially into sticky-price inflation, ignoring those shocks risks understating persistent inflationary pressures and delaying appropriate policy action.

Empirically, the literature on energy and inflation has emphasised that not all energy shocks are alike and that their macroeconomic effects vary by shock origin and over time (Baumeister & Peersman, 2013; Kilian, 2009). However, at the euro area level, it remains underexplored how energy shocks propagate to measures of underlying inflation, how large and persistent the effects are, and how transmission varies with macroeconomic conditions.

To address these questions, the paper combines externally identified energy supply shocks (Känzig, 2021) with linear and state-dependent local projections (Auerbach & Gorodnichenko, 2012, 2013; Jordà, 2005; Jordà et al., 2015). The linear specification traces the average dynamic response of euro area core inflation and its components to exogenous energy shocks while controlling for lagged inflation, monetary policy, cyclical slack, and labour market conditions. The nonlinear extension allows impulse responses to vary with the macroeconomic environment, including wage growth, inflation expectations, headline inflation, and the size of energy price movements. Following the smooth-transition local-projection approach of Auerbach and Gorodnichenko (2012, 2013), the model accommodates continuous switching variables through a logistic transition function and binary regimes through interacted local projections, enabling a transparent assessment of state-dependent pass-through.

This paper documents how energy supply shocks transmit to inflation in the euro area and

[1] While there is no universally agreed definition of underlying inflation, it is commonly measured by core inflation (defined as headline inflation excluding food and energy) and is frequently referenced in central bank policy statements.

[2] This distinction is formalized in models that map energy and unprocessed food prices into a largely flexible-price sector, while core goods and services are predominantly sticky-price. Dhyne et al. (2006) show for the euro area that unprocessed food and energy prices adjust three to eight times more frequently than prices of core goods and services.

shows that this transmission differs sharply across inflation components and macroeconomic states. In linear estimates, energy, food, and headline inflation respond quickly but transitorily to energy shocks, reflecting the direct and largely mechanical role of energy prices in the consumption basket. Core inflation, by contrast, responds with a substantial delay, as its increase becomes statistically significant roughly one year after the shock and remains elevated for an extended period. Decomposing core inflation shows that this persistence is driven primarily by non-energy goods, particularly non-durables, while services inflation reacts more gradually and less strongly, consistent with propagation along energy-intensive production chains rather than immediate wage-price dynamics.

Allowing for nonlinearities reveals that the average core response masks pronounced state dependence. Pass-through into core inflation is economically and statistically meaningful only when inflationary pressures are already elevated. Across specifications, high wage growth is associated with greater persistence of the core response, while elevated expectations or headline inflation amplify the initial transmission without necessarily prolonging it. Large energy price shocks further strengthen and accelerate pass-through relative to moderate shocks, highlighting that the size and context of the energy shock jointly determine its effect on underlying inflation. In low-pressure environments, by contrast, pass-through is negligible.

Taken together, these findings refine the interpretation of energy-driven inflation dynamics implied by the "look-through" doctrine. On average, the delayed onset and eventual attenuation of the core inflation response support the view that many energy price fluctuations primarily reflect transitory, relative price adjustments with limited implications for underlying inflation. At the same time, the pronounced state dependence documented in the data indicates that energy shocks can, under certain conditions, propagate beyond relative price changes and leave more persistent imprints on core inflation. Accordingly, the informational content of energy-driven headline inflation depends critically on the prevailing macroeconomic environment, and the pass-through of energy shocks to underlying inflation cannot be summarised by a single, state-invariant coefficient.

The remainder of the paper is organised as follows. Section 2.2 situates the paper within the related theoretical and empirical literatures. Section 2.3 documents stylised facts and provides empirical motivation for the analysis. Section 2.4 describes the baseline (linear) empirical framework, identification strategy, and data. Section 2.5 presents the results from the linear framework. Section 2.6 introduces the methodology for the nonlinear extension and discusses the associated findings. Section 2.7 concludes.

2.2 Related Literature

This paper relates to three strands of the literature. First, it connects to theoretical work on core (or underlying) inflation and the "look-through" doctrine, which motivates the exclusion of volatile components from policy-relevant inflation measures. Second, it contributes to the empirical literature on energy price shocks and their transmission into inflation. Third, it is connected to the literature on state dependence and inflation regimes, which emphasises that the macroeconomic effects of shocks can vary with the prevailing inflation environment.

Measures of underlying inflation aim to filter out high-frequency volatility in order to

recover the low-frequency component of inflation dynamics. From a policy perspective, the most relevant measures are those that predict medium-term inflation and are amenable to monetary control, which explains the widespread use of core inflation as a proxy (Bermingham, 2007; Ehrmann et al., 2018; Engemann & Owyang, 2005; Mishkin, 2007; Rosengren, 2011).[3] This logic underpins the "look-through" doctrine, according to which central banks should abstract from temporary movements in food and energy prices.

This guidance is grounded in optimal monetary policy theory. In New Keynesian models with sectoral price rigidities, welfare-maximising policy stabilises inflation in sticky-price sectors, while allowing relative prices to adjust in flexible-price sectors (Aoki, 2001; Benigno, 2004; La'O & Tahbaz-Salehi, 2022; Rubbo, 2023; Woodford, 2003). Energy and food prices, which change substantially more frequently than core goods and services (Dhyne et al., 2006), are typically modelled as flexible, while core prices are sticky. When shocks to flexible-price sectors do not propagate to sticky sectors, headline inflation conveys little information about medium-term inflationary pressures, justifying the "look-through" approach, particularly when inflation expectations are well anchored.

A large empirical literature studies the macroeconomic effects of oil and energy price shocks. Early contributions emphasise that the effects of oil price movements depend critically on their underlying source, such as supply disruptions versus global demand shocks (Kilian, 2009). Subsequent work documents sizeable effects of energy price shocks on inflation and other macroeconomic outcomes across countries and time periods, while also highlighting substantial heterogeneity (Känzig, 2021; Kilian, 2014; Kilian & Logan, 2011; Kilian & Murphy, 2014).

Much of this literature focuses on the pass-through from global oil and commodity prices into domestic headline inflation (see, among others, Casoli et al., 2024; Chen, 2009; Choi et al., 2018; Kilian and Zhou, 2023). These studies generally find rapid and statistically significant effects, though estimates vary. For example, Choi et al. (2018) find that a 10 percent increase in global oil inflation raises domestic inflation by around 0.4 percentage points on impact, with effects lasting up to two years, while Conflitti and Lucciani (2017) report smaller but more persistent responses for the United States and Europe. Panel studies further document cross-country heterogeneity, with stronger pass-through in emerging economies than in advanced economies (Baba & Lee, 2022; Gelos & Ustyugova, 2017; Nasir et al., 2019).

By contrast, evidence on the transmission of energy price shocks to core inflation is more limited and mixed. For the United States, Evans and Fisher (2011) find little evidence of systematic pass-through into core inflation, whereas other studies report economically meaningful but generally modest effects (Choi et al., 2018; Conflitti & Lucciani, 2017; Hooker, 2002). Overall, the classic pass-through literature largely focuses on headline inflation, while studies that examine core inflation typically rely on linear specifications and tend to find limited direct effects, consistent with the "look-through" doctrine.

More recent contributions emphasise that the transmission of supply and energy shocks is state dependent. Baumeister and Peersman (2013) and related work show that the macroeconomic effects of oil shocks vary with the prevailing inflation environment and

[3] As energy and food prices are largely driven by shocks beyond the direct control of monetary policy, this makes core inflation a more informative indicator for policy analysis.

monetary policy regime, while Afrouzi et al. (2024) reinterpret relative price changes as aggregate supply shocks whose inflationary consequences depend on nominal rigidities and the policy response. Consistent with this view, Arndt and Enders (2024) document stronger and more persistent effects of supply shocks in high-inflation regimes, and recent euro area studies highlight the role of expectations and wage dynamics in shaping energy price pass-through (Boeck & Zörner, 2025; Casoli et al., 2024). Collectively, these findings suggest that the inflationary impact of energy shocks cannot be summarised by a single, time-invariant coefficient.

However, this literature has largely focused on headline inflation, leaving open the question of whether, and under what conditions, energy price shocks propagate into underlying inflation, which may be more relevant for monetary policy. In particular, while previous work on the pass-through into core inflation suggests modest impact (Choi et al., 2018; Conflitti & Lucciani, 2017; Evans & Fisher, 2011; Hooker, 2002), it remains unclear whether the "look-through" doctrine remains valid in high-inflation environments, when expectations may become less anchored, or second-round effects more likely.

Several mechanisms can generate this type of state dependence. In particular, in state-dependent pricing (menu-cost) models, firms adjust prices only when shocks are large, producing size-dependent pass-through (Bils & Klenow, 2004; Dotsey et al., 1999; Golosov & Lucas, 2007). Wage-bargaining with indexation or staggered contracts allows high headline inflation to spill into wages and core prices (Erceg et al., 2000), while sticky information and rational inattention imply that persistent shocks are more likely to trigger second-round effects (Mankiw & Reis, 2002; Sims, 2003). Production-network models further highlight the role of sectoral linkages and macro regimes in shaping transmission (Acemoglu et al., 2012).

This paper contributes to the literature by comparing linear and state-dependent pass-through of energy shocks into core inflation in the euro area, combining aggregate and disaggregated measures to identify the channels of transmission and assess the circumstances under which the "look-through" doctrine is likely to hold.

2.3 Empirical Motivation

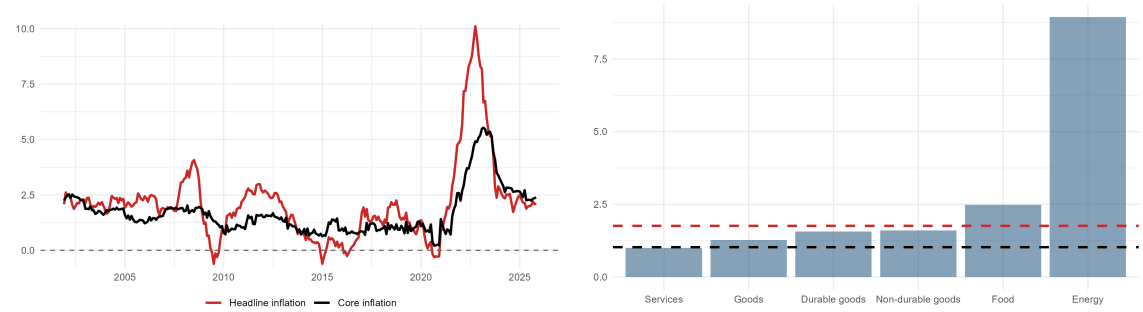
Before presenting the empirical strategy and impulse-response estimates, the paper documents a set of motivating stylised facts that summarise key patterns in euro area inflation to show salient comovements and time-variation that the analysis in Sections 2.5 and 2.6 seeks to explain.

As discussed in Section 2.2, headline inflation may provide a noisy signal of medium-term inflationary pressures because it includes food and energy prices. Core inflation instead captures the more persistent component of inflation dynamics and underpins the "look-through" rationale from the optimal-policy literature (Aoki, 2001; Benigno, 2004; Woodford, 2003). Figure 2.1 illustrates this by plotting monthly euro area headline inflation together with core inflation over the full sample (Figure 2.1a) and showing the standard deviations of inflation components (Figure 2.1b). Headline inflation stands out as markedly more volatile and exhibits pronounced short-run swings, whereas inflation evolves more smoothly and displays greater persistence, with muted responses during earlier energy-driven headline surges (notably in 2008 and 2011). This difference in behaviour reflects the composition of the consumption basket and is consistent with the theoretical distinction between a volatile

flexible-price sector (food and energy) and a sticky-price sector (core goods and services). Energy inflation is by far the most volatile component of the consumption basket (with standard deviation five times higher than headline), while services inflation exhibits the lowest volatility. Core inflation inherits low frequency and persistence from its services and (non-energy) goods composition, which illustrates its appeal as a policy signal.

Figure 2.1. Headline inflation is more volatile than core inflation

(a) Time series of headline and core inflation **(b)** Volatility across HICP components



Note: The left panel reports inflation rates in percentage points. The right panel reports standard deviations. Dashed lines indicate the standard deviation of headline inflation (red; 1.76) and core inflation (black; 1.02). HICP: Harmonised Index of Consumer Prices. Data source: Eurostat.

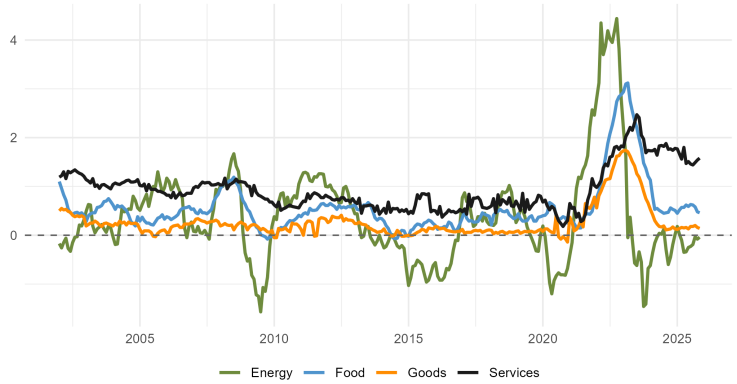
Figure 2.1a also shows that while core inflation exhibited little to no comovement with headline inflation following earlier energy price surges, the 2021/22 episode is distinctive in that core and headline inflation display substantially stronger and more persistent comovement. As headline inflation rose sharply in 2021/22, core inflation followed it closely, in contrast to earlier energy-driven episodes. Further insight into this period is provided by Figure 2.2, which decomposes headline inflation into the contributions of energy, food, goods, and services. The breakdown shows that the initial phase of the inflation surge was overwhelmingly driven by energy prices. However, as energy inflation subsequently receded, both core (and headline) inflation remained elevated, increasingly reflecting contributions from goods and, in particular, services.

This pattern points to the importance of second-round effects (operating through production costs, wages, or inflation expectations) that can propagate energy price shocks into stickier components of inflation. Hence, it motivates the paper's central empirical question of whether and under what macroeconomic conditions, energy-driven movements in headline inflation transmit into underlying inflation with meaningful persistence.

Despite the contrast in the dynamics of core and headline inflation, energy prices are not orthogonal to movements in core inflation. Figure 2.3a illustrates the comovement between energy inflation (based on the Harmonised Index of Consumer Prices; HICP) and both headline and core inflation. While the strong correlation with headline inflation is partly mechanical, the correlation with core inflation (though weaker) is consistent with pass-through from energy prices into core inflation.[4] Moreover, the upward curvature in the nonpara-

[4]Figures B.1 and B.2 report analogous correlations using Brent crude prices and energy import prices instead of HICP energy inflation. The correlations are qualitatively similar but lower, reflecting incomplete pass-through from global and import prices into domestic consumer energy prices.

Figure 2.2. Contributions of major HICP components to headline inflation



Note: The figure reports percentage point contributions to headline inflation. Data source: Eurostat.

metric locally weighted scatterplot smoothing (LOWESS)[5] fit suggests that comovement between energy and core inflation increases when energy inflation is high and indicates that large spikes in energy inflation may have disproportionate effects on underlying inflation. Figure 2.3b corroborates this nonlinearity by showing that the correlation between core and energy inflation varies significantly based on the level of prevailing inflation expectations and the level of energy inflation. These patterns are consistent with models featuring state-dependent price and wage adjustment or sluggish updating of expectations, in which large or persistent relative-price shocks generate disproportionate second-round effects (Dotsey, King, and Wolman 1999; Erceg, Henderson, and Levin 2000; Mankiw and Reis 2002; Baumeister and Peersman 2013; Afrouzi, Bhattarai, and Wu 2024), and provide a prima facie motivation for estimating state-dependent impulse responses.[6]

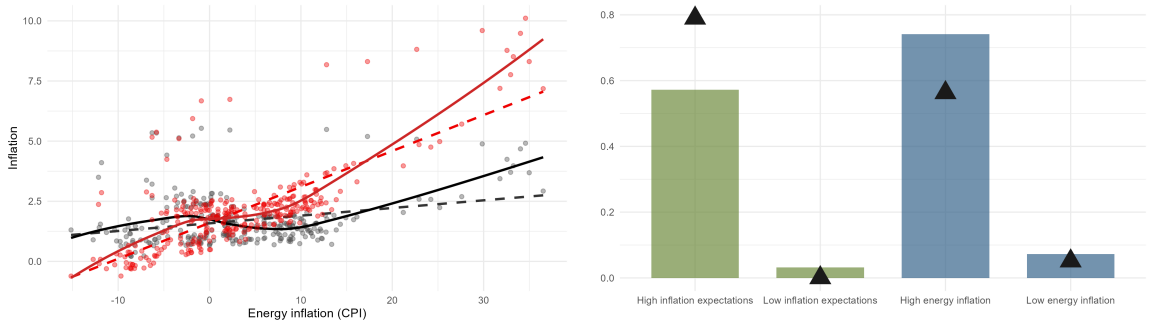
It can also be helpful to look at these correlations over time (rather than for the full sample period as above), to see how much they vary and if they are conditional on the sample selection. To this end, Figure 2.4 documents the evolution of the relationship between energy and inflation over time using two-year rolling correlations. The correlation between energy and headline inflation is consistently high and relatively stable, reflecting the direct index linkage, whereas the correlation between energy and core inflation varies substantially across episodes. Importantly, the elevated comovement observed in 2021/22 is not unprecedented, with similar levels appearing during earlier periods (notably following the energy surges in 2008 and the early to mid-2010s), which indicates that elevated comovement is not unique to the post-Covid period but rather regime-dependent. This time variation reinforces the need for an empirical framework that allows for state-dependence and for coefficients to vary with the macroeconomic environment, rather than imposing a single time-invariant pass-through rate.

[5]LOWESS is a nonparametric regression technique that fits local linear regressions to subsets of the data to trace out smooth relationships without imposing a global functional form (Cleveland, 1979). For technical details, see Fan and Gijbels (1996) and Loader (1999).

[6]Table B.1 shows correlations between energy inflation and both headline and core inflation across states. While both are nonlinear, correlations vary more across states for core than for headline inflation, raising the question for future research whether the degree of state dependence in the pass-through differs between the two.

Figure 2.3. Correlations of energy inflation with core and headline inflation

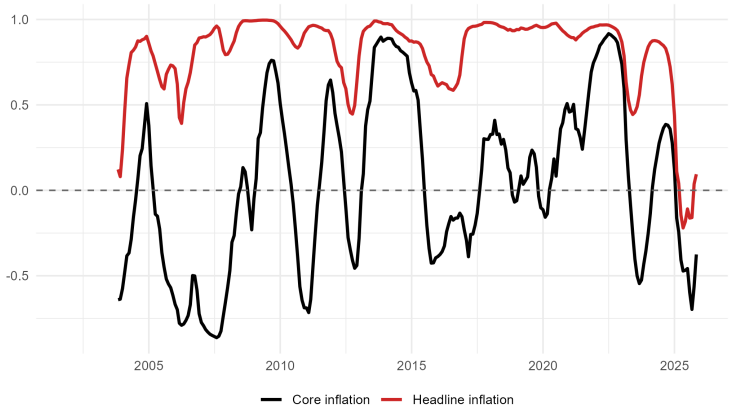
(a) Linear and nonparametric (LOWESS) fit **(b)** Nonlinear correlations



Note: Left panel: Scatterplots of energy HICP inflation against headline inflation (red) and core inflation (black). Pearson correlation is 0.75 (0.28) for headline (core) inflation. Dashed lines show linear regression fits; solid lines show LOWESS fits. Right panel: Pearson correlations between energy and core inflation computed across different states of the economy. Bars indicate correlations below and above the sample mean; triangles denote correlations at the mean plus $\pm$ one standard deviation of energy inflation and inflation expectations. Data source: Eurostat.

Collectively, the stylised facts motivate three key features of the empirical analysis. First, headline inflation is inherently noisy, providing a rationale for stripping out energy and focusing on core inflation (despite central banks' mandates oftentimes being defined in terms of headline inflation). Second, energy price surges have not always been associated with the same relationship between headline and core inflation. The 2021/22 episode is distinctive in that it coincided with a more persistent rise in core inflation, driven in particular by services. Third, while the average correlation between energy and core inflation is low, it exhibits substantial time variation (considerably more so than the correlation between energy and headline inflation) and appears to depend on macroeconomic conditions. Taken together, these observations suggest that the "look-through" logic is not uniformly safe across episodes and motivate an empirical analysis that explicitly accounts for state dependence. The empirical strategy developed in Section 2.4 is designed to address these considerations.

Figure 2.4. Rolling correlations of energy inflation with core and headline inflation



Note: The figure shows Pearson correlations computed over rolling two-year periods (backward-looking). Data source: Eurostat.

2.4 Methodology & Data

2.4.1 Empirical Framework

To quantify the dynamic pass-through from energy price shocks into core inflation, this paper adopts a reduced-form approach based on local projections (LPs) à la Jordà (2005). Rather than imposing a specific structural model, LPs allow tracing the medium-run response of inflation to identified energy shocks under minimal assumptions on dynamic adjustment. The empirical framework is motivated by an augmented Phillips Curve, in which core inflation depends on monetary policy, real economic slack, and cost-push disturbances.

The baseline specification estimates the response of euro area inflation to an exogenous energy price shock in a time-series framework. Let π_t^k denote monthly inflation of component k. For each horizon $h = 0, 1, \ldots, H$ and each k, the following local projection is estimated:

$$\pi_{t+h}^k = a_h + \sum_{j=1}^{J} \rho_{j,h}\, \pi_{t-j}^k + \sum_{l=1}^{L} \delta_{l,h}'\, Z_{t-l} + \theta_h\, \varepsilon_t^E + u_{t+h} \tag{2.1}$$

where ε_t^E is an exogenous energy price shock, Z_t is a vector of macroeconomic controls, and u_{t+h} is an error term. The sequence $\{\theta_h\}_{h=0}^{H}$ traces out the impulse response of inflation component k to the energy shock. The analysis focuses primarily on core inflation, while headline inflation and subcomponents (goods and services) are examined for comparison.

A key challenge in estimating pass-through effects is the identification of exogenous energy price movements, since observed energy prices respond endogenously to global demand conditions and macroeconomic developments. To address this issue, the paper uses the oil supply news shock constructed by Känzig (2021). This measure isolates unexpected revisions to future oil supply expectations using high-frequency information around OPEC production announcements and has been widely adopted in the recent empirical literature

to study macroeconomic responses to supply–driven oil price movements.[7]

In the baseline specifications, the oil supply news shock enters Equation (2.1) directly as ε_t^E, following recent applications that use the Känzig (2021) series as an exogenous shock (Gomes et al., 2025; Sardar & Qureshi, 2024; Zhu et al., 2025). To account for potential measurement error in the shock series, the paper additionally implements a two-stage least squares instrumental variable (2SLS LP-IV) local projection (Jordà et al., 2015) as a robustness check (see Afrouzi et al., 2024; Drossidis et al., 2024), using the Känzig shock as an external instrument for different energy inflation series. Appendix B.2 provides details on the 2SLS LP-IV design.

The inclusion of lagged inflation terms in Equation (2.1) captures intrinsic persistence, while the control variables account for macroeconomic conditions that may jointly influence inflation dynamics. In the main specification, the vector Z_t includes the short-term policy interest rate, a measure of the output gap, and the non-accelerating wage rate of unemployment (NAWRU), proxying for the monetary policy stance, cyclical demand pressures, and labour market slack. In the baseline estimation, both the dependent variable and the control variables enter the regression with six monthly lags ($J = L = 6$), providing sufficient flexibility to capture short-run dynamics without overfitting. Robustness checks consider alternative control sets and lag specifications.

The maximum horizon is set to $H = 30$ months, allowing tracking pass-through effects over the medium-run. Local projections are estimated by ordinary least squares, and confidence intervals are constructed using heteroskedasticity- and autocorrelation-robust standard errors (Newey & West, 1987) to account for serial correlation induced by overlapping forecast horizons. The number of lags used in the standard error correction increases with the forecast horizon. The LP approach offers several advantages for the present application. First, it avoids the need to specify and invert a full vector autoregressive system, reducing sensitivity to potential mis-specification of the underlying dynamic structure. Second, it allows for straightforward extensions to nonlinear and state-dependent specifications, which are presented and discussed in Section 2.6.

2.4.2 Data

The empirical analysis uses monthly euro area data spanning January 2001 to January 2025 (subject to data availability for individual series in some robustness exercises). Inflation measures are based on the Harmonised Index of Consumer Prices (HICP) published by Eurostat and are constructed at monthly frequency on a year-on-year basis. The analysis considers headline inflation, core inflation, and a detailed decomposition into energy, food,

[7] Building on high-frequency identification methods in the spirit of Gertler and Karadi (2015) and Ramey (2016), Känzig (2021) measures changes in oil futures prices within a narrow event window around these announcements. The identifying assumption is that macroeconomic conditions and demand expectations are already priced in at the time of the announcement and are unlikely to change materially within the event window. Announcements implying lower (higher) future oil supply are classified as negative (positive) supply news. By focusing on price movements within a tight window around these announcements, the approach isolates unexpected supply-related information while plausibly ruling out contemporaneous feedback from global demand or macroeconomic conditions. Figure B.3 plots the histogram and time series of the Känzig shock, showing that the shock exhibits a well-behaved empirical distribution.

services, and goods components, with further disaggregation of goods into durable and non-durable categories. This allows tracing the transmission of energy price shocks across components of the consumption basket that differ in price flexibility and exposure to input costs.

To control for domestic macroeconomic conditions relevant for inflation dynamics, monetary policy is proxied by the euro area short-term (three-month) nominal policy interest rate at monthly frequency. Measures of economic slack include the output gap and the NAWRU, which are available at annual frequency, as well as a labour cost index capturing wage dynamics, observed at quarterly frequency. These series are converted to monthly frequency using cubic spline interpolation, which preserves low-frequency variation while avoiding the introduction of spurious high-frequency movements.[8] The unemployment gap is constructed as the difference between the seasonally adjusted unemployment rate (for individuals aged 25–74) and the interpolated NAWRU series, capturing cyclical labour market slack while abstracting from slow-moving structural trends.

As part of the robustness analysis, alternative measures of energy prices are considered, including consumer energy inflation (HICP energy and HICP fuel), Brent crude oil prices, and import prices for energy and crude petroleum.[9] These series capture the high volatility of energy markets and provide context for the magnitude and persistence of energy price fluctuations over the sample period. Inflation expectations are used in robustness checks and measured using twelve-month-ahead consumer inflation expectations from the European Commission's Business and Consumer Survey, which provides harmonised and timely information across euro area countries.

All variables are aggregated at the euro area level unless otherwise stated (see Section 2.5.4, which explores cross-country variation in the energy shock pass-through into core inflation). The euro area is defined as a weighted but constant set of all EA-20 countries to avoid compositional changes arising from euro area enlargement over the sample period. Summary statistics for the main variables used in the analysis are reported in Table B.3.

2.5 Linear Pass-Through of Energy Price Shocks

This section documents the dynamic pass-through from exogenous energy price shocks to inflation in the euro area. The analysis proceeds in three steps. First, it establishes the baseline impulse responses of headline, energy, food, and core inflation to an energy supply news shock. Second, it assesses the robustness of these responses using alternative energy price measures and an instrumental-variables framework. Third, it explores heterogeneity

[8] This approach is standard in empirical macroeconomic applications combining inflation data with lower-frequency measures, see Stock and Watson (1999).

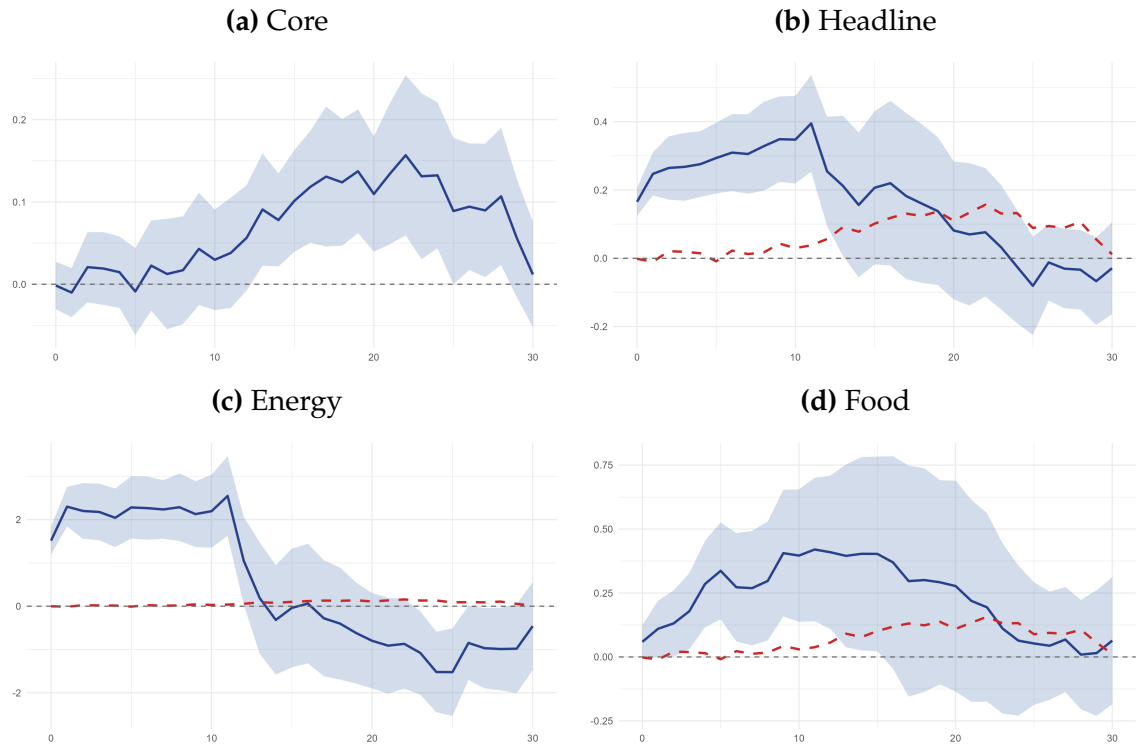
[9] HICP energy and import prices for energy cover a broader set of energy products than HICP fuel and crude petroleum import prices, respectively, as they also include electricity and gas. While gas prices played an important role during the 2021/22 episode and existing research shows that gas and oil supply shocks can have distinct macroeconomic effects (e.g., Adolfsen et al., 2024), the analysis does not consider gas and electricity prices independently. In many euro area countries, these prices are fully or partially administered, implying that their pass-through to consumer prices is shaped by institutional and regulatory features that differ fundamentally from those governing fuel prices. Studying their pass-through dynamics therefore requires a different empirical framework and would be an interesting extension for future work.

along dimensions that are central for policy, particularly across components of core inflation and across euro area member states.

2.5.1 Baseline Empirical Results

Figure 2.5 reports impulse response functions to a one percentage point upward energy supply shock identified using the methodology of Känzig (2021).[10] The responses reveal a sharp contrast between the short-run behaviour of headline and non-core inflation and the medium-run dynamics of core inflation, both in terms of timing and persistence.

Figure 2.5. Responses of major HICP components to energy supply shock



Note: Impulse responses are reported in percentage point deviations from baseline inflation after a one percentage point shock. The red-dashed line overlays the core response for scale comparability across panels. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: Eurostat, EC/AMECO, Känzig (2021).

The response of consumer energy inflation is immediate and large, reflecting the direct nature of the shock. Energy inflation rises by around 1.5 percentage points on impact and continues to increase over the following months, peaking at approximately 2.5 percentage points eleven months after the shock. The response is statistically significant throughout

[10] A one percentage point energy shock lies at approximately the 95th percentile of the empirical distribution of the Känzig shock (Figure B.3a), indicating that the shock magnitude considered is large but not extreme. In particular, a shock of this size remains within the historical range of observed realizations rather than constituting an outlier. Figure B.3b further shows that shocks of one percentage point or larger occur during well-defined episodes of elevated energy price pressures, including the 2007/08 commodity price surge, periods in the early and mid-2010s, and the COVID-19 episode.

the first year before dissipating as base effects unwind. This pattern is consistent with rapid pass-through from wholesale energy prices to retail energy components of the HICP basket. Food inflation also increases following the energy shock, but with a slower and more muted adjustment. The response builds gradually over the first year, reaching a peak of about 0.42 percentage points after eleven months, and remains statistically significant at the 90 percent confidence level for just over a year. The delayed profile is consistent with energy costs being transmitted to food prices through production, transportation, and processing channels, which operate with longer lags than retail energy pricing.

Given that food and energy together account for roughly one quarter of the HICP basket in the euro area, these dynamics translate into a pronounced response of headline inflation. Headline inflation increases on impact by about 0.16 percentage points and continues to rise over subsequent months, peaking at approximately 0.39 percentage points around eleven months after the shock. As with energy and food inflation, the response of headline inflation is short-lived and statistical significance largely disappears after about one year, reflecting the transitory nature of relative price adjustments and the mechanical unwinding of base effects.

In contrast, the response of core inflation exhibits markedly different timing and persistence. Core inflation increases only gradually following the energy shock and remains statistically insignificant for almost a full year. It becomes positive and significant only thereafter, peaking at roughly 0.16 percentage points 22 months after the shock. Although the peak response is less than half the magnitude of the headline response, once it materialises it proves highly persistent, remaining statistically significant over most of the 2.5-year horizon considered.

This contrast between headline and core dynamics is central to the paper's contribution. While the initial response of headline inflation is driven primarily by direct relative price effects in energy and food components, the delayed and persistent increase in core inflation points to indirect, second-round transmission channels. These include the gradual propagation of higher energy costs into production margins, wages, and pricing decisions across non-energy sectors and produce a gradual, longer-lived response in core inflation. From a policy perspective, the transitory increase in headline inflation and the relatively small, though persistent, rise in core inflation explain why central banks may "look-through" energy-driven spikes. At the same time, it shows that persistent energy shocks can generate sustained inflationary pressures in components most relevant for medium-term price stability.

The baseline results are robust across a wide range of specification checks. Appendix B.4 shows that the qualitative pattern (rapid, transitory responses in non-core components versus delayed, persistent responses in core inflation) persists under modest sample changes (Figure B.6) and alternative controls, such as excluding the interest rate, substituting the output gap with the unemployment gap, including survey-based inflation expectations, or omitting the NAWRU (Figures B.7–B.10). The persistence of the core response is also preserved under alternative treatments of trend and smoothing in the output gap and NAWRU measures.

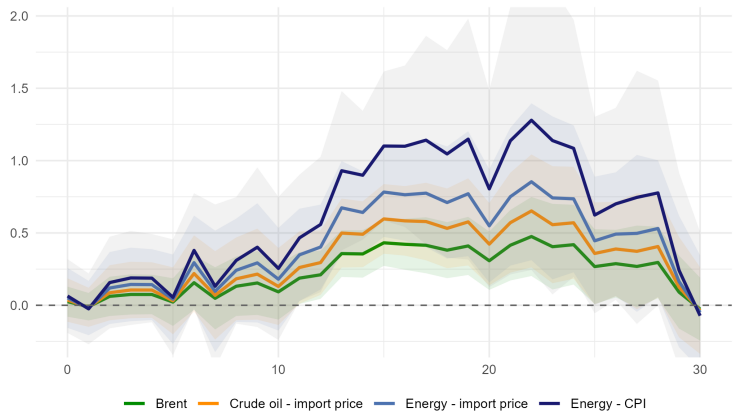
2.5.2 Robustness with Instrumental Variable Approach

For the main estimation, the Känzig (2021) shock is used directly as an exogenous variable. Although widely used, this shock is an imperfect proxy as it can miss relevant supply news and be subject to measurement error (see discussion in Känzig, 2021). To address these concerns, the paper implements a two-stage least squares IV–local projection (2SLS LP-IV) extension (Jordà et al., 2015), using the Känzig shock as an instrument for alternative measures of energy inflation. The instrumented series include Brent (global oil) inflation, crude oil import inflation, energy import prices, HICP fuel inflation, and HICP energy inflation. This IV strategy both validates the baseline results and tests their sensitivity to the chosen energy price measure. Details of the estimation setup are reported in Appendix B.2, and Table B.3 presents first-stage diagnostics for the instrument.[11]

Figure 2.6 overlays the impulse responses of core inflation across these alternative specifications. To make the responses comparable across series with different volatility, each response is scaled to a one standard deviation shock in the instrumented series. Because this standardisation changes the units relative to Figure 2.5, the magnitudes are not directly comparable and the focus should therefore be on the shape and timing of the responses. Across all specifications the dynamic shape of the core response is consistent as the impact emerges after roughly one year, peaks near the two-year horizon, and decays thereafter.

The consistency of the response shape across instruments strengthens the interpretation of the baseline results. It implies that the delayed and persistent transmission to core inflation is not an artifact of any single energy price measure but instead reflects a more general propagation mechanism from energy costs to underlying inflation.

Figure 2.6. Core inflation response (2SLS LP-IV)



Note: Impulse responses are reported in percentage point deviations from baseline inflation, following a one standard deviation shock. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: Eurostat, EC/AMECO, FRED, Känzig (2021).

[11] Figures B.4 and B.7 show that the different energy inflation series broadly follow the same trends. The largest differences are in volatility, where Brent is the most volatile, followed by import prices, while HICP energy inflation is comparatively smooth (while also being the most volatile item within the HICP basket; see Figure 2.1b).

While the main purpose of the 2SLS extension is to check robustness against alternative estimation methods and to address potential measurement error in the Känzig (2021) shock, the exercise also provides additional, economically meaningful information about the transmission of global energy prices. Specifically, the peak core responses to a one-standard-deviation shock range from roughly 0.40 percentage points for Brent (1.1 percent pass-through) to 1.27 percentage points for HICP energy (14.1 percent pass-through), with intermediate values for crude and energy import prices and HICP fuel. This ordering is intuitive as global commodity price movements transmit into import prices, which in turn feed into consumer energy prices, with some attenuation at each stage. Differences in peak magnitudes appear driven by attenuation along the price chain (from volatile global prices to smoother consumer prices), not by fundamentally different transmission channels. While these differences are not the focus of the analysis, they illustrate that the choice of shock series in IV estimation can substantially affect estimated magnitudes, and that variation in how shocks are measured and scaled may contribute to the dispersion of pass-through estimates across the literature.

2.5.3 Differences Across Components of Core Inflation

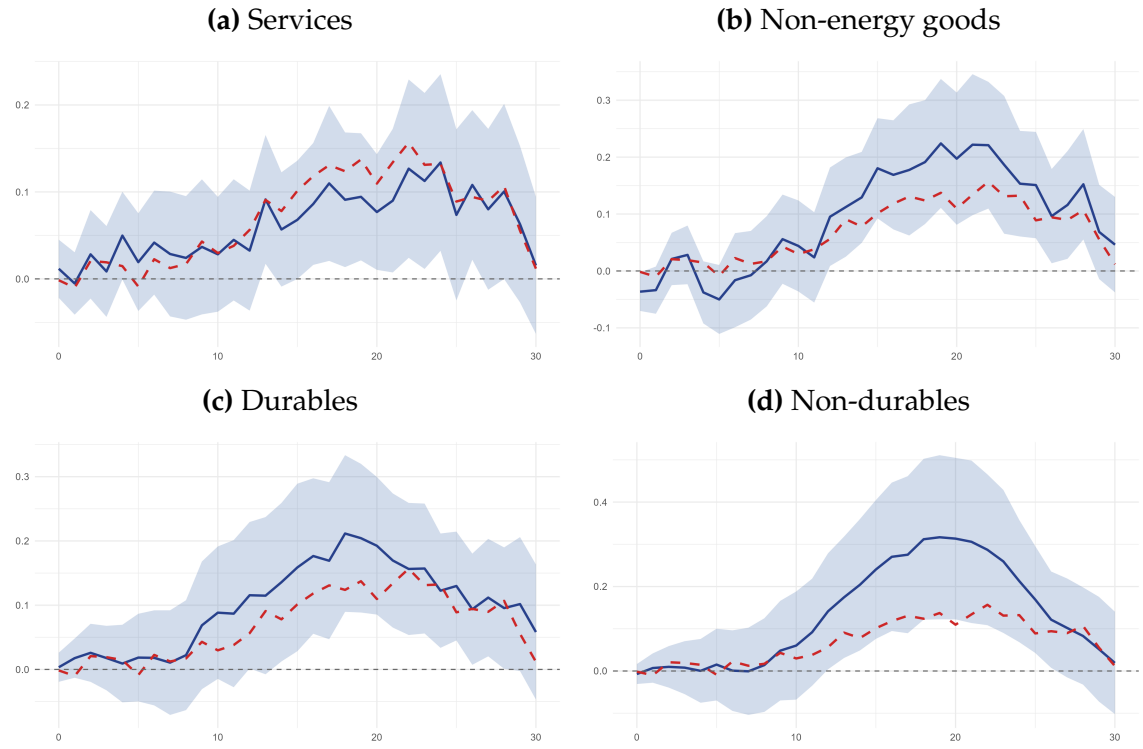
To identify the sources underlying the core inflation response, Figure 2.7 decomposes core inflation into services and non-energy industrial goods (NEIG), with the latter further split into durables and non-durables.

Services inflation responds only weakly to the energy shock. The response becomes significant later than the core inflation response discussed above and peaks below core, at 0.13 percentage points, two years after the shock. This muted response is consistent with services prices being driven primarily by labour costs and domestic demand conditions, which adjust only gradually to energy price movements. By contrast, NEIG inflation reacts more strongly and somewhat earlier. The response peaks at 0.22 percentage points 19 months after the shock and remains significant for roughly twenty-eight months. This stronger response likely reflects the more direct role of energy as an input in the production and distribution of goods, as well as greater exposure to global value chains. The goods response is concentrated in non-durables, which peak at about 0.32 percentage points at 19 months, whereas durable goods exhibit a smaller peak of similar timing. These findings are consistent with non-durables being more energy-intensive and subject to more frequent price adjustment, amplifying the transmission of cost shocks.

Taken together, these compositional results indicate that the persistence of the core inflation response is driven primarily by goods prices (especially non-durables) rather than services, consistent with direct cost-pass-through mechanisms operating through production and distribution sectors that are relatively energy-intensive and adjust prices more frequently than services. Additional results for major COICOP categories are reported in Figure B.11.[12]

[12]The impulse responses show that energy shocks have heterogeneous effects across consumption categories. Energy-intensive categories such as Housing, water, electricity, gas (CP04) and Transport (CP07) exhibit the largest positive responses, with CP04 showing a large but transitory effect and CP07 a sharp initial spike followed by a gradual decline. Furnishings, household equipment, and maintenance (CP05) also respond strongly and persistently. In contrast, more service-oriented or less energy-sensitive categories, such as Alcohol & tobacco (CP02), Clothing & footwear (CP03), Health (CP06), Communications (CP08), Recreation & culture (CP09), and Education (CP10), show small, short-lived, or negligible responses, indicating limited pass-through.

Figure 2.7. Responses across goods and services



Note: Impulse responses are reported in percentage point deviations from baseline inflation after a one percentage point shock. The red-dashed line overlays the core inflation response for scale comparability across panels. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: Eurostat, EC/AMECO, Känzig (2021).

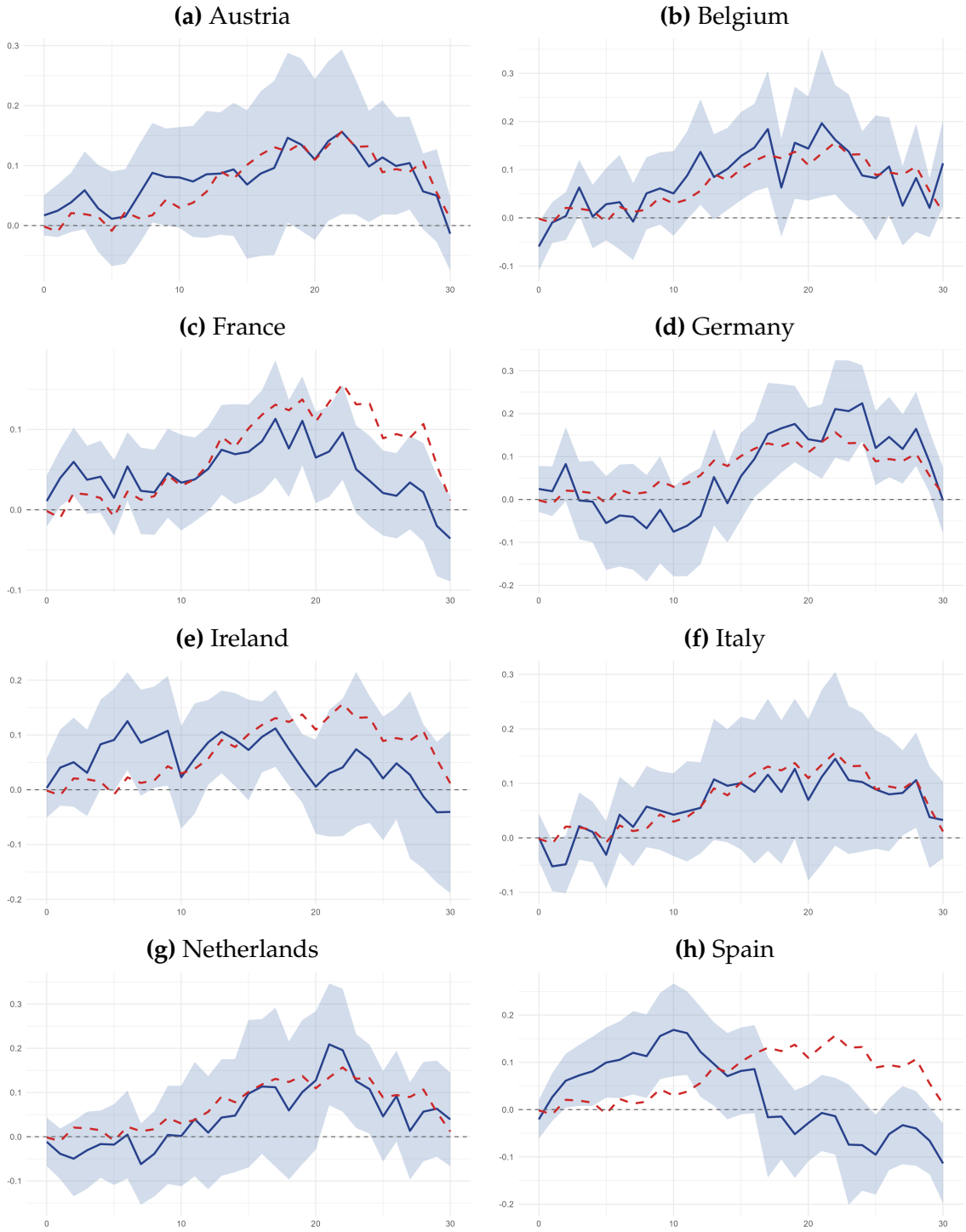
2.5.4 Cross-Country Heterogeneity Within the Euro Area

This section explores the heterogeneity across the pass-through from energy shocks into core inflation of individual euro area member states. The country-level local projections reveal substantial heterogeneity in the magnitude and timing of pass-through across euro area members (Figure 2.8 displays the eight largest euro area economies; results for all remaining countries are reported in Figures B.12 and B.13). Italy and Austria display responses close to the euro area aggregate but with weaker statistical significance. Spain (and Ireland to a lesser degree) manifests an earlier core response, with core inflation increasing within the first year following the shock. France shows a response that resembles the euro area aggregate shape but with attenuated magnitude, which is plausibly linked to the prevalence of administered electricity and gas prices in France (Kuik et al., 2022), which dampen the transmission of energy cost shocks. Germany stands out as the country with the largest and most persistent response. Core inflation in Germany peaks at 0.22 percentage points exactly two years after the shock and remains statistically significant for almost the entire horizon considered. The larger German response is consistent with its larger industrial sector, and the earlier decomposition result that NEIG inflation responds more than services inflation, implying greater exposure to energy cost shocks and stronger pass-through to underlying inflation. These cross-country differences underscore that aggregate euro area estimates mask economically meaningful heterogeneity that arises from sectoral composition, pricing

institutions and national energy market structures.

Taken together, the results in Section 2.5 suggest that exogenous energy supply shocks produce large but short-lived increases in energy, food, and headline inflation, which typically dissipate within a year. Their effect on core inflation, by contrast, is delayed but persistent, as higher energy costs gradually propagate through production costs and wages, predominantly via goods, and with substantial cross-country heterogeneity. These results broadly support the conventional view that central banks can initially "look-through" transitory energy-driven spikes. At the same time, they highlight important nuances - persistent or large energy shocks, particularly in energy-intensive sectors or specific countries, can feed into underlying inflation and generate lasting pressures relevant for medium-term price stability. The next section investigates how these transmission patterns vary systematically with the state of the economy.

Figure 2.8. Heterogeneous responses across countries



Note: Impulse responses are reported in percentage point deviations from baseline inflation after a one percentage point shock. The red-dashed line overlays the aggregate euro area core inflation response for scale comparability across panels. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: Eurostat, EC/AMECO, Känzig (2021).

2.6 Nonlinear Transmission of Energy Shocks

2.6.1 Methodology

Based on the descriptive evidence in Section 2.3 and the results in Section 2.5, a natural next step is to assess whether it is possible to identify conditions under which a monetary policy "look-through" stance to energy supply shocks is appropriate versus those under which it risks underestimating the build-up of underlying inflation. To this end, the paper extends the baseline linear local projection framework to allow for state-dependent impulse responses, examining whether the transmission of energy supply shocks to core inflation varies with the macroeconomic environment.

As before, π_t^C denotes core inflation, Z_t is a vector of control variables, and the Känzig (2021) shock, ϵ_t^E, enters directly as an externally identified shock. Unlike Equation 2.1, however, the framework now incorporates a switching variable z_t that governs regime dependence. The local projection estimated at horizon h is:

$$\begin{aligned}\pi_{t+h}^C = \alpha_h &+ \sum_{j=1}^{J}\left[(1-\Omega_{t-1})\rho_{j,h}^{(1)} + \Omega_{t-1}\rho_{j,h}^{(2)}\right]\pi_{t-j}^C \\ &+ \sum_{l=1}^{L}\left[(1-\Omega_{t-1})\delta_{l,h}^{(1)} + \Omega_{t-1}\delta_{l,h}^{(2)}\right]Z_{t-l} \\ &+ \left[(1-\Omega_{t-1})\theta_h^{(1)} + \Omega_{t-1}\theta_h^{(2)}\right]\epsilon_t^E + u_{t+h},\end{aligned} \tag{2.2}$$

The model therefore allows the coefficients on lagged core inflation, control variables, and the energy shock to differ across regimes, with regime weights given by $1-\Omega_{t-1}$ and Ω_{t-1}. The switching variable enters the transition function with a lag, so that z_{t-1} determines the regime prevailing at time t. This ensures that the state is predetermined with respect to the energy shock, mitigating concerns about contemporaneous feedback effects (Auerbach & Gorodnichenko, 2012, 2013).

The regime weight Ω_{t-1} is defined as:

$$\Omega_{t-1} = \begin{cases} F(z_{t-1}) = \dfrac{\exp(-\gamma z_{t-1})}{1+\exp(-\gamma z_{t-1})}, & \text{if } z_{t-1} \text{ is continuous,} \\ D_{t-1} \in \{0,1\}, & \text{if } z_{t-1} \text{ is discrete.} \end{cases} \tag{2.3}$$

When z_t is continuous, the specification follows the smooth-transition local projection approach of Auerbach and Gorodnichenko (2012, 2013). The switching variable is demeaned and HP-filtered prior to applying the logistic function $F(\cdot)$, isolating medium-term fluctuations and preventing regime classification from being driven by high-frequency noise.[13] The parameter γ governs the steepness of the transition function, with lower values implying gradual transitions across regimes and larger values approximating a discrete threshold model.[14]

When the switching variable is discrete, the framework collapses to a standard interacted local projection specification. The continuous switching variables considered in the analysis

[13] The smoothing parameter is set to $\lambda = 14,400$, following (Ravn & Uhlig, 2002).

[14] As $\gamma \to \infty$, the smooth-transition specification converges to a binary regime-switching model.

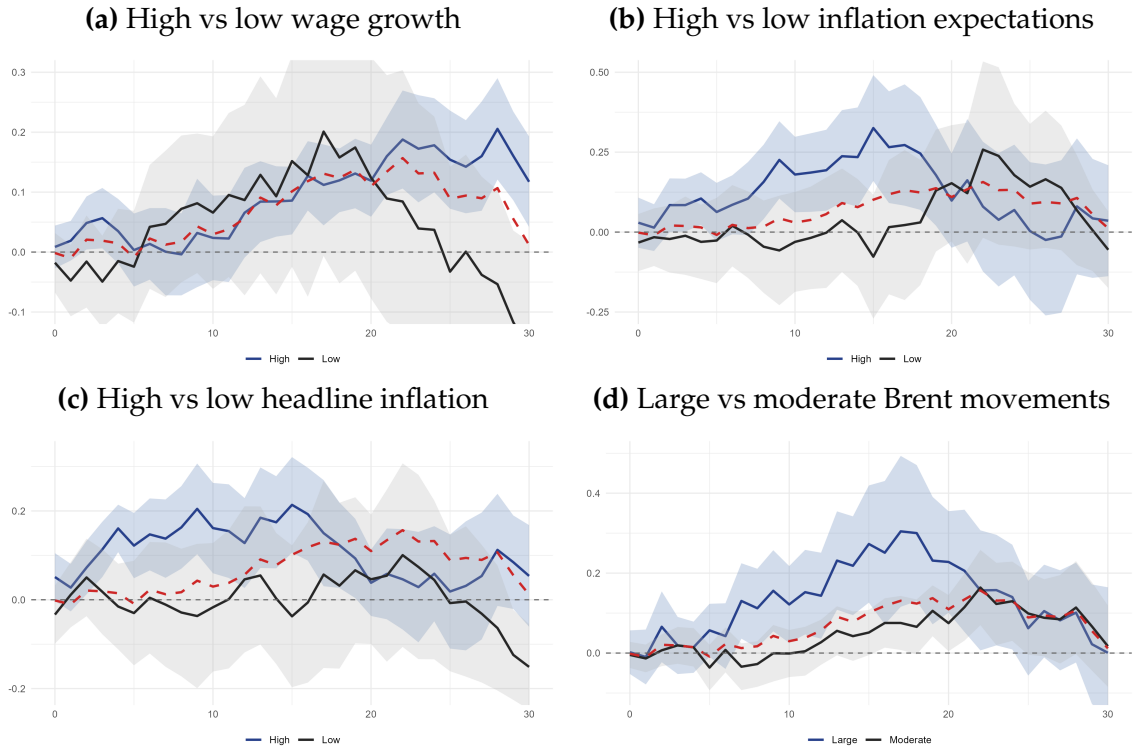
are inflation expectations, wage growth, and headline inflation, while the binary specification classifies regimes according to whether Brent inflation lies outside a band defined by its mean plus or minus one standard deviation, proxying for large versus moderate energy price movements.

Impulse responses are constructed separately for the "low" and "high" regimes as the estimated sequences $\{\theta_h^{(1)}\}$ and $\{\theta_h^{(2)}\}$, respectively. The horizon length, lag structure, and inference procedures are kept identical to those used in the linear baseline throughout.

2.6.2 Nonlinear Results

The nonlinear estimates reveal pronounced state dependence in the pass-through from energy supply shocks to core inflation. Allowing impulse responses to vary across macroeconomic regimes uncovers substantial heterogeneity that is obscured in the linear specification. Figure 2.9 summarises the nonlinear responses across alternative definitions of the inflationary environment. A clear organising principle emerges: energy shocks propagate into core inflation primarily when inflationary pressures are already elevated, while pass-through is weak or absent when such pressures are subdued.

Figure 2.9. Pass-through nonlinearity across switching variables



Note: Impulse responses are reported in percentage point deviations from baseline inflation after a one percentage point shock. The red-dashed line overlays the core inflation response for scale comparability across panels. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: Eurostat, EC/AMECO, Känzig (2021).

Across all specifications, regimes characterised by elevated inflationary pressures are associated with faster, stronger, and economically meaningful pass-through from energy supply

shocks to core inflation. When wage growth is high, an energy shock generates a sizable and persistent increase in core inflation (Figure 2.9a). The response becomes statistically significant earlier than in the linear benchmark, peaks at approximately 0.20 percentage points, and remains significant until the end of the projection horizon. This pattern suggests that strong wage dynamics facilitate the transmission of energy cost shocks into underlying inflation, consistent with second-round effects operating through wage-setting and price adjustment frictions.

A similarly amplified transmission is observed when inflation expectations are elevated (Figure 2.9b). In high-expectation regimes, core inflation already responds significantly within the first year following the shock and reaches a peak of roughly 0.33 percentage points, substantially above the unconditional estimate in Figure 2.5. While the response decays more rapidly than in the wage-based specification, its magnitude and early significance indicate that unanchored expectations materially strengthen the initial pass-through of energy shocks into core prices.

High headline inflation regimes display comparable dynamics (Figure 2.9c). In these states, energy shocks transmit into core inflation almost immediately, with statistically significant effects emerging after only a few months and peak responses exceeding 0.20 percentage points. Relative to the linear benchmark, transmission is shifted forward in time but also dissipates more quickly, suggesting that elevated headline inflation accelerates price adjustment without necessarily prolonging inflationary pressures.

Finally, large energy price movements (proxied by Brent inflation exceeding its standard deviation around the mean) also trigger a markedly stronger and faster pass-through into core inflation (Figure 2.9d). In this regime, the response peaks at approximately 0.30 percentage points around 18 months after the shock. This finding indicates that sufficiently large energy shocks activate transmission mechanisms that remain largely dormant during more moderate price fluctuations.

In contrast, when inflationary pressures are muted, energy supply shocks exhibit little to no pass-through into core inflation. In regimes characterised by low wage growth, anchored inflation expectations, low headline inflation, or moderate energy price movements, the estimated responses of core inflation are uniformly small and statistically indistinguishable from zero across most horizons. In these states, energy shocks are largely absorbed without generating persistent underlying inflation.

Taken together, these results indicate that the modest average pass-through documented in the linear analysis masks substantial state dependence. Energy supply shocks translate into core inflation primarily when the macroeconomic environment is already inflationary (i.e., when wages are rising rapidly, expectations are elevated, headline inflation is high, or energy price increases are unusually large). Conversely, in low-pressure environments, pass-through is negligible. These findings underscore the importance of accounting for nonlinearities in empirical models of inflation dynamics and caution against interpreting average pass-through estimates as policy-invariant. From a policy perspective, they imply that "looking-through" energy shocks may be appropriate in low-inflation regimes, but considerably riskier when inflationary pressures are already entrenched.

2.7 Conclusion

This paper studies the transmission of exogenous energy supply shocks to underlying inflation in the euro area. Motivated by the prominent role of energy price movements in recent inflationary episodes, the analysis asks whether, and under which conditions, energy shocks propagate beyond energy inflation into core inflation. To address this question, the paper combines the externally identified energy supply shocks from Känzig (2021) with local projection methods, allowing for rich dynamics, alternative price measures, and nonlinear state dependence.

The empirical results point to three main findings. First, energy supply shocks generate a sharp but transitory increase in energy and food inflation, which passes through quickly to headline inflation and largely dissipates within a year. Core inflation, by contrast, responds much more slowly as the pass-through materialises only with a substantial delay, peaks after roughly two years, and remains considerably more persistent. This temporal pattern highlights a fundamental distinction between direct price effects operating through the HICP basket and indirect effects operating through wages, expectations, and pricing decisions. The dynamics of the core inflation response are robust to alternative empirical specifications and implementations.

Second, a decomposition of core inflation shows that non-energy industrial goods account for a disproportionate share of the response, while services inflation reacts more gradually and less strongly. Cross-country evidence reveals substantial heterogeneity across euro area members, with Germany exhibiting a particularly pronounced and persistent response, consistent with its larger industrial sector.

Third, and most importantly, the pass-through from energy shocks to core inflation is highly state dependent. When wage growth, inflation expectations, or headline inflation are elevated, energy shocks transmit into core inflation faster, with substantially larger peak effects, and in some cases with greater persistence. Instead, in low-pressure environments, the same shocks generate little or no response in core inflation. Large energy price movements further amplify pass-through relative to moderate shocks. These nonlinearities imply that average, linear estimates obscure economically meaningful variation across states of the economy and can be misleading guides to policy.

Taken together, these findings support a nuanced interpretation of energy-driven inflation dynamics. On average, the pass-through from energy shocks to core inflation is modest and unfolds slowly - a conclusion that, when viewed through the lens of a linear model, lends empirical support to the view that central banks can generally "look-through" energy price fluctuations. However, the strong state dependence documented in the nonlinear analysis fundamentally qualifies this view and cautions against treating energy shocks as uniformly benign. When inflation expectations are elevated, wage growth is strong, or headline inflation is already high, energy shocks are far more likely to trigger second-round effects that risk entrenching underlying inflation.

From a policy perspective, the results suggest that the appropriate response to energy price shocks depends critically on the inflationary environment in which they occur. They highlight that credibility, expectation anchoring, and labour market conditions play a central role in determining whether energy shocks remain temporary disturbances or evolve into persistent inflationary pressures. For researchers, they underscore the importance of

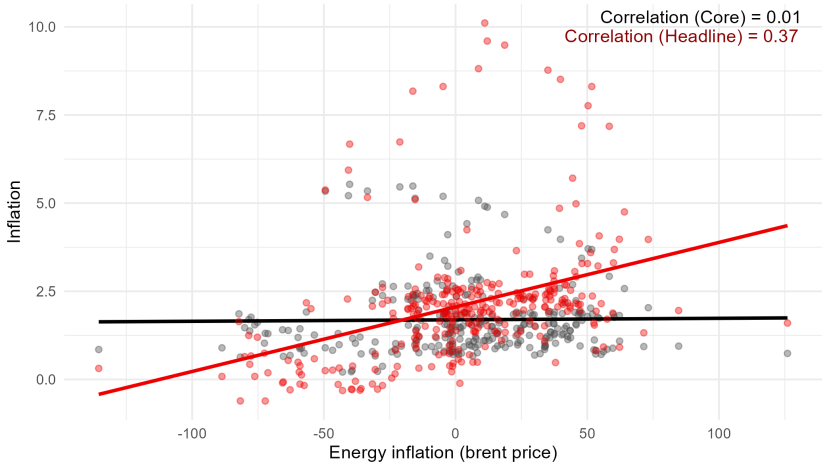
allowing for nonlinear transmission mechanisms when modelling inflation dynamics.

Appendix B

Appendix of Chapter 2

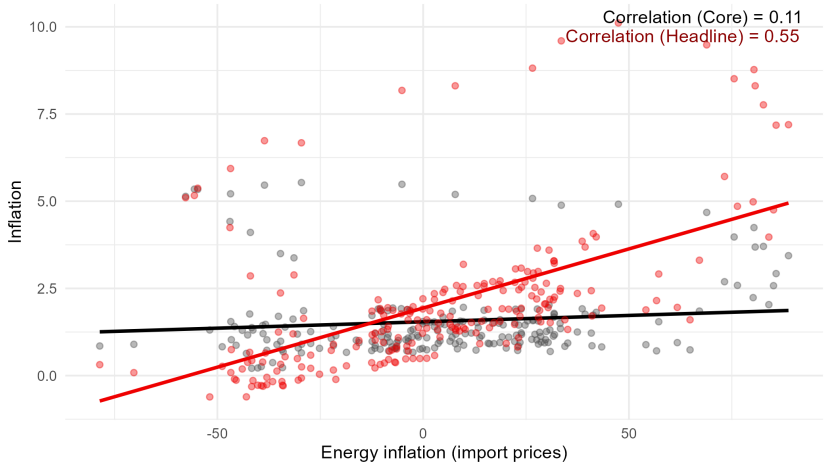
B.1 Supporting Figures and Empirical Evidence

Figure B.1. Correlations of Brent inflation with core and headline inflation



Note: Scatterplots of Brent inflation against headline inflation (red) and core inflation (black). Pearson correlation coefficients included. Solid lines show linear regression fit. Data sources: Eurostat, FRED/U.S. EIA.

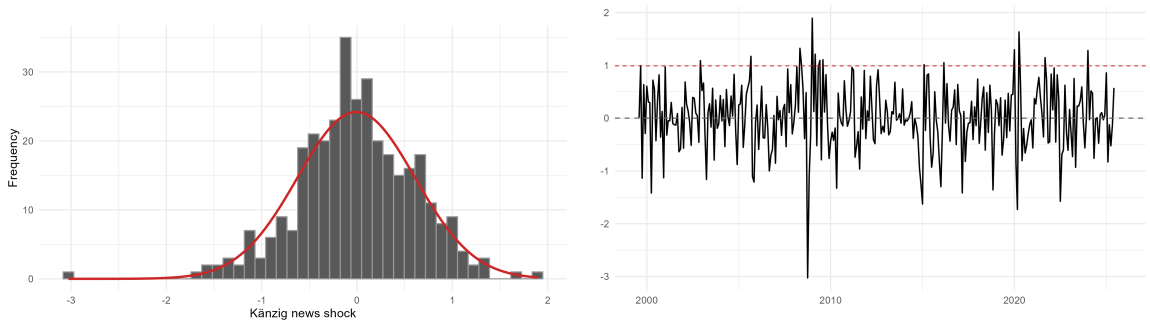
Figure B.2. Correlations of energy import inflation with core and headline inflation



Note: Scatterplots of euro area energy import price inflation against headline inflation (red) and core inflation (black). Pearson correlation coefficients included. Solid lines show linear regression fit. Data source: Eurostat.

Figure B.3. Properties of the Känzig-shock

(a) Histogram **(b)** Time series



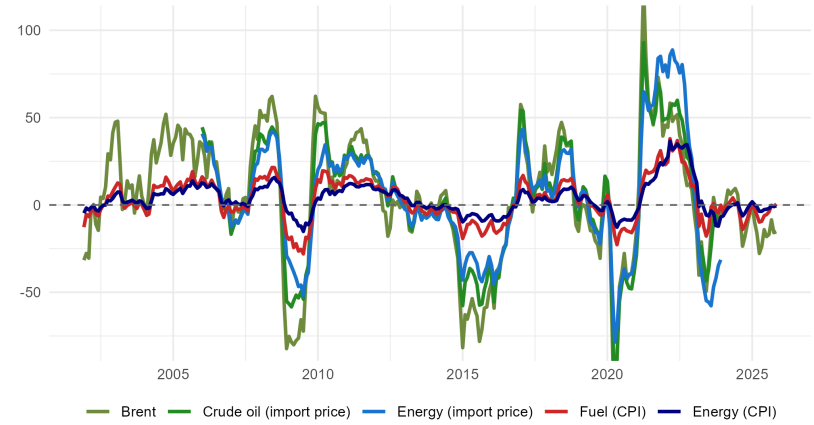
Note: Full sample series used. Data source: Känzig (2021).

Table B.1. Correlations of energy inflation with core and headline inflation

State	Corr(core, energy)	Corr(headline, energy)	$\mathcal{C}_{core,1} - \mathcal{C}_{core,2}$	$\mathcal{C}_{headline,1} - \mathcal{C}_{headline,2}$	Diff-in-diff
1: High inflation expectations	0.573	0.880	0.541	0.402	0.139
2: Low inflation expectations	0.032	0.479			
1: High energy inflation	0.741	0.889	0.669	0.478	0.191
2: Low energy inflation	0.072	0.411			
1: High headline inflation	0.018	0.644	0.028	-0.108	0.137
2: Low headline inflation	-0.011	0.752			
1: Large Känzig shock	0.428	0.823	0.222	0.109	0.113
2: Small Känzig shock	0.206	0.713			
1: Low unemployment	0.250	0.744	-0.069	-0.165	0.096
2: High unemployment	0.319	0.909			
1: High IP growth	0.625	0.884	0.431	0.198	0.233
2: Low IP growth	0.195	0.686			

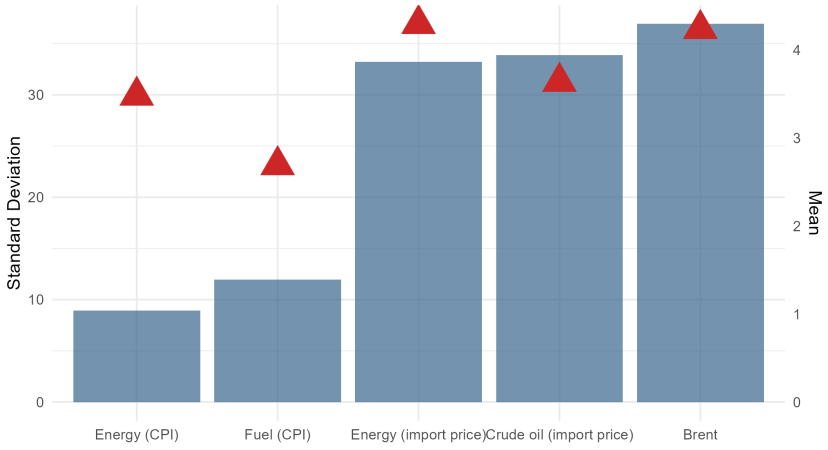
Note: High and low states are defined by whether the variable is above or below its sample mean. Large shocks are observations with an absolute value greater than one standard deviation from the mean, while small shocks lie within this range. $\mathcal{C}_{x,y}$ corresponds to the correlation between energy inflation and variable x in state y. Diff-in-diff $= (\mathcal{C}_{core,1} - \mathcal{C}_{core,2}) - (\mathcal{C}_{headline,1} - \mathcal{C}_{headline,2})$

Figure B.4. Energy inflation series over time



Data sources: Eurostat, FRED/U.S. EIA.

Figure B.5. First and second moments of energy inflation series



Data sources: Eurostat, FRED/U.S. EIA.

B.2 Instrumental Variable Local Projections

To assess robustness to potential measurement error in the Känzig (2021) oil supply news shock, the paper implements an instrumental variable strategy within a local projection framework following Jordà et al. (2015). Rather than using the Känzig shock directly as an exogenous regressor, it is applied as an external instrument to isolate exogenous variation in alternative measures of energy inflation.

Second-stage local projection. The second-stage equation mirrors the baseline LP specification in Equation (2.1), with the difference that the energy shock is replaced by an instrumented energy inflation series. For each horizon $h = 0, 1, \ldots, H$, the estimated equation is:

$$\pi^C_{t+h} = a_h + \sum_{j=1}^{J} \rho_{j,h}\, \pi^C_{t-j} + \sum_{l=1}^{L} \delta'_{l,h}\, Z_{t-l} + \theta_h\, \widehat{\pi}_t{}^E + u_{t+h}, \tag{B.1}$$

where π^C_t denotes monthly core inflation and $\widehat{\pi}_t{}^E$ is the fitted value from the first-stage regression described below. As in the baseline specification, Z_t is the vector of macroeconomic controls and u_{t+h} is an error term. The sequence $\{\theta_h\}_{h=0}^{H}$ traces out the impulse response of core inflation to an exogenous energy price shock identified through the instrument.

First-stage regression. In the first stage, alternative measures of energy inflation are instrumented using the oil supply news shock constructed by Känzig (2021). For each energy inflation series π^E_t, the first-stage regression is

$$\pi^E_t = \alpha + \gamma\, \varepsilon^E_t + \sum_{j=1}^{J} \psi_j\, \pi^C_{t-j} + \sum_{l=1}^{L} \phi'_l\, Z_{t-l} + v_t, \tag{B.2}$$

where ε^E_t denotes the Känzig oil supply news shock. The fitted values $\widehat{\pi}_t{}^E$ are then used in Equation (B.1). Within the IV local projection framework, this two-stage least squares procedure is implemented separately at each horizon, as in Jordà et al. (2015).

The instrumented energy price measures, π^E_t, include global oil price inflation (Brent), crude oil import prices, energy import prices, HICP fuel inflation, and HICP energy inflation, consistent with the robustness analysis in Section 2.5.2. To facilitate comparison across energy price measures with markedly different volatilities (see Figure B.7), all energy inflation series are standardised prior to estimation. Specifically, each series is scaled by its sample standard deviation, such that the reported impulse responses correspond to a one standard deviation increase in the respective energy price measure. This standardisation ensures that differences in response magnitudes across specifications reflect economic transmission mechanisms rather than arbitrary differences in units or volatility.

B.3 Data and Descriptive Statistics

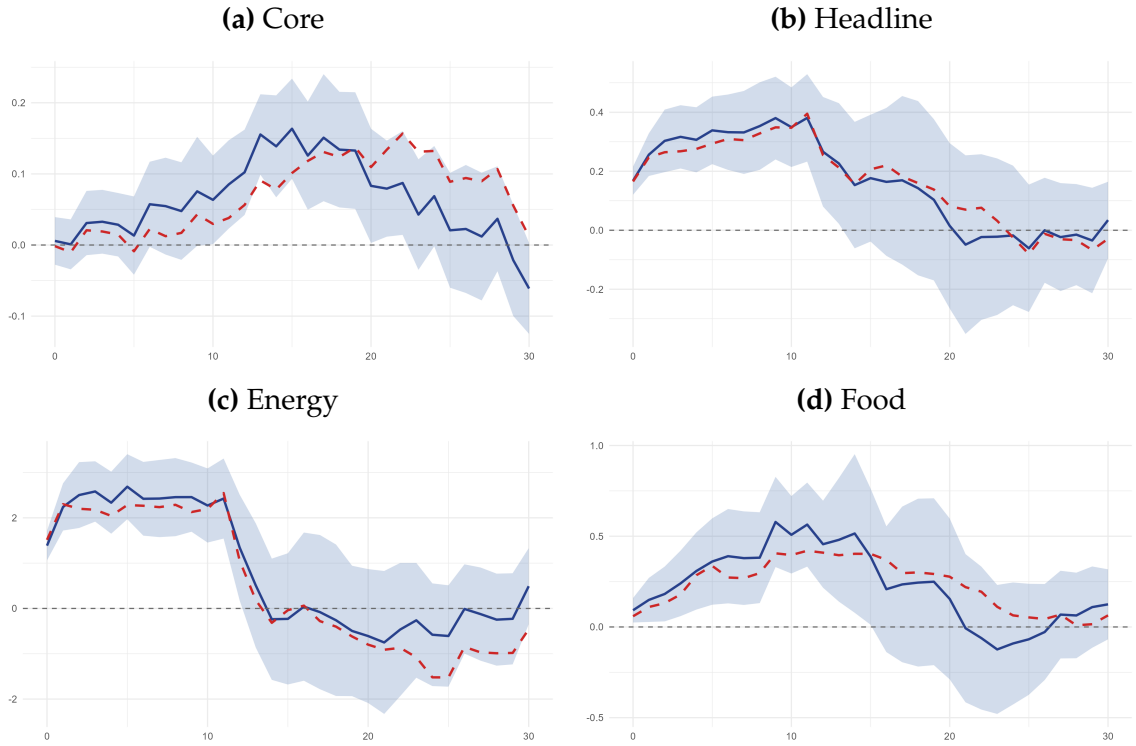
Table B.2. Summary statistics

Variable	Source	Start	End	Mean	Min	Max	SD	IQR
Brent crude infl	U.S. EIA	2001-01	2025-01	4.3	-135.5	126.0	36.2	46.1
CP01: Food & non-alc. HICP infl	Eurostat	2001-01	2025-01	2.6	-1.6	16.1	3.0	1.9
CP02: Alc. & tobacco HICP infl	Eurostat	2001-01	2025-01	3.8	1.3	8.2	1.5	1.6
CP03: Clothing & footwear HICP infl	Eurostat	2001-01	2025-01	0.8	-3.3	6.1	1.2	1.2
CP04: Housing, water, elect., gas HICP infl	Eurostat	2001-01	2025-01	2.8	-6.3	20.8	3.6	3.0
CP05: Furnishings, household equip. HICP infl	Eurostat	2001-01	2025-01	1.3	-0.5	8.7	1.7	1.2
CP06: Health HICP infl	Eurostat	2001-01	2025-01	1.7	-0.6	8.1	1.5	1.3
CP07: Transport HICP infl	Eurostat	2001-01	2025-01	2.3	-5.7	13.6	3.4	4.1
CP08: Commun. HICP infl	Eurostat	2001-01	2025-01	-1.7	-8.8	1.0	1.4	1.8
CP09: Rec. & culture HICP infl	Eurostat	2001-01	2025-01	1.0	-1.4	6.4	1.4	1.5
CP10: Education HICP	Eurostat	2001-01	2025-01	2.1	-3.6	9.0	2.2	2.9
CP11: Rest. & hotels HICP infl	Eurostat	2001-01	2025-01	2.8	0.2	8.5	1.7	1.6
CP12: Miscellaneous HICP infl	Eurostat	2001-01	2025-01	2.1	0.5	5.4	1.0	1.0
Core HICP infl	Eurostat	2001-12	2025-01	1.7	0.2	5.5	1.0	0.9
Crude oil import infl	Eurostat	2006-01	2023-11	3.6	-108.2	92.9	33.9	42.3
Durable goods HICP infl	Eurostat	2001-12	2025-01	0.4	-1.1	6.8	2.5	0.7
Energy HICP infl	Eurostat	2001-01	2025-01	3.6	-15.2	36.5	9.0	10.7
Energy import infl	Eurostat	2006-01	2023-12	4.3	-78.6	88.8	33.5	43.5
Food HICP infl	Eurostat	2001-01	2025-01	2.9	-0.4	14.4	2.5	1.7
Fuel HICP infl	Eurostat	2001-01	2025-01	2.9	-28.0	38.0	12.1	16.3
Headline HICP infl	Eurostat	2001-01	2025-01	2.1	-0.6	10.1	1.8	1.3
Ind. non-energy goods HICP infl	Eurostat	2001-12	2025-01	1.0	-0.5	6.6	1.3	0.7
Inflation expectations (12 months ahead)	EC	2001-01	2025-01	20.3	-6.8	64.5	10.5	14.3
Känzig shock	Känzig (2021)	2001-01	2025-01	0.0	-3.0	1.9	0.6	0.8
Labour cost index	Eurostat	2002-01	2025-01	2.5	-2.0	5.7	1.2	1.5
NAWRU	EC	2001-01	2025-01	8.4	6.6	9.3	0.9	1.5
Nominal interest rate	Eurostat	2001-01	2025-01	1.5	-0.6	5.1	1.7	3.3
Non-durable goods HICP infl	Eurostat	2001-12	2025-01	1.9	0.2	9.1	1.6	1.2
Output gap	EC	2001-01	2025-01	-0.6	-6.0	2.7	1.8	2.6
Services HICP infl	Eurostat	2001-12	2025-01	2.1	0.4	5.5	1.0	1.2
Unemployment gap	Author calc.	2001-01	2025-01	-0.5	-2.7	2.0	1.2	1.3
Unemployment rate	Eurostat	2001-01	2025-01	7.9	5.4	10.9	1.5	2.1

HICP: Harmonised Index of Consumer Prices, NAWRU: Non-Accelerating Wage Rate of Unemployment, EC: European Commision, EIA: Energy Information Administration, SD: Standard Deviation, IQR: Interquartile Range.

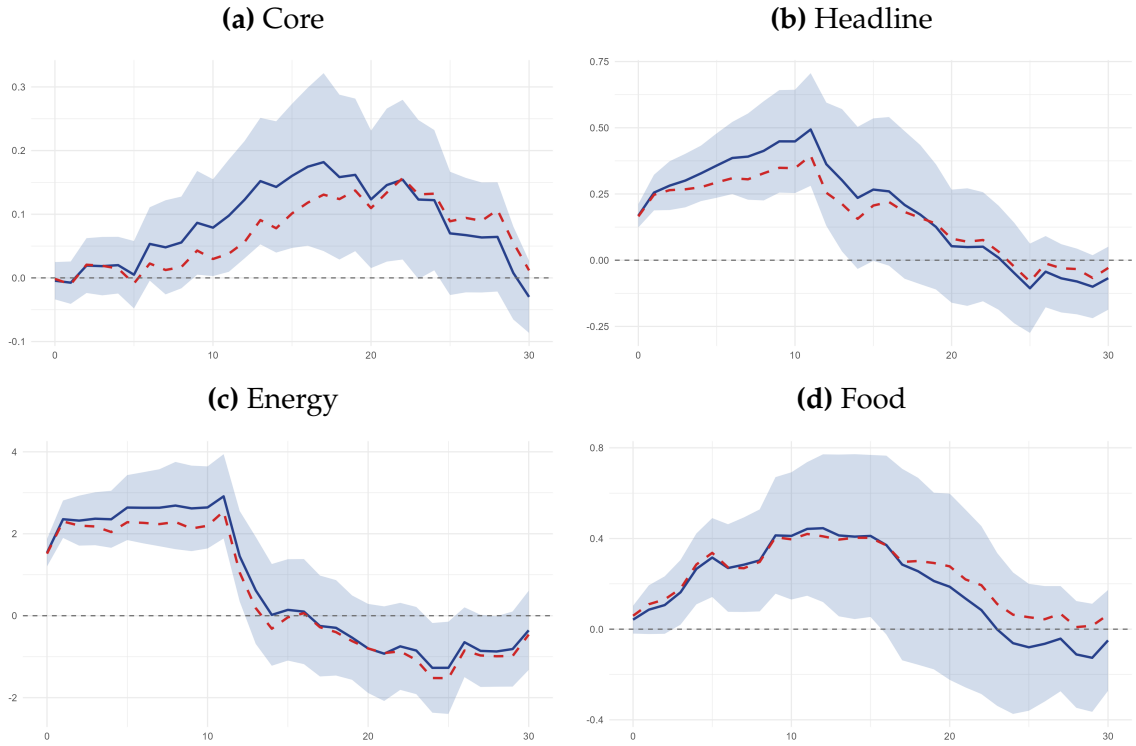
B.4 Robustness of Pass-Through Responses

Figure B.6. Robustness to sample period (January 2002 - January 2022)



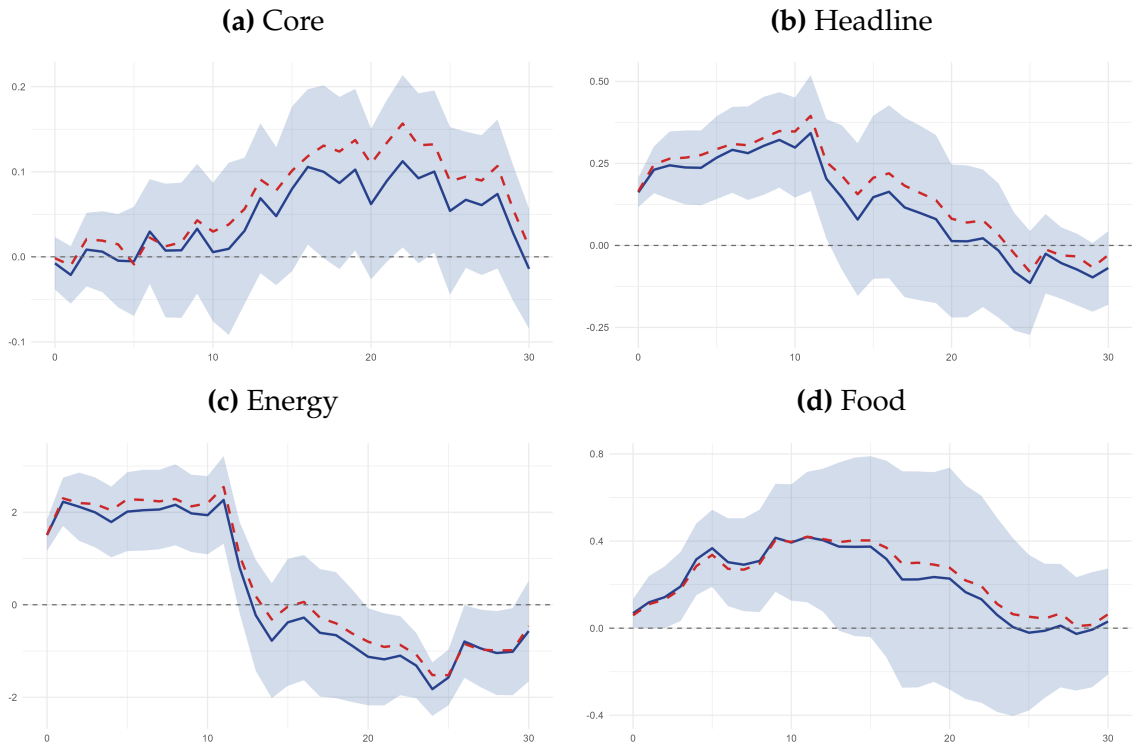
Note: Impulse responses are reported in percentage point deviations from baseline inflation after a one percentage point shock. Time sample shortened to January 2022. The red-dashed line overlays the baseline response from Figure 2.5 for comparison. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: Eurostat, EC/AMECO, Känzig (2021).

Figure B.7. Robustness to omitting the interest rate



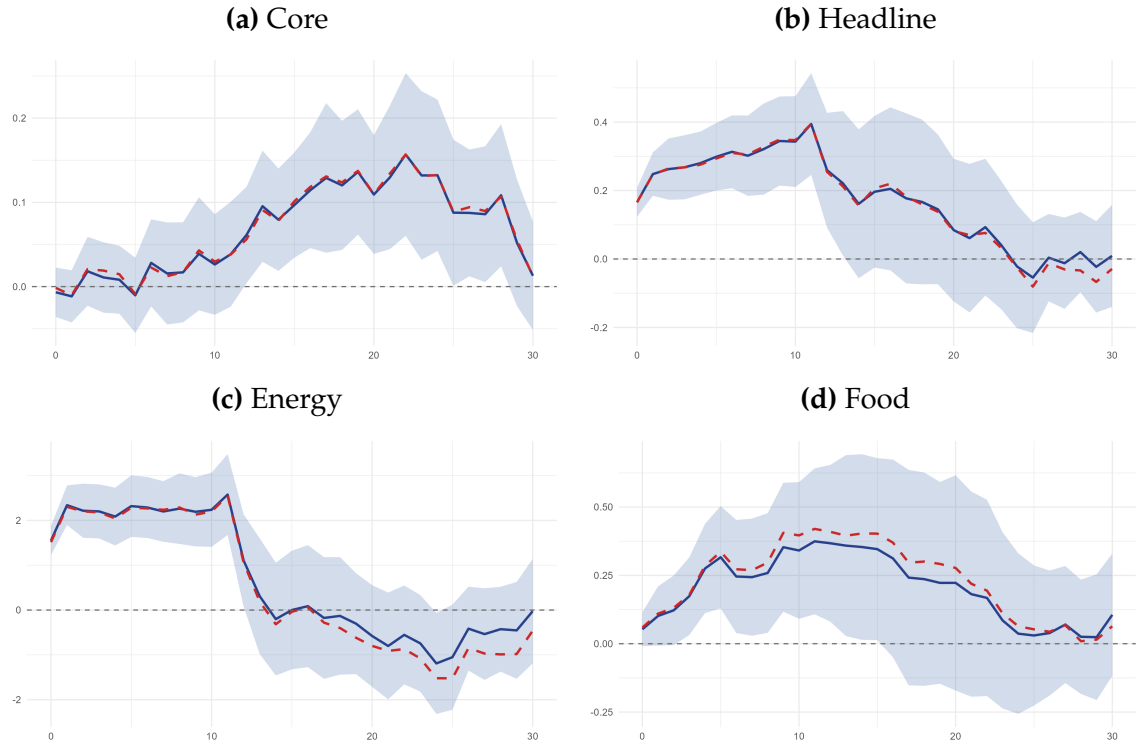
Note: Impulse responses are reported in percentage point deviations from baseline inflation after a one percentage point shock. The red-dashed line overlays the baseline response from Figure 2.5 for comparison. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: Eurostat, EC/AMECO, Känzig (2021).

Figure B.8. Robustness to using the unemployment gap



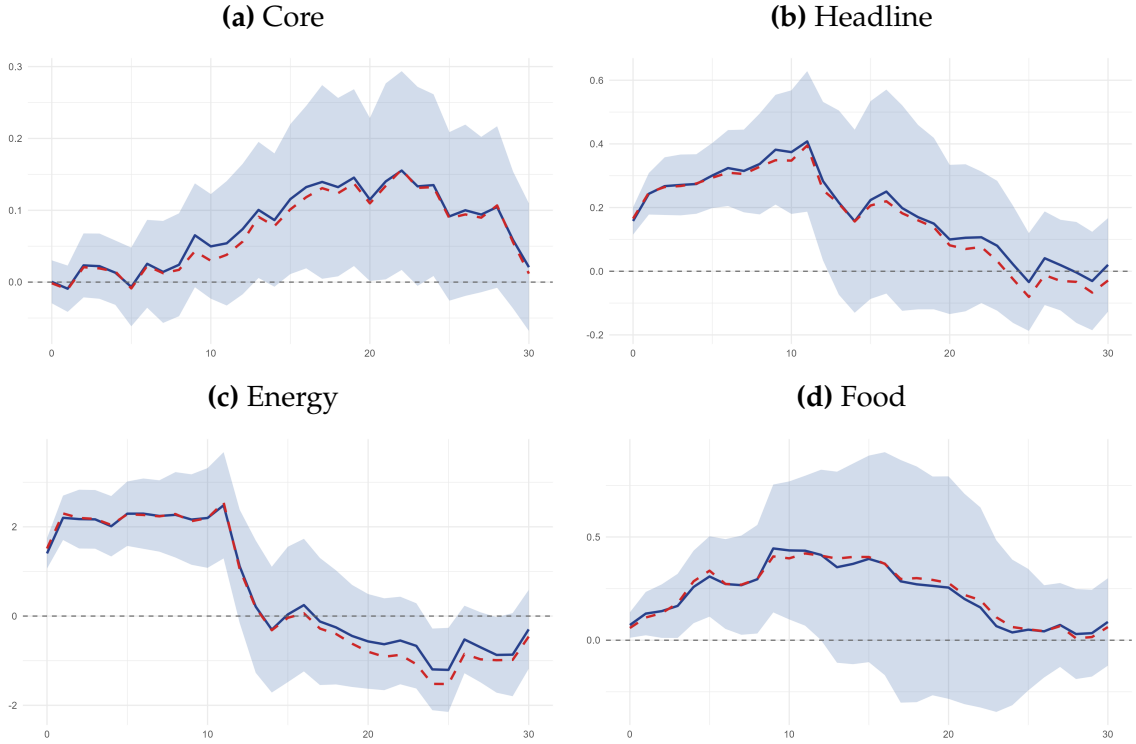
Note: Impulse responses are reported in percentage point deviations from baseline inflation after a one percentage point shock. The unemployment gap is used to replace the output gap. The red-dashed line overlays the baseline response from Figure 2.5 for comparison. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: Eurostat, EC/AMECO, Känzig (2021).

Figure B.9. Robustness to including inflation expectations



Note: Impulse responses are reported in percentage point deviations from baseline inflation after a one percentage point shock. The red-dashed line overlays the baseline response from Figure 2.5 for comparison. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: Eurostat, EC/AMECO, Känzig (2021).

Figure B.10. Robustness to omitting the NAWRU



Note: Impulse responses are reported in percentage point deviations from baseline inflation after a one percentage point shock. The red-dashed line overlays the baseline response from Figure 2.5 for comparison. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: Eurostat, EC/AMECO, Känzig (2021).

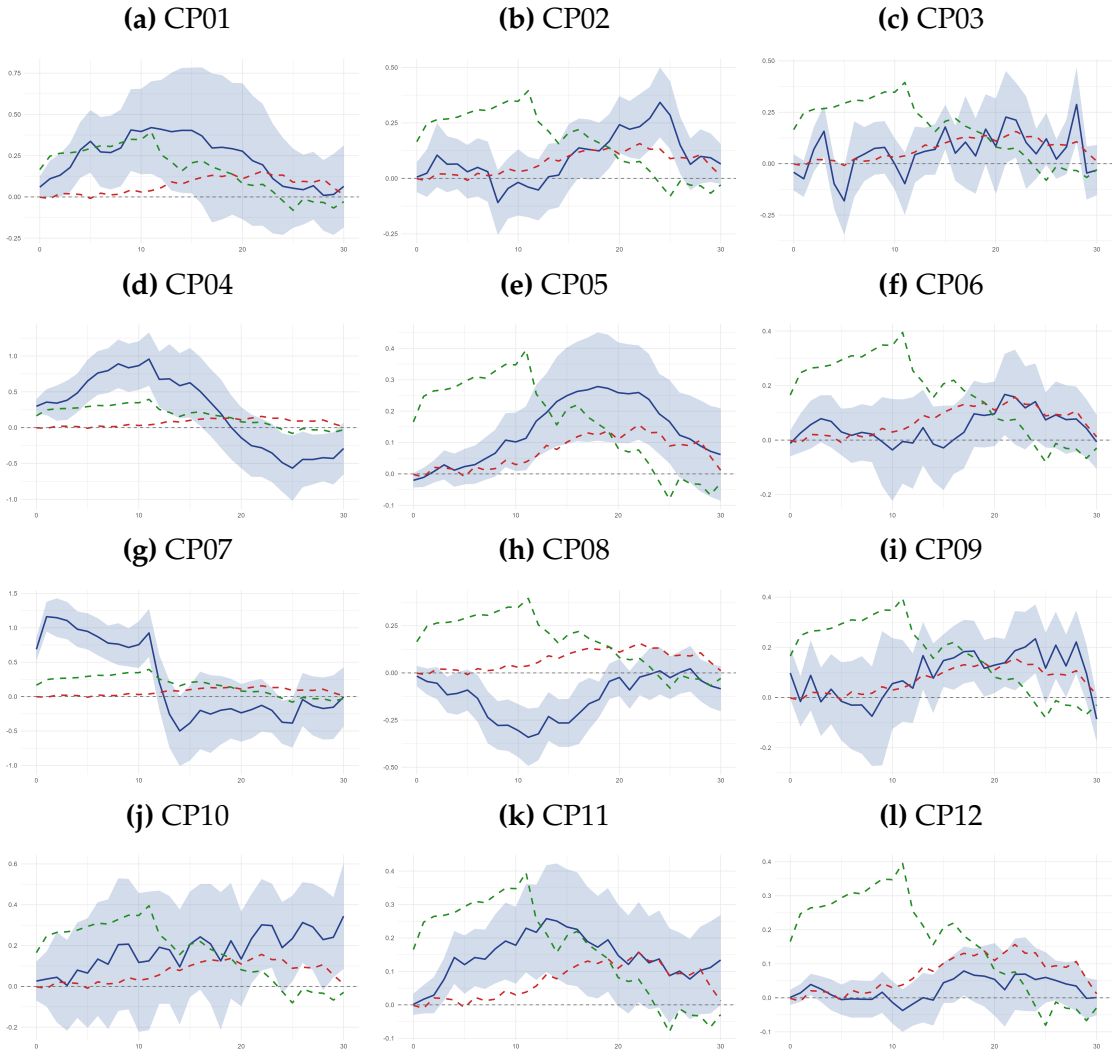
Table B.3. First-stage F-statistics across horizons

Horizon	Energy import inflation	Brent inflation	Crude oil import inflation	Energy HICP inflation
0	207.41	200.20	200.79	215.84
1	140.99	127.93	129.95	150.18
2	99.17	83.94	86.63	108.84
3	82.05	65.47	68.83	92.47
4	77.73	58.38	62.59	90.98
5	75.48	53.39	58.10	89.26
6	75.98	51.98	56.79	91.40
7	63.56	42.76	46.64	76.31
8	54.05	37.40	40.20	66.64
9	47.26	32.66	35.26	57.04
10	44.50	30.65	33.02	52.47
11	40.53	28.12	30.28	45.98
12	42.71	30.86	32.91	44.61
13	44.71	33.36	35.27	45.87
14	42.39	32.86	34.73	43.07
15	38.27	30.02	31.62	38.47
16	35.44	28.16	29.65	34.77
17	32.09	26.81	27.69	31.11
18	27.98	24.32	24.91	26.79
19	27.73	25.19	25.58	26.50
20	28.29	26.44	26.87	26.73
21	27.10	26.04	26.20	25.66
22	25.67	25.26	25.25	24.49
23	25.32	25.34	25.13	24.27
24	24.70	25.00	24.72	23.96
25	24.29	24.78	24.49	23.91
26	24.74	25.35	25.03	24.56
27	24.94	25.54	25.28	24.85
28	25.43	25.77	25.60	25.43
29	26.71	26.62	26.60	26.67
30	27.17	27.00	27.00	27.06

All first-stage F-statistics from the instrumental-variable approach discussed in Section 2.5.2 exceed the Staiger-Stock threshold of 10. For estimation details, see Appendix B.2.

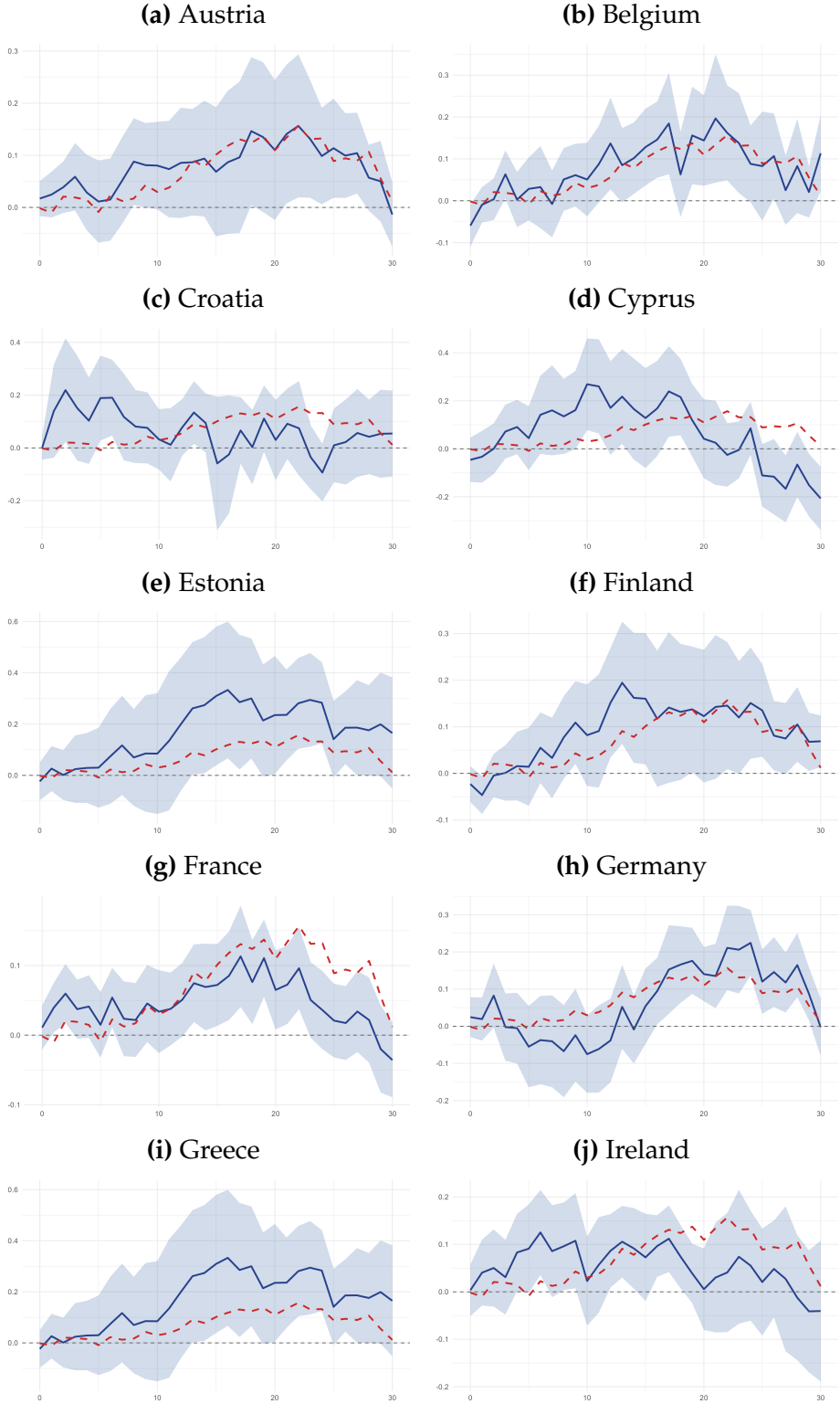
B.5 Disaggregated Responses Across Items and Countries

Figure B.11. Impulse responses by COICOP groups



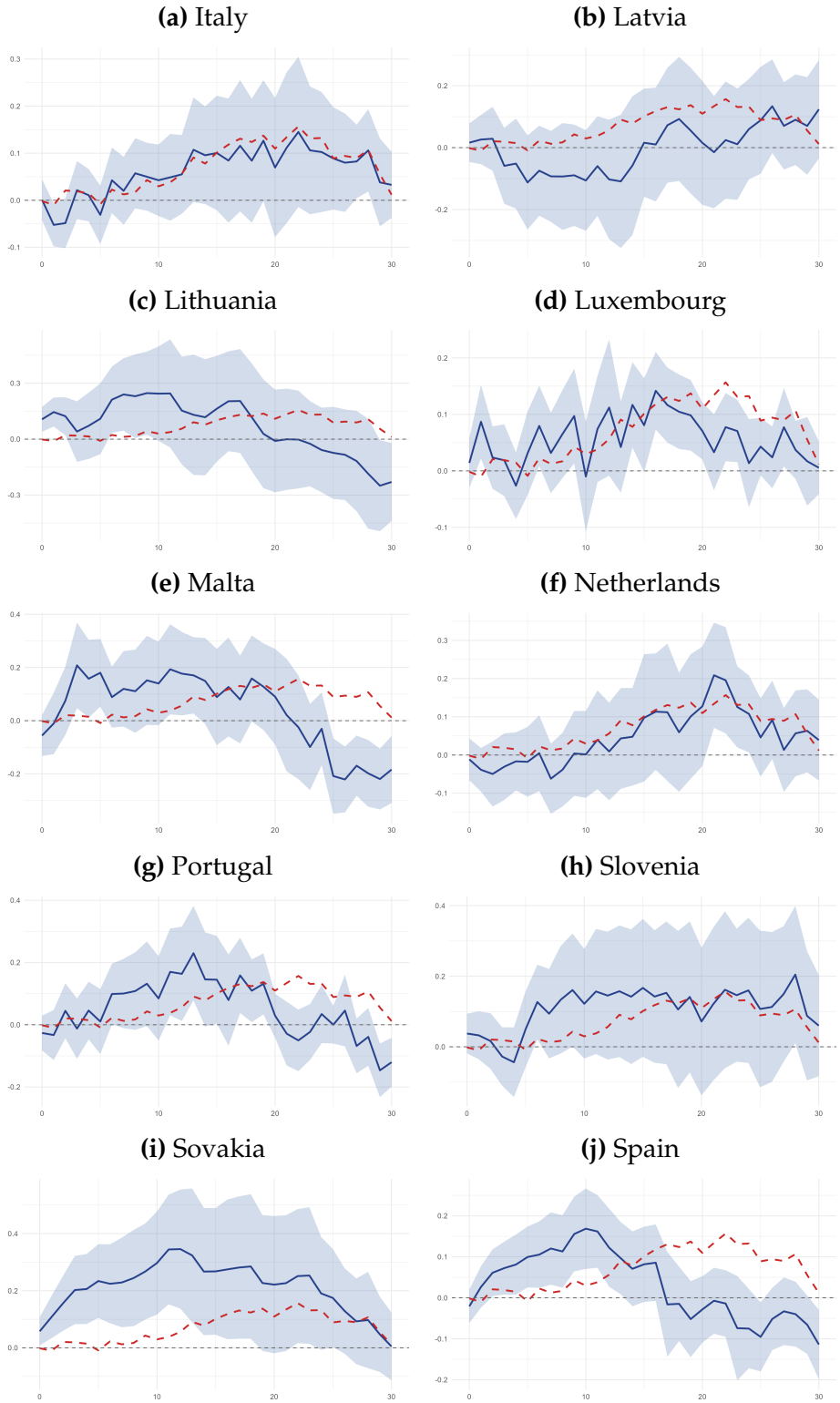
Note: COICOP classification used. CP01: Food and non-alc. beverages; CP02: Alc. and tobacco; CP03: Clothing and footwear; CP04: Housing, water, electricity, and gas; CP05: Furnishings, household equipment, and maintenance; CP06: Health; CP07: Transport; CP08: Communication; CP09: Recreation and culture; CP10: Education; CP11: Restaurants and hotels; CP12: Misc. goods and services. The red-dashed line overlays the core inflation response for scale comparability across panels. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: Eurostat, EC/AMECO, Känzig (2021).

Figure B.12. Impulse responses across euro area members - part 1



Note: The red-dashed line overlays the euro area aggregate core inflation response for scale comparability across panels. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: Eurostat, EC/AMECO, Känzig (2021).

Figure B.13. Impulse responses across euro area members - part 2



Note: The red-dashed line overlays the euro area aggregate core inflation response for scale comparability across panels. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: Eurostat, EC/AMECO, Känzig (2021).

Chapter 3

Indexation and Cyclicality of Fiscal Policy: Evidence from a Panel Data Analysis*

Abstract This paper examines how automatic indexation of government spending affects fiscal policy cyclicality. A novel panel dataset of indexation practices for public wages, social security, and social assistance is constructed for over 100 countries from 2002 to 2023, alongside a weighted index capturing indexation intensity. The findings indicate that, on average, indexation does not show a significant association with fiscal cyclicality. However, the relationship varies markedly across countries. In advanced economies, indexation is associated with weaker countercyclicality by constraining fiscal discretion, whereas in emerging markets and developing economies it is linked to lower procyclicality by acting as a commitment device against political-economy distortions, restraining expenditures in booms and sustaining them in downturns. The countercyclical effect on expenditure is the strongest where fiscal institutions are weak. These results extend previous work on social security to broader spending categories and show that the relationship between indexation and cyclicality depends on country characteristics.

Keywords: Cyclicality; Indexation; Fiscal Policy; Fiscal Institutions.
JEL: D02, E31, E64, H55.

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3.1 Introduction

Countercyclical fiscal policy, characterised by running deficits during economic downturns and surpluses during economic upswings, plays a key role in managing short-term fluctuations and stabilising the economy. Such a policy helps build buffers against future shocks, and when coordinated with monetary policy, can also contribute to maintaining price stability. In practice, however, fiscal policies in many countries, particularly emerging markets, often amplify rather than smooth output fluctuations (e.g., Alesina et al., 2008; Frankel et al., 2013; Galeano et al., 2021; Gavin and Perotti, 1997; Ilzetzki and Végh, 2008; Jalles, 2018; Kaminsky et al., 2004; Mendoza and Oviedo, 2006; Tornell and Lane, 1999). A range of explanations has been offered to account for this procyclicality in emerging markets, such as limited fiscal space (Altug & Kabaca, 2017; DeLong & Summers, 2012; Neumeyer & Perri, 2005; Romer & Romer, 2019), vulnerability to external shocks, natural resource dependence (Frankel, 2013), and political considerations exacerbated by institutional weaknesses (Alesina et al., 2008; Calderón et al., 2016; Frankel et al., 2013; Furceri & Jalles, 2018; Jalles et al., 2024; Larch et al., 2021; Marioli & Végh, 2023; Végh & Vuletin, 2015).

One institutional feature that has recently gained attention is *indexation* - the automatic adjustment of public spending to inflation, wages, or other economic indicators. Balasundharam et al. (2023) document that automatic indexation of budgetary items is more prevalent in advanced economies compared to emerging markets and developing economies and is positively correlated with institutional quality.[1] While indexation can help shield households (Collyer et al., 2022), workers, and taxpayers (Beer et al., 2023) from inflation, increase transparency, and stabilise real benefits, it can also introduce trade-offs such as reduced flexibility, higher fiscal costs, risks of wage-price spirals (Abdallah et al., 2023; IMF, 2023), and potential challenges to the effectiveness of monetary policy (Hofmann et al., 2012).[2]

Although indexation is primarily designed to maintain purchasing power and not necessarily to address fiscal procyclicality, its relationship with fiscal stabilisation is of clear policy relevance. Existing work by Galeano et al. (2021) provides an important first step in this direction by empirically analysing whether indexation rules affect the cyclicality of social security spending. They find that 'automatic expenditure'[3] is often procyclical in emerging markets, in part due to the lack of formula-based indexation for social security. Yet their analysis is narrow in scope, focusing only on social security. Furthermore, the relationship between indexation and fiscal cyclicality is acknowledged but not developed as the main

[1] In 2022/23, social security expenditure was indexed in 90 percent of advanced economies, 45 percent of emerging markets and 25 percent of low-income developing countries; see Balasundharam et al. (2023) for more details.

[2] Much of the academic interest in indexation emerged during the Great Inflation of the 1970s (Bordo & Orphanides, 2013). Early contributions focused primarily on wage indexation, analysing how the automatic adjustment of nominal wages to inflation affects inflation dynamics and stabilisation policy (Barro, 1976; Blanchard, 1979; Fischer, 1977; Gray, 1976), as well as the implications for inflation persistence (Fischer, 1983). Later research on indexation shifted away from its role in amplifying inflationary shocks toward its interaction with monetary policy (Ascari & Sbordone, 2014; Bernanke, 2004; Giannone et al., 2008; Stock & Watson, 2003). Recent literature on social security and tax indexation focuses on associated fiscal costs and distributional impact of indexation (OECD, 2022; Pomerlaeau, 2018; Sutherland et al., 2008; Whitehouse, 2009).

[3] Galeano et al. (2021) define automatic government spending as non-discretionary spending that is legally mandated and benefits individuals who meet certain eligibility criteria.

question of research, leaving scope for a more comprehensive examination.

This paper builds on and extends this line of inquiry in three ways. First, it introduces a novel panel dataset covering indexation practices for public wages, social security, and social assistance across more than 70 countries from 2002 to 2023 (with broader coverage of social security for more than 180 countries). This dataset is, to the best of our knowledge, the most comprehensive panel dataset on automatic indexation practices. In this dataset, indexation is coded as a binary variable, with one indicating the presence of some rules-based adjustment mechanism, and zero otherwise. It also introduces the *Weighted Index of Spending Indexation* (WISI), a continuous measure of indexation intensity that reflects the overall degree of automatic adjustment in a country's budgetary spending. Second, the relationship between indexation and fiscal cyclicality is assessed across spending categories and country groups. The empirical strategy builds on a regression-based measure of cyclicality, introducing interactions between economic growth and indexation to evaluate the marginal effect of indexation on fiscal cyclicality.[4] To control for potential endogeneity, an instrumental variable approach with indexation mechanisms of neighbouring countries as instruments for domestic practices is employed (see Caselli and Reynaud, 2020). Finally, the paper explores heterogeneity in the effects of indexation using a two-step procedure, whereby the estimated country-year-specific marginal effects of indexation on cyclicality are recovered and then regressed on country characteristics, including growth and inflation, their respective volatilities, public debt, supply shocks, and institutional indicators.

Using the constructed dataset, the paper documents that indexation practices have remained broadly stable over the past two decades with countries seldom switching indexation mechanisms on and off. Average levels and volatility of public spending differ markedly between indexed and non-indexed expenditure. In particular, social security spending is generally higher and more volatile in emerging markets and low-income developing countries with indexation, while the opposite is true for advanced economies. In light of these stylised facts, the effect of automatic indexation on fiscal cyclicality is expected to differ systematically across country groups and institutional environments.

The empirical analysis confirms that the relationship between indexation and cyclicality is nuanced. The relationship between indexation and cyclicality appears muted in the full sample. However, when disaggregated by country development level, significant differences emerge. Specifically, in advanced economies, indexation appears less conducive to countercyclical policy. Over the past two decades (when inflation and the business cycle often moved in tandem in these countries) indexation appears to have mechanically increased nominal outlays during expansions while offering limited cushioning during contractions. By contrast, in emerging markets and developing economies, indexation is associated with lower procyclicality by serving as a guardrail to foster fiscal discipline (i.e., limiting the increase in benefits during economic booms and sustaining real spending during recessions). These findings are in line with the political economy literature, which suggests that automatic indexation mechanisms can mitigate the tendency of governments in weaker institutional environments to treat temporary revenue windfalls as permanent,

[4]This follows the methodology of recent studies on fiscal rules and other determinants of fiscal cyclicality (Bergman & Hutchison, 2020; Combes et al., 2017; De Jong & Gilbert, 2020; Kameník, 2019; Keita & Turcu, 2023; Larch et al., 2021; Liao et al., 2025).

thus amplifying cyclical fluctuations.[5] Within this country group, the stabilising effect of indexation is more pronounced in countries lacking fiscal rules, experiencing high inflation and output volatility, and less reliant on commodity revenues. Institutional quality and governance therefore emerge as key characteristics behind these heterogeneous patterns, indicating that the stabilising or amplifying role of indexation depends on country characteristics. These results remain robust across alternative specifications, endogeneity checks, and estimation methods.

The rest of the paper is organised as follows. Section 3.2 introduces the novel dataset and presents stylised facts on indexation practices. Section 3.3 outlines the methodological framework and discusses the empirical results. Finally, Section 3.4 concludes with key takeaways and suggestions for future research.

3.2 Data and Stylised Facts

3.2.1 Construction of the Indexation Practices Database

The paper assembles a novel panel of indexation practices for three automatic-expenditure items: social security (pensions), social assistance, and public wages. The dataset builds on the cross-sectional indexation data for 2022/23 collected by Balasundharam et al. (2023). We extend it by investigating changes in indexation practices for expenditure items over the last two decades.[6] This dataset allows exploration of trends across a large number of countries and provides additional insights on the relationship between indexation and cyclicality.

To expand the dataset on social security and social assistance, we revisit the primary sources used by Balasundharam et al. (2023) – specifically the biennial reports on "Social Security Programs Throughout the World", published by the U.S. Social Security Administration in collaboration with the International Social Security Association (ISSA, 2022) for 2002-2019 and IMF Staff surveys for 2022/2023. Given that the ISSA reports are available only every other year, the panel dataset is constructed with alternate-year observations, using detailed text analysis to encode the qualitative information.[7] For each country-year and expenditure item, a binary indicator is coded as one if the programme is subject to an automatic, formula-based adjustment to a predetermined price or wage series (e.g., CPI, wage index, etc.). The ISSA-based indexation data on social security and social assistance are verified and the coverage for public wages extended over time using official government websites as well as reports and datasets from the IMF, OECD, ECB, and the World Bank. In a second step, the

[5] Marioli and Végh (2023) underscore that emerging markets frequently fail to save windfall or temporary revenue gains and tend to treat booms as permanent, producing the classic "when it rains, it pours" phenomenon (Kaminsky et al., 2004). Galeano et al. (2021) highlight similar channels, noting that over-optimism, institutional weaknesses, and political-economy distortions help explain procyclicality in social security when indexation is absent.

[6] Balasundharam et al. (2023) also document cross-sectional patterns in the indexation of personal income taxes. This paper focuses on time-varying indexation in public expenditures, but extending similar coverage to personal income taxes over time is an important direction for future work.

[7] While ISSA reports do not always provide fully explicit information on the details of indexation practices, the data are coded to reflect the available information as accurately as possible.

data are interpolated to obtain an annual series suitable for regression analysis.[8] The final dataset spans 2002-2023. Figures C.1-C.3 show the full indexation dataset across the three categories, while Table C.1 presents an overview of the data breakdown across regions and income groups.

The data on indexation mechanisms of social security are the most comprehensive, covering 180 countries of which 40 advanced economies, 89 emerging markets, and 51 low-income developing countries. Social assistance indexation data is available for 83 countries across all geographical regions, including 34 advanced economies, 33 emerging markets and 16 low-income developing countries, and the public sector wage indexation data is available for 74 countries, including 34 advanced economies, 27 emerging markets, and 13 low-income developing countries.

The raw indexation data are recorded as binary indicators, Index_{jit}, with one indicating the existence of indexation for expenditure item $j = \{\text{Public wage}, \text{Social security}, \text{Social assist.}\}$ in country i at time t, and zero otherwise. In reality, the design of indexation mechanisms varies significantly across countries on several dimensions, including the choice of index, frequency of indexation and whether the indexation is forward or backward-looking. Appendix C.1 provides examples to illustrate the intricacies of indexation practices. Nevertheless, because the focus of this study is on the relationship between indexation and the direction of fiscal cyclicality rather than on the precise magnitude of effects, the binary indicators are considered sufficient. The underlying hypothesis is that indexation provides guardrails for fiscal outcomes, a feature that holds irrespective of the specific design of individual programmes.

To summarise the overall degree of automatic adjustment in a country's expenditure, rather than examining individual spending items separately, a continuous *Weighted Index of Spending Indexation* (WISI) is constructed:

$$\text{WISI}_{it} = \sum_{j=1}^{3} \omega_{jit} \, \text{Index}_{jit} \in [0, 1]$$

The weight ω_{jit} denotes the relative expenditure share of item j among the three spending categories in the data:

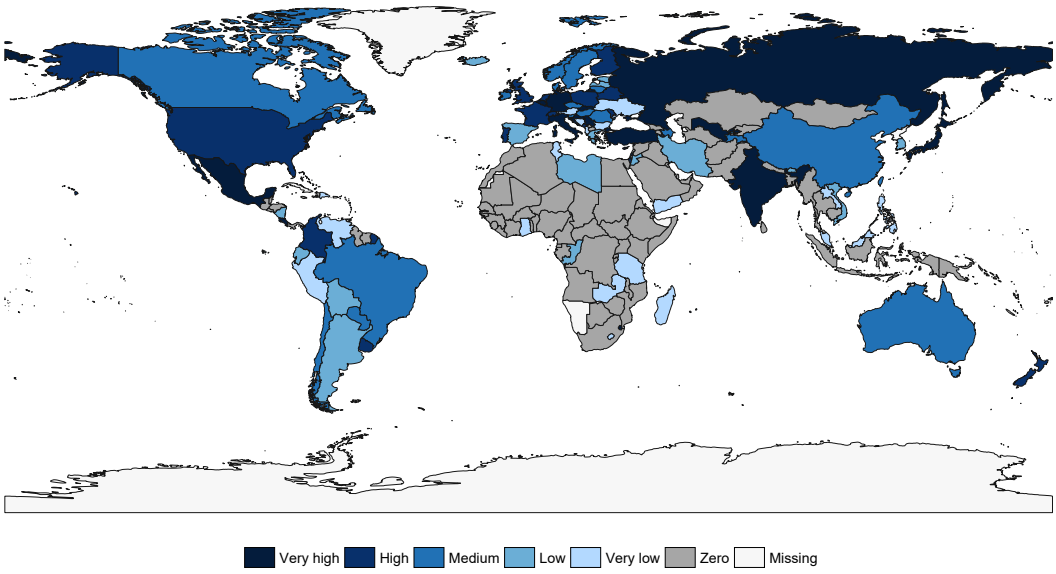
$$\omega_{jit} = \frac{E_{jit}}{\sum_{j=1}^{3} E_{jit}} \geq 0$$

where E_{jit} is the nominal spending of expenditure item j in country i at time t. The resulting WISI index therefore reflects the overall intensity of indexation, ranging from zero (no items indexed) to one (full indexation across all items), with proportional weights. Figure 3.1 highlights sharp differences in average WISI values across regions. Higher indexation is concentrated in advanced economies (particularly in Europe), while little or none is found in many low-income countries. Emerging markets display wide dispersion, motivating an analysis of how indexation relates to fiscal cyclicality *within* the income group.

For the empirical analysis in Section 3.3, the indexation dataset is complemented with publicly available data on public expenditure on automatic budget spending items. Data

[8] Since the biennial data show indexation to be highly persistent (discussed in Section 3.2.2), with few changes over time, linear interpolation is applied for years without ISSA reports, including the COVID-19 period (2020/21).

Figure 3.1. Global distribution of average WISI values



Note: Figure shows the country-level average WISI values across the full sample period. Data sources: US Social Security Administration, ISSA, IMF, OECD, ILO, World Bank, news, and government webpages.

on public wage bill expenditure are drawn from the IMF FAD Harmonised Wage Bill and Employment Dataset, social security expenditure data come from the IMF FAD Expenditure Assessment Tool and the OECD Social Expenditure Database, and social assistance expenditure data are obtained from both the IMF FAD Social Protection and Labor Toolkit (SPL-AT) and the OECD Social Expenditure Database.[9] Furthermore, for the WISI regressions, the overall deficit (defined as the negative of the general government net lending/borrowing series) is taken from IMF World Economic Outlook Database. To separate the cyclical component from the structural component of the fiscal variables, the Hodrick-Prescott (HP, 1997) filter is applied to construct cyclically adjusted expenditure-to-GDP ratios.[10] For most countries, expenditure data are available from 2002 to 2023. However, in cases where significant gaps exist in expenditure coverage (particularly in low-income developing economies), countries are excluded from the analysis, even when complete indexation information is available. Appendix C.2 provides a full overview of all variables and sources.

3.2.2 Stylised Facts on Indexation

Figures 3.2 and 3.3 illustrate the prevalence of indexation in social security, social assistance, and public wages, together with the weighted indexation intensity (WISI), across the full

[9]The measure of social assistance programmes (defined as the residual of social benefits and social security) includes unemployment benefits and might be somewhat too broad, however data limitations prevent their consistent exclusion across countries.

[10]The smoothing parameter of the HP filter is set to $\lambda = 6.25$, following standard practices for series at annual frequency (Ravn & Uhlig, 2002).

sample of countries. Four key patterns stand out.

I. The share of countries with indexation mechanisms varies significantly across categories and income groups. Social security and social assistance are indexed far more frequently than public wages, and advanced economies maintain substantially higher prevalence than emerging markets and low-income developing countries.

II. Indexation is persistent over time, with adoption rates evolving gradually and with modest, short-lived swings around longer-run levels. In the early 2000s, over 80 percent of advanced economies indexed social security benefits, compared with just over 30 percent of emerging markets and less than a quarter of low-income developing countries (Figures 3.2 and 3.3a). There is a modest increase in social security indexation in the years leading up to the Great Financial Crisis (GFC), followed by a slight temporary decline among advanced economies, while emerging markets experienced more gradual gains throughout the sample period. More recently, the pace of adoption has accelerated following the inflation surge of 2021/22, and by 2022/23 social security indexation was present in nearly all advanced economies, almost half of emerging markets, and more than a quarter of low-income developing countries.

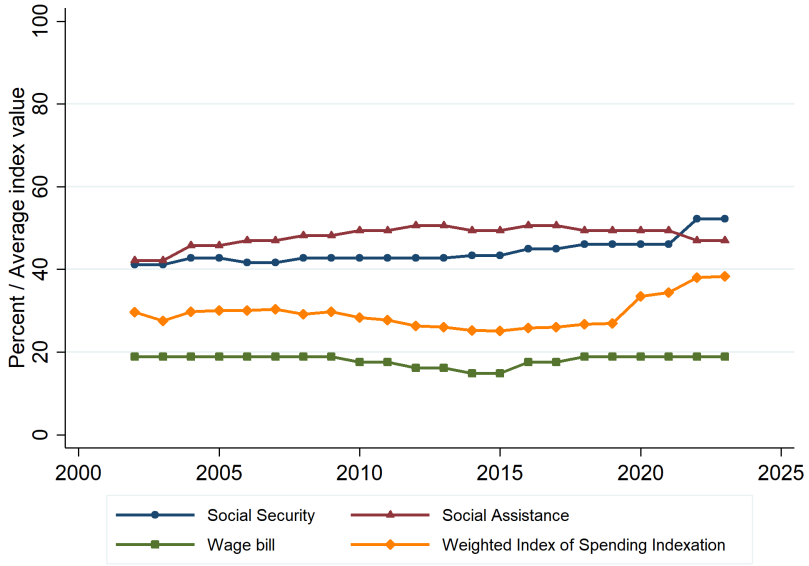
Indexation of social assistance programmes has been the most prevalent form of indexation throughout most of the sample period (Figures 3.2 and 3.3b). Leading up to the mid-2010s, prevalence rose gradually, driven by emerging markets where coverage increased from below 30 percent to nearly half, before declining slightly to around 40 percent in the early 2020s. In some countries, such as Argentina and Mexico, recent declines partly reflect shifts toward alternative social protection strategies. Roughly 70 percent of advanced economies indexed social assistance in the early 2000s and have maintained high prevalence since. In low-income developing countries, adoption has remained limited, but shows isolated increases in recent years, possibly reflecting improved data availability.

Indexation of public wages is the least common of the three expenditure categories in the sample (Figures 3.2 and 3.3c). At the start of the sample period, fewer than 20 percent of advanced economies and about 30 percent of emerging markets had such mechanisms in place, while none were present in low-income developing countries. Prevalence declined somewhat in the early-2010s, largely due to fiscal adjustment programmes in some European countries (e.g., Belgium, Italy, Cyprus) but subsequently recovered to pre-GFC levels by the late-2010s. In emerging markets, the share of countries with indexation has remained broadly stable, while low-income developing countries continued to abstain from this practice throughout the period.

Finally, as expected, the average WISI index lies between the share of countries with indexation mechanisms of the three expenditure categories (Figures 3.2 and 3.3d). Given that it captures both variation in indexation practices and changes in expenditure weights, it is somewhat more volatile, though still remarkably stable overall. The series shows a modest decline in the early 2010s, driven primarily by advanced economies, followed by a more recent broad increase across all three income groups.

Further, to better understand the differences between countries that index expenditure versus those that do not, this section looks at how indexation relates to the average level of spending as a share of GDP and the volatility of spending. Figure 3.4 plots mean spending shares and standard deviations for indexed and non-indexed social security,

Figure 3.2. Share of countries with indexation mechanisms



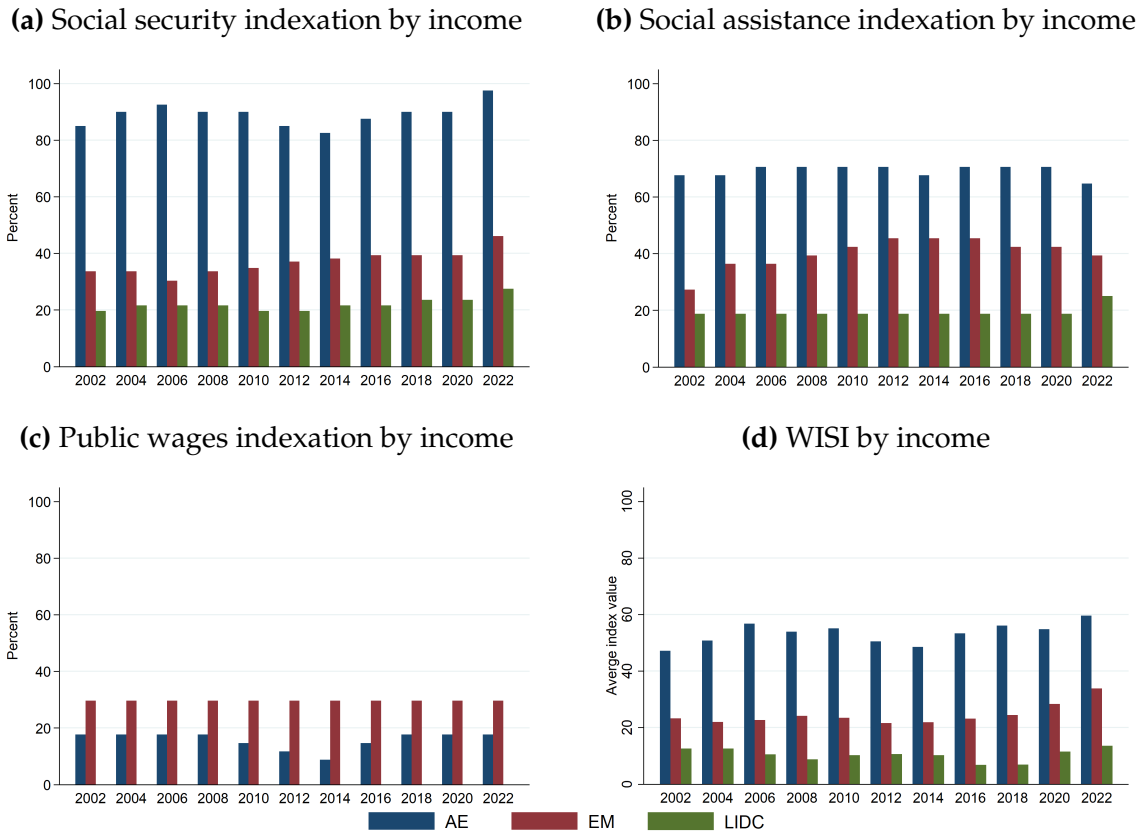
Note: Figure shows the share of countries with indexation for each expenditure item as a percentage of all countries in the sample. The WISI shows the average index value due to its continuity. Data sources: US Social Security Administration, ISSA, IMF, OECD, ILO, World Bank, news, and government webpages.

social assistance, and public wages across different country groups.

III. Overall, indexed programmes are often associated with higher levels of spending relative to GDP and sometimes with lower volatility. However, there are important exceptions that require cautious interpretation as the data show substantial heterogeneity across items, income groups, and macroeconomic contexts. For social security (Figures 3.4a and 3.4b), the relationship between indexation and programme size or volatility differs by income group. In emerging markets and low-income developing countries, spending on indexed social security programmes is, on average, larger and more volatile than non-indexed programmes. The same pattern emerges when splitting countries by export dependence or level of inflation, reflecting the fact that emerging markets and low-income developing countries account for nearly 80 percent of the available social security indexation data. By contrast, in advanced economies, this relation is reversed, likely reflecting demographic pressures and generous statutory benefits, so indexed spending does not exceed non-indexed spending uniformly across groups. For social assistance (Figures 3.4c and 3.4d), indexed programmes tend to be larger in advanced economies, export-dependent economies, and countries with inflation lower than the income group's average. In low-income developing countries and in high-inflation or non-export-dependent economies, the size advantage of indexed programmes is weaker or absent. For public wages (Figures 3.4e and 3.4f), average spending levels are broadly similar between indexed and non-indexed programmes. In advanced economies and in export-dependent or low-inflation countries, indexed spending is somewhat larger, while volatility is generally (but not always) lower.

IV. Correlations are typically more negative for indexed programmes than for non-indexed ones across many income groups, contexts, and spending categories. Country-level correlations between spending as a share of GDP and real GDP growth (Figure

Figure 3.3. Indexation indicators across income groups

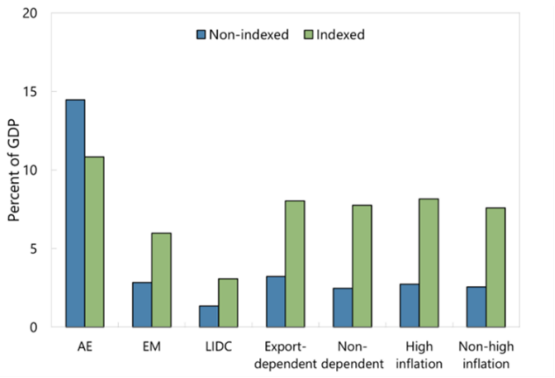


Note: Figures 3.3a-3.3c show the percentage share of indexed countries within each income group. Figure 3.3d shows the average index value for the WISI. Data sources: US Social Security Administration, ISSA, IMF, OECD, ILO, World Bank, news, and government webpages.

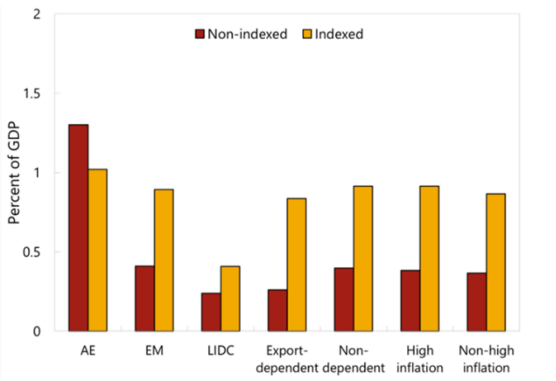
3.5) show that correlations are typically more negative for indexed programmes than for non-indexed ones across many income groups, contexts, and spending categories (without claiming causality). For social security and social assistance (Figures 3.5a and 3.5b), the main exception to this pattern is advanced economies where correlations are more negative for non-indexed programmes. In the case of public wage bill spending (Figure 3.5c), other cross-cuts matter too: high inflation countries and economies without strong export dependence show more negative correlations for indexed programmes, whereas in export-dependent or low-inflation countries the opposite is observed. Section 3.3 examines the relationship between indexation and cyclicality more formally, while accounting for institutional and macroeconomic characteristics.

Figure 3.4. Average level and volatility of public spending (share of GDP)

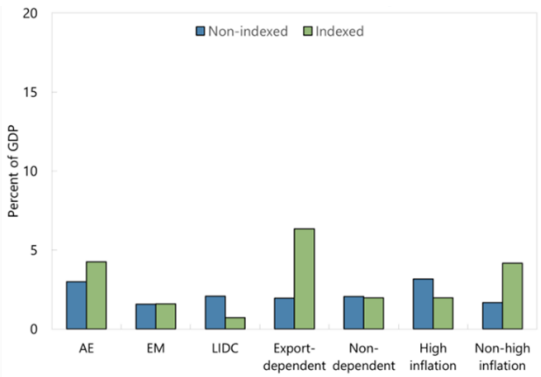
(a) Social security: Average



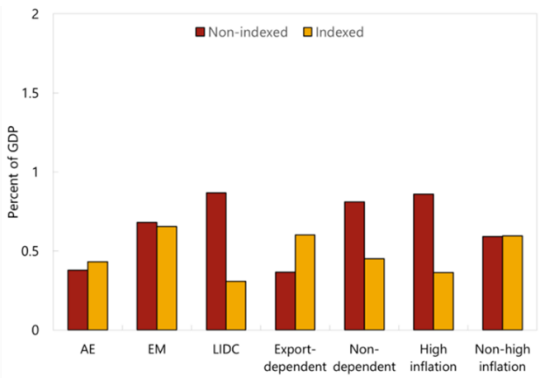
(b) Social security: Volatility



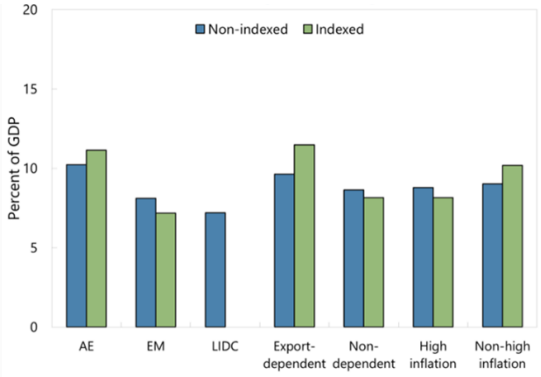
(c) Social assistance: Average



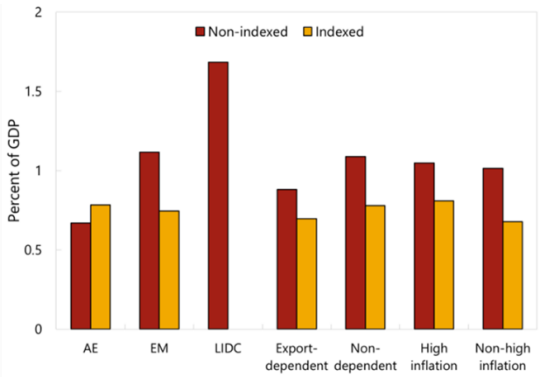
(d) Social assistance: Volatility



(e) Public wages: Average

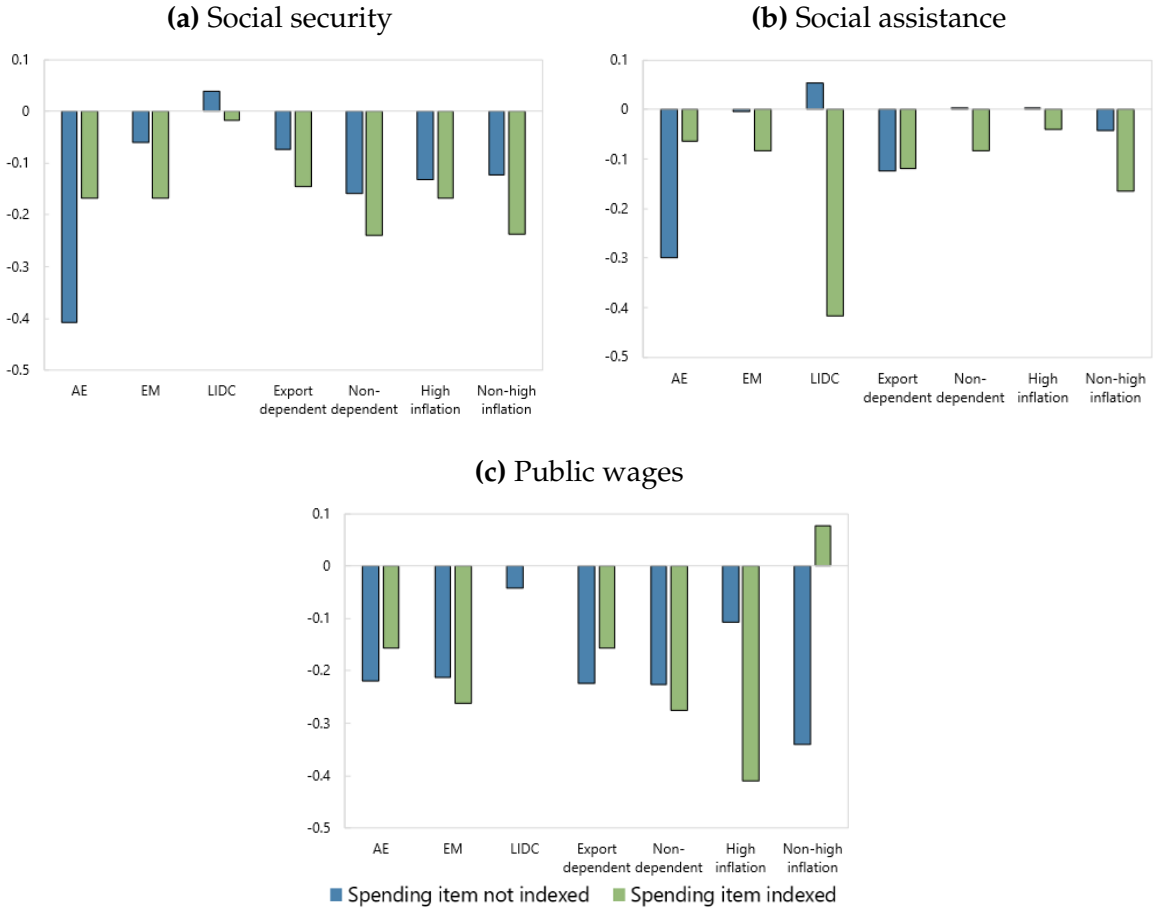


(f) Public wages: Volatility



Note: Figure shows mean (left column) and standard deviation (right column) of spending on social security, social assistance and public wages as a share of GDP. Export-dependent countries are countries with historical average trade balance greater than zero and average export share higher than 30 percent of GDP. High-inflation countries are countries with average inflation higher than the income group's average. AE = advanced economies, EM = emerging market economies, LIDC = low-income developing countries. Data sources: US Social Security Administration, ISSA, IMF, OECD, ILO, World Bank, news, and government webpages.

Figure 3.5. Correlations between public spending and GDP growth



Note: Figure shows correlation coefficients between spending calculated as percent of GDP and real GDP growth. AE = advanced economies, EM = emerging market economies, LIDC = low-income developing countries. Data sources: US Social Security Administration, ISSA, IMF, OECD, ILO, World Bank, news, and government webpages.

Two plausible mechanisms can reconcile the contrast between advanced economies and emerging markets and developing economies: (i) in advanced economies indexation may track inflation that co-moves with expansions, producing weaker countercyclicality; (ii) in emerging market and developing economies indexation can act as an automatic stabiliser by preserving real benefits during downturns and acting as a ceiling during booms.

3.3 Empirical Analysis

This section presents the empirical analysis of fiscal policy cyclicality and the role of indexation across public expenditure categories. The analysis proceeds in four steps. Section 3.3.1 establishes a baseline measure of fiscal cyclicality across income groups. Section 3.3.2 examines the effect of indexation on fiscal cyclicality, the main empirical focus. Section 3.3.3 assesses whether the impact of indexation differs across 'boom' and 'bust' phases of the business cycle. Finally, Section 3.3.4 explores the sources of cross-country heterogeneity in the effects of indexation. Each subsection presents the empirical specification alongside the

corresponding results, with additional methodological details and full regression tables reported in Appendix C.3 and C.4.

3.3.1 Baseline Estimation of Fiscal Cyclicality

Literature offers different approaches to estimating the cyclicality of fiscal policy. Broadly, two main methods are used: simple correlations between government spending and output (similar to those shown in Figure 3.5), and regression-based estimates (Heimberger, 2023). As emphasised by Forbes and Rigobon (2002) and Lane (2003), raw correlations of HP-filtered series, such as those in Agénor et al. (2000) and Talvi and Végh (2005), can be misleading when countries differ in output volatility. Given the substantial heterogeneity in volatility across the sample of advanced, emerging, and developing economies, the paper follows Lane (2003) and subsequent contributions (see Afonso and Carvalho, 2022; Bergman and Hutchison, 2020; Chrysanthakopoulos and Tagkalakis, 2023; Combes et al., 2017; De Jong and Gilbert, 2020; Jalles, 2018, 2021; Jalles et al., 2024; Kameník, 2019; Keita and Turcu, 2023; Larch et al., 2021; Liao et al., 2025) in adopting a regression-based cyclicality measure.

Fiscal cyclicality can be assessed either in aggregate, using the overall budget balance, or through a disaggregated approach that considers its individual components (Jalles, 2021). This paper adopts both perspectives and estimates the following panel specification separately for each fiscal outcome j:

$$\frac{X_{jit}}{Y_{it}} = \alpha_{ji} + \nu_{jt} + \beta_j \widetilde{y}_{it} + \theta_j' C_{it} + \epsilon_{jit}, \tag{3.1}$$

where $X_{jit} \in \{\text{Overall Deficit}_{it},\ \text{Public Wage Bill}_{it},\ \text{Social Security}_{it},\ \text{Social Assistance}_{it}\}$ denotes either the overall fiscal deficit (measured as total expenditure minus total revenue) or one of the three expenditure categories for which indexation data is available, each normalised by nominal GDP, Y_{it}. The term α_{ji} captures country-specific fixed effects, while ν_{jt} denotes time fixed effects to control for common shocks affecting all countries. The coefficient β_j measures the cyclicality of each government spending category, capturing how the fiscal variables respond to real GDP growth, $\widetilde{y_{it}} = \Delta \ln(y_{it})$. Negative β_j suggests countercyclicality as expenditure shares decline during expansions, indicating a stabilising fiscal response. In contrast, a positive β_j suggests procyclicality, with expenditure shares rising in good times.[11] C_{it} is a vector of control variables that includes the lagged real GDP growth, CPI inflation, and a measure of regulatory quality from the World Bank's World Governance Indicators.[12]

The analysis begins by examining how fiscal policy responds to the cycle across country income groups. Figure 3.6 plots the estimated coefficients on growth, β_j, and Table C.2

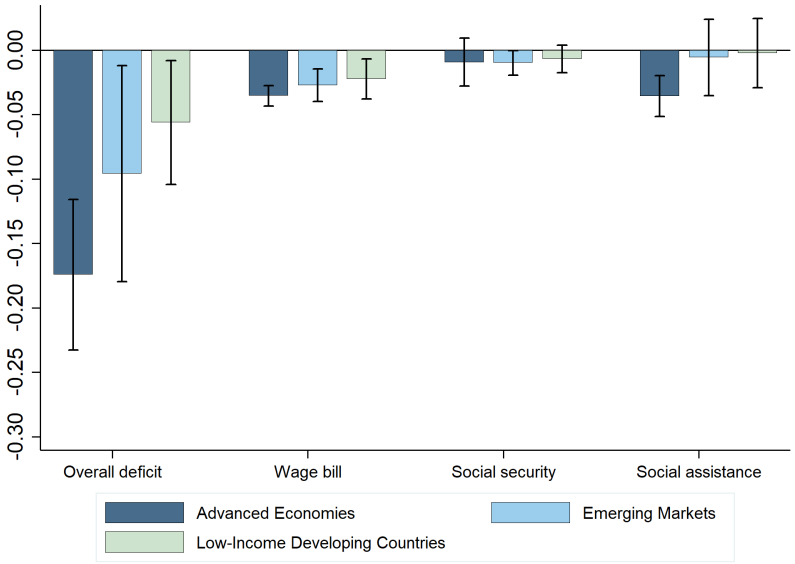
[11] Values above unity signify that spending reacts more than proportionally to changes in output as pointed out by Lane (2003).

[12] The specification in Equation (3.1) captures the reduced-form relationship between government spending and output growth. The literature has not reached consensus on how fiscal cyclicality should be measured, with different approaches relying on alternative cyclical indicators, filtering techniques, and control variables (Heimberger, 2023). The above specification with HP-filtered fiscal variables is adopted as a baseline but given the potential shortcomings of the HP-filter (Hamilton, 2018), specifications without HP-filtering are also tested for robustness. Real GDP growth serves as the main cyclical indicator due to the limited availability of output gap estimates, but robustness checks confirm that the results are similar when the output gap is used instead.

reports the full regression results from Equation (3.1). The estimates show that fiscal policy is countercyclical on average, but the extent of countercyclicality rises with the level of development. Advanced economies display the strongest countercyclical patterns, followed by emerging markets, while the response is weakest in low-income developing countries.

This gradient is visible both for the overall deficit and for individual expenditure components. In advanced economies, the overall deficit falls significantly in response to higher growth, reflecting stronger countercyclicality. Emerging markets exhibit a smaller but still negative response, while in low-income developing countries the effect is weaker and only marginally significant. Disaggregating expenditures echoes this pattern. The wage bill moves countercyclically across all groups, but the response is strongest in advanced economies and fades as income levels decline, while social assistance transfers play little stabilising role outside advanced economies.

Figure 3.6. Fiscal cyclicality by spending category and income group



Note: Vertical axis shows β_j coefficients from Equation (3.1), estimated using the 'within' (fixed effects) estimator. Standard errors are clustered at the country level. 90 percent confidence intervals are indicated by the whiskers.

These results are consistent with the broader literature linking fiscal cyclicality to country income levels (see Jalles et al., 2024).[13] While the degree of countercyclicality differs across spending categories, the common pattern is that fiscal policy in higher-income countries provides more systematic stabilisation, whereas in lower-income countries the response is more limited. A range of robustness checks are conducted with qualitatively unchanged

[13]Michaud and Rothert (2018) find that social transfers are countercyclical in industrial countries and procyclical in developing ones. In our estimates, social transfers in emerging markets and low-income countries are not procyclical, but they are still less countercyclical than in advanced economies, in line with the general trend.

results across all exercises (see Appendix C.4).[14]

3.3.2 Marginal Impact of Indexation on Fiscal Cyclicality

This section extends the baseline measurement of fiscal cyclicality in Section 3.3.1 to assess how indexation affects the cyclicality of fiscal policy and presents the corresponding results.

3.3.2.1 Interaction-Based Specification

To examine the effect of indexation on the countercyclicality of fiscal policy, Equation (3.1) is extended following a common approach in the literature that investigates how fiscal rules, institutions, or other factors shape fiscal cyclicality. Specifically, while Equation (3.1) assumes a linear and uniform cyclical response across countries, we can allow responsiveness to vary with country-specific characteristics (e.g., Bergman and Hutchison, 2020; Combes et al., 2017; De Jong and Gilbert, 2020; Kameník, 2019; Keita and Turcu, 2023; Larch et al., 2021; Liao et al., 2025).[15]

In this setting, the focus is on indexation practices. The indexation variable, $Index_{jit}$, is introduced and interacted with growth to capture how indexation alters the cyclical behaviour of government expenditure and the overall deficit. For the public wage bill, social security, and social assistance programmes, $Index_{jit}$ is a binary indicator. For the overall deficit, the WISI is employed, capturing more granular variation in indexation intensity.

Specifically, for each fiscal outcome j the following specification is estimated:

$$\frac{X_{jit}}{Y_{it}} = \alpha_{ji} + \nu_{jt} + \beta_j \widetilde{y_{it}} + \gamma_j Index_{jit} + \delta_j \widetilde{y_{it}} Index_{jit} + \theta_j' C_{jit} + \epsilon_{jit} \tag{3.2}$$

where C_{jit} now also includes the interaction between $Index_{jit}$ and inflation, and other variables are defined as before. Parameter γ_j captures the level effect of indexation on the expenditure-to-GDP ratio. Due to the inclusion of country fixed effects, a time-invariant indexation indicator would be absorbed by these effects. As a result, γ_j is identified only from within-country changes when $Index_{jit}$ is binary (i.e., from countries that switch indexation on or off during the sample period).

The coefficient β_j now measures cyclicality in the absence of indexation, while the linear combination of $\beta_j + \delta_j$ reflects the cyclicality of fiscal expenditure when indexation mechanisms are in place. The interaction coefficient δ_j is therefore the key parameter of interest, as it captures the *marginal impact* of indexation on cyclicality (i.e., how the cyclical

[14] Robustness checks include specifications using the output gap instead of real GDP growth, the non–cyclically adjusted versions of the fiscal variables, as well as additional controls (e.g., lagged inflation, lagged public debt, the export-to-GDP ratio to account for export-dependence, and the real interest rate). Following Lane (2003), this two-way fixed effects approach is often most suitable for studying fiscal cyclicality, as there is little justification to exclude equilibrium feedback effects from fiscal policy to output. Nevertheless, GMM estimation is also implemented to address potential concerns about endogeneity (Table C.4.1).

[15] Afonso et al. (2022) similarly employ the interaction-based approach to analyse marginal effects, albeit in a different setting and not in relation to cyclicality.

behaviour of expenditure changes with indexation).[16] Importantly, δ_j is identified from the time variation in growth and differences in indexation across observations, so even where $Index_{jit}$ is time-invariant for some countries, the interaction term remains well-identified. A negative δ_j suggests that indexation is associated with muted cyclical fluctuations and greater countercyclicality, reflecting more stable expenditure during downturns, whereas a positive δ_j implies that indexation is associated with amplified fluctuations and more procyclical fiscal policy.

Equation (3.2) is estimated separately for each expenditure category, both for the full sample of countries and for subgroups of advanced economies and emerging markets and developing economies.[17]

While Figures 3.2 and 3.3 (and Figures C.1-C.3) show that indexation has remained fairly stable over time (suggesting that it is unlikely to be closely tied to business cycle dynamics), the presence of indexation could be correlated with unobserved political or macroeconomic factors that also influence fiscal cyclicality, biasing within-group ordinary least squares (OLS) estimates. To address potential endogeneity of domestic indexation, each type of indexation is instrumented using the prevalence of the same indexation rule in neighbouring countries.[18] Likewise, the interaction between growth and indexation is instrumented using the corresponding interaction with neighbouring countries' indexation practices. This approach follows recent contributions that instrument potentially endogenous domestic variables with their counterparts in neighbouring countries or with averages across neighbours (see Altunbaş and Thornton, 2017; Apeti et al., 2024; Balima et al., 2017; Balvir, 2024; Bambe, 2025; Capasso et al., 2025; Caselli and Reynaud, 2020; Cherif et al., 2026).[19]

The underlying intuition is that governments are more likely to adopt indexation rules when nearby countries do so, either through policy diffusion, peer pressure, learning, competition, or regional policy harmonisation (see Buera et al., 2011; Dobbin et al., 2007; Giuliano et al., 2013; Huntington, 1991; Markoff, 1996; Shipan and Volden, 2008; Weyland, 2008). The identifying assumption is that neighbouring countries' indexation affects domestic fiscal cyclicality only through its impact on domestic indexation, rather than directly.[20] This

[16] For the overall fiscal balance, where the continuous WISI measure is employed instead of a binary indicator, δ_j should be interpreted as the marginal change in cyclicality per unit increase in indexation intensity.

[17] Emerging markets and low-income developing countries are grouped into one combined category, 'emerging markets and developing economies', because of fewer countries with indexation mechanisms and data availability for low-income developing countries.

[18] The instrumental variable for the prevalence of indexation of each spending item is a binary variable equal to one if at least one of the neighbouring countries indexes the same spending item. For the WISI index, the instrument is a weighted average of neighbouring countries' indexation across spending categories, using the same domestic expenditure weights as in the domestic WISI calculation.

[19] For example, Caselli and Reynaud (2020) instrument the adoption of fiscal rules with the introduction of such rules in neighbouring countries, arguing that neighbours' reforms provide exogenous variation that influences domestic policy through diffusion rather than directly affecting fiscal outcomes.

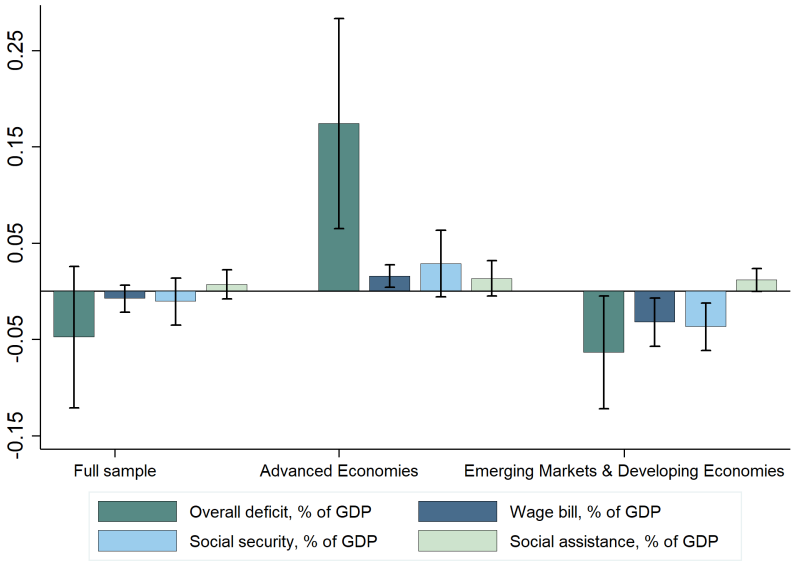
[20] To test for underidentification (i.e., instrument relevance), weak instruments, and overidentification (i.e., instrument validity) in the IV estimation, respectively, the Kleibergen and Paap (2006) rk LM statistic, the Kleibergen and Paap (2006) rk Wald F statistic, and the Hansen J statistic are reported.

instrumental variable approach isolates plausibly exogenous variation in indexation and mitigates possible endogeneity bias between indexation and fiscal cyclicality.

3.3.2.2 Empirical Results

Figure 3.7 plots the marginal effects of indexation, δ_j, from IV estimates using neighbouring-country practices as an instrument.[21] The results point to an asymmetry in how indexation affects cyclicality between advanced economies and emerging market and developing economies (EMDEs). For the overall deficit, the complete country sample shows no systematic difference in the cyclicality between countries with higher or lower indexation. Instead, indexation appears to weaken countercyclicality in advanced economies. While deficits are strongly countercyclical under non-indexation (-0.203^{***} when $WISI_{it} = 0$), this stabilising role is reduced by about 0.05 percentage points when the WISI increases from its 25th to 75th percentile value in the sample. In advanced economies, which typically have relatively strong fiscal frameworks, inflation-linked spending rules appear to constrain governments' ability to respond flexibly to the cycle, potentially introducing procyclical pressures and, in some cases ($WISI_{it} = 1$), nearly offsetting their stabilising capacity entirely.

Figure 3.7. Marginal impact of indexation on fiscal cyclicality



Note: Vertical axis plots δ_j coefficients from Equation (3.2), estimated using 2SLS-IV. Standard errors are clustered at the country level. 90 percent confidence intervals are indicated by the whiskers.

By contrast, the interaction term is negative and significant in EMDEs. Deficits are countercyclical without indexation, -0.064^{***} (albeit less so than in non-indexed advanced economies in line with the previous results from Table C.2), but become materially more countercyclical with higher indexation intensity. Moving the WISI from the 20th to the 80th percentile value in the sample improves countercyclicality by 0.026 percentage points, while the countercyclical effect when indexation is fully implemented ($WISI_{it} = 1$) is twice as

[21] The full regression table can be found in Table C.3.

large as when there is no indexation ($WISI_{it} = 0$).[22] Mechanically, formulaic indexation thus appears to play a role in providing a ceiling on procyclical spending increases during booms and sustaining real expenditure during downturns, ensuring it keeps pace with inflation. This echoes Galeano et al. (2021), who show that the absence of indexation in social security spending can be destabilising in developing countries. This paper extends this evidence by showing that the effect is not confined to social security but is visible in broader expenditure aggregates.

The asymmetric pattern by country group broadly holds across spending categories. For the wage bill, the full sample again shows no clear effect of indexation on cyclicality, and the group-level estimates further mirror those for the overall deficit. In advanced economies, indexation is associated with weaker countercyclicality (from 0.045 without indexation to around 0.03 with indexation),[23] whereas in EMDEs, it significantly strengthens it, shifting acyclical spending into the countercyclical territory. Estimates show that under indexation, the usual pattern of advanced economies being more countercyclical than EMDEs is reversed, as indexed wage bill spending is more countercyclical in EMDEs. For social security, coefficients are positive in advanced economies and negative in EMDEs, with only the latter being statistically significant. This suggests indexation has no clear effect in advanced economies but is consistent with the idea that in settings with weaker fiscal frameworks, formula-based adjustments can mitigate procyclical expansions during booms and sustain real transfers in recessions. Given the growing weight of social security in public budgets, these findings underline the importance of social security indexation design for fiscal stabilisation, especially in aging societies. For social assistance, coefficients are small and insignificant in both groups, likely reflecting limited coverage and data availability.[24]

The above IV specification is adopted as the preferred baseline, as it directly addresses the key endogeneity concern about the indexation variable. To further check robustness, the paper implements two complementary approaches: a dynamic Arellano and Bond (1991) GMM estimator, which tackles dynamic panel bias and additional sources of endogeneity,[25] and an inverse probability weighting (IPW) strategy within a multi-treatment effects framework.[26] Together, these provide robustness checks for the IV approach and 'naïve' within-group estimates. Figure 3.8 (and Table C.4) replicate the analysis using a 'naïve'

[22] The shift from the 25th to the 75th percentile produces a negligible change (0.002), reflecting a distribution for WISI in EMDEs that is heavily concentrated at zero with a large mass point at the lower bound.

[23] Total cyclicality in the presence of indexation is determined by the linear combination of the β_j and δ_j coefficients.

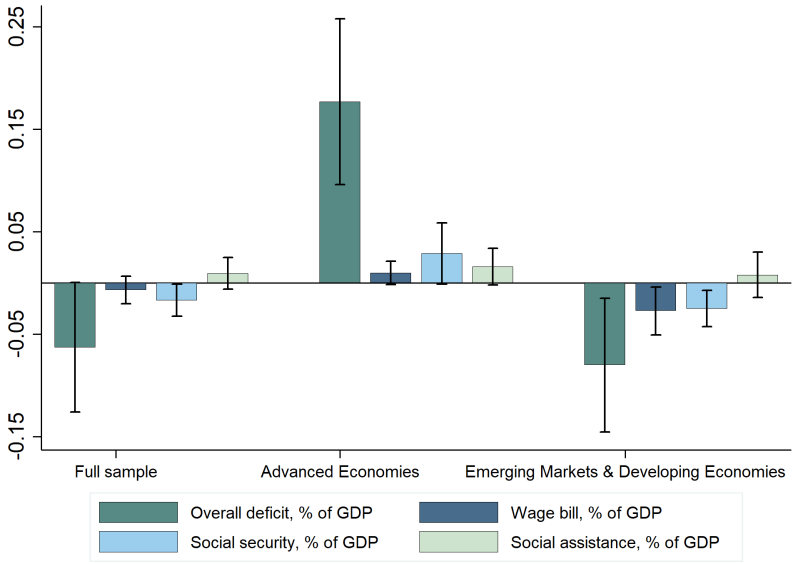
[24] To formally test whether the marginal impact of indexation differs statistically across AEs and EMDEs, Table C.8 pools the sample and introduces a triple interaction, $\widetilde{y_{it}}\text{Index}_{it}\text{EMDE}_i$, which captures how being an EMDE economy affects the marginal impact of indexation. The estimated differences are negative and statistically significant for the overall deficit, the wage bill, and social security.

[25] The model includes lagged dependent variables to capture persistence, with deeper lags (two periods and beyond) serving as instruments in first differences.

[26] In the first stage, we jointly model the probability of experiencing an economic boom and adopting indexation using a probit model that incorporates macro-fiscal determinants, including lagged real GDP growth, the lagged debt-to-GDP ratio, lagged CPI inflation, indicators of institutional quality and financial openness, as well as country fixed effects. In the second stage, IPW is applied to correct for potential endogeneity following the methodology of Imbens and Wooldridge (2009).

within-group estimator without instruments. The results are qualitatively unchanged from those obtained using the IV strategy above.[27]

Figure 3.8. Robustness to baseline estimates of the marginal impact



Note: Vertical axis plots δ_j coefficients from Equation (3.2), estimated using the 'within' (fixed effects) estimator. Standard errors are clustered at the country level. 90 percent confidence intervals are indicated by the whiskers.

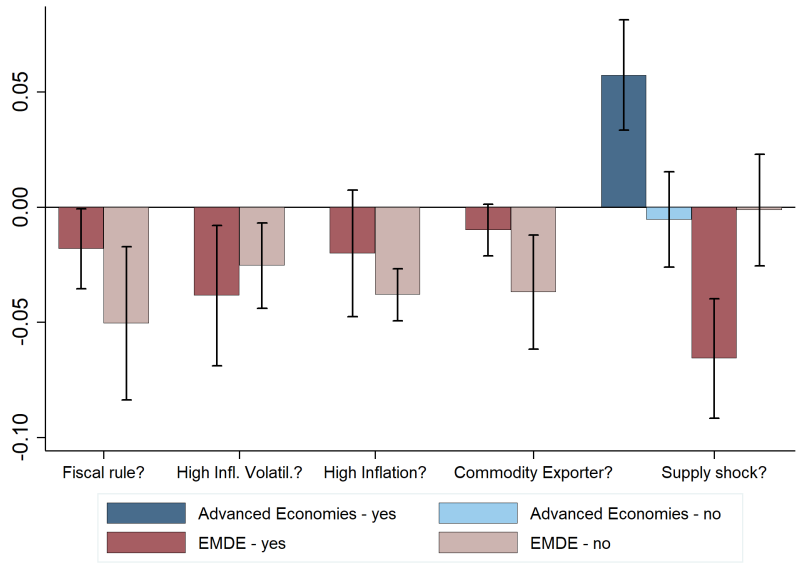
Section 3.3.4 explores what contributes to the heterogeneous impact of indexation more formally. However, it can still be helpful to explore how the effects of indexation vary across countries with different structural characteristics, where Equation (3.2) is run across more refined subsamples. For this, the focus is on social security spending, where data coverage is widest as wage bill and social assistance data do not allow us to split further into subgroups before losing significant statistical power. Figure 3.9 visualises the marginal impact of indexation on cyclicality within each subgroup (see full regression results in Table C.5).

Indexation appears to be more effective in strengthening countercyclicality in EMDEs when fiscal rules are absent, inflation volatility is higher, but the average inflation rate is moderate.[28] In these contexts, formulaic rules appear to assist weaker institutions by restraining procyclical spending during booms and sustaining it in recessions. By contrast, in EMDEs with fiscal rules and lower inflation volatility, the effect is muted and resembles

[27] Appendix C.4.2 further shows that results are robust to alternative controls (including lagged inflation, lagged public debt, export dependence, and the real interest rate; see Tables C.9-C.12), alternative definitions of the fiscal variables (non-cyclically adjusted series) and the alternative measure of the cyclical position of the economy (output gap), as well as different estimation strategies. Both Arellano-Bond-style system-GMM (Table C.13) and IPW estimators (Table C.14) are included to account for potential endogeneity and yield results consistent with those presented above.

[28] The number of advanced economies that lack fiscal rules, are commodity exporters, or fall into the 'high inflation' or 'high inflation volatility' groups is too small to support meaningful subgroup analysis. Accordingly, these splits are restricted to EMDEs, while advanced economies are included only in the supply–demand shock classification.

Figure 3.9. Impact of social security indexation on fiscal cyclicality



Note: Vertical axis plots δ_j coefficients from Equation (3.2), estimated using 2SLS-IV. Standard errors are clustered at the country level. 'High inflation' and 'High inflation volatility' correspond to observations above their respective sample means. Supply shocks are identified using the Shapiro (2024) methodology. EMDE: Emerging markets and developing economies. 90 percent confidence intervals are indicated by the whiskers.

the advanced economies pattern discussed above. This is intuitive, as EMDEs with fiscal rules share some institutional characteristics typical for advanced economies, making indexation rules less binding. Indexation is also associated with stronger countercyclicality in non-commodity exporters than in commodity exporters, consistent with the procyclical tendencies of resource revenues. Finally, distinguishing between supply and demand shocks shows that the asymmetric effects of indexation between advanced economies and EMDEs are concentrated in periods of supply shocks.[29] Under supply shocks, indexation weakens countercyclicality in advanced economies but strengthens it in EMDEs. By contrast, under demand shocks, indexation appears broadly acyclical for both groups, with estimated effects insignificant and close to zero.[30]

Taken together, the estimates indicate that the impact of indexation is not uniform. Instead, it tends to reduce the countercyclicality of fiscal policy in advanced economies, while strengthening it in EMDEs, though the strength of this effect depends systematically on fiscal frameworks, inflation environments, resource dependence, and the nature of shocks hitting the economy. These results extend and qualify earlier findings (Galeano et al., 2021), suggesting that while indexation can play a stabilising role, its effectiveness is highly context dependent.

[29]For supply shocks, the residual-based approach following Shapiro (2024) is employed. For each country, growth and inflation are regressed on the lags of both, and the residuals (i.e., unpredictable components once dynamics are stripped out) are taken as 'innovations'. Shocks are then classified based on the sign of the product of these innovations (positive = demand shock, negative = supply shock).

[30]The results are robust to alternative control variables and different estimation techniques (within-group, GMM estimation, and IPW correction).

3.3.3 Indexation During 'Boom' and 'Bust' Episodes

This section formally evaluates how the relationship between indexation and fiscal cyclicality varies across phases of the economic cycle. To capture this, the indexation variable is interacted with indicators for economic booms and recessions to capture how the presence of indexation affects government expenditure differently during expansions and contractions, respectively. This approach allows an assessment of whether indexation dampens or amplifies fiscal cyclicality in good and bad times. Formally, the following specification is estimated for each j:

During 'booms':

$$\frac{X_{jit}}{Y_{it}} = \alpha_{ji} + \nu_{jt} + \beta_j \widetilde{y_{it}} + \gamma_j Index_{jit} + \zeta_j^{+} boom_{it} + \delta_j^{+} boom_{it} Index_{jit} + \theta' C_{jit} + \epsilon_{jit} \tag{3.3}$$

During 'busts':

$$\frac{X_{jit}}{Y_{it}} = \alpha_{ji} + \nu_{jt} + \beta_j \widetilde{y_{it}} + \gamma_j Index_{jit} + \zeta_j^{-} bust_{it} + \delta_j^{-} bust_{it} Index_{jit} + \theta' C_{jit} + \epsilon_{jit} \tag{3.4}$$

where $boom_{it}$ and $bust_{it}$ are dummy variables identifying the phase of the economic cycle, defined as $\widetilde{y_{it}} > 3$ for booms and $\widetilde{y_{it}} < 0$ for recessions. The coefficients δ_j^{+} and δ_j^{-} capture how the effect of indexation on fiscal cyclicality differs across business cycle phases.[31]

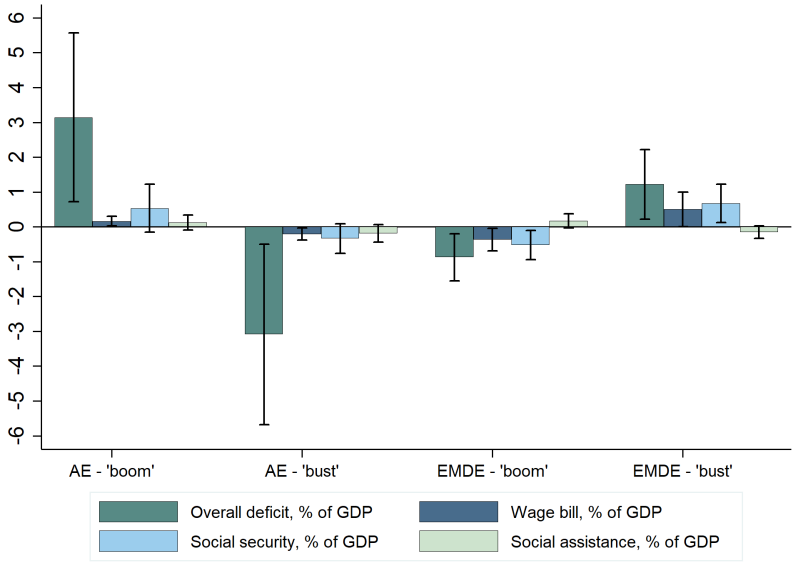
Their interpretation is therefore phase-specific: In booms (positive growth with $\widetilde{y_{it}} > 3$), a negative δ_j^{+} indicates that indexation reduces deficits or spending as a share of GDP, strengthening countercyclicality. A positive δ_j^{+} implies the opposite: indexation increases deficits or spending in expansions, weakening countercyclicality or even imparting procyclical pressures. In busts (negative growth, $\widetilde{y_{it}} < 0$), the meaning is reversed. A negative δ_j^{-} implies that indexation reduces spending when growth is falling (i.e., amplifying the downturn and acting procyclically). A positive δ_j^{-} instead suggests that indexation sustains or increases spending in recessions, thereby reinforcing countercyclicality.

As in Section 3.3.2, the IV strategy that instruments domestic indexation with the prevalence of indexation in neighbouring countries is adopted. Figure 3.10 plots the coefficients, δ_j^{+} and δ_j^{-}, where the differences between the impact of indexation between advanced economies and EMDEs are highlighted further (see Table C.6 for full regression estimates). The most robust and consistent pattern concerns the overall deficit. All four phase-group combinations are statistically significant, indicating that indexation interacts significantly with both booms and busts in advanced economies and in EMDEs. In advanced economies, the boom interaction is positive and the bust interaction is negative, suggesting that indexation raises the deficit share in expansions and provides little stabilising effect in contractions. Specifically, moving the WISI from the 25th to the 75th percentile value for advanced economies reduces countercyclicality by 0.836 points during booms and by 0.822 points in

[31] This specification differs from the analysis in Section 3.3.2 as the interaction coefficients, δ_j^{+} and δ_j^{-}, now capture the marginal impact of indexation on fiscal cyclicality in expansions or contractions, rather than on cyclicality per se. Estimating these interactions separately for each expenditure category and across country groups provides a richer picture of how the role of indexation varies with the business cycle.

busts. In EMDEs, the coefficient signs are reversed as the boom interaction is negative and the bust interaction is positive, so indexation appears to reduce deficit pressure in upturns and to cushion deficits in downturns. Moving from the WISI's 25th to 75th percentile for EMDEs raises countercyclicality by 0.028 in booms and 0.039 in busts (and by 0.358 and 0.500, respectively, when moving from the 20th to 80th percentile values, reflecting the WISI's large mass point at zero for EMDEs).

Figure 3.10. Indexation impact across 'boom' and 'bust' episodes



Note: Vertical axis plots δ_j^+ and δ_j^- coefficients from Equations (3.3) and (3.4), estimated using 2SLS-IV. Standard errors are clustered at the country level. 90 percent confidence intervals are indicated by the whiskers.

The wage bill results follow the same sign pattern and are statistically significant for both booms and busts in advanced economies. In EMDEs, the bust interaction for the wage bill is statistically significant while the boom interaction is not; the point estimates in both phases, however, align with the same sign pattern. For social security, the evidence is strongest in EMDEs: both boom and bust interactions are statistically significant and consistent with indexation strengthening countercyclicality in those countries. Coefficients for social security in advanced economies are not statistically significant, although the point estimates point in the same direction as the deficit and wage bill results. For social assistance the estimates are generally imprecise. In advanced economies, the point estimates follow the same sign pattern as for the deficit and wage bill but are not significant; EMDE estimates are even less precise because of limited coverage.

Interpreting these findings together, indexation acts as a ceiling and a floor in many EMDEs: in booms it restrains nominal increases in indexed items and reduces the spending or deficit share, while in busts it prevents real expenditure from collapsing, thereby enhancing stabilisation across both. In advanced economies, indexation tends to increase indexed spending during expansions (likely driven by rising inflation during growth episodes) and does not provide a meaningful countercyclical floor in recessions, which reduces fiscal flexibility and can introduce procyclical dynamics in growth episodes. The estimates therefore document a reversal in the role of indexation across country groups but suggest

it is not phase-dependent. These findings are robust to alternative specifications and alternative estimation strategies, including GMM (see Table C.15) and IPW (see Table C.16) to address endogeneity concerns. In all cases, the qualitative patterns mirror the baseline. The consistency of results across estimators strengthens confidence that these findings are not driven by model specification or endogeneity.

3.3.4 Examining the Variation in the Effects of Indexation

To examine heterogeneity in the impact of indexation on fiscal cyclicality, a two-step procedure is adopted. In the first step, rolling-window regressions are estimated separately for each country to obtain country-specific, time-varying marginal effects of indexation.[32] Unlike Equations (3.2)-(3.4), which are estimated in a panel setting, the country-by-country approach adopted here means that δ_j is only identified when a country experiences changes in its indexation regime. This makes identification particularly challenging for wage bill, social security, and social assistance expenditures. Thus, using the WISI index as a continuous measure of indexation intensity is especially valuable, since it provides variation even in the absence of discrete switches. Moreover, focusing on the overall deficit helps mitigate data limitations, as it is more consistently available than the expenditure subcomponents.

Specifically, for each country i the following specification is estimated:

$$\frac{D_t}{Y_t} = \alpha + \beta \widetilde{y_t} + \gamma WISI_t + \delta \widetilde{y_t} WISI_t + \theta' C_t + \epsilon_t \tag{3.5}$$

where D_t denotes the overall deficit and all other variables are defined as in Equation (3.2).[33] From this first stage, the fitted values of the interaction term, $\widehat{\delta_{it}}$, which captures the country-year-specific marginal effect of indexation on fiscal cyclicality, are recovered. In the second step, the estimated marginal effects are regressed on structural and institutional characteristics in a panel framework:

$$\widehat{\delta_{it}} = \alpha_i + \nu_t + \beta \widetilde{y_{it}} + \theta' Z_{it} + \epsilon_t \tag{3.6}$$

where Z_{it} is a vector of institutional and macroeconomic controls, including growth volatility, inflation and inflation volatility, institutional quality, and supply shocks. To account for the estimation precision, the dependent variable is weighted by the inverse of its estimated standard error. This second stage allows us to identify which structural and institutional features shape the effectiveness of indexation as a fiscal stabiliser. Table 3.1 reports the second-stage regression results from Equation (3.6), where the estimated country-year marginal effects are regressed on alternative sets of structural and macroeconomic determinants. Three main insights emerge.

First, the inflation environment matters. Higher contemporaneous inflation is consistently associated with less countercyclical indexation, reflecting a more mechanical response: in high-inflation environments, indexation tends to amplify fiscal fluctuations rather than stabilise them. This underscores that indexation is most effective when linked to moderate price developments.

[32] To ensure reliability, only coefficients based on windows with at least 10 observations are retained.

[33] Subscript j is dropped as the specification looks at the overall deficit alone. The rolling-window design ensures sufficient within-country time variation while capturing the evolution of the marginal effect of indexation over time.

Table 3.1. Estimates of the marginal impact determinants

	Marginal impact of indexation (fitted values)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Growth	-0.011	0.001	-0.012	-0.009	-0.011	-0.014	-0.016	0.022
	(0.013)	(0.013)	(0.013)	(0.016)	(0.013)	(0.013)	(0.040)	(0.050)
Lag growth			-0.042***	-0.037**	-0.041***	-0.045***	-0.104**	-0.061
			(0.015)	(0.015)	(0.015)	(0.016)	(0.045)	(0.049)
Inflation	0.037**	0.037**	0.035*	0.046**	0.035*	0.036*	0.043	0.065**
	(0.016)	(0.016)	(0.020)	(0.021)	(0.020)	(0.019)	(0.028)	(0.030)
Lag inflation			0.010	0.014	0.010	0.010	0.015	0.015
			(0.025)	(0.027)	(0.025)	(0.025)	(0.039)	(0.037)
Institutional quality	3.304***	3.418***	3.467***	3.590***	3.388***	3.376***	4.072***	3.419**
	(1.010)	(1.026)	(1.040)	(1.112)	(1.052)	(1.006)	(1.335)	(1.393)
Public debt, % of GDP	-0.025**	-0.028**	-0.026*	-0.032**	-0.026*	-0.025*	-0.033*	-0.036*
	(0.013)	(0.013)	(0.014)	(0.016)	(0.014)	(0.014)	(0.018)	(0.020)
Lag public debt, % of GDP			-0.004	0.000	-0.003	-0.007	-0.008	0.006
			(0.015)	(0.017)	(0.015)	(0.016)	(0.021)	(0.026)
Supply shock	0.061	0.040	-0.024	-0.068	-0.039	-0.031	0.036	-0.058
	(0.185)	(0.189)	(0.187)	(0.200)	(0.187)	(0.189)	(0.236)	(0.279)
Boom		-0.550**	-0.485**	-0.575**	-0.498**	-0.467**	-0.721**	-0.842***
		(0.230)	(0.225)	(0.230)	(0.226)	(0.227)	(0.281)	(0.294)
Bust		-0.279	-0.785	-0.799	-0.763	-0.869	-0.408	-0.609
		(0.270)	(0.681)	(0.722)	(0.680)	(0.709)	(0.780)	(0.923)
Inflation-growth comovement			-0.414	-0.302	-0.413	-0.471	-0.315	-0.272
			(0.602)	(0.619)	(0.602)	(0.619)	(0.654)	(0.691)
Exports, % of GDP				0.015				0.033
				(0.013)				(0.021)
Trade, % of GDP				-0.022**				-0.072***
				(0.010)				(0.017)
Fiscal rule					0.941**			1.052
					(0.472)			(0.674)
Fiscal council						0.549		1.451**
						(0.453)		(0.669)
Consolidation							-0.215	-0.139
							(0.357)	(0.369)
R^2	0.984	0.984	0.984	0.984	0.984	0.984	0.984	0.984
Observations	898	898	897	856	897	897	657	645

Note: All regressions include country and year fixed effects. Standard errors are clustered at the country level and reported in parentheses. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, **, and *, respectively.

Second, cyclical and fiscal conditions contribute to the effect of indexation. The negative coefficients on lagged growth and boom episodes suggest that in stronger cyclical positions indexation tends to reinforce countercyclicality, whereas during downturns or in the presence of persistent low growth the stabilising role of indexation is attenuated. Public debt also emerges as a relevant factor: higher debt levels are associated with stronger countercyclicality, pointing to the possibility that indexation partly substitutes for discretionary policy when fiscal space is limited. Countries with higher trade-to-GDP ratios also exhibit

more countercyclical indexation.

Third, and most importantly, institutions stand out as the dominant determinant of indexation's marginal impact. Fiscal rules and the presence of a fiscal council have similar effects, although they are less consistently significant. Institutional quality consistently enters with large and highly significant positive coefficients across all specifications, making it the most robust factor in shaping the effects of indexation. This finding is in line with the earlier argument that institutional frameworks condition the effectiveness of indexation rules. In settings with weaker institutions, indexation appears to provide a rule-based anchor that can enhance stabilisation by constraining procyclical expenditure splurges or cuts. By contrast, in stronger institutional environments, indexation reduces policymakers' scope for discretionary adjustment and links it more tightly to inflation, thereby potentially introducing procyclical pressures.

Taken together, these results underscore that the role of indexation as a fiscal stabiliser is conditional rather than uniform. Its effectiveness depends critically on institutional strength, while inflation, cyclical conditions, public debt, and trade openness further modulate whether indexation strengthens or weakens countercyclicality.

3.4 Conclusion

This paper constructs a novel cross-country panel dataset of indexation practices (i.e., automatic adjustments of spending to inflation or wages) for public wages, social security, and social assistance from 2002 to 2023, and uses it to investigate the relationship between indexation and fiscal policy cyclicality. The paper documents that indexation practices have remained relatively stable over the past two decades, but that there is substantial heterogeneity in the share of countries with indexation mechanisms across the three expenditure categories and across advanced economies, emerging markets, and low-income developing countries. To capture indexation intensity, the time- and country-varying *Weighted Index of Spending Indexation* is introduced.

Regression-based measures of cyclicality, including controls for potential endogeneity, are applied to assess how indexation interacts with fiscal stabilisation. Estimates indicate that, on average, across all countries in the sample, indexation does not exert a significant effect on fiscal cyclicality. However, when differentiated by development level, distinct patterns emerge. In advanced economies, indexation tends to weaken countercyclicality as it may constrain desirable discretionary policy. By contrast, in emerging markets and developing economies, indexation is associated with lower procyclicality, restraining expenditures during expansions and preserving them during contractions. In these settings, indexation may serve as a commitment device in the presence of weaker fiscal institutions, mitigating political-economy biases toward procyclicality. These findings extend Galeano et al. (2021) by showing that the beneficial role of indexation in emerging market and developing economies is not confined to social security but also appears in broader categories of public expenditure. Within emerging markets and developing economies, indexation is more stabilising where fiscal rules are absent, inflation is moderate, but inflation volatility is high, supply shocks are present, and countries are not commodity-dependent.

Taken together, the analysis underscores that indexation is neither inherently stabilising nor destabilising. Its effects are context-dependent and shaped by institutional quality, inflation,

and the cyclical conditions. From a policy perspective, the decision to adopt or adjust indexation rules involves balancing the goal of protecting real benefits (especially for vulnerable groups) with the need for countercyclical flexibility and fiscal sustainability. Predictable, rules-based indexation mechanisms, which ideally incorporate regular recalibrations and built-in flexibility, could help balance responsiveness to economic shocks with governments' fiscal objectives (IMF, 2023). For fiscal projections, the results imply that indexation effects should be explicitly integrated into forecasts to enhance their credibility. This requires incorporating realistic inflation assumptions and building buffers or contingency measures to address inflation surprises.

At the same time, several limitations of the analysis should be acknowledged. The dataset does not capture important design features of indexation rules, such as whether adjustments are backward- or forward-looking, the frequency of adjustment, or the benchmark variable used (e.g., indexation to wages is likely to be more procyclical than indexation to prices). These features are likely to shape both the magnitude and the timing of stabilisation effects. Moreover, while the study identifies statistically significant effects on the impact of indexation on the cyclicality of fiscal policy, the economic significance remains less clear, and the framework does not allow for a full cost-benefit assessment of indexation relative to other policy instruments. Future work could build on these findings by incorporating richer information on the design of indexation rules, employing event-study or difference-in-differences approaches to exploit rare episodes of adoption and removal (and testing whether effects are symmetric), study the long-term and persistence effects of indexation, and embedding indexation mechanisms within dynamic general equilibrium models to evaluate trade-offs more comprehensively. Longitudinal studies tracking these effects across multiple economic cycles would be particularly valuable, and the extensive indexation database presented here provides a resource for future research.

Appendix C

Appendix of Chapter 3

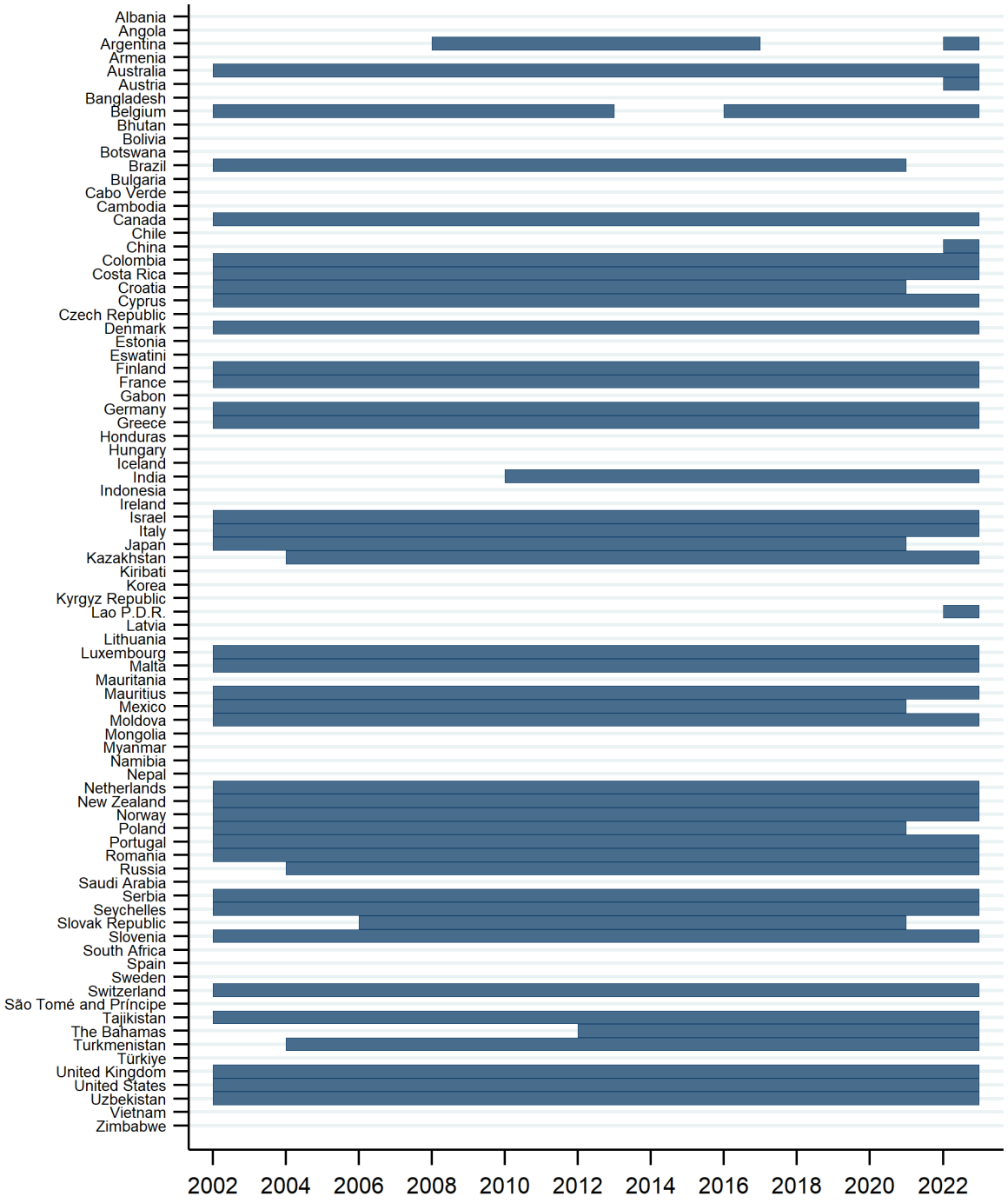
C.1 Indexation Data Overview

Figure C.1. Overview of public wage bill indexation data



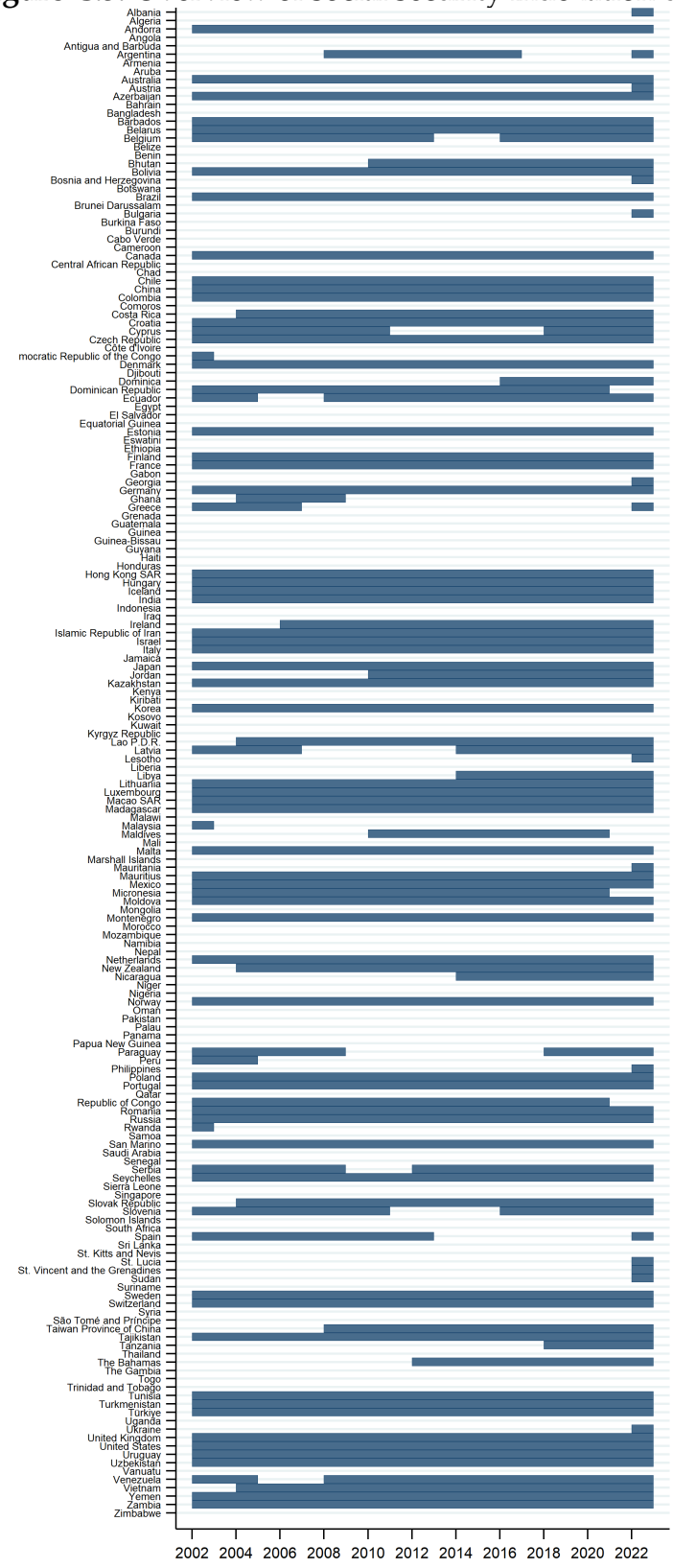
Sources: US Social Security Administration, ISSA, IMF, OECD, ILO, World Bank, news, and government webpages.

Figure C.2. Overview of social assistance indexation data



Sources: US Social Security Administration, ISSA, IMF, OECD, ILO, World Bank, news, and government webpages.

Figure C.3. Overview of social security indexation data



Sources: US Social Security Administration, ISSA, IMF, OECD, ILO, World Bank, news, and government webpages.

Table C.1. Geographic and income distribution of the indexation database

Income Group	Africa	Asia-Pacific	Europe	Middle East & Central Asia	Western Hemisphere	Total
Advanced Economies	0	8	29	1	2	40
Emerging Markets	11	20	13	15	30	89
Low Income & Developing Countries	32	13	1	5	3	54
Total	**43**	**41**	**43**	**21**	**35**	**183**

Sources: US Social Security Administration, ISSA, IMF, OECD, ILO, World Bank, news, and government webpages.

Examples of indexation practices

- *Australia*: Pensions and other social assistance benefits are adjusted either yearly or twice yearly. The indexation factor is calculated by comparing the CPI number for the reference quarter (usually the most recent quarter) to the CPI number for the base quarter (usually either six or twelve months before the reference quarter.
- *Belgium*: The "health index" underpins the indexation of public sector wages, most private sector wages, pensions and social security benefits. This reference index removes alcoholic beverages, tobacco products and motor fuels (except LPG) from the CPI and it is smoothed using a 4-month moving average. When this index surpasses a predefined threshold (the "pivot index" is 2 percent), wages, pensions, and social transfers are automatically adjusted. Social benefits are indexed one month after the pivot index is exceeded, while public employee salaries are indexed two months afterwards. This threshold-based indexation means that multiple adjustments are possible in a single year, depending on the level of inflation.
- *Mexico*: Unidad de Medida y Actualización is the reference index to adjust most social benefits, including pensions. It started out at the level of the minimum wage in 2016 and is indexed yearly with CPI inflation of the previous year.
- *Romania*: The pension point value is adjusted each January based on 100 percent of the annual inflation rate plus 50 percent of the annual change in average real wages. Social Reference Indicator determines the amount of various social assistance and unemployment benefits and is linked to the average annual inflation rate.
- *Turkey*: Under collective labor agreements, public sector employees are entitled to biannual raises with inflation adjustments if actual price increases exceed scheduled rates during the 6-month period. Pensions are also adjusted to inflation on a biannual basis.
- *United Kingdom*: The state pension is under a "Triple Lock" whereby the pensions increase annually (in April) by the maximum of the rate of inflation (measured by the CPI), average earnings growth, or a minimum of 2.5 percent. It uses the September CPI rate from the previous year and the average increase in wages across the country from the May-July period of the previous year.

- *United States*: Social security benefits have annual cost-of-living adjustments for current beneficiaries, which links benefit increases to inflation based on the CPI for Urban Wage Earners and Clerical Workers from the third quarter.

C.2 Data and Sources

Variable	Source
Bilateral distance and common border	GeoDist (CEPII)
Commodity exporters	Jalles et al. (2021)
CPI inflation (period average)	IMF World Economic Outlook
Exports in percent of GDP	World Bank Development Indicators
Financial openness index	Chinn and Ito (2006)
Fiscal rules	IMF Fiscal Rules Dataset: 1985–2024
General government net lending/ borrowing (Overall fiscal balance)	IMF World Economic Outlook
General government gross debt	IMF World Economic Outlook
Institutional quality	World Governance Indicators (World Bank)
Nominal GDP	IMF World Economic Outlook
Public wage expenditure	IMF World Economic Outlook, IMF FAD Harmonized Wage Bill and Employment Dataset
Public wage indexation	IMF, news and government webpages
Real GDP	IMF World Economic Outlook
Real interest rate	World Bank Development Indicators, IFS, Haver Analytics
Regulatory quality	World Governance Indicators (World Bank)
Social assistance expenditure	IMF World Economic Outlook, IMF FAD Social Protection and Labor Toolkit (SPL-AT), the OECD Social Expenditure Database
Social assistance indexation	US Social Security Administration, ISSA, IMF, OECD
Social security expenditure	IMF World Economic Outlook, IMF FAD Expenditure Assessment Tool, OECD Social Expenditure Database
Social security indexation	US Social Security Administration, ISSA, IMF, OECD, news and government webpages
Trade openness (sum of exports and imports in percent of GDP)	IMF World Economic Outlook

C.3 Complete Estimation Results

Table C.2. Within-group estimates of fiscal cyclicality

	Overall deficit, % of GDP			Wage bill, % of GDP			Social security, % of GDP			Social assistance, % of GDP		
	AE	EM	LIDC	AE	EM	LIDC	AE	EM	LIDC	AE	EM	LIDC
Growth	-0.174***	-0.096*	-0.056*	-0.035***	-0.027***	-0.022**	-0.009	-0.010*	-0.007	-0.036***	-0.006	-0.002
	(0.035)	(0.051)	(0.029)	(0.005)	(0.008)	(0.009)	(0.011)	(0.006)	(0.006)	(0.010)	(0.018)	(0.016)
Lag growth	0.013	-0.009	-0.036	0.002	-0.001	-0.003	-0.005	-0.004**	0.003	0.013	-0.017***	0.010
	(0.025)	(0.018)	(0.026)	(0.005)	(0.004)	(0.005)	(0.005)	(0.002)	(0.003)	(0.009)	(0.005)	(0.012)
Inflation	-0.069	0.000***	-0.010***	-0.006	0.000***	-0.005***	-0.010	-0.000	-0.001***	-0.004	-0.006*	-0.001**
	(0.092)	(0.000)	(0.002)	(0.012)	(0.000)	(0.001)	(0.010)	(0.000)	(0.000)	(0.008)	(0.003)	(0.000)
Lag overall deficit,	-0.059	-0.096***	-0.206***									
% of GDP	(0.081)	(0.031)	(0.035)									
Lag wage bill,				0.179***	-0.025	0.017						
% of GDP				(0.050)	(0.035)	(0.031)						
Lag soc. security,							0.135**	-0.182***	-0.103**			
% of GDP							(0.051)	(0.046)	(0.046)			
Lag social assist.,										-0.001	-0.076	-0.112
% of GDP										(0.042)	(0.083)	(0.089)
Regulatory quality	-0.154	0.148	0.032	-0.003	-0.062	0.098*	-0.096	-0.023	0.074*	-0.067	0.103	0.098
	(0.201)	(0.247)	(0.250)	(0.046)	(0.046)	(0.055)	(0.080)	(0.029)	(0.037)	(0.055)	(0.195)	(0.085)
Within R^2	0.536	0.208	0.088	0.523	0.201	0.118	0.525	0.165	0.119	0.348	0.093	0.150
Observations	777	1907	1159	758	1709	1038	711	1217	628	396	423	203
Countries	37	92	57	37	87	54	37	84	47	19	21	10

Note: Equation (3.1). AE = Advanced Economies; EM = Emerging Markets; LIDC = Low-Income Developing Countries. All regressions include country and year fixed effects. Commodity exporters excluded. Standard errors are clustered at the country level and reported in parentheses. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table C.3. Marginal impact of indexation on fiscal cyclicality

	Overall deficit, % of GDP			Wage bill, % of GDP			Social security, % of GDP			Social assistance, % of GDP		
	All	AE	EMDE	All	AE	EMDE	All	AE	EMDE	All	AE	EMDE
Growth	-0.103***	-0.203***	-0.064***	-0.024*	-0.045***	-0.005	-0.016	-0.036*	-0.017	-0.002	-0.011	0.003
	(0.034)	(0.036)	(0.023)	(0.013)	(0.007)	(0.019)	(0.010)	(0.019)	(0.012)	(0.007)	(0.009)	(0.009)
Lag growth	-0.029**	0.023	-0.037***	0.010**	0.005	0.017***	-0.000	-0.006	0.003	0.003	-0.002	0.007
	(0.013)	(0.022)	(0.010)	(0.004)	(0.008)	(0.004)	(0.005)	(0.006)	(0.006)	(0.007)	(0.003)	(0.011)
Lag overall deficit, % of GDP	-0.132***	-0.010	-0.160***									
	(0.032)	(0.099)	(0.038)									
Weighted Index of Spending Index.	0.111	-0.403	0.391									
	(0.305)	(0.549)	(0.267)									
WISI x Growth	**-0.048**	**0.174*** **	**-0.064***									
	(0.044)	**(0.066)**	**(0.036)**									
WISI x Inflation	-0.022	-0.076	-0.015									
	(0.019)	(0.066)	(0.014)									
Lag wage bill, % of GDP				0.084**	0.151***	0.030						
				(0.036)	(0.042)	(0.039)						
Wage bill indexation				-0.055	-0.002	-0.452						
				(0.063)	(0.066)	(0.627)						
Wage bill index. x Growth				**-0.008**	**0.016** **	**-0.032** **						
				(0.009)	**(0.007)**	**(0.015)**						
Wage bill index. x Inflation				0.000	-0.009	-0.000						
				(0.001)	(0.012)	(0.002)						
Lag social security, % of GDP							-0.072	0.112**	-0.177***			
							(0.062)	(0.056)	(0.038)			
Social security indexation							0.052	-0.071	0.160**			
							(0.071)	(0.090)	(0.064)			
Social security index. x Growth							**-0.011**	**0.029**	**-0.037** **			
							(0.015)	**(0.021)**	**(0.015)**			
Social security index. x Inflation							-0.005	0.017	-0.006*			
							(0.004)	(0.019)	(0.003)			
Lag social assist., % of GDP										-0.066	-0.005	-0.124*
										(0.049)	(0.031)	(0.072)
Social assistance indexation										-0.054	-0.140	0.165*
										(0.088)	(0.113)	(0.095)
Social assistance index. x Growth										**0.007**	**0.013**	**0.012**
										(0.009)	**(0.011)**	**(0.007)**
Social assistance index. X Inflation										-0.003***	-0.020*	-0.005***
										(0.001)	(0.012)	(0.002)
Inflation	-0.011***	-0.067	-0.009***	-0.005***	0.001	-0.005***	-0.002***	-0.018	-0.002***	-0.001***	-0.003	-0.001***
	(0.002)	(0.087)	(0.001)	(0.000)	(0.016)	(0.000)	(0.000)	(0.020)	(0.000)	(0.000)	(0.011)	(0.000)
Regulatory quality	-0.214	0.078	-0.175	0.086	0.013	0.262	-0.129**	-0.116	-0.110	0.037	0.009	0.114
	(0.180)	(0.257)	(0.221)	(0.093)	(0.038)	(0.236)	(0.060)	(0.075)	(0.094)	(0.059)	(0.044)	(0.099)
Centered R^2	0.278	0.578	0.172	0.302	0.58	0.209	0.282	0.551	0.233	0.246	0.37	0.235
KP rk LM (p-value)	0.000	0.001	0.001	0.096	.	0.283	0.001	0.120	0.012	0.086	0.069	0.191
KP rk Wald F	21.813	50.721	30.093	3.500	.	0.474	147.456	28.781	69.078	2.447	1.068	36.589
Hansen J (p-value)	0.262	0.861	0.552	0.266	.	.	0.187	0.163	0.774	.	.	.
Observations	2069	630	1439	951	559	392	1437	582	855	558	357	201
Countries	100	30	70	48	27	21	89	30	59	27	17	10

Note: Equation (3.2). AE = Advanced Economies; EMDE = Emerging Markets and Developing Economies. All regressions include country and year fixed effects. Commodity exporters excluded. Standard errors are clustered at the country level and reported in parentheses. Kleibergen and Paap (2006) rk LM, Kleibergen and Paap (2006) rk Wald F, and Hansen J statistics included. Overidentification statistic not reported when number of clusters insufficient to calculate robust covariance matrix. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, ***, and *, respectively.

Table C.4. Robustness of the marginal impact estimates

	Overall deficit, % of GDP			Wage bill, % of GDP			Social security, % of GDP			Social assistance, % of GDP		
	All	AE	EMDE	All	AE	EMDE	All	AE	EMDE	All	AE	EMDE
Growth	-0.083***	-0.201***	-0.057***	-0.026**	-0.046***	-0.007	-0.007	-0.036**	-0.008	-0.003	-0.013	0.003
	(0.028)	(0.028)	(0.021)	(0.012)	(0.007)	(0.019)	(0.008)	(0.016)	(0.009)	(0.008)	(0.009)	(0.011)
Lag growth	-0.047***	0.003	-0.054***	0.009**	0.003	0.016***	-0.002	-0.004	-0.003	0.002	-0.001	0.006
	(0.015)	(0.024)	(0.016)	(0.004)	(0.007)	(0.004)	(0.004)	(0.005)	(0.003)	(0.007)	(0.003)	(0.012)
Lag overall deficit,	-0.163***	-0.052	-0.166***									
% of GDP	(0.030)	(0.086)	(0.032)									
Weighted Index of	0.424*	0.152	0.627**									
Spending Index.	(0.253)	(0.428)	(0.275)									
WISI x Growth	**-0.063**	**0.177*** **	**-0.080** **									
	(0.038)	**(0.049)**	**(0.039)**									
WISI x Inflation	-0.033	-0.150**	-0.021									
	(0.024)	(0.067)	(0.019)									
Lag wage bill,				0.074**	0.140***	0.022						
% of GDP				(0.035)	(0.039)	(0.041)						
Wage bill indexation				0.016	0.034	-0.005						
				(0.047)	(0.073)	(0.109)						
Wage bill index.				**-0.007**	**0.010**	**-0.027***						
x Growth				**(0.008)**	**(0.007)**	**(0.014)**						
Wage bill index.				0.000	-0.010	-0.000						
x Inflation				(0.002)	(0.010)	(0.002)						
Lag social security,							-0.049	0.142***	-0.178***			
% of GDP							(0.063)	(0.050)	(0.045)			
Social security							0.070	-0.101	0.153**			
indexation							(0.053)	(0.081)	(0.059)			
Social security							**-0.017***	**0.029**	**-0.025** **			
index. x Growth							**(0.009)**	**(0.018)**	**(0.011)**			
Social security index.							-0.006	0.022	-0.006*			
x Inflation							(0.004)	(0.021)	(0.003)			
Lag social assist.,										-0.068	-0.007	-0.124
% of GDP										(0.051)	(0.032)	(0.083)
Social assistance										-0.065	-0.114	0.058
indexation										(0.068)	(0.078)	(0.095)
Social assistance										**0.009**	**0.016**	**0.008**
index. x Growth										**(0.009)**	**(0.011)**	**(0.013)**
Social assistance										-0.003**	-0.020	-0.004*
index. X Inflation										(0.001)	(0.012)	(0.002)
Inflation	-0.012***	-0.018	-0.011***	-0.005***	-0.006	-0.005***	-0.002***	-0.029	-0.001***	-0.001***	-0.002	-0.001**
	(0.002)	(0.088)	(0.002)	(0.000)	(0.014)	(0.000)	(0.000)	(0.022)	(0.000)	(0.000)	(0.010)	(0.000)
Regulatory quality	-0.117	-0.141	-0.047	0.063	0.042	0.181	-0.095**	-0.071	-0.060	0.019	-0.002	0.048
	(0.156)	(0.222)	(0.186)	(0.074)	(0.042)	(0.229)	(0.043)	(0.079)	(0.054)	(0.056)	(0.048)	(0.111)
Within R^2	0.136	0.548	0.088	0.292	0.547	0.188	0.268	0.531	0.206	0.232	0.356	0.216
Observations	2873	777	2096	1133	702	431	1852	711	1141	600	378	222
Countries	139	37	102	57	34	23	116	37	79	29	18	11

Note: Equation (3.2). AE = Advanced Economies; EMDE = Emerging Markets and Developing Economies. All regressions include country and year fixed effects. Commodity exporters excluded. Standard errors are clustered at the country level and reported in parentheses. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, ***, and *, respectively.

Table C.5. Marginal impact of social security indexation

	Fiscal rule? EMDE		High infl. volatility? EMDE		High inflation? EMDE		Commodity exporter? EMDE		Supply shock? AE		Supply shock? EMDE	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Growth	-0.017*	-0.015	-0.023	-0.007	-0.038*	-0.004	-0.001	-0.017	-0.072***	0.006	-0.016	-0.025**
	(0.009)	(0.015)	(0.017)	(0.010)	(0.019)	(0.009)	(0.002)	(0.012)	(0.008)	(0.011)	(0.015)	(0.010)
Lag growth	-0.013***	0.008	0.009	-0.011***	0.004	-0.001	-0.001	0.003	-0.018	-0.007	0.014*	-0.009**
	(0.004)	(0.006)	(0.007)	(0.004)	(0.007)	(0.006)	(0.001)	(0.006)	(0.011)	(0.006)	(0.007)	(0.004)
Lag social security,	0.015	-0.196***	-0.199***	0.001	-0.177***	-0.165*	-0.062	-0.177***	0.168*	0.017	-0.093	-0.176
% of GDP	(0.067)	(0.039)	(0.036)	(0.065)	(0.029)	(0.096)	(0.056)	(0.038)	(0.095)	(0.080)	(0.069)	(0.135)
Social security	-0.039	0.245***	0.193***	0.145*	0.086	0.085	-0.034	0.160**	-0.143	-0.141	0.313***	-0.047
indexation	(0.090)	(0.068)	(0.074)	(0.082)	(0.085)	(0.072)	(0.063)	(0.064)	(0.130)	(0.096)	(0.085)	(0.090)
Social security	**-0.018***	**-0.051****	**-0.038****	**-0.025****	**-0.020**	**-0.038*****	**-0.010**	**-0.037****	**0.057*****	**-0.005**	**-0.066*****	**-0.001**
index. x Growth	**(0.011)**	**(0.020)**	**(0.019)**	**(0.011)**	**(0.017)**	**(0.007)**	**(0.007)**	**(0.015)**	**(0.015)**	**(0.013)**	**(0.016)**	**(0.015)**
Social security index.	0.005	-0.012***	-0.006*	-0.023***	-0.000	-0.010	0.002	-0.006*	0.010	0.078***	-0.011**	-0.000
x Inflation	(0.003)	(0.003)	(0.003)	(0.009)	(0.004)	(0.010)	(0.002)	(0.003)	(0.024)	(0.030)	(0.005)	(0.007)
Inflation	-0.006**	-0.001***	-0.002***	0.004	-0.009**	-0.001***	-0.002	-0.002***	-0.009	-0.085***	-0.001***	-0.003
	(0.003)	(0.000)	(0.000)	(0.005)	(0.004)	(0.000)	(0.002)	(0.000)	(0.023)	(0.027)	(0.000)	(0.005)
Regulatory quality	-0.091	-0.162	-0.097	-0.087	-0.180	0.028	0.009	-0.110	0.168*	-0.399***	-0.157	-0.023
	(0.067)	(0.140)	(0.140)	(0.058)	(0.120)	(0.088)	(0.030)	(0.094)	(0.089)	(0.151)	(0.131)	(0.095)
Centered R^2	0.36	0.244	0.265	0.313	0.332	0.198	0.136	0.233	0.557	0.603	0.383	0.22
KP rk LM (p-value)	0.037	0.002	0.003	0.063	0.059	0.148	0.14	0.012	0.129	0.176	0.01	0.003
KP rk Wald F	12.842	179.329	34.641	48.9	20.918	.	7.919	69.078	230.809	14.913	59.874	23.446
Hansen J (p-value)	0.867	0.239	.	0.182	0.379	.	0.816	0.774	0.951	0.205	0.28	0.24
Observations	326	527	415	440	534	321	593	855	264	317	440	408
Countries	30	38	27	32	38	21	42	59	29	30	57	52

Note: Equation (3.2). AE = Advanced Economies; EMDE = Emerging Markets and Developing Economies. All regressions include country and year fixed effects. Standard errors are clustered at the country level and reported in parentheses. Kleibergen and Paap (2006) rk LM, Kleibergen and Paap (2006) rk Wald F, and Hansen J statistics included. Overidentification statistic not reported when number of clusters insufficient to calculate robust covariance matrix. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, ***, and *, respectively.

Table C.6. Marginal impact of indexation across 'boom' and 'bust' episodes

	Overall deficit, % of GDP				Wage bill, % of GDP				Social security, % of GDP				Social assistance, % of GDP			
	AE		EMDE		AE		EMDE		AE		EMDE		AE		EMDE	
	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust
Growth	-0.158***	-0.162***	-0.066**	-0.064**	-0.043***	-0.044***	-0.003	-0.009	-0.006	-0.007	-0.039*	-0.031*	-0.012*	-0.004	0.002	0.005
	(0.032)	(0.033)	(0.026)	(0.027)	(0.006)	(0.005)	(0.018)	(0.015)	(0.011)	(0.012)	(0.020)	(0.019)	(0.007)	(0.008)	(0.013)	(0.015)
Lag overall deficit, % of GDP	-0.060	-0.064	-0.146***	-0.147***												
	(0.060)	(0.060)	(0.035)	(0.035)												
Weighted Index of Spending Index.	-1.144	0.780	0.782**	0.019												
	(0.755)	(0.545)	(0.387)	(0.192)												
Lag wage bill, % of GDP					0.135***	0.135***	-0.001	0.001								
					(0.036)	(0.037)	(0.036)	(0.037)								
Wage bill indexation					-0.013	0.053	-0.372	-0.408								
					(0.072)	(0.086)	(0.646)	(0.444)								
Lag social security, % of GDP									0.139***	0.127**	-0.199***	-0.197***				
									(0.050)	(0.058)	(0.047)	(0.043)				
Social security indexation									-0.174	0.043	0.380**	-0.081				
									(0.156)	(0.082)	(0.167)	(0.082)				
Lag social assist., % of GDP													-0.005	0.001	-0.126*	-0.129*
													(0.032)	(0.028)	(0.070)	(0.068)
Social assistance indexation													-0.155	-0.101	0.105	0.226***
													(0.139)	(0.119)	(0.128)	(0.080)
Boom	-1.482*		-0.032		-0.011		0.049		-0.613		0.347*		-0.012		0.021	
	(0.779)		(0.163)		(0.036)		(0.101)		(0.380)		(0.179)		(0.098)		(0.091)	
Bust		0.997		0.102		-0.037		-0.189		0.430*		-0.295		0.179		0.014
		(0.686)		(0.264)		(0.044)		(0.199)		(0.233)		(0.203)		(0.130)		(0.158)
WISI x Boom	**3.144****		**-0.875****													
	(1.466)		**(0.408)**													
WISI x Bust		**-3.090****		**1.220****												
		(1.570)		**(0.604)**												
Wage bill index. x Boom					**0.159***		**-0.373***									
					(0.084)		**(0.196)**									
Wage bill index. x Bust						**-0.209****		**0.502***								
						(0.104)		**(0.303)**								
Social security index. x Boom									**0.535**		**-0.524****					
									(0.417)		**(0.253)**					
Social security index. x Bust										**-0.337**		**0.674****				
										(0.257)		**(0.337)**				
Social assistance index. x Boom													**0.126**		**0.169**	
													(0.130)		**(0.122)**	
Social assistance index. x Bust														**-0.188**		**-0.155**
														(0.154)		**(0.109)**
WISI x Inflation	-0.075	-0.096	-0.019	-0.013												
	(0.073)	(0.080)	(0.014)	(0.014)												
Wage bill index. x Inflation					-0.009	-0.013	0.000	0.001								
					(0.012)	(0.013)	(0.002)	(0.002)								
Social assistance index. x Inflation									0.006	0.025	-0.006*	-0.005				
									(0.017)	(0.020)	(0.003)	(0.003)				
Social assistance index. X Inflation													-0.020	-0.018	-0.005***	-0.006***
													(0.012)	(0.012)	(0.002)	(0.002)
Inflation	-0.063	-0.052	-0.008***	-0.008***	0.002	0.003	-0.005***	-0.005***	-0.010	-0.029	-0.002***	-0.002***	-0.003	-0.005	-0.001***	-0.001***
	(0.075)	(0.074)	(0.001)	(0.001)	(0.018)	(0.017)	(0.000)	(0.000)	(0.017)	(0.021)	(0.000)	(0.000)	(0.011)	(0.010)	(0.000)	(0.000)
Regulatory quality	-0.020	-0.179	-0.127	-0.134	0.013	0.012	0.284	0.206	-0.088	-0.108	-0.093	-0.101	0.014	-0.000	0.111	0.106
	(0.250)	(0.226)	(0.210)	(0.210)	(0.039)	(0.041)	(0.247)	(0.205)	(0.080)	(0.074)	(0.098)	(0.097)	(0.046)	(0.046)	(0.103)	(0.109)
Centered R^2	0.541	0.559	0.164	0.165	0.574	0.579	0.193	0.187	0.53	0.555	0.208	0.175	0.371	0.358	0.226	0.231
KP rk LM (p-value)	0.001	0.000	0.000	0.009	0.100	0.078	0.195	0.285	0.038	0.068	0.000	0.000	0.049	0.071	0.181	0.124
KP rk Wald F	18.382	24.094	45.279	27.204	24.007	49.355	0.687	0.473	13.871	22.070	19.154	24.163	1.218	1.098	13.732	8.978
Hansen J (p-value)	0.948	0.235	0.515	0.934	.	.	.	.	0.134	0.164	0.567	0.988	.	.	.	.
Observations	630	630	1440	1440	559	559	392	392	582	582	855	855	357	357	201	201
Countries	30	30	70	70	27	27	21	21	30	30	59	59	17	17	10	10

Note: Equations (3.3) and (3.4). AE = Advanced Economies; EMDE = Emerging Markets and Developing Economies. All regressions include country and year fixed effects. Commodity exporters excluded. Standard errors are clustered at the country level and reported in parentheses. Kleibergen and Paap (2006) rk LM, Kleibergen and Paap (2006) rk Wald F, and Hansen J statistics included. Overidentification statistic not reported when number of clusters insufficient to calculate robust covariance matrix. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, ***, and *, respectively.

C.4 Supplementary Robustness Analysis

C.4.1 Robustness of Fiscal Cyclicality Estimates

Table C.7. Robustness of cyclicality estimates to alternative estimation methods

	Overall deficit, % of GDP			Wage bill, % of GDP			Social security, % of GDP			Social assistance, % of GDP		
	AE	EM	LIDC	AE	EM	LIDC	AE	EM	LIDC	AE	EM	LIDC
Growth	-0.202***	-0.169***	-0.104***	-0.040***	-0.042***	-0.035***	-0.014	-0.016*	-0.009	-0.033***	-0.002	-0.002
	(0.035)	(0.061)	(0.036)	(0.006)	(0.008)	(0.009)	(0.014)	(0.009)	(0.007)	(0.008)	(0.016)	(0.013)
Lag growth	0.008	-0.026	-0.075**	-0.002	-0.007	-0.004	-0.006	-0.009**	0.006	0.006	-0.011	0.015
	(0.025)	(0.016)	(0.038)	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)	(0.006)	(0.008)	(0.014)
Inflation	-0.115	0.000***	-0.015***	-0.014	0.000***	-0.006***	-0.018*	0.000	-0.001***	-0.011	-0.006**	-0.002***
	(0.126)	(0.000)	(0.004)	(0.015)	(0.000)	(0.001)	(0.011)	(0.000)	(0.000)	(0.009)	(0.003)	(0.000)
Lag overall deficit, % of GDP	-0.046	-0.095**	-0.244***									
	(0.103)	(0.046)	(0.050)									
Lag wage bill, % of GDP				0.242***	-0.023	0.058						
				(0.065)	(0.054)	(0.047)						
Lag soc. security, % of GDP							0.198***	-0.216***	-0.107			
							(0.062)	(0.055)	(0.067)			
Lag social assist., % of GDP										0.082	-0.091	-0.149
										(0.071)	(0.089)	(0.104)
Regulatory quality	-0.508	-0.288	0.288	-0.034	-0.128	-0.071	-0.264**	-0.120	0.035	-0.070	0.306	0.053
	(0.572)	(0.639)	(0.721)	(0.073)	(0.115)	(0.117)	(0.105)	(0.086)	(0.064)	(0.064)	(0.492)	(0.100)
Wald χ^2	2010	1702	2906	10805	801	2189	1675	1500	55793	8802	1251	56
Prob > χ^2	0	0	0	0	0	0	0	0	0	0	0	0
Observations	703	1723	1046	684	1532	928	637	1048	534	358	380	183
Countries	37	92	57	37	86	54	37	83	45	19	21	10

Note: This table reports robustness checks to Table C.2. Dynamic GMM estimation applied. All regressions include country and year fixed effects. Commodity exporters excluded. Standard errors are clustered at the country level and reported in parentheses. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, ***, and *, respectively.

C.4.2 Robustness of Marginal Impact Estimates

Table C.8. Instrumental variable estimates with 'triple interaction'

	Overall deficit, % of GDP	Wage bill, % of GDP	Social security, % of GDP	Social assistance, % of GDP
Growth	-0.199***	-0.046***	-0.053**	-0.012
	(0.018)	(0.008)	(0.021)	(0.008)
Lag growth	-0.030***	0.012**	0.000	0.003
	(0.010)	(0.005)	(0.005)	(0.007)
EMDE x growth	0.145***	0.038***	0.043*	0.015
	(0.032)	(0.014)	(0.022)	(0.014)
Lag overall deficit,	-0.104**			
% of GDP	(0.044)			
Weighted Index of	-0.453			
Spending Indexation	(0.449)			
WISI x EMDE	1.063*			
	(0.547)			
WISI x growth	0.080			
	(0.062)			
WISI x EMDE	**-0.152****			
x growth	**(0.075)**			
WISI x Inflation	-0.023			
	(0.019)			
Lag wage bill,		0.084***		
% of GDP		(0.032)		
Wage bill indexation		-0.055		
		(0.045)		
Wage bill indexation		0.176***		
x EMDE		(0.064)		
Wage bill indexation		0.016**		
x growth		(0.007)		
Wage bill indexation		**-0.050*****		
x EMDE x growth		**(0.017)**		
Wage bill indexation		-0.001		
x inflation		(0.001)		
Lag social security,			-0.067	
% of GDP			(0.059)	
Social security			-0.076	
indexation			(0.084)	
Social security index.			0.270**	
x EMDE			(0.105)	
Social security index.			0.034	
x growth			(0.025)	
Social security index.			**-0.075****	
x EMDE x growth			**(0.030)**	
Social security index.			-0.006	
x Inflation			(0.004)	
Lag social assistance,				-0.082*
% of GDP				(0.049)
Social assistance				-0.261*
indexation				(0.142)
Social assistance index.				0.457**
x EMDE				(0.183)
Social assistance index.				0.015
x growth				(0.010)
Social assistance				**-0.009**
index. x EMDE x				**(0.014)**
Social assistance index.				-0.005***
x inflation				(0.001)
Inflation	-0.009***	-0.004***	-0.002***	-0.001***
	(0.001)	(0.000)	(0.000)	(0.000)
Regulatory quality	-0.165	0.086	-0.138*	0.049
	(0.177)	(0.093)	(0.073)	(0.057)
Centered R^2	0.299	0.326	0.301	0.25
KP rk LM (p-value)	0.000	.	0.000	0.328
KP rk Wald F	14.982	.	8.882	0.751
Hansen J (p-value)	0.528	.	0.339	.
Observations	2069	951	1437	558
Countries	100	48	89	27

Note: All regressions include country and year fixed effects. Commodity exporters excluded. Standard errors are clustered at the country level and reported in parentheses. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, ***, and *, respectively.

Table C.9. Robustness to alternative controls: overall deficit marginal effects

	Overall deficit, % of GDP																	
	Full Sample				Advanced Economies								Emerginf Markets and Developing Economies					
Growth	-0.103***	-0.103***	-0.115***	-0.106**	-0.116***	-0.122***	-0.210***	-0.203***	-0.207***	-0.259***	-0.214***	-0.257***	-0.063***	-0.064***	-0.067***	-0.058***	-0.066***	-0.071***
	(0.034)	(0.034)	(0.037)	(0.042)	(0.037)	(0.043)	(0.033)	(0.036)	(0.037)	(0.054)	(0.034)	(0.051)	(0.024)	(0.024)	(0.020)	(0.016)	(0.020)	(0.017)
Lag growth	-0.029**	-0.031**	-0.030*	-0.030**	-0.032*	-0.031*	0.021	0.023	0.021	0.107**	0.019	0.124**	-0.038***	-0.040***	-0.046***	-0.040***	-0.050***	-0.046***
	(0.014)	(0.014)	(0.017)	(0.014)	(0.018)	(0.017)	(0.022)	(0.022)	(0.022)	(0.050)	(0.023)	(0.051)	(0.010)	(0.011)	(0.013)	(0.012)	(0.014)	(0.015)
Inflation	-0.010***	-0.011***	-0.012***	-0.010***	-0.011***	-0.010***	-0.029	-0.072	-0.066	-0.047	-0.031	-0.219	-0.009***	-0.009***	-0.010***	-0.010***	-0.009***	-0.010***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.104)	(0.090)	(0.086)	(0.131)	(0.104)	(0.154)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Lag overall deficit, % of GDP	-0.134***	-0.131***	-0.132***	-0.085	-0.131***	-0.074	-0.008	-0.010	-0.008	0.475*	-0.005	0.491*	-0.162***	-0.158***	-0.167***	-0.122**	-0.166***	-0.122**
	(0.033)	(0.032)	(0.036)	(0.059)	(0.036)	(0.069)	(0.099)	(0.099)	(0.100)	(0.286)	(0.100)	(0.266)	(0.038)	(0.038)	(0.040)	(0.056)	(0.039)	(0.060)
WISI	0.104	0.116	0.038	0.322	0.021	0.175	-0.411	-0.443	-0.386	-2.022	-0.450	-2.891**	0.382	0.432	0.327	0.611**	0.379	0.480*
	(0.306)	(0.310)	(0.310)	(0.545)	(0.322)	(0.536)	(0.523)	(0.563)	(0.542)	(1.336)	(0.530)	(1.410)	(0.271)	(0.266)	(0.249)	(0.275)	(0.255)	(0.275)
WISI x Growth	-0.048	-0.047	-0.034	-0.049	-0.032	-0.030	0.182***	0.175***	0.175***	0.097	0.184***	0.024	-0.064*	-0.065*	-0.056	-0.040	-0.056	-0.023
	(0.045)	(0.045)	(0.046)	(0.062)	(0.047)	(0.063)	(0.067)	(0.066)	(0.066)	(0.217)	(0.068)	(0.216)	(0.036)	(0.035)	(0.035)	(0.034)	(0.034)	(0.036)
WISI x Inflation	-0.022	-0.022	-0.018	-0.053**	-0.019	-0.044**	-0.075	-0.074	-0.076	-0.104	-0.072	0.047	-0.015	-0.015	-0.009	-0.048**	-0.010	-0.037**
	(0.019)	(0.020)	(0.019)	(0.025)	(0.019)	(0.022)	(0.064)	(0.066)	(0.065)	(0.292)	(0.063)	(0.325)	(0.014)	(0.014)	(0.013)	(0.021)	(0.012)	(0.017)
Regulatory quality	-0.218	-0.262	-0.124	0.076	-0.153	0.078	0.108	0.048	0.106	0.138	0.084	0.686	-0.180	-0.217	-0.056	0.123	-0.036	0.168
	(0.181)	(0.193)	(0.183)	(0.227)	(0.198)	(0.267)	(0.244)	(0.294)	(0.251)	(0.782)	(0.266)	(0.847)	(0.224)	(0.237)	(0.243)	(0.206)	(0.248)	(0.254)
Lag Inflation	-0.001				-0.001	-0.002	-0.071				-0.077	0.193	-0.001				-0.001	-0.002**
	(0.001)				(0.001)	(0.001)	(0.050)				(0.049)	(0.120)	(0.001)				(0.001)	(0.001)
Lag public debt, % GDP		-0.002**			-0.004	-0.000		-0.002			-0.002	0.038**		-0.002**			-0.005	-0.002
		(0.001)			(0.003)	(0.002)		(0.003)			(0.003)	(0.016)		(0.001)			(0.004)	(0.003)
Exports, % GDP			0.001		0.002	-0.004			0.009		0.009	0.020***			-0.004		-0.004	-0.005
			(0.005)		(0.005)	(0.004)			(0.008)		(0.008)	(0.006)			(0.003)		(0.003)	(0.004)
Real interest rate				0.012		0.010				0.278**		0.331***				0.003		-0.000
				(0.011)		(0.011)				(0.121)		(0.110)				(0.008)		(0.008)
Centered R^2	0.279	0.28	0.294	0.249	0.297	0.269	0.58	0.579	0.58	0.653	0.582	0.674	0.172	0.173	0.179	0.183	0.183	0.197
KP rk LM (p-value)	0	0	0	0.001	0	0.002	0.001	0.001	0.001	0.094	0.001	0.079	0.001	0.001	0.001	0	0.001	0
KP rk Wald F	21.809	21.694	22.115	25.84	21.943	26.246	50.483	59.843	50.193	35.267	58.478	48.178	30.021	30.477	29.057	61.394	29.375	40.85
Hansen J (p-value)	0.243	0.227	0.224	0.179	0.145	0.145	0.907	0.918	0.73	.	.	.	0.468	0.427	0.463	0.475	0.225	0.339
Observations	2068	2044	1942	1245	1923	1153	630	628	630	195	628	193	1438	1416	1312	1050	1295	960
Countries	100	99	96	72	95	67	30	30	30	13	30	13	70	69	66	59	65	54

Note: This table reports robustness checks to Table C.3. Alternative controls applied. All regressions include country and year fixed effects. Commodity exporters excluded. Standard errors are clustered at the country level and reported in parentheses. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, ***, and *, respectively.

Table C.10. Robustness to alternative controls: wage bill marginal effects

	Wage bill, % of GDP																	
	Full Sample				Advanced Economies								Emerginf Markets and Developing Economies					
Growth	-0.025**	-0.024*	-0.021	-0.007	-0.022	-0.006	-0.045***	-0.046***	-0.045***	-0.030**	-0.045***	-0.026**	-0.006	-0.005	0.003	-0.005	0.002	-0.003
	(0.013)	(0.013)	(0.015)	(0.016)	(0.014)	(0.019)	(0.007)	(0.007)	(0.007)	(0.012)	(0.007)	(0.011)	(0.019)	(0.019)	(0.022)	(0.017)	(0.021)	(0.021)
Lag growth	0.012***	0.010**	0.009*	0.004	0.012**	0.000	0.005	0.006	0.005	0.006	0.006	0.006	0.019***	0.017***	0.015***	0.006	0.016***	-0.001
	(0.005)	(0.004)	(0.005)	(0.010)	(0.005)	(0.012)	(0.008)	(0.008)	(0.008)	(0.007)	(0.008)	(0.006)	(0.004)	(0.005)	(0.005)	(0.010)	(0.006)	(0.012)
Inflation	-0.005***	-0.005***	-0.005***	-0.004***	-0.005***	-0.004***	0.000	0.001	-0.001	-0.005	-0.001	-0.009	-0.005***	-0.005***	-0.005***	-0.004***	-0.005***	-0.005***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.018)	(0.016)	(0.016)	(0.009)	(0.018)	(0.008)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)
Lag wage bill, % of GDP	0.108***	0.083**	0.083**	0.014	0.106***	0.034	0.150***	0.151***	0.150***	0.630***	0.150***	0.624***	0.060	0.029	0.018	-0.017	0.048	-0.007
	(0.033)	(0.036)	(0.037)	(0.060)	(0.035)	(0.061)	(0.041)	(0.042)	(0.042)	(0.141)	(0.042)	(0.136)	(0.038)	(0.039)	(0.039)	(0.062)	(0.040)	(0.060)
Wage bill indexation	-0.037	-0.056	-0.074	-0.076	-0.058	-0.066	-0.000	-0.003	-0.004	-0.027	-0.005	-0.001	-0.409	-0.459	-0.485	-0.478	-0.410	-0.285
	(0.057)	(0.065)	(0.075)	(0.063)	(0.070)	(0.064)	(0.065)	(0.067)	(0.059)	(0.092)	(0.059)	(0.080)	(0.584)	(0.651)	(0.712)	(0.349)	(0.649)	(0.371)
Wage bill indexation x Growth	-0.007	-0.008	-0.008	-0.008	-0.007	-0.007	0.015**	0.016**	0.015**	-0.000	0.015**	-0.003	-0.031**	-0.032**	-0.031**	-0.021	-0.030**	-0.023
	(0.008)	(0.008)	(0.009)	(0.012)	(0.009)	(0.013)	(0.007)	(0.007)	(0.007)	(0.005)	(0.007)	(0.005)	(0.014)	(0.015)	(0.015)	(0.016)	(0.015)	(0.018)
Wage bill indexation x Inflation	-0.000	0.000	0.001	0.009	0.001	0.014	-0.009	-0.009	-0.009	0.067*	-0.010	0.067*	-0.001	-0.000	0.001	0.010*	0.001	0.013
	(0.001)	(0.001)	(0.002)	(0.006)	(0.002)	(0.012)	(0.012)	(0.012)	(0.012)	(0.036)	(0.012)	(0.036)	(0.002)	(0.002)	(0.003)	(0.005)	(0.003)	(0.010)
Regulatory quality	0.061	0.092	0.082	-0.008	0.067	-0.065	0.011	0.023	0.015	-0.143*	0.029	-0.220	0.204	0.267	0.245	-0.012	0.182	-0.085
	(0.080)	(0.105)	(0.084)	(0.125)	(0.086)	(0.139)	(0.037)	(0.039)	(0.040)	(0.085)	(0.039)	(0.167)	(0.218)	(0.255)	(0.233)	(0.152)	(0.223)	(0.176)
Lag Inflation	0.002***				0.002***	0.001***	0.002				0.001	0.025	0.002***				0.002***	0.001***
	(0.000)				(0.000)	(0.000)	(0.006)				(0.006)	(0.022)	(0.001)				(0.001)	(0.000)
Lag public debt, % GDP		0.000			0.000	-0.001		0.000			0.001	-0.001		0.000			-0.001	-0.003
		(0.001)			(0.001)	(0.002)		(0.000)			(0.000)	(0.004)		(0.001)			(0.002)	(0.003)
Exports, % GDP			-0.004**		-0.004*	-0.002			-0.003		-0.003	-0.004			-0.006**		-0.005*	-0.001
			(0.002)		(0.002)	(0.003)			(0.002)		(0.002)	(0.003)			(0.003)		(0.003)	(0.003)
Real interest rate				0.017***		0.018***				0.068***		0.066***				0.015***		0.016***
				(0.004)		(0.005)				(0.013)		(0.016)				(0.004)		(0.004)
Centered R^2	0.308	0.302	0.322	0.32	0.328	0.354	0.58	0.58	0.582	0.776	0.583	0.781	0.217	0.209	0.24	0.312	0.248	0.354
KP rk LM (p-value)	0.096	0.096	0.1	0.072	0.1	0.084	.	.	.	.	.	.	0.283	0.283	0.28	0.235	0.28	0.233
KP rk Wald F	3.487	3.506	3.179	7.387	3.116	7.667	.	.	.	.	.	.	0.472	0.475	0.473	0.837	0.485	0.943
Hansen J (p-value)	0.265	0.268	0.377	0.418	0.39	.	.	.	.	.	.	.	.	.	.	.	.	.
Observations	950	950	924	444	922	420	559	559	559	136	559	136	391	391	365	308	363	284
Countries	48	48	47	29	47	28	27	27	27	10	27	10	21	21	20	19	20	18

Note: This table reports robustness checks to Table C.3. Alternative controls applied. All regressions include country and year fixed effects. Commodity exporters excluded. Standard errors are clustered at the country level and reported in parentheses. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, ***, and *, respectively.

Table C.11. Robustness to alternative controls: social security marginal effects

	Social security, % of GDP																	
	Full Sample					Advanced Economies							Emerginf Markets and Developing Economies					
Growth	-0.016	-0.016	-0.016	-0.021*	-0.016	-0.021*	-0.033*	-0.037*	-0.035*	-0.091**	-0.033*	-0.096**	-0.018	-0.017	-0.017	-0.025**	-0.017	-0.025**
	(0.010)	(0.010)	(0.010)	(0.012)	(0.010)	(0.011)	(0.019)	(0.019)	(0.019)	(0.046)	(0.019)	(0.047)	(0.012)	(0.011)	(0.012)	(0.011)	(0.012)	(0.011)
Lag growth	0.000	-0.001	-0.000	0.001	0.000	0.001	-0.005	-0.005	-0.005	0.006	-0.004	0.009*	0.004	0.002	0.003	-0.002	0.003	-0.003
	(0.005)	(0.005)	(0.005)	(0.003)	(0.005)	(0.003)	(0.007)	(0.006)	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)	(0.003)	(0.005)	(0.003)
Inflation	-0.002***	-0.002***	-0.002***	-0.001***	-0.002***	-0.001***	-0.027	-0.016	-0.019	-0.004	-0.025	-0.032	-0.002***	-0.001***	-0.001***	-0.001***	-0.002***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.026)	(0.021)	(0.020)	(0.013)	(0.026)	(0.028)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Lag social security,	-0.070	-0.071	-0.072	-0.137***	-0.070	-0.137***	0.116**	0.108*	0.113**	0.069	0.111*	0.076	-0.172***	-0.176***	-0.177***	-0.127*	-0.171***	-0.127*
% of GDP	(0.062)	(0.062)	(0.062)	(0.048)	(0.063)	(0.050)	(0.056)	(0.057)	(0.056)	(0.075)	(0.057)	(0.080)	(0.040)	(0.038)	(0.038)	(0.068)	(0.040)	(0.069)
Social security	0.047	0.048	0.052	0.137	0.044	0.122	-0.066	-0.061	-0.069	0.000	-0.053	0.000	0.147**	0.152**	0.161**	0.210**	0.142**	0.195*
indexation	(0.071)	(0.071)	(0.072)	(0.133)	(0.071)	(0.130)	(0.094)	(0.087)	(0.091)	(.)	(0.090)	(.)	(0.064)	(0.062)	(0.065)	(0.105)	(0.064)	(0.100)
Social security index.	-0.011	-0.011	-0.011	0.000	-0.011	0.000	0.027	0.030	0.029	0.098**	0.028	0.103**	-0.037**	-0.038**	-0.037**	-0.036*	-0.038**	-0.038*
x Growth	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.016)	(0.022)	(0.021)	(0.021)	(0.047)	(0.022)	(0.048)	(0.015)	(0.015)	(0.015)	(0.020)	(0.015)	(0.020)
Social security index.	-0.006	-0.005	-0.005	-0.004	-0.006*	-0.005	0.017	0.015	0.017	0.027	0.015	0.044*	-0.007**	-0.006*	-0.006*	-0.006	-0.007**	-0.007
x Inflation	(0.004)	(0.004)	(0.004)	(0.005)	(0.003)	(0.004)	(0.018)	(0.019)	(0.019)	(0.022)	(0.019)	(0.026)	(0.003)	(0.003)	(0.003)	(0.005)	(0.003)	(0.004)
Regulatory quality	-0.139**	-0.136**	-0.136**	-0.085	-0.149**	-0.107	-0.131*	-0.084	-0.118	-0.192	-0.097	-0.187	-0.133	-0.110	-0.116	-0.087	-0.137	-0.114
	(0.059)	(0.061)	(0.059)	(0.074)	(0.060)	(0.078)	(0.078)	(0.084)	(0.077)	(0.139)	(0.087)	(0.167)	(0.093)	(0.093)	(0.094)	(0.109)	(0.091)	(0.109)
Lag Inflation	0.000				0.000	-0.000	0.015				0.016	0.026	0.001				0.001	-0.000
	(0.000)				(0.000)	(0.000)	(0.018)				(0.018)	(0.017)	(0.000)				(0.000)	(0.000)
Lag public debt,		-0.000			-0.000	-0.000		0.001			0.001*	0.000		-0.001			-0.001	-0.001
% GDP		(0.001)			(0.001)	(0.001)		(0.001)			(0.001)	(0.003)		(0.001)			(0.001)	(0.001)
Exports, % GDP			-0.001		-0.001	-0.000			-0.001		-0.001	0.001			-0.002		-0.001	-0.000
			(0.001)		(0.001)	(0.001)			(0.001)		(0.001)	(0.001)			(0.001)		(0.001)	(0.001)
Real interest rate				0.006**		0.006**				0.016*		0.019*				0.005**		0.005**
				(0.003)		(0.002)				(0.009)		(0.011)				(0.002)		(0.002)
Centered R^2	0.284	0.282	0.284	0.212	0.285	0.214	0.553	0.552	0.552	0.612	0.554	0.616	0.236	0.235	0.234	0.247	0.237	0.25
KP rk LM (p-value)	0.001	0	0	0.023	0	0.018	0.107	0.118	0.125	0.527	0.106	0.521	0.012	0.01	0.012	0.01	0.009	0.008
KP rk Wald F	146.637	148.225	148.195	36.348	148.571	36.918	28.334	28.678	30.135	143.093	29.579	146.26	68.273	68.747	70.591	60.592	68.778	63.248
Hansen J (p-value)	0.189	0.199	0.213	0.71	0.217	0.712	0.173	0.174	0.197	.	.	.	0.737	0.699	0.737	0.977	0.649	0.904
Observations	1436	1432	1419	853	1413	836	582	580	582	176	580	174	854	852	837	677	833	662
Countries	89	89	87	62	87	60	30	30	30	13	30	13	59	59	57	49	57	47

Note: This table reports robustness checks to Table C.3. Alternative controls applied. All regressions include country and year fixed effects. Commodity exporters excluded. Standard errors are clustered at the country level and reported in parentheses. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, ***, and *, respectively.

Table C.12. Robustness to alternative controls: social assistance marginal effects

	Social assistance, % of GDP																	
	Full Sample					Advanced Economies							Emerginf Markets and Developing Economies					
Growth	-0.004	-0.003	-0.002	-0.002	-0.005	-0.006	-0.011	-0.011	-0.011	0.039	-0.011	0.045	-0.001	-0.001	0.003	-0.014	-0.004	-0.020
	(0.007)	(0.007)	(0.007)	(0.013)	(0.007)	(0.013)	(0.008)	(0.009)	(0.009)	(0.029)	(0.008)	(0.028)	(0.008)	(0.008)	(0.009)	(0.016)	(0.008)	(0.017)
Lag growth	0.004	0.004	0.003	0.000	0.005	0.003	-0.001	-0.001	-0.001	-0.010	-0.001	-0.011	0.008	0.010	0.007	-0.002	0.012	0.005
	(0.008)	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)	(0.003)	(0.003)	(0.003)	(0.011)	(0.003)	(0.008)	(0.011)	(0.010)	(0.011)	(0.010)	(0.010)	(0.011)
Inflation	-0.002***	-0.001***	-0.001***	-0.002*	-0.002***	-0.002**	-0.006	-0.002	-0.005	0.053***	-0.005	0.052***	-0.002***	-0.002***	-0.001***	-0.002**	-0.002***	-0.003**
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.012)	(0.012)	(0.011)	(0.017)	(0.013)	(0.017)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)
Lag social assist.,	-0.044	-0.065	-0.067	-0.105	-0.046	-0.070	-0.005	-0.004	-0.005	0.091	-0.005	0.084	-0.093	-0.121*	-0.124*	-0.081	-0.095	-0.033
% of GDP	(0.053)	(0.048)	(0.049)	(0.075)	(0.052)	(0.080)	(0.030)	(0.031)	(0.031)	(0.200)	(0.030)	(0.199)	(0.077)	(0.070)	(0.072)	(0.095)	(0.074)	(0.096)
Social assistance	-0.032	-0.005	-0.058	-0.239*	0.013	-0.040	-0.131	-0.102	-0.155	0.000	-0.102	0.000	0.177*	0.290**	0.170*	-0.283*	0.290**	-0.081
indexation	(0.093)	(0.100)	(0.091)	(0.137)	(0.109)	(0.139)	(0.114)	(0.125)	(0.124)	(.)	(0.132)	(.)	(0.098)	(0.135)	(0.101)	(0.154)	(0.137)	(0.166)
Social assistance	0.008	0.007	0.007	0.004	0.008	0.008	0.013	0.013	0.013	-0.009	0.013	-0.011	0.013*	0.014**	0.011	0.029**	0.017**	0.038***
index. x Growth	(0.009)	(0.009)	(0.009)	(0.013)	(0.009)	(0.013)	(0.010)	(0.011)	(0.011)	(0.008)	(0.011)	(0.009)	(0.007)	(0.007)	(0.007)	(0.014)	(0.007)	(0.011)
Social assistance	-0.004***	-0.004***	-0.003***	0.006**	-0.004***	0.004	-0.020*	-0.022*	-0.019	0.048	-0.021*	0.053	-0.006***	-0.007***	-0.005***	0.001	-0.007***	-0.002
index. X Inflation	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.003)	(0.012)	(0.013)	(0.012)	(0.032)	(0.013)	(0.035)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.004)
Regulatory quality	0.020	0.054	0.031	0.041	0.030	0.100	0.004	0.020	0.008	-0.285	0.014	-0.339	0.092	0.120	0.122	0.063	0.077	0.074
	(0.046)	(0.058)	(0.055)	(0.121)	(0.043)	(0.085)	(0.049)	(0.048)	(0.043)	(0.254)	(0.052)	(0.345)	(0.081)	(0.087)	(0.108)	(0.114)	(0.079)	(0.060)
Lag Inflation	0.001***				0.001***	0.001*	0.005				0.005	0.008	0.001***				0.001**	0.001*
	(0.000)				(0.000)	(0.000)	(0.011)				(0.011)	(0.026)	(0.000)				(0.000)	(0.001)
Lag public debt,		0.001**			0.001**	0.004**		0.000			0.001	-0.002		0.004**			0.004**	0.005
% GDP		(0.001)			(0.001)	(0.002)		(0.000)			(0.000)	(0.002)		(0.002)			(0.002)	(0.004)
Exports, % GDP			-0.001		-0.001*	-0.003			-0.001		-0.001	-0.004			0.001		-0.002	-0.005
			(0.001)		(0.001)	(0.002)			(0.001)		(0.001)	(0.005)			(0.002)		(0.002)	(0.004)
Real interest rate				-0.002		-0.002				0.016		0.013				-0.004		-0.005
				(0.005)		(0.006)				(0.014)		(0.012)				(0.006)		(0.006)
Centered R^2	0.252	0.248	0.247	0.249	0.253	0.267	0.37	0.37	0.37	0.646	0.371	0.647	0.239	0.245	0.235	0.227	0.247	0.25
KP rk LM (p-value)	0.076	0.104	0.094	0.01	0.098	0.01	0.063	0.064	0.072	.	0.06	.	0.167	0.185	0.171	0.059	0.156	0.079
KP rk Wald F	2.154	2.472	2.406	27.653	2.194	22.39	1.073	1.307	1.131	.	1.347	.	28.23	30.503	36.19	13.18	19.851	12.011
Hansen J (p-value)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Observations	557	558	558	221	557	220	357	357	357	74	357	74	200	201	201	147	200	146
Countries	27	27	27	15	27	15	17	17	17	6	17	6	10	10	10	9	10	9

Note: This table reports robustness checks to Table C.3. Alternative controls applied. All regressions include country and year fixed effects. Commodity exporters excluded. Standard errors are clustered at the country level and reported in parentheses. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, ***, and *, respectively.

Table C.13. Robustness of marginal impact estimates to GMM estimation

	Overall deficit, % of GDP			Wage bill, % of GDP			Social security, % of GDP			Social assistance, % of GDP		
	All	AE	EMDE	All	AE	EMDE	All	AE	EMDE	All	AE	EMDE
Growth	-0.134***	-0.230***	-0.098***	-0.043***	-0.056***	-0.019	-0.009	-0.034*	-0.012	-0.004	-0.014*	0.002
	(0.039)	(0.032)	(0.029)	(0.010)	(0.006)	(0.013)	(0.009)	(0.018)	(0.009)	(0.007)	(0.008)	(0.008)
Lag growth	-0.083***	-0.000	-0.088***	-0.000	-0.001	0.011**	-0.004	-0.004	-0.004	0.009	-0.002	0.017
	(0.019)	(0.022)	(0.021)	(0.003)	(0.005)	(0.004)	(0.005)	(0.005)	(0.004)	(0.008)	(0.003)	(0.012)
Lag overall deficit, % of GDP	-0.184***	-0.039	-0.192***									
	(0.043)	(0.107)	(0.045)									
Weighted Index of Spending Index.	1.148*	-0.099	2.362***									
	(0.688)	(0.711)	(0.812)									
WISI x Growth	**-0.085**	**0.201*** **	**-0.150*** **									
	(0.054)	**(0.075)**	**(0.048)**									
WISI x Inflation	-0.108**	-0.203**	-0.096**									
	(0.051)	(0.098)	(0.048)									
Lag wage bill, % of GDP				0.112**	0.184***	0.046						
				(0.050)	(0.045)	(0.066)						
Wage bill indexation				-0.118	-0.101	0.034						
				(0.111)	(0.113)	(0.163)						
Wage bill index. x Growth				**-0.005**	**0.009**	**-0.019**						
				(0.008)	**(0.008)**	**(0.012)**						
Wage bill index. x Inflation				-0.007	-0.012	-0.002						
				(0.005)	(0.014)	(0.003)						
Lag social security, % of GDP							-0.051	0.198***	-0.207***			
							(0.079)	(0.065)	(0.059)			
Social security indexation							0.098	-0.238***	0.321**			
							(0.098)	(0.090)	(0.129)			
Social security index. x Growth							**-0.023****	**0.023**	**-0.025****			
							(0.011)	**(0.022)**	**(0.012)**			
Social security index. x Inflation							-0.012**	0.013	-0.011***			
							(0.006)	(0.017)	(0.004)			
Lag social assist., % of GDP										-0.088	0.015	-0.184**
										(0.061)	(0.049)	(0.080)
Social assistance indexation										-0.030	-0.042	0.206
										(0.122)	(0.087)	(0.140)
Social assistance index. x Growth										**0.015**	**0.022****	**0.009**
										(0.010)	**(0.010)**	**(0.012)**
Social assistance index. X Inflation										0.001	-0.024**	-0.001
										(0.002)	(0.010)	(0.003)
Inflation	-0.024**	-0.056	-0.021**	-0.006***	-0.016	-0.006***	-0.003*	-0.028	-0.003**	-0.002***	-0.008	-0.001***
	(0.010)	(0.111)	(0.009)	(0.001)	(0.015)	(0.001)	(0.002)	(0.018)	(0.001)	(0.000)	(0.010)	(0.000)
Regulatory quality	-0.308	-0.340	0.186	0.090	0.031	0.069	-0.401***	-0.203*	-0.266**	0.007	-0.001	0.076
	(0.517)	(0.645)	(0.627)	(0.114)	(0.081)	(0.209)	(0.103)	(0.112)	(0.123)	(0.126)	(0.066)	(0.162)
Wald χ^2	1967.995	11625.726	2502.962	7967.546	23502.963	353.833	938.195	2360.93	3990.673	3865.921	1098.799	20.644
Prob > χ^2	0	0	0	0	0	0	0	0	0	0	0	0.024
Observations	2596	703	1893	1015	634	381	1619	637	982	541	342	199
Countries	139	37	102	56	34	22	113	37	76	29	18	11

Note: This table reports robustness checks to Table C.3. Dynamic GMM estimation applied. All regressions include country and year fixed effects. Commodity exporters excluded. Standard errors are clustered at the country level and reported in parentheses. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, ***, and *, respectively.

Table C.14. Robustness of marginal impact estimates to IPW estimation

	Wage bill, % of GDP			Social security, % of GDP			Social assistance, % of GDP		
	All	AE	EMDE	All	AE	EMDE	All	AE	EMDE
Growth	-0.041***	-0.056***	-0.010	-0.004	-0.022***	-0.008	-0.012**	-0.016***	0.000
	(0.009)	(0.005)	(0.018)	(0.005)	(0.007)	(0.007)	(0.005)	(0.004)	(0.015)
Lag growth	0.012***	0.010*	0.014**	-0.002	-0.009	-0.003	0.004	0.002	0.006
	(0.004)	(0.005)	(0.006)	(0.003)	(0.006)	(0.003)	(0.007)	(0.004)	(0.011)
Lag wage bill,	0.091**	0.120**	0.067						
% of GDP	(0.037)	(0.059)	(0.049)						
Wage bill indexation	0.018	0.025	-0.070						
	(0.065)	(0.065)	(0.129)						
Wage bill index.	**-0.005**	**0.008**	**-0.026**						
x Growth	**(0.012)**	**(0.008)**	**(0.023)**						
Wage bill index. x	-0.003	0.005	-0.003						
Inflation	(0.002)	(0.016)	(0.003)						
Lag social security,				0.017	0.172***	-0.095			
% of GDP				(0.060)	(0.049)	(0.057)			
Social security				0.127*	-0.091	0.180***			
indexation				(0.070)	(0.090)	(0.061)			
Social security				**-0.023****	**0.015**	**-0.026*****			
index. x Growth				**(0.009)**	**(0.011)**	**(0.010)**			
Social security index.				-0.008*	0.068*	-0.008*			
x Inflation				(0.005)	(0.034)	(0.004)			
Lag social assist.,							-0.082	-0.031	-0.159
% of GDP							(0.061)	(0.057)	(0.106)
Social assistance							-0.087	-0.167	0.066
indexation							(0.076)	(0.097)	(0.099)
Social assistance							**0.010**	**0.016**	**0.004**
index. x Growth							**(0.008)**	**(0.009)**	**(0.017)**
Social assistance							0.003**	-0.017*	0.000
index. X Inflation							(0.001)	(0.010)	(0.002)
Inflation	-0.007***	-0.010	-0.007***	-0.002***	-0.078**	-0.001***	-0.001***	-0.001	-0.001
	(0.001)	(0.013)	(0.001)	(0.001)	(0.036)	(0.000)	(0.000)	(0.013)	(0.001)
Regulatory quality	-0.101*	-0.091*	0.099	-0.150***	-0.110	-0.105*	-0.013	-0.001	-0.014
	(0.055)	(0.046)	(0.266)	(0.052)	(0.087)	(0.060)	(0.039)	(0.050)	(0.087)
Within R^2	0.494	0.736	0.199	0.378	0.691	0.21	0.458	0.667	0.212
Observations	1079	670	409	1847	709	1138	600	378	222

Note: This table reports robustness checks to Table C.3. IPW correction applied. All regressions include country and year fixed effects. Commodity exporters excluded. Standard errors are clustered at the country level and reported in parentheses. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, ***, and *, respectively.

C.4.3 Robustness Across Alternative Episodes

Table C.15. Robustness of 'boom/bust' estimates to GMM estimation

	Overall deficit, % of GDP				Wage bill, % of GDP				Social security, % of GDP				Social assistance, % of GDP			
	AE		EMDE		AE		EMDE		AE		EMDE		AE		EMDE	
	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust
Growth	-0.197***	-0.201***	-0.088***	-0.099***	-0.058***	-0.058***	-0.024*	-0.020	-0.009	-0.011	-0.028*	-0.023	-0.014	-0.004	0.006	0.004
	(0.035)	(0.036)	(0.033)	(0.032)	(0.006)	(0.005)	(0.014)	(0.013)	(0.014)	(0.014)	(0.017)	(0.015)	(0.009)	(0.009)	(0.009)	(0.011)
Lag overall deficit, % of GDP	-0.056	-0.056	-0.186***	-0.185***												
	(0.086)	(0.087)	(0.044)	(0.045)												
Weighted Index of Spending Index.	-0.190	0.538	2.720***	1.668**												
	(0.640)	(0.668)	(0.993)	(0.787)												
Lag wage bill, % of GDP					0.190***	0.191***	0.029	0.027								
					(0.042)	(0.042)	(0.066)	(0.066)								
Wage bill indexation					-0.099	-0.066	0.059	-0.032								
					(0.119)	(0.094)	(0.179)	(0.191)								
Lag social security, % of GDP									0.202***	0.207***	-0.209***	-0.210***				
									(0.061)	(0.064)	(0.064)	(0.059)				
Social security indexation									-0.160*	-0.146**	0.424***	0.232*				
									(0.093)	(0.070)	(0.137)	(0.141)				
Lag social assist., % of GDP													0.034	0.036	-0.180***	-0.178***
													(0.045)	(0.049)	(0.067)	(0.061)
Social assistance indexation													-0.002	-0.008	0.171	0.195
													(0.074)	(0.071)	(0.124)	(0.142)
Boom	-0.496		-0.092		0.018		0.060		-0.037		0.192*		0.047		0.014	
	(0.313)		(0.298)		(0.026)		(0.085)		(0.083)		(0.107)		(0.055)		(0.065)	
Bust		0.204		-0.193		-0.029		0.008		0.286***		-0.036		0.135*		-0.031
		(0.433)		(0.394)		(0.058)		(0.106)		(0.110)		(0.091)		(0.072)		(0.174)
WISI x Boom	**0.956***		**-1.050***													
	(0.495)		**(0.569)**													
WISI x Bust		**-1.348****		**1.651****												
		(0.681)		**(0.660)**												
Wage bill index. x Boom					**0.020**		**-0.150**									
					(0.063)		**(0.106)**									
Wage bill index. x Bust						**-0.113**		**0.254***								
						(0.111)		**(0.138)**								
Social security index. x Boom									**-0.124***		**-0.282*****					
									(0.068)		**(0.067)**					
Social security index. x Bust										**-0.193****		**0.181**				
										(0.094)		**(0.114)**				
Social assistance index. x Boom													**0.051**		**0.017**	
													(0.051)		**(0.139)**	
Social assistance index. x Bust														**-0.087**		**-0.094**
														(0.088)		**(0.104)**
WISI x Inflation	-0.149	-0.188*	-0.109**	-0.104**												
	(0.093)	(0.103)	(0.049)	(0.047)												
Wage bill index. x Inflation					-0.009	-0.016	-0.002	-0.002								
					(0.014)	(0.013)	(0.003)	(0.003)								
Social assistance index. x Inflation									0.013	0.017	-0.011***	-0.011***				
									(0.017)	(0.017)	(0.004)	(0.004)				
Social assistance index. X Inflation													-0.023**	-0.020**	-0.000	-0.001
													(0.010)	(0.009)	(0.003)	(0.003)
Inflation	-0.078	-0.063	-0.018**	-0.018**	-0.017	-0.017	-0.006***	-0.006***	-0.032*	-0.036**	-0.003**	-0.003**	-0.008	-0.012	-0.001***	-0.001***
	(0.104)	(0.100)	(0.007)	(0.007)	(0.015)	(0.015)	(0.001)	(0.001)	(0.018)	(0.016)	(0.001)	(0.001)	(0.009)	(0.009)	(0.000)	(0.000)
Regulatory quality	-0.528	-0.528	0.216	0.222	0.030	0.029	0.046	0.032	-0.227*	-0.200*	-0.238*	-0.242**	-0.006	-0.010	0.060	0.066
	(0.582)	(0.584)	(0.630)	(0.628)	(0.079)	(0.080)	(0.210)	(0.220)	(0.118)	(0.114)	(0.122)	(0.117)	(0.063)	(0.062)	(0.175)	(0.171)
Wald χ^2	4472.903	2494.132	2034.682	2144.344	23327.01	21200.622	239.976	148.512	2917.722	3523.728	2491.605	2502.827	1783.287	1101.552	39.279	34.464
Prob > χ^2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Observations	703	703	1893	1893	634	634	381	381	637	637	982	982	342	342	199	199
Countries	37	37	102	102	34	34	22	22	37	37	76	76	18	18	11	11

Note: This table reports robustness checks to Table C.6. Dynamic GMM estimation applied. All regressions include country and year fixed effects. Commodity exporters excluded. Standard errors are clustered at the country level and reported in parentheses. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, **, and *, respectively.

Table C.16. Robustness of 'boom/bust' estimates to IPW estimation

	Wage bill, % of GDP				Social security, % of GDP				Social assistance, % of GDP			
	AE		EMDE		AE		EMDE		AE		EMDE	
	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust
Growth	-0.053***	-0.054***	-0.012	-0.016	-0.007	-0.007	-0.019	-0.016	-0.016***	-0.014***	0.003	0.005
	(0.004)	(0.004)	(0.018)	(0.014)	(0.012)	(0.012)	(0.012)	(0.010)	(0.002)	(0.003)	(0.017)	(0.016)
Lag wage bill, % of GDP	0.087*	0.091*	0.028	0.031								
	(0.050)	(0.048)	(0.049)	(0.049)								
Wage bill indexation	0.067	0.050	-0.056	-0.150								
	(0.080)	(0.078)	(0.120)	(0.116)								
Lag social security, % of GDP					0.175***	0.196***	-0.093	-0.095				
					(0.054)	(0.051)	(0.062)	(0.060)				
Social security indexation					-0.012	-0.017	0.261***	0.038				
					(0.075)	(0.061)	(0.064)	(0.039)				
Lag social assist., % of GDP									-0.019	-0.016	-0.168	-0.165
									(0.055)	(0.058)	(0.098)	(0.096)
Social assistance indexation									-0.125	-0.119	0.115	0.090
									(0.106)	(0.107)	(0.127)	(0.056)
Boom	0.016		0.047		-0.103		0.123		0.040		0.024	
	(0.041)		(0.108)		(0.093)		(0.078)		(0.043)		(0.071)	
Bust		-0.099*		-0.161		0.332**		-0.027		0.055		0.030
		(0.054)		(0.251)		(0.123)		(0.069)		(0.075)		(0.102)
Wage bill index. x Boom	**-0.012**		**-0.126**									
	(0.061)		**(0.137)**									
Wage bill index. x Bust		**-0.033**		**0.250**								
		(0.092)		**(0.272)**								
Social security index. x Boom					**-0.029**		**-0.263*** **					
					(0.086)		**(0.063)**					
Social security index. x Bust						**-0.227****		**0.246****				
						(0.098)		**(0.099)**				
Social assistance index. x Boom									**0.020**		**-0.040**	
									(0.058)		**(0.152)**	
Social assistance index. x Bust										**-0.059**		**0.005**
										(0.089)		**(0.135)**
Wage bill index. x Inflation	0.004	0.002	-0.002	-0.002								
	(0.015)	(0.015)	(0.003)	(0.003)								
Social assistance index. x Inflation					0.062*	0.072**	-0.008*	-0.008*				
					(0.033)	(0.032)	(0.004)	(0.004)				
Social assistance index. X Inflation									-0.016	-0.015	0.001	0.001
									(0.010)	(0.010)	(0.003)	(0.003)
Inflation	-0.007	-0.005	-0.007***	-0.007***	-0.078**	-0.086**	-0.002***	-0.002***	-0.000	-0.002	-0.001	-0.001
	(0.014)	(0.014)	(0.001)	(0.001)	(0.035)	(0.034)	(0.001)	(0.001)	(0.013)	(0.013)	(0.001)	(0.000)
Regulatory quality	-0.081	-0.080*	0.090	0.070	-0.131	-0.097	-0.053	-0.057	0.002	-0.008	-0.020	-0.019
	(0.048)	(0.047)	(0.262)	(0.232)	(0.087)	(0.083)	(0.061)	(0.058)	(0.050)	(0.050)	(0.084)	(0.087)
R^2	0.734	0.736	0.188	0.189	0.696	0.694	0.206	0.198	0.667	0.664	0.209	0.209
Observations	670	670	409	409	709	709	1138	1138	378	378	222	222

Note: This table reports robustness checks to Table C.6. IPW correction applied. All regressions include country and year fixed effects. Standard errors are clustered at the country level and reported in parentheses. Significance levels: $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by ***, ***, and *, respectively.

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