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Energy price shocks, conflict inflation, and income distribution in a three-sector model☆

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ABSTRACT

The paper presents a model of conflict inflation to investigate the distributional effects of energy price shocks. We argue that periods of high inflation are always periods of significant redistribution of income. We analyse how such redistribution occurs along two dimensions: between workers and firms and between sectors of the economy. To study the distributional outcomes of the recent inflationary episode, we build a three-sector model comprising a domestic energy sector which provides inputs for a goods and a services sector. The model is calibrated to US sectoral data with the Method of Simulated Moments. While energy prices are set internationally, non-energy prices and nominal wages are set by firms and workers, giving rise to conflicting claims over the distribution of income. We consider three shocks that trigger inflationary distributional conflict: an energy price shock combined with demand and supply shocks to the goods sector. We find that the recent inflationary episode constitutes a price-wage rather than a wage-price spiral. The combined shocks induce non-energy firms to raise prices, which undermines real wages, and redistributes income towards firms. The sectoral demand shift towards goods in combination with pandemic-related supply bottlenecks further raises mark-ups, accelerating inflation and leading to divergence in sectoral profit margins. We compare three anti-inflationary policies: redistributing windfall profits to workers, nominal wage restraint, and aggregate demand contraction through monetary or fiscal policy. The redistribution of profits via a windfall tax is most effective in reducing inflation without reinforcing reductions in employment and labour shares.

1. Introduction

After more than a decade of sluggish price growth in advanced economies, inflation is back. Since the summer of 2021, many advanced countries have seen inflation rates above ten percent — well beyond most central bank inflation targets. There appears to be broad agreement that key drivers of the recent inflation surge include supply-chain disruptions and shifts in consumer demand caused by the COVID-19 pandemic, amplified by increasing energy prices which peaked as a result of Russia's occupation of Ukraine (Bernanke and Blanchard, 2023; Bräuning et al., 2022; Kilian and Zhou, 2022a; Storm, 2022; Shapiro, 2022; Weber et al., 2022).[1]

While the macroeconomic policy debate is strongly focused on how to bring inflation rates down, there is a growing empirical literature documenting the distributional effects. A striking phenomenon is that adverse shocks were accompanied by a rise in profit margins in several sectors. Recent evidence documents record profits of oil firms like Shell and BP.[2] Notably, increases in profit margins are not limited to energy producers. Hayes and Jung (2022), Weber and Wasner (2023) and Unite (2022) show that some firms increased their profit margins considerably between 2019 and 2021. Konczal and Lusiani (2022) find that firms that enjoyed considerable mark-ups before the pandemic further raised them since the lifting of COVID restrictions, demonstrating an association between pricing power and inflation. In addition, several papers argue that firms in the goods sector increased mark-ups because

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[1] The role of fiscal policy amidst pandemic-driven constraints to the supply-side has also been debated; see Baqaee and Farhi (2022), di Giovanni et al. (2022), Jorda and Nechio (2022) and Shapiro (2022).

[2] BP reported record profits of $ 30 billion in the first three quarters of 2022 compared to $ 14.9 billion in the first three quarters of 2019.

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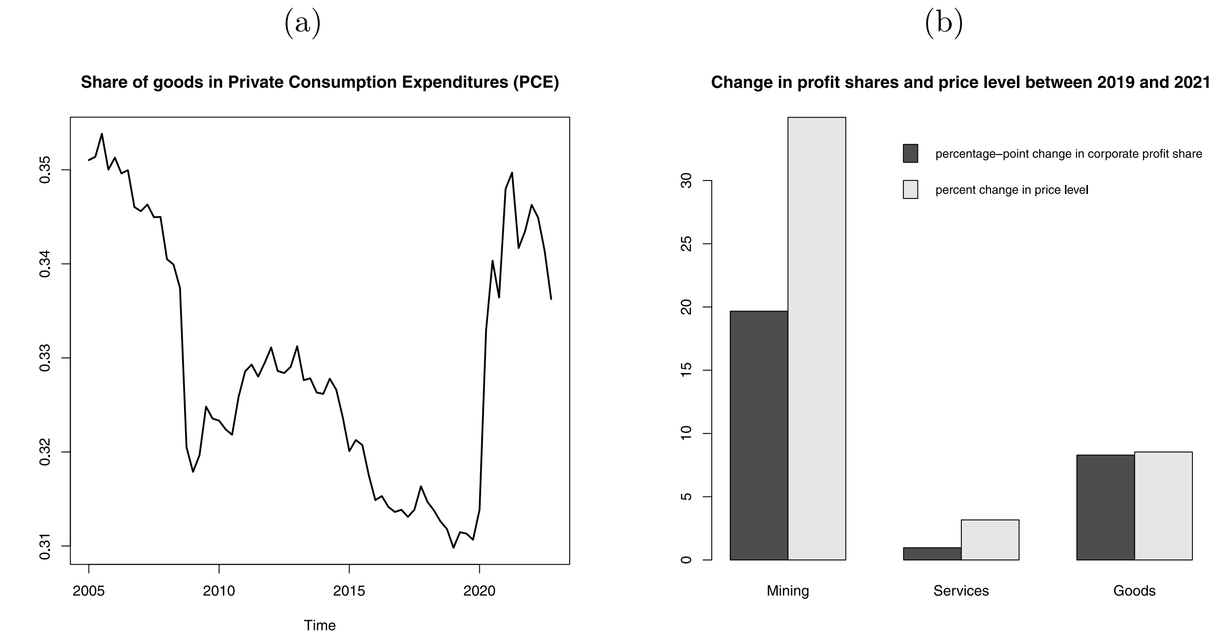

Fig. 1. Demand for consumer goods and US corporate profit shares.
The share of goods in private consumption expenditure (PCE) in panel (a) is based on BEA Table 2.3.5 and profit shares in panel (b) are defined as corporate profits before tax (without IVA and CCAdj) for domestic industries (BEA Table 6.17D) over final output (value added). For sector definitions see Appendix F.

they struggled to keep up with rampant demand due to a shift in consumption from services towards goods since the pandemic (Jorda et al., 2020; Furman, 2021; Storm, 2022). This change in the composition of demand is well-documented in the U.S., where the fraction of consumer spending on goods increased by about 13% between 2020 and 2021 (Fig. 1, panel a), while expenditure on services declined by roughly 7% (Storm, 2022). This shift together with disrupted supply chains and shortages in crucial inputs like microchips left many companies struggling to increase their production levels but allowed them to increase their markups. The resulting increase in profit shares highlights the fact that periods of high inflation do not only generate losers, but also winners (Fig. 1, panel b).

Crucially, increases in mark-ups do not occur uniformly across the economy, instead the recent empirical evidence demonstrates a high degree of heterogeneity across firms and sectors (Hayes and Jung, 2022; Konczal and Lusiani, 2022; Storm, 2022). Thus, aggregate inflation coincides with changes in both sector-specific profitability and in real wages. In other words, periods of high inflation are periods of income redistribution. However, what mechanisms determine which groups and sectors benefit or lose is an open question which has received relatively little theoretical attention.

This paper develops a three-sector model of inflation dynamics, building on the underutilised theory of conflict inflation in which conflicting claims over the distribution of income determine the growth rate of nominal wages and prices (Rowthorn, 1977; Blanchard, 1986; Blecker and Setterfield, 2019; Ratner and Sim, 2022; Hein, 2023; Lorenzoni and Werning, 2023). By extending the conflict inflation approach to a three-sector economy, we make three contributions to the literature: First, our multi-sector framework allows us to link the defining features of the recent macroeconomic environment: spiking energy prices, shifting consumer spending habits and supply bottlenecks combined with high corporate profitability. We thus go beyond approaches that only focus on one of these aspects in isolation (Guerrieri et al., 2021; Ratner and Sim, 2022) or use a one-sector framework, which cannot explain profit heterogeneity (Setterfield, 2022; Lorenzoni and Werning, 2023). Second, we empirically calibrate the structural parameters of our model with the Method of Simulated Moments using industry-level time-series data for the US (Franke and Westerhoff, 2012; Franke, 2022; Reissl, 2020). Third, we use the model to analyse and compare different anti-inflationary policies with respect to their impact on inflation and income distribution.

Our analysis yields four main results. First, a pure energy price shock leads to higher aggregate inflation and a reduction in profit *margins* in non-energy sectors, while energy profit margins increase. Non-energy sector profit *shares* may increase, depending on the bargaining power of firms relative to workers. Thus an increase in energy prices alone can explain rising profit shares but not the increases in profit margins outside the energy sector. Second, a combination of higher energy prices, a shift in consumer demand towards goods, and supply bottlenecks in the goods sector lead to higher inflation as well as higher profit margins in the energy and goods sector. Third, distributional outcomes in response to these shocks are fought out based on relative pricing power between firms in different industries and between firms and workers. Thus distributional conflict arises along multiple dimensions. Fourth, our policy analysis shows that a wide range of measures is effective in reducing inflation (windfall taxes, contractionary aggregate demand policy as well as wage restraint); however, out of these only a windfall profit tax combined with household transfers succeeds in curbing inflation while stabilising real incomes and employment.

By providing a theoretically rigorous account of the recent surge in inflation, our paper offers clarity to an ongoing public debate about wage-price spirals versus ‘profiteering’ (or ‘price gouging’). In our model higher inflation rates are triggered by two factors. Firstly, by higher energy prices which result in increased profit margins in the energy sector. Secondly, by increased markups in the non-energy sectors which are in turn caused by the shift in consumer spending towards goods and supply bottlenecks. Subsequently, workers experiencing a fall in their living standards raise nominal wages to defend their real wage. The increase in nominal wages raises firms’ costs, which are partially passed on to prices, and thereby amplify the inflationary shock. We call the described process a *price-wage spiral*. Our model allows us to formally distinguish the former from a *wage-price spiral* which is triggered by an increase in workers' nominal wage demands. In contrast a price-wage spiral is triggered by an increase in firms' input costs or target profit margins. While both spirals lead to higher inflation rates, wage-price spirals lead to an increase in real wages whereas price-wage spirals lead to falling real wages as well as rising profit margins within the sector which triggered it.[3] Highlighting the adverse distributional outcomes of price-wage spirals is a key objective this paper shares with the proponents of 'profiteering'. However, in our framework markups can only increase in response to higher capacity utilization (due to a sector-specific demand shift or supply bottlenecks); thus, demand and supply shocks are a key component of our argument.[4] Overall, we argue that the conflict inflation framework in this paper reconciles the different aspects highlighted in the debate and helps identify policies such as re-distributive taxes that both mitigate inflation and improve the distribution of income.

The rest of the paper is organised as follows: Section 2 presents the model, Section 3 discusses the empirical calibration of the structural parameters, Section 4 presents simulation results and considers three different policy scenarios. Section 5 concludes.

2. Model

Our model builds on the existing literature on conflict inflation, which has mostly been developed in the post-Keynesian tradition (Rowthorn, 1977) and only recently integrated into New Keynesian frameworks (Lorenzoni and Werning, 2023). Specifically, our model extends the approach of Setterfield (2022, 2006), and is closely related to Hein and Stockhammer (2010), Argitis and Dafermos (2011), and Martins and Skott (2021) as well as the conceptual argument in Weber and Wasner (2023). Our approach however differs in several important aspects. First, we develop a framework which takes the profits generated in domestic energy sectors explicitly into account, instead of modelling the inputs they produce as entirely imported (e.g. Hein, 2014, chap. 5.2). This allows us to analyse the effect of energy price shifts in countries with a domestic energy sector. Specifically, we can distinguish the effect of energy price shifts on the distribution of income between capital and labour (captured by the profit share) and on the profitability between sectors (captured by profit margins).[5] Second, the combination of a shift in the composition of demand, supply bottlenecks in the goods sector, and the existence of a capacity utilisation-elastic mark-up (in line with, e.g., Kaldor 1985, Flaschel and Skott 2006) allows us to replicate the observed divergence in profit margins across sectors (Weber and Wasner, 2023).[6] Third, workers in our model target a real wage denominated by the final good price rather than a sector-specific wage share, which makes the modelling of wage demands more realistic.

[3] IMF (2022) has a more loosely defined notion of a wage-price spiral as a period where both wage- and price inflation temporarily accelerates. Such a definition is consistent with our model but does not allow for a distinction between wage-price and price-wage spirals.

[4] Some accounts have suggested that excess demand might not be necessary if the energy cost shocks lead to a decline in the price elasticity of demand (Weber and Wasner, 2023; Donovan, 2023).

[5] Profit margins are equivalent to real unit profits which take the three-way distribution of sector revenues between capital, labour and intermediary inputs into account. They provide an absolute measure of capital remuneration in a given sector in the same way in which real (unit) wages provide a measure of labour's remuneration. For this reason profit margins are our preferred measure of sectoral profitability (see Section 2.1.3).

[6] Diverging profit margins in response to cost shocks (such as energy price shocks) can arise for various reasons, including differences in market concentration or the shape of demand functions faced by different sectors (Bräuning et al., 2022). Recent survey data provided by Dogra et al. (2023) support the importance of demand conditions in driving the price-setting behaviour of firms, in line with our assumption of a capacity utilisation-elastic mark-up.

We start with a two sector model with a domestic energy sector that provides intermediate inputs to a domestic final output sector. This two sector framework allows us to develop some of our main results in an analytically tractable way. We will show that a domestic energy sector plays a significant role for the observed cross-sector heterogeneity in profitability between energy and non-energy sectors (Konczal and Lusiani, 2022). It is when we move to the joint analysis of energy price shifts, demand shifts and supply bottlenecks that we introduce a three-sector model (energy, goods, and services) for which we provide a mix of analytical discussion and numerical simulation based on empirically calibrated parameters.

Before we proceed, a number of remarks about scope and limitations are in order. First, our model focuses on short- to medium-run dynamics of inflation and income distribution rather than long-run growth. The capital stock and productivity are thus assumed to be predetermined.[7] Second, we assume that the real wage targets of workers are exogenous. This assumption departs from standard wage-Phillips curve frameworks, in which economic activity feeds into the inflationary process via the bargaining power of workers. By contrast, in the three-sector version of our model, economic activity affects firms' price setting. This allows us to focus on the determination of mark-ups, which has been a key object of interest in the recent inflation debate, and to model an exogenous reduction in wage targets, e.g. by forcing workers to accept a lower real wage, as has been suggested in policy debates. That said, our model still exhibits the standard inflation-output trade-off, however without the existence of an exogenous NAIRU. Third, for simplicity, households do not consume energy directly. Energy is typically provided to households through intermediaries such as gas stations or utilities, which themselves purchase energy from energy providers. Fourth, we model the persistent increase in global energy prices as a permanent shift rather than a one period shock. We see this as a reasonable simplification of the observed persistence of increased global energy prices. In the rest of the paper we refer to shifts in a variable or parameter as a permanent change. Fifth, our model does not include rational expectations of firms or workers. Instead we assume that workers pursue a standard of living which is given in the short run while firms pursue target profit margins. Both actors manage to change nominal wages and prices only with a delay.[8] Finally, the model does not include fixed overhead costs of production that could mechanically lead to increasing profit shares in economic expansions (Lavoie, 2023). We abstract from this mechanism because of the recent evidence of rising mark-ups which requires an explanation beyond fixed overhead costs.

2.1. *A two-sector benchmark model*

The two-sector benchmark model contains two sectors indexed as $i = 1, 2$, a domestic energy sector (sector 1) and a final output sector (sector 2).[9] Energy is used as an intermediate input in sector 2. We begin by characterising output determination in the goods market, which clears instantaneously through quantity adjustment, before specifying the dynamics of workers' wage-setting and firms' price-setting behaviour, which pins down income distribution. The latter feeds back into economic activity via its impact on consumption demand. In the two-sector model there is no feedback yet from the goods market to wage and price setting, which will only be introduced in the three-sector extension below.

[7] For this reason, we also abstract from other, medium- to long-run drivers of rising markups or changes in income distribution, such as technology-induced network effects, rising market concentration or changes in bargaining institutions (Autor et al., 2020; Barkai, 2020; De Loecker et al., 2020; Guschanski and Onaran, 2022).

[8] Hein and Stockhammer (2010) provide a conflict inflation model with adaptive expectations.

[9] A full list of variable definitions and equilibrium solutions can be found in Appendix B.

2.1.1. The goods market

Sector 1 produces the intermediate input (Y_1), taken as energy.[10] The production technology is such that each unit of sector 2 output (Y_2) requires δ units of intermediate input. Thus δ is the energy intensity of output in sector 2. The energy sector sets an exogenous real price for energy (ϵ), which we discuss in detail in Section 2.1.2 .

$$Y_1 = \delta Y_2 \tag{1}$$

$$\epsilon = \frac{p_1}{p_2}. \tag{2}$$

Nominal value added (VA_i) is defined as revenues minus intermediate inputs, where p_i gives the price of the i^{th} sector's output:

$$VA_1 = p_1 Y_1 \tag{3}$$

$$VA_2 = p_2 Y_2 - p_1 Y_1. \tag{4}$$

Both sectors exhibit constant labour productivity (υ_i) measured as physical units of output (Y_i) per worker employed (L_i):

$$\upsilon_i = \frac{Y_i}{L_i}. \tag{5}$$

Nominal gross profits ($p_2 \Pi$) are defined as the difference between nominal value added and nominal wages paid. The aggregate wage sum (W) is the product of the sector's nominal wage (w_i) and the sector's employment (L_i):

$$p_2 \Pi = VA_1 - w_1 L_1 + VA_2 - w_2 L_2 \tag{6}$$

$$p_2 \; W = w_1 L_1 + w_2 L_2. \tag{7}$$

Real final output (Y_2) is determined by consumption (C) and autonomous demand (X). The latter represents demand components other than consumption which are independent of changes in income such as discretionary government spending and autonomous investment.[11] Aggregate real income consists of the real wage bill (W) and aggregate profits (Π):

$$Y_2 = C + X = W + \Pi. \tag{8}$$

Agents are either workers or capitalists. The former receive wage income which is fully consumed and the latter receive profit income out of which a proportion (s) is saved. This two-class framework introduces a functional distribution of income and is a stylised representation of the well-documented higher propensity to consume out of wage compared to profit income (Onaran and Galanis, 2014). The resulting aggregate consumption function is of the following form:

$$C = W + (1 - s)\Pi. \tag{9}$$

Combining Eqs. (6), (3), (4) and (5), (8) and (9) yields the following goods market equilibria:

$$Y_2^* = \frac{X}{sh} \tag{10}$$

$$Y_1^* = \frac{\delta X}{sh}, \tag{11}$$

The aggregate profit share $h = \frac{\Pi}{Y_2}$ is given by:

$$h = 1 - \delta\frac{\omega_1}{\upsilon_1} - \frac{\omega_2}{\upsilon_2}. \tag{12}$$

where ω_i are the sector real consumption wages ($\omega_i = \frac{w_i}{p_2}$). The sector profit shares are defined as nominal sector profits over nominal sector value added, $h_i = \frac{p_2 \Pi_i}{VA_i} = \frac{VA_i - w_i L_i}{VA_i}$, which yields

$$h_1 = 1 - \frac{\omega_1}{\upsilon_1 \epsilon} \tag{13}$$

$$h_2 = 1 - \frac{\omega_2}{\upsilon_2 (1 - \delta\epsilon)}. \tag{14}$$

From Eqs. (10) and (11) it can readily be seen that the profit share and output are inversely related, which reflects the higher marginal propensity to consume out of wage relative to profit income. Next we model how nominal wages and prices evolve as the result of wage bargaining and price setting by firms. This allows us to analyse how an exogenous increase in energy prices affects income distribution and output.

2.1.2. Wage and price setting

The energy sector sets an exogenous real price for energy ($\epsilon = p_{1,t}/p_{2,t}$). Modelling the price of energy as exogenous is motivated by the fact that a key component of energy prices is determined in global markets. In doing so we follow the theoretical literature on commodity price shocks (Medina and Soto, 2005; Sánchez, 2008).[12] We further assume a constant real wage in the energy sector:[13]

$$\omega_1 = \frac{w_{1,t}}{p_{2,t}}. \tag{15}$$

In the non-energy sector, workers and firms try to influence real wages by setting nominal wages and prices, respectively. Our specification for conflict inflation builds on Blecker and Setterfield (2019, chap. 5)'s one-sector model, but adds a domestic intermediate input sector. Workers in the final output sector (sector 2) adjust nominal wages (w_2) with the aim of achieving a real wage target (ω_2^W). We assume that the relevant aspiration of workers are real consumption wages (i.e., in prices of the final good $p_{2,t}$) rather than real product wages (i.e. in the price of the corresponding sector), because real consumption wages represent workers' purchasing power (see Aboobaker 2022). The bigger the gap between workers' aspirations (ω_2^W) and the actual real wage ($\omega_{2,t}$), the higher the increase in nominal wages.

$$w_{2,t+1} = w_{2,t} + w_{2,t}\phi_2\left(\omega_2^W - \omega_{2,t}\right) \tag{16}$$

Workers will only be able to partially realise their real wage target. Their adjustment speed depends on bargaining institutions, represented by parameter ϕ_2 in Eq. (16). Institutional factors influencing ϕ_2 include protective trade union legislation, bargaining coordination, union density, and collective bargaining coverage (Guschanski and Onaran, 2022; Bhuller et al., 2022).

Sector 2 firms set prices in pursuit of a target profit margin (r_2^T). How quickly and how aggressively firms seek to close the gap between their

[10] We drop all time subscripts in Section 2.1.1 in order to avoid clutter. The dynamics of the model depend entirely on the interaction between wages and prices which are discussed in Section 2.1.2, which is where we introduce time subscripts. This means for simplicity some variables have no time subscripts in Section 2.1.1 but will have time subscripts in later sections.

[11] There is a long tradition of modelling investment as endogenous to profit margins or capacity utilisation in post-Keynesian models (e.g. Hein (2014, chap. 5)). We adopt this simplifying assumption because our focus is on how energy price shifts affect distribution through price and wage-setting behaviour.

[12] If instead the *nominal* energy price would grow at an exogenous rate, relative prices would either go to infinity or to zero. Kilian and Zhou (2022b) suggest that the US consumer price index and the nominal gasoline price may be cointegrated, yielding a stationary real price. Our specification could be viewed as a simplified version of that assumption.

[13] Holding real consumption wages in the energy sector fixed is motivated by the fact that energy sector workers are uniquely positioned to defend their real wages when inflation rises due to energy price hikes. For example, the oil major Shell paid an 8% bonus to all staff in 2022.

target and the realised profit margin ($r_{2,t}$) is captured by parameter ψ_2 and depends on intra-sector competition as well as market regulation:

$$p_{2,t+1} = p_{2,t} + p_{2,t}\upsilon_2\psi_2\left(r_2^T - r_{2,t}\right). \tag{17}$$

Realised profit margins are defined as sector profits relative to sector sales ($\frac{\Pi_{i,t}}{Y_{i,t}}$), rather than relative to sector value added in the case of the profit share ($\frac{p_{i,t}\Pi_{i,t}}{VA_{i,t}}$). Another useful way of defining the profit margin of a sector is as the share of unit profits in unit sales. Unit profits are defined as the difference between price ($p_{i,t}$) and unit costs ($c_{i,t}$). The latter consist of unit labour costs ($w_{i,t}/\upsilon_i$) and unit energy costs ($\delta p_{1,t}$), except for sector 1 which does not use energy as an input itself:

$$r_{2,t} = \frac{p_i\Pi_i}{p_iY_i} = \frac{p_{2,t}-c_{2,t}}{p_{2,t}} = \frac{p_{2,t} - \frac{w_{2,t}}{\upsilon_2} - \delta p_{1,t}}{p_{2,t}} = 1 - \frac{\omega_{2,t}}{\upsilon_2} - \delta\epsilon \tag{18}$$

$$r_1 = 1 - \frac{\omega_1}{\epsilon\upsilon_1}. \tag{19}$$

In contrast to the sector profit share, which measures the distribution of value added between firms and workers within a sector and which will be discussed below, the profit margin is a measure of the profitability across sectors.

Eq. (20) defines firms' target price as a mark-up over unit costs.[14] The target profit margin (r_2^T) is then solely determined by the target mark-up:

$$p_{2,t}^T = (1+\theta^T)c_{2,t} \tag{20}$$

$$r_2^T = \frac{p_{2,t}^T - c_{2,t}}{p_{2,t}^T} = \frac{\theta^T}{1+\theta^T}. \tag{21}$$

Together, Eqs. (16) and (17) constitute a formal representation of conflict inflation. For example, an increase in prices due to an increase in firms' target mark-up will lead to a response by workers in the form of higher nominal wages, which in turn feeds into higher prices. As will be shown in the next section, this process will settle around a stable real wage and inflation rate.

2.1.3. Income distribution and inflation in equilibrium

The dynamic Eqs. (16) and (17) admit an equilibrium that is characterised by a balanced nominal growth path in wages and prices, resulting in a stable real wage.[15]

Proposition 1. *With prices and nominal wages growing at the same rate $\hat{p}_2 = \hat{w}_2$, the equilibrium real wage and inflation rate are given by:*

$$\omega_2^* = \frac{\phi_2\omega_2^W + \psi_2\upsilon_2\left(1 - r_2^T - \delta\epsilon\right)}{\psi_2+\phi_2} \tag{22}$$

$$\hat{p}_2^* = \frac{\psi_2\phi_2}{\psi_2+\phi_2}\left[\omega_2^W - \upsilon_2\left(1 - r_2^T - \delta\epsilon\right)\right]. \tag{23}$$

Using sector 2 firms' internal markup pricing approach (20) we can define the expression $\upsilon_2\left(1 - r_2^T - \epsilon\delta\right)$ as firms' implicit desired real wage ω_2^F.[16] The equilibrium real wage is thus a weighted average of workers' actual and firms' implicit real wage targets (ω_2^W and ω_2^F), with weights given by the nominal wage and price adjustment speeds (ϕ_2 and ψ_2). A strictly positive equilibrium real wage requires the terms r_2^T and $\epsilon\delta$ to be sufficiently small. Economically this means the real energy price, the energy intensity of production, and the target mark-up cannot become too high.

The larger the gap between workers' and firms' real wage targets, the higher the inflation rate. Bargaining power also affects inflation through the two adjustment speeds, if firms (or workers) manage to adjust prices (or nominal wages) faster, the result is not only higher inflation but also a lower (higher) real wage.

We can use these equilibria to distinguish between wage-price and price-wage spirals. While both lead to higher inflation, their distributional effects are different. A wage-price spiral is triggered by an increase in ω_2^W or ϕ_2 and lead to an increase in the equilibrium real wage ω_2^*. In contrast a price-wage spiral is triggered by an increase in r_2^T, ψ_2 or ϵ and leads to a lower real wage in addition to a higher equilibrium inflation rate.

Proposition 1 requires prices and wages to grow at the same rate. Proposition 2 derives the conditions under which this is likely to occur (see Appendix C for a discussion). A positive equilibrium inflation rate requires that workers' real wage target exceeds firms' implicit real wage target ($\omega_2^W > \omega_2^F$) and that the energy price or firms' target profit margin does not become too large relative to workers' real wage target.

Proposition 2. *If workers' real wage target exceeds firms' implicit real wage target ($\omega_2^W > \omega_2^F$) and $\phi_2\omega_2^W + \psi_2\omega_2^F > 0$, then the system given by (16)–(17) is likely to exhibit exponential growth with equal growth rates for $w_{2,t}$ and $p_{2,t}$ and positive equilibrium solutions for the real wage and inflation rate.*

Proof. See Appendix C. ■

Consider an exogenous increase in the real energy price (ϵ). This will increase the gap between target and realised profit margins in sector 2 and therefore will negatively affect equilibrium real wages:

$$\frac{\partial\omega_2^*}{\partial\epsilon} = -\frac{\upsilon_2\psi_2\delta}{\psi_2+\phi_2} < 0. \tag{24}$$

Given that energy sector workers fully defend their real wage by Eq. (15), whereas real wages in the final output sector fall, an energy price shift thus leads to changes in the between-sector wage distribution.

Furthermore, by Eq. (23), the shift in energy prices will increase the equilibrium inflation rate. The size of this effect depends again on the combined bargaining power as well as on the energy intensity of the final output sector (δ) and labour productivity (υ_2):

$$\frac{\partial\hat{p}_2^*}{\partial\epsilon} = \frac{\psi_2\phi_2\upsilon_2\delta}{\psi_2+\phi_2} > 0. \tag{25}$$

Next, we examine the distributional impact of energy prices on the aggregate and sector profit shares as well as profit margins, whose equilibrium expressions are given by:

$$h^* = 1 - \frac{\omega_2^*}{\upsilon_2} - \delta\frac{\omega_1}{\upsilon_1} \tag{12}$$

$$r_1 = 1 - \frac{\omega_1}{\epsilon\upsilon_1} = h_1 \tag{13}$$

$$r_2^* = 1 - \frac{\omega_2^*}{\upsilon_2} - \delta\epsilon \neq h_2^* \tag{26}$$

$$h_2^* = 1 - \frac{\omega_2^*}{\upsilon_2}\frac{1}{1-\delta\epsilon}. \tag{14}$$

For sector 1 the realised profit margin is equal to the profit share. This follows directly from the fact that no intermediate inputs are used in sector 1. In contrast in sector 2 unit sales are divided between

[14] This mark-up pricing approach to internal planning is well established not only in the post-Keynesian literature (e.g. Hein, 2014, chap. 5; Lavoie, 2014, chap. 3) but also in Management Accounting (Drury, 2017; Burns et al., 2013) and in practice (Drury and Tayles, 2006).

[15] Since we assume constant labour productivity the real wage must be constant for a balanced growth path. Including growing labour productivity into the model would not alter the results substantially. See e.g. Hein (2014, chap. 8) and Blecker and Setterfield (2019, chap. 5.2) for one-sector models with labour productivity growth.

[16] It is easy to show that $\omega_{2,t} - \omega_2^F = \upsilon_2(r_2^T - r_{2,t})$. Thus firms' price setting equation could also be written in terms of ω_2^F.

wages, profits and intermediate inputs. As a result the distribution of income (value added) within the sector as measured by the profit share (h_2^*) does not coincide with the profit margin (r_2^*). Thus, sector 2 profit margins can in principle react differently to an energy price shock than profit shares. It is therefore important to separately analyse income distribution within sectors (measured by the profit shares) and profitability between sectors (measured by the profit margin).

Both the aggregate and sector 1 profit share unambiguously increases in response to a positive shift in the price of energy (see Eqs. (27) and (28)). By contrast, in sector 2 the increase in energy prices leads to a reduction in profit margins (see Eq. (29)) which is greater for higher energy intensity (δ) and higher worker's bargaining power ($\phi_2/(\phi_2+\psi_2)$). Thus changes in the real price of energy increase heterogeneity in profitability between sectors.

$$\frac{\partial h^*}{\partial \epsilon} = \frac{\delta\psi_2}{\phi_2+\psi_2} > 0 \tag{27}$$

$$\frac{\partial h_1}{\partial \epsilon} = \frac{\partial r_1}{\partial \epsilon} = \frac{\omega_1}{v_1\epsilon^2} > 0 \tag{28}$$

$$\frac{\partial r_2^*}{\partial \epsilon} = -\frac{\delta\phi_2}{\psi_2+\phi_2} < 0 \tag{29}$$

A key result is the effect of the energy price shift on the profit share in sector 2:

Proposition 3. *The response of the profit share in sector 2 (h_2^*) to a shift in real energy prices is ambiguous. It depends on the relative strength of the bargaining relationship, specifically on the relative size of ϕ_2 and ψ_2, and the gap between firms' target profit margin (r_2^T) and workers real wage target (ω_2^W).*

Proof.

$$\frac{\partial h_2^*}{\partial \epsilon} = \delta\frac{\psi_2 r_2^T - \phi_2\frac{\omega_2^W}{v_2}}{(1-\epsilon\delta)^2(\psi_2+\phi_2)} \lesseqgtr 0. \quad \blacksquare \tag{30}$$

Thus, it is not *a priori* clear which class within sector 2 bears how much of the adjustment burden in response to an increase in energy prices. The outcome depends on bargaining power: if the price-setting power of firms is sufficiently large, profit shares of domestic non-energy sectors may *rise* in response to an energy cost shock. This notable result is closely linked to the recent debate on rising profits in response to adverse economic shocks (Konczal and Lusiani, 2022; Weber and Wasner, 2023; Unite, 2022). It shows that with conflict inflation, the redistribution of income from workers to firms due to a pure energy price shocks may not be limited to energy firms but can occur more widely across different sectors of the economy. By contrast, a pure energy price shock cannot explain an increase in profit *margins* in non-energy sectors.

The decline in real wages due to an increase in the real energy price increases the aggregate profit share, which depresses consumption demand and thus output:

$$\frac{\partial Y_2^*}{\partial \epsilon} = -\left(\frac{X}{sh^2}\right)\left(\frac{\psi_2\delta}{\phi_2+\psi_2}\right) < 0 \tag{31}$$

$$\frac{\partial Y_1^*}{\partial \epsilon} = -\left(\frac{X}{sh^2}\right)\left(\frac{\psi_2\delta^2}{\phi_2+\psi_2}\right) < 0. \tag{32}$$

With constant labour productivity (and a fixed labour force in the short run), the fall in output will be accompanied by an increase in unemployment.

The causal structure of the model is summarised in the directed graph in Fig. 2.[17] An increase in the real price of energy (ϵ) leads to a

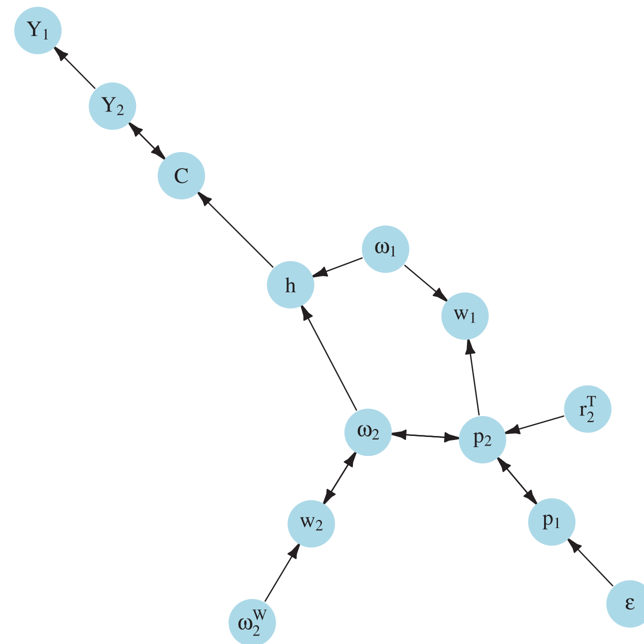

Fig. 2. Directed graph of two-sector model.

rise in final output prices (p_2), a fall in the sector 2 real wage, and thus a change of the wage distribution. Workers in the energy sector retain their living standard but obtain a smaller share of the sector's output (the profit share increases). Profit margins increase in sector 1 and drop in sector 2, however the effect on the distribution of income between labour and capital in sector 2 is ambiguous and depends on the relative strength of workers and firms in the bargaining process. However, the aggregate profit share rises, which depresses consumption, output, and employment.

2.2. A three sector extension

While the two-sector model captures the redistribution of income from workers to firms, it fails to fully account for the divergence in profit margins across non-energy firms which occurred since the pandemic (Hayes and Jung, 2022; Konczal and Lusiani, 2022; Weber and Wasner, 2023). We account for this by disaggregating final output into goods and services, yielding a three-sector model. This allows us to capture supply bottlenecks across various industries as well as the significant shift in demand away from services towards goods that occurred during the pandemic due to lockdowns and physical distancing. The combination of a capacity utilisation-elastic mark-up in the goods sector and sector-specific demand and supply shocks allows us to replicate the empirically observed divergence in profit margins across non-energy sectors (Hayes and Jung, 2022). The utilisation-sensitive mark-up represents the idea that firms tend to increase prices when they struggle to meet demand Flaschel and Skott (2006), Weber and Wasner (2023).[18] The endogenous mark-up further introduces a feedback effect from the goods market into the inflationary process that gives rise to a relationship that is similar to the traditional Phillips curve, but runs via price- rather than wage-setting.

[17] Exogenous factors are represented by nodes with only outward-pointing arrows. Other exogenous parameters (e.g. labour productivity, energy intensity, propensity to save out of profits) are omitted for simplicity.

[18] Weber and Wasner (2023, p. 10) argue that 'where a sector furthermore experiences a supply-side bottleneck or a demand shock – granting firms within the sector temporary augmented monopoly power – profit margins may even be enhanced, thereby not only propagating but also amplifying the initial cost shocks'. Our model can be seen as a formalisation of this argument.

2.2.1. The goods market

The three sector model consists of two final outputs, services (sector 2) and goods (sector 3), which are used for consumption (C_n) and autonomous components of demand (X_n) such as government spending (the subscript n refers to nominal quantities). Final output (Y_n) is equal to total income which consists of the wage bill (W_n) and aggregate profits (Π_n). Equality between aggregate income and expenditures as well as the aggregation of final output is defined in nominal terms:[19]

$$Y_n = p_2 Y_2 + p_3 Y_3 = C_n + X_n = \Pi_n + W_n \tag{33}$$

Both final output sectors use inputs from sector 1 (energy) in a fixed but sector-specific proportion (δ_i) representing the energy intensity of sector i which is defined based on real quantities:

$$Y_1 = \delta_2 Y_2 + \delta_3 Y_3. \tag{34}$$

The definitions of aggregate profits, wages, and value added are equivalent to those introduced in Section 2.1.1 and are therefore omitted for brevity. We use the same consumption function as before (Eq. (9)). Households spend a fixed proportion of their nominal income on goods and services, respectively, yielding a fixed ratio (γ) of nominal sector 2 output to total final output:

$$\gamma = \frac{p_2 Y_2}{Y_n}. \tag{35}$$

The aggregate price level is the weighted geometric mean of final output prices, using the fixed proportions of final output as weights:

$$p = p_2^{\gamma} p_3^{1-\gamma}. \tag{36}$$

We use the aggregate price index to define real quantities such as real autonomous demand $X = \frac{X_n}{p}$ and real aggregate output $Y = \frac{Y_n}{p}$. Relative prices are define as $\mu = \frac{p_2}{p_3}$. The fixed nominal proportion γ in combination with fixed sector 1 input coefficients yield the real output proportions $Y_2 = \frac{\gamma}{(1-\gamma)\mu} Y_3$ and $Y_1 = \left(\delta_2 \frac{\gamma}{(1-\gamma)\mu} + \delta_3\right) Y_3$. By the same procedure as in Section 2.1.1, we obtain the following goods market equilibrium expressions for nominal and real output:

$$Y_n^* = \frac{Xp}{sh} \tag{37}$$

$$Y^* = \frac{X}{sh} \tag{38}$$

The aggregate profit share is given by real unit labour costs in all three sectors (ω_i/v_i) and the relative size of the sectors which in turn depend on the economy's energy intensity (δ_i), the composition of final demand (γ) and relative final output prices (μ):

$$h = 1 - (1-\gamma)\mu^{\gamma}\left(\frac{\omega_3}{v_3}\right) - \gamma\mu^{\gamma-1}\left(\frac{\omega_2}{v_2}\right) - \left[\gamma\delta_2\mu^{\gamma-1} + (1-\gamma)\delta_3\mu^{\gamma}\right]\left(\frac{\omega_1}{v_1}\right). \tag{39}$$

Sector profit shares are defined as nominal sector profits relative to sector value added $h_i = \frac{p_i \Pi_i}{VA_i}$. They are directly related to real wages $\omega_i = w_i/p$, the real price of energy, $\epsilon = \frac{p_1}{p}$, and the relative price of the two final outputs, μ. As in the two sector model the real wage in the energy sector (ω_1) is assumed to be exogenous.

$$h_1 = 1 - \frac{w_1}{p_1}\frac{1}{v_1} = 1 - \frac{\omega_1}{\epsilon v_1} \tag{40}$$

$$h_2 = 1 - \frac{w_2}{v_2\left(p_2 - p_1\delta_2\right)} = 1 - \frac{\omega_2}{v_2\left[(\mu)^{1-\gamma} - \epsilon\delta_2\right]} \tag{41}$$

$$h_3 = 1 - \frac{w_3}{v_3\left(p_3 - p_1\delta_3\right)} = 1 - \frac{\omega_3}{v_3\left[\mu^{-\gamma} - \epsilon\delta_3\right]} \tag{42}$$

2.2.2. Wage and price setting

This section introduces wage bargaining and price setting. Following the two-sector benchmark model, we keep the real energy price and the real wage in the energy sector fixed, using the price index as the deflator:

$$\epsilon = \frac{p_{1,t}}{p_t} \tag{43}$$

$$\omega_1 = \frac{w_{1,t}}{p_t}. \tag{44}$$

Workers set nominal wages depending on how far actual real wages ($\omega_{i,t}$) are from workers' target real wage (ω_i^W):

$$w_{2,t+1} = w_{2,t} + w_{2,t}\phi_2\left(\omega_2^W - \omega_{2,t}\right) \tag{45}$$

$$w_{3,t+1} = w_{3,t} + w_{3,t}\phi_3\left(\omega_3^W - \omega_{3,t}\right) \tag{46}$$

Firms in both sectors set prices depending on the gap between the realised ($r_{i,t}$) and target profit margin (r_2^T and $r_{3,t}^T$):[20]

$$p_{2,t+1} = p_{2,t} + p_{2,t}\psi_2 v_2\left(r_2^T - r_{2,t}\right) \tag{47}$$

$$p_{3,t+1} = p_{3,t} + p_{3,t}\psi_3 v_3\left(r_{3,t}^T - r_{3,t}\right) \tag{48}$$

Realised profit margins $r_{i,t} = \frac{p_{i,t} - c_{i,t}}{p_{i,t}} = 1 - \frac{w_{i,t}}{p_{i,t}v_i} - \frac{\delta_i p_{1,t}}{p_{i,t}}$ depend on prices relative to real unit costs ($c_{i,t}/p_{i,t}$). The latter can be broken down into real unit labour costs ($\frac{w_{i,t}}{p_{i,t}v_i}$) and real energy costs ($\frac{\delta_i p_{1,t}}{p_{i,t}}$).

The key difference between sector 2 (services) and sector 3 (goods) lies in the determination of the target mark-up, which is exogenous in sector 2 but endogenous in sector 3. This simplified assumption captures established evidence that goods (and especially durables) change prices more frequently over the business cycle than services (Klenow and Malin, 2010). Following Flaschel and Skott (2006), we assume that the target mark-up in sector 3 reacts to the rate of capacity utilisation given by $\frac{Y_{3,t}}{Y_3^P}$, where Y_3^P is potential output (taken to be exogenous in the short run):

$$\theta_{3,t}^T = \beta_0 + \beta_1\left(\frac{Y_{3,t}}{Y_3^P}\right) \tag{49}$$

In equilibrium, $Y_3 = (1-\gamma)\mu^{\gamma} Y$; thus mark-ups in sector 3 can change both due to aggregate (Y) and sector demand shocks (γ), as well as supply shocks, e.g. bottlenecks, represented by temporary exogenous changes to potential output (Y_3^P).

Target profit margins are given by the target mark-ups as before: $r_i^T = \frac{\theta_i^T}{1+\theta_i^T}$. The realised profit margins become:

$$r_1 = h_1 \tag{50}$$

$$r_2 = 1 - \mu^{\gamma-1}\frac{\omega_2}{v_2} - \mu^{\gamma-1}\delta_2\epsilon \neq h_2 \tag{51}$$

$$r_3 = 1 - \mu^{\gamma}\frac{\omega_3}{v_3} - \mu^{\gamma}\delta_3\epsilon \neq h_3 \tag{52}$$

Profit margins thus do not coincide with profit shares for sectors which use intermediary inputs.

Finally, it is worth discussing how the distinction between the goods and services sector affects our analysis. By adding a domestic energy sector to the model, the conflict over the distribution of income expanded from one dimension (firms vs workers) to two dimensions (energy firms vs final goods firms). With two final output sectors, the firm vs firm dimension now also includes a distributional conflict

[19] As in the two sector model, we drop all time subscripts in Section 2.2.1 in order to avoid clutter. The dynamics of the model depend entirely on the interaction between wages and prices which are discussed in Section 2.2.2, which is where we introduce time subscripts. This means some variables have no time subscripts in Section 2.2.1 but will have time subscripts in later sections.

[20] In line with Aboobaker (2022) this implies that workers care about the real consumption wage $\omega_{i,t} = \frac{w_{i,t}}{p_t}$, whereas for firms the real product wage $\frac{w_{i,t}}{p_{i,t}}$ is key.

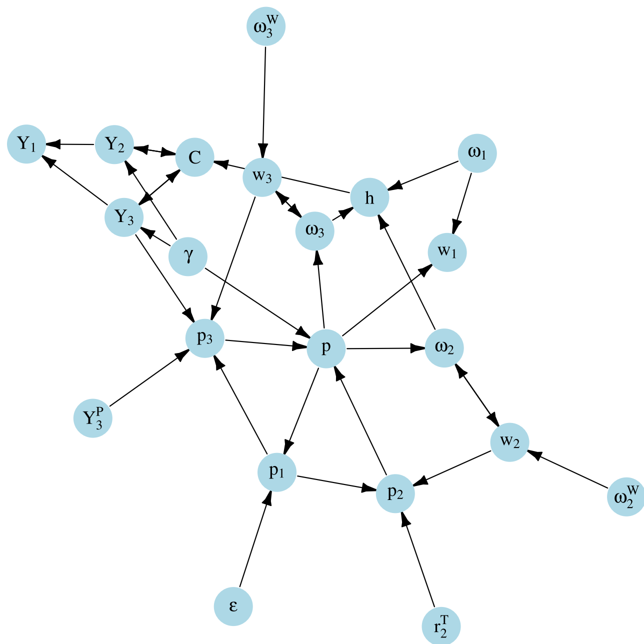

Fig. 3. Directed Graph of three-sector model.

between the two final output producers. This latter point stems from the fact that both input costs, nominal wages w_i and the nominal energy price p_1, react to changes in the aggregate price level (p_t). Thus, if sector i manages to increase prices at a faster pace than the aggregate price level, its profit margin increases permanently even if it achieves above-average price growth only for a limited period. Overall, the three sector model provides a rich framework for analysing cost shocks and anti-inflationary policies and their implications for distributional as well as macroeconomic outcomes. Crucially it allows us to study not only the conflict between firms and workers within a sector but also between firms across sectors.

2.2.3. Income distribution and inflation in equilibrium

The system given by (45)–(49) is likely to exhibit balanced growth in nominal wages and prices over a wide range of parameters (see Appendix D). While prices and nominal wages are unstable (i.e. grow over time), the system converges to stable equilibrium real wages that are below workers' targets (see Appendix E). The causal structure of the model is summarised in Fig. 3.[21] The crucial determinants of inflation and distribution on which we focus in this model are the exogenous real energy price (ϵ), the share of goods in total output ($1-\gamma$), and potential output in the goods sector (Y_3^P). These factors determine sectoral price setting via their impact on costs and the target mark-up in sector 3. Sectoral prices then determine the aggregate price level and real wages, which feed back into the inflationary process via wage-setting. Together these determine the functional as well as inter sector distribution of income. The former determines equilibrium output, which feeds back into the bargaining process.

Analogous to the two sector model we can distinguish between wage-price and price-wage spirals. Both spirals lead to higher equilibrium inflation but with distinct distributional outcomes. A wage-price spiral in sector i is triggered by an increase in ω_i^W or ϕ_i and leads to an increase in the equilibrium real wage ω_i^*. In contrast, a price-wage spiral is triggered by an increase in r_i^T, ψ_i or ϵ and leads to a lower real wage.

[21] Some exogenous factors such as energy intensity and labour productivity are omitted for simplicity.

3. Empirical calibration

To analyse the effects of policy interventions, we complement the analytical discussion with numerical simulations. We calibrate 16 of the model's parameters with the Method of Simulated Moments (MSM) using sector data for the US. The MSM calibrates parameters so as to minimise the distance between simulated and empirical moments (Franke and Westerhoff, 2012; Franke, 2022; Reissl, 2020). In this way, we aim to obtain more realistic simulation results compared to an arbitrary parameterisation. However, a number of limitations needs to be flagged. First, the model is relatively small-scale and will thus omit certain macroeconomic processes that impact the empirical series. Second, our model does not allow for any parameter instabilities in the data-generating process, e.g. due to changes in institutions or technology. Correspondingly, we do not aim to maximise the model's empirical fit, nor do we consider its parameters to be strictly causally identified. Instead, the purpose of the calibration is to incorporate empirical information into an analysis that is essentially theoretical. Thus, any counterfactual policy analysis should be considered a theoretical exercise to gauge possible responses rather than a quantitatively precise prediction.

For the calibration, we use annual time series at the two digit NAICS sector level for the US over the period 2000–2021.[22] We construct tree sectors: a domestic energy sector (S1), a services sector (S2), and a goods sector (S3) (see Appendix F for details on the data).

We construct data for (i) sector real outputs,[23] (ii) the inflation rates of sector price indices, (iii) the sector profit shares, and (iv) an energy price index that is deflated by the price indices of the goods and service sectors. From these series, we obtain 18 empirical moments[24]

The stochastic components used to obtain the simulated counterparts to these empirical moments are twofold. First, we directly feed the empirical real energy price index into the model. Second, we add an autocorrelated aggregate demand shock u_t to Eq. (33), which follows the process $u_t = \rho u_{t-1} + e_t$, with $e_t \sim N(0, \sigma)$. We then run 30 Monte Carlo simulations of the stochastic version of the model over a time horizon $H = 16T$ (with $T = 22$), discard $H/2$ initial periods, and then compute the simulated moments based on the mean values across Monte Carlo runs.

Having obtained $q = 18$ empirical moments and their simulated counterparts, we calibrate $p = 16$ parameters, which are listed in Table 1. Let the ($p\times 1$) vector of parameters to be calibrated be denoted as Θ, the vector of empirical moments m^{emp}, and the vector of simulated moments by m^{sim}. The MSM then consist of minimising the following quadratic loss function:

$$L(\Theta) = (m^{sim}(\Theta) - m^{emp})' W (m^{sim}(\Theta) - m^{emp}) \tag{53}$$

where W is a ($q\times q$) weighting matrix. Following Franke and Westerhoff (2012), we use the inverse of the bootstrapped variance–covariance

[22] Data availability constraints restrict the latest data point to 2021 and preclude the use of quarterly data.

[23] The real output series were detrended using the regression filter proposed in Hamilton (2018).

[24] The contemporaneous cross-correlations between the real energy price index and (i) the sector price indices (moments 1 - 3), (ii) the profit shares in S2 and S3 (moments 4–5), and (iii) real final output (sum of real output in S2 and S3) (moment 6). Furthermore, we use the cross-correlation of the inflation rate in S1 and (i) the profit share in S1 (moment 7) and (ii) the final output inflation rate (growth rate of price index of S2 and S3) (moment 8). To capture persistence in the data, we use the first-order autocorrelation coefficients of the aggregate inflation rate (moment 9), of the profit shares in S2 and S3 (moments 10–11), and of real final output (moment 12). Finally, we use the mean of the final output inflation rate (moment 13) as well as the standard deviations of (i) the inflation rates in S2 and S3 (moments 14–15), (ii) the profit shares in S2 and S3 (moments 16–17), and (iii) real final output (moment 18).

Table 1
Empirically calibrated parameters.

Symbol	Definition	Pre-determined range	Calibrated value
θ_2	Mark-up, S2	$(0.4, 1)$	0.73
β_0	Autonomous component of mark-up, S3	$(0.1, 0.4)$	0.19
β_1	Sensitivity of mark-up to rate of capacity utilisation, S3	$(0.1, 0.9)$	0.31
ϕ_2	Adjustment speed of nominal wage, S2	$(0.5, 1.5)$	0.71
ϕ_3	Adjustment speed of nominal wage, S3	$(0.5, 1.5)$	0.55
ψ_2	Adjustment speed of price, S2	$(1.8, 1.8)$	1.59
ψ_3	Adjustment speed of price, S3	$(1.8, 1.8)$	1.76
ω_1	Real wage, S1	$(0.1, 0.8)$	0.44
ω_2^W	Real wage target of workers, S2	$(0.25, 0.65)$	0.25
ω_3^W	Real wage target of workers, S3	$(0.25, 0.65)$	0.57
s	Propensity to save	$(0.2, 0.8)$	0.64
Y_3^P	Potential output, S3	$(1, 4)$	2.19
ρ	AR(1) coefficient of demand shock	$(0.1, 0.8)$	0.39
σ	Standard deviation of demand shock	$(0.1, 0.4)$	0.19
δ_2	Energy coefficient, S2	$(0.2, 0.8)$	0.36
δ_3	Energy coefficient, S3	$(0.2, 0.8)$	0.51

Notes: S1: sector 1 (energy), S2: sector 2 (services), S3: sector 3 (goods). The parameter γ was calibrated directly from the sector data to $\gamma = 0.55$. The labour coefficients v_i were normalised to unity. Autonomous demand was set to $X = 3$.

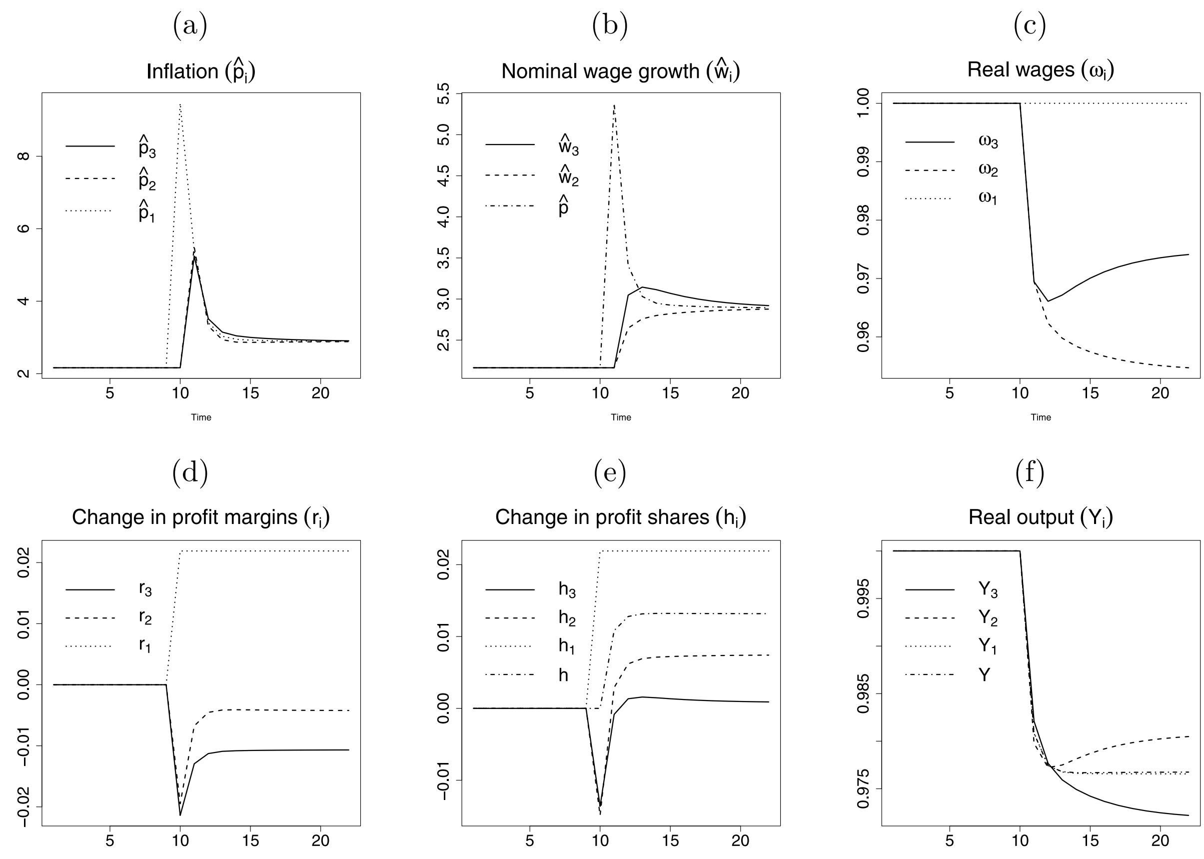

Fig. 4. Scenario 1: Energy price (ϵ) shift.
Notes: Response to a permanent increase in real energy prices in period 10. Responses in panels a and b show growth rates: $\frac{\Delta x_t}{x_{t-1}}$. Responses in panels c and f are normalised by their initial (steady state) values: x_t/x^*. Panels d and e show the percentage point change in profit margins and shares from the initial steady state: $x_t - x^*$.

matrix of m^{emp} to construct W. The loss function is then minimised using the parameter vector Θ as the choice variable:

$$\hat{\Theta} = \underset{\Theta}{\text{argmin}}[L(\Theta)]. \tag{54}$$

To find a parameter vector that minimises the loss function, we follow Reissl (2020) and use Latin hypercube sampling by drawing S samples from a predetermined parameter space to construct a $(S \times p)$ parameter grid. We set $S = 10000$, run Monte Carlo simulations for each parameter combination, compute the simulated moments, and calculate the corresponding value of the loss function.[25] This procedure is repeated several times to narrow down the parameter range. We then choose the parameterisation that yields the smallest value of the loss function (see Table 1).

[25] We discard parameterisations for which $\hat{p}^* < 0$ or $cor(\epsilon, h_2) < 0$ given that a positive inflation rate and a positive correlation between the energy price shock and profit shares in S2 are key empirical facts we want to capture.

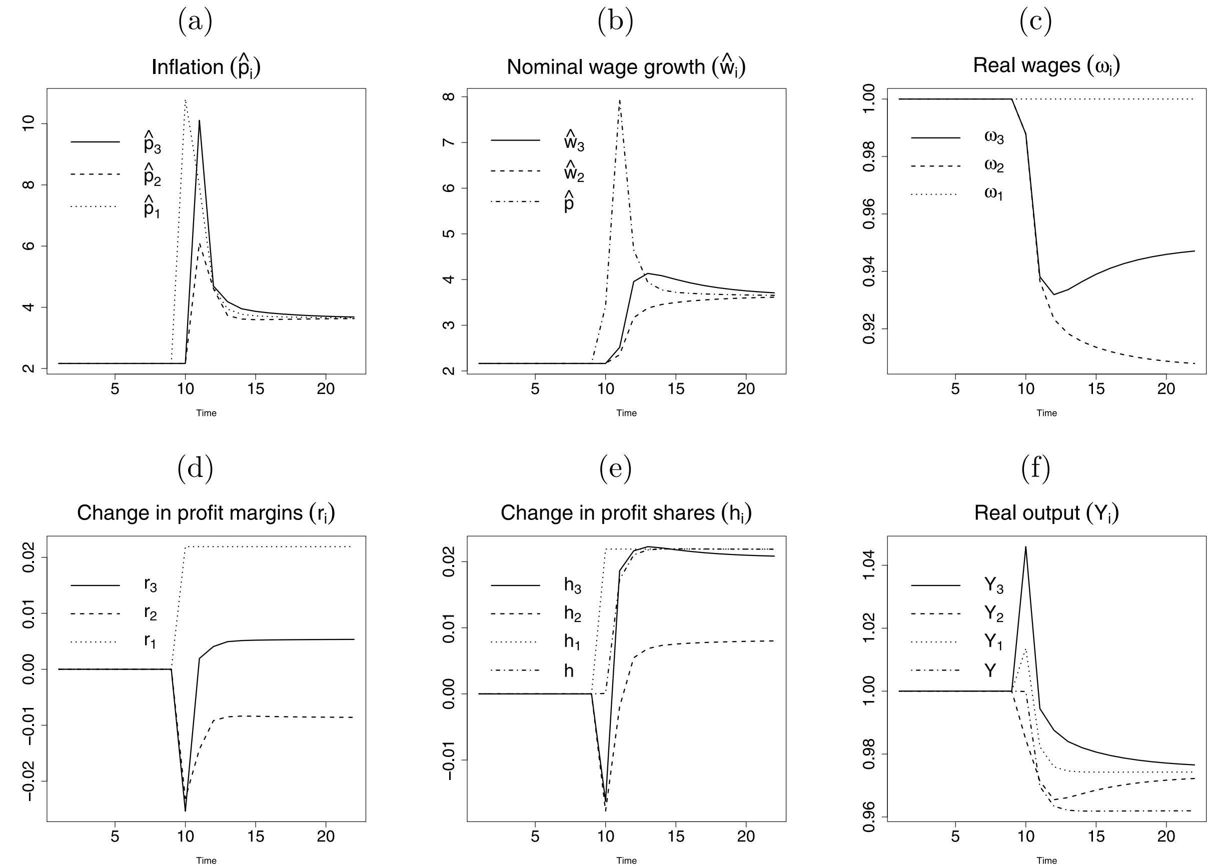

Fig. 5. Scenario 2 (baseline): Energy price (ϵ), demand composition $(1-\gamma)$ and supply bottleneck (Y_3^P) shifts.
Notes: Responses to a joint permanent increase in real energy prices (ϵ), the demand for goods $(1-\gamma)$, and a reduction in potential output in sector 3 (Y_P^3) in period 10. Responses in panels a and b show growth rates: $\frac{\Delta x_t}{x_{t-1}}$. Responses in panels c and f are normalised by their initial (steady state) values: x_t/x^*. Panels d and e show the percentage point change in profit margins and shares from the initial steady state: $x_t - x^*$.

4. Simulation results

Using the empirically calibrated parameters, we analyse the model's dynamics under five different scenarios. The first scenario (Scenario 1) is a permanent increase in real energy prices. The second scenario (Scenario 2) adds to the increase in energy prices a shift of demand towards goods (sector 3) as well as a reduction in potential output (Y_3^P) to capture pandemic-induced disruptions. We consider this our baseline scenario. Subsequently, we analyse the effects of three policy interventions: first, a windfall tax on energy sector profits which is used to compensate workers in the other sectors. Such a tax has been introduced in the UK, Italy, Spain and Greece and debated in many other countries (e.g. Austria, Germany, France, and Belgium; see Enache, 2022), but not been implemented in the US. Second, a policy of wage restraint in an attempt to reduce inflation, as called for by e.g. Domash and Summers (2022) (and e.g. Bailey (2022) and Hunt (2022)). We model this as an exogenous decrease in workers' real wage target (ω_2^W). Third, a reduction in aggregate demand, e.g. through contractionary fiscal or monetary policy, represented by a fall in autonomous demand X. We will compare these policies with respect to their effect on inflation, output (unemployment), and the distribution of income.

4.1. Scenario 1: Energy price shift

The first scenario consists of a permanent increase in the real price of energy (ϵ). The model's results are plotted in Fig. 4. As expected a permanent increase in ϵ leads to an increase in the sectoral inflation rates ($\hat{p}_i$) (panel a). Panel (b) shows that aggregate prices start to rise before nominal wage inflation picks up, demonstrating that an energy price shock triggers a price-wage spiral. Real wages fall in sectors 2 and 3, but stay constant in the energy sector (panel c). The increased price of energy boosts the energy sector's profit margin as well as its profit share (panels d and e). In sector 2 and 3, profit margins fall while at the same time the profit shares increase, implying that worker's bear a bigger share of the increase in energy prices compared to firms. The aggregate profit share increases, indicating that over the whole economy firms' share of total income increases. Finally, output falls across all three sectors (panel f) due to the fall in consumption demand.[26]

Overall, the new equilibrium is characterised by lower real wages and reduced profit margins outside the energy sector, and higher profit shares in most sectors and in the aggregate. Workers lose out not only in relative terms (profit shares) but also in absolute terms due to declining real wages (sectors 2 and 3) and through a fall in employment due to falling output (in all sectors).

4.2. Scenario 2 (baseline): Energy price shift combined with sectoral demand shift and supply disruption

Our baseline scenario involves (i) an increase in the real energy price (ϵ), (ii) an increase in the share of goods in total output $(1-\gamma)$, (iii) and a reduction in potential output of the goods sector (Y_3^P). The

[26] Sector 3 output falls the most because of the temporary higher inflation compared to sector 2 (due to a higher adjustment speed ψ_3 in sector 3) which means the fixed proportion of nominal household income spent on sector 3 translates into lower demand for sector 3 in real terms.

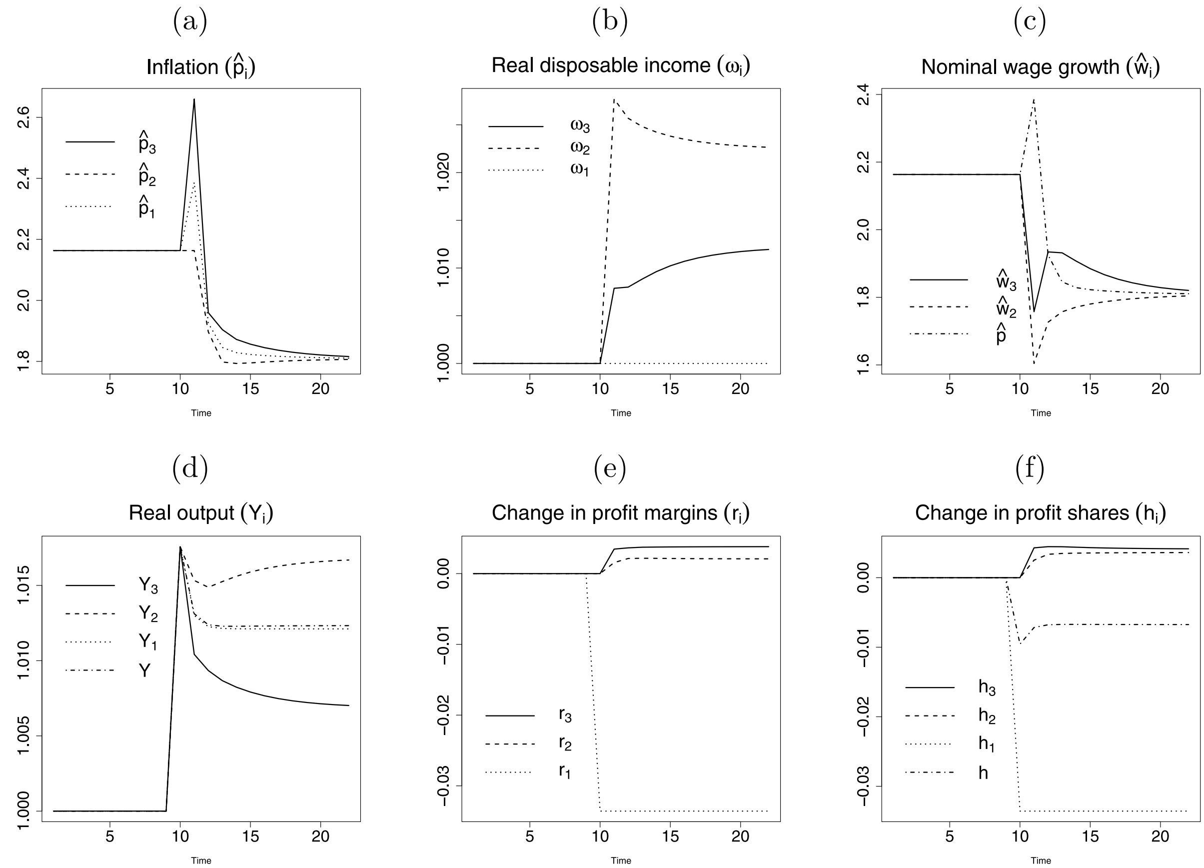

Fig. 6. Policy Scenario 1: Corporate income tax and income transfer.
Notes: Response to the introduction of corporate income tax in the energy sector in period 10. Responses in panels a and c show growth rates: $\frac{\Delta x_t}{x_{t-1}}$. Responses in panels b and d are normalised by their initial (steady state) values: x_t/x^*. Note that panel b shows workers' real disposable income, defined as wages plus transfer receipts. Panels e and f show the percentage point change in profit margins and shares from the initial steady state: $x_t - x^*$.

results are displayed in Fig. 5. Compared to the pure energy price shock scenario 1, we obtain a stronger increase in the sectoral inflation rates (panel a), with a much higher spike in inflation in the goods sector. Again, there is a price-wage spiral as prices start to increase before wage inflation picks up, with a higher peak inflation rate as well as a higher equilibrium inflation rate compared to scenario 1 (panel b). Real wages in sectors 2 and 3 fall more compared to scenario 1 (panel c). The demand shift towards sector 3 in combination with supply bottlenecks leads to an increase in sector 3's target markup, which translates into higher profit margins (panel d). By contrast, sector 2's profit margins are squeezed. With respect to the distribution of income between labour and capital within sectors, the profit share increases in all sectors and in the aggregate (panel e). Real output again falls across sectors (panel f).

In sum, the combined shock scenario not only leads to an increase in aggregate inflation and a fall in aggregate output, it also comes with an increased variation of profit margins across sectors. Crucially this increase in heterogeneity is not only driven by energy sector profits but also by increased profitability in the goods sector. Thus the defining features of the recent macroeconomic environment, high energy prices, pandemic-related supply bottlenecks and changes in consumer demand patterns, contribute to increasing differences in profitability across sectors. Sectors that are able to not just maintain but to increase their target mark-ups in response to shifts in demand or supply constraints manage to raise their profit margins in an overall adverse macroeconomic environment as highlighted in Weber and Wasner (2023). This increase in target markups further amplifies aggregate inflation. Between firms, the combined shocks produce winners (sector 1 and 3) and losers (sector 2) measured in terms of profit margins. The increase in inflation redistributes income towards firms through falling real wages. As a result, workers lose out across all sectors. Sector 1 workers enjoy stable real wages but obtain a smaller share of valued added produced in their sector, while workers in the final output sectors lose out in absolute terms (falling real wages) as well as in relative terms (increasing profit shares). Workers in all sectors also suffer from lower employment.

4.3. Policy scenario 1: Corporate income tax and income transfer

Consider first the introduction of a corporate income tax on the energy sector (Fig. 6).[27] In keeping this scenario as simple as possible, we assume that a proportional tax on corporate profits in sector 1 is introduced and the revenues are immediately paid out as a lump sum to workers in sectors 2 and 3, keeping the government's budget balanced (see Appendix A for the details of the model extension). The corporate income tax-financed transfer to workers is effective in reducing inflation rates (panel a). The transfer increases workers' real disposable income, which is defined as wage plus transfer income. Since nominal wages in sector 2 are lower compared to sector 3, the lump sum transfer results in a proportional larger wage increase in sector 2 (panel b). As a result, workers moderate their nominal wage demands and the economy settles at a lower inflation rate (panel c). The increase in worker's disposable income further leads to an output expansion via higher consumption demand (panel d), which translates into a rise in

[27] Note that all policy scenarios only exhibit a policy change but no change in energy prices.

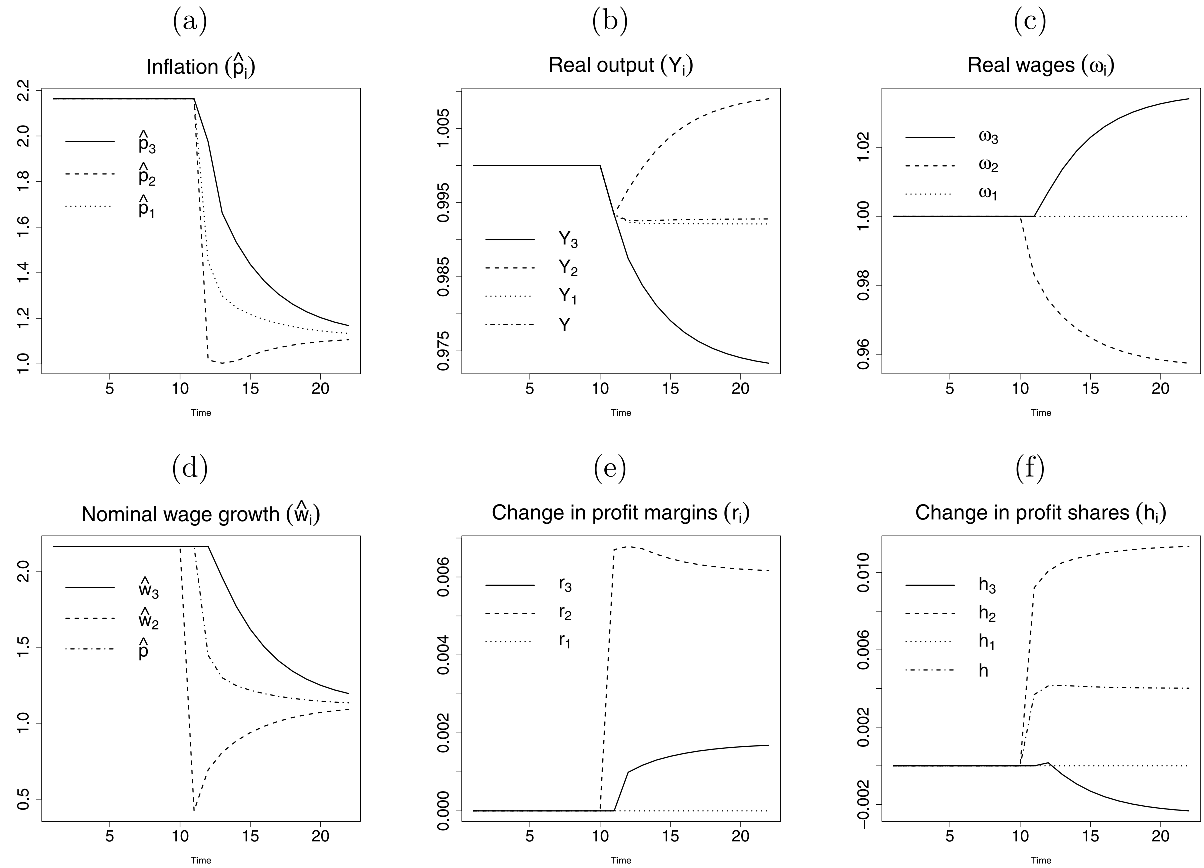

Fig. 7. Policy Scenario 2: Sector 2 wage restraint.
Notes: Responses to a permanent reduction in workers' real wage target (ω_2^W) in period 10. Responses in panels a and d show growth rates: $\frac{\Delta x_t}{x_{t-1}}$. Responses in panels b and c are normalised by their initial (steady state) values: x_t/x^*. Panels e and f show the percentage point change in profit margins and shares from the initial steady state: $x_t - x^*$.

employment. Lower nominal wage growth leads to an increase in sector 2 firms' profit margin. Profit margins also increase in sector 3 due to the increased mark up (panel e). Finally, profit shares in sectors 2 and 3 increase slightly, while the aggregate (post-tax) profit share declines.

Overall, introducing a corporate income tax in the energy sector proves to be an effective tool for reducing inflation while also stabilising workers' disposable income and employment. The key mechanism through which this policy works is the transfer paid to households which helps soften the conflict over the distribution of income.

4.4. Policy scenario 2: Wage restraint

The second scenario is a wage-restraint policy where workers in the sector which undergoes a fall in demand (sector 2), lower their real wage target (ω_2^W), i.e. accept a fall in living standards (Fig. 7). Convincing or forcing workers to halt nominal wage demands does lead to a fall in aggregate inflation (panel a) but also to a fall in output (panel b). Real wages decline for sector 2 workers but increase for sector 3 workers (panel c). The mechanism at play is that workers in sector 3 lower their nominal wage demand more slowly than the aggregate inflation falls (panel d). Wage growth below sector price growth allows both sectors to increase their profit margin (panel e), but only sector 2 manages to claim a larger share of sector value added (panel f), which however is large enough to also increase the aggregate profit share.

Overall, while effective in reducing inflation, a policy of wage restraint shifts the distribution of income towards firms and towards those workers who are able to maintain their real wage targets. Firms in those sectors where workers do engage in wage restraint (the services sector in our scenario), experience a boost in their profitability and a higher profit share. In the context of the current macroeconomic environment, a policy of sectoral wage restraint amounts to exacerbating inter-sectoral wage inequality as well as further depressing real wages of workers in that sector. Thus, confronting elevated inflation rates by wage restraint may curb inflation, but shifts the burden heavily on those workers who are not able to defend their real wages. It further boosts profit incomes which tend to be concentrated at the top of the income distribution.

4.5. Policy scenario 3: Contractionary macroeconomic policy

The last policy scenario is a reduction in autonomous aggregate demand (X), e.g., via a cut to fiscal expenses or contractionary monetary policy (Fig. 8). The reduction in aggregate demand leads to a fall in aggregate inflation as well as output and employment (panels a and b). The inflation rate falling faster than nominal wage growth, leads to an increase in real wages in sectors 2 and 3 (panels c and d). The fall in output leads to a reduction of the mark-up in sector 3 and as a result to lower profit margins (panel e). The aggregate profit share falls as well as in sector 3 (panel f).

Thus, contracting aggregate demand leads to a reduction in inflation, but is associated with significant costs in the form of lower output and employment. Our analysis thus identifies major shortcomings in the form of adverse distributional side-effects of macroeconomic policies that aim to bring down inflation via wage-restraint or demand-contraction.

5. Conclusion

The paper proposes a three-sector model of conflict inflation to analyse the distributional effects of energy price shocks in economies

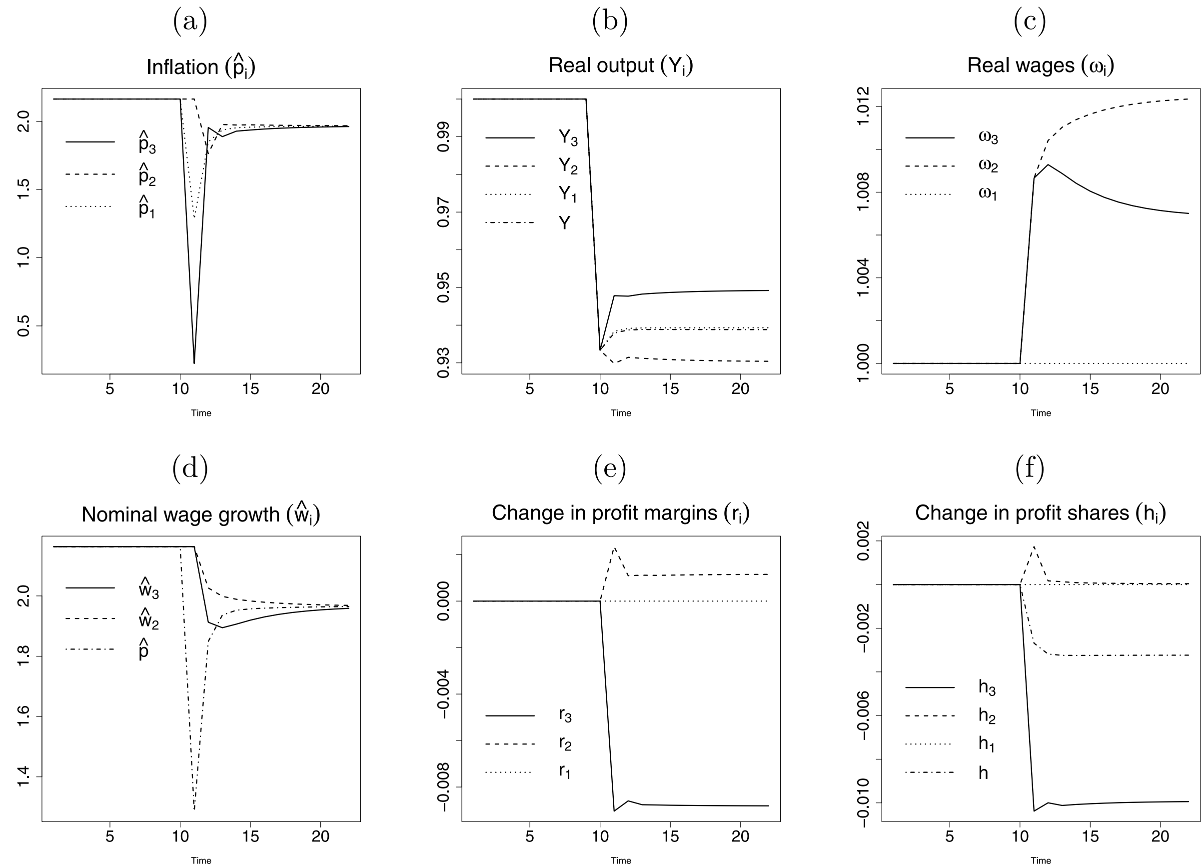

Fig. 8. Policy Scenario 3: Contractionary macroeconomic policy.
Notes: Responses to a permanent reduction in autonomous demand (X) period 10. Responses in panels a and d show growth rates: $\frac{\Delta x_t}{x_{t-1}}$. Responses in panels b and c are normalised by their initial (steady state) values: x_t/x^*. Panels e and f show the percentage point change in profit margins and shares from the initial steady state: $x_t - x^*$.

with domestic energy production. We use this model to study the recent experience of energy price increases combined with a pandemic-induced shift in consumer spending towards goods, and the occurrence of supply bottlenecks. Our main results, based on a calibration of the model to US data, are as follows. Firstly, energy price shocks allow energy firms to increase both their profit margins and profit shares, while in non-energy sectors only profit shares increase. Workers in the non-energy sectors get squeezed by falling real wages. Importantly, energy price shocks alone cannot explain increasing profit *margins* outside the energy sector in our framework. Second, to explain the empirically observed increased profit margins outside the energy sector (Bräuning et al., 2022; Hayes and Jung, 2022; Konczal and Lusiani, 2022; Weber and Wasner, 2023), pandemic-induced demand shifts and supply bottlenecks in the goods sector need to be considered. In this context, our model is able to reproduce recent empirical evidence indicating that inflation is not only driven by energy prices but also by increasing mark-ups (Hayes and Jung, 2022; Konczal and Lusiani, 2022; Weber and Wasner, 2023), where increases in mark-ups are in turn driven by the shift in consumer demand towards goods-producing sectors and supply bottlenecks in these sectors. Third, periods of high inflation are periods of income redistribution. The struggle over who bears the cost of higher energy prices and excess demand is shaped by the relative pricing power of firms between sectors as well as the relative strength of labour and capital within sectors. Fourth, our policy analysis suggests that a corporate tax on windfall profits in the energy sector that are transferred to workers is effective in reducing inflation, while at the same time sustaining workers' real disposable income. By contrast, a policy of wage restraint reduces inflation but leads to a significant reduction in disposable income for the affected workers, on top of the fall in real wages due to higher energy prices. The reduction in real wages further amplifies the contractionary effects of the energy price hike on aggregate demand. A reduction in aggregate demand through contractionary policy does reduce inflation but amplifies the reduction in output and unemployment caused by the energy price hike. Put plainly: if a policy requires severe unemployment rates to bring down inflation, suspicions may abound regarding whether the disease is better than the cure.[28]

Overall, our analysis points out that different anti-inflationary policies have different distributional consequences, which should be taken into account (Onaran, 2022). In the short term, policies which reduce the conflict over the distribution of income, for example by channelling excess profits to workers hit by higher energy costs, can have a deflationary effect. In the medium term, addressing the root causes of energy-driven inflation seems to be the most promising approach. In this respect, our model highlights the key role of energy intensity as a factor that amplifies the adverse inflationary and distributional effects of shocks to global fossil fuel markets. Reducing energy intensity may thus not only help to decarbonise the economy but also stabilise inflation and income distribution in the face of global shocks. Our model furthermore highlights that increasing mark-ups can fuel inflation. Thus, policies that reduce the pricing power of firms should be considered. This is particularly important in the light of the recent increase in industrial action and wage demands in response to declining real wages. Limiting the pricing power of firms would dampen the

[28] The Volcker shock has proven that high enough interest rates will eventually bring down inflation, but the negative side effects were substantial and indiscriminate. The US unemployment rate peaked at 10.8% in December 1982.

fall in households' living standards and thereby reduce the risk of inflationary spirals. These conclusions are particularly important for countries like the US which has not introduced a windfall tax, but where the labour share of income has been declining (Guschanski and Onaran, 2022) while income inequality has been increasing (Saez and Zucman, 2020). They gain urgency in light of the rise in industrial action and wage demands in response to declining real wages after the energy price shock. The implications of our analysis contrast with a theoretical paradigm that is insensitive to the distributional drivers of inflation (Amiti et al., 2022; Barrett and Adams, 2022; Hazell et al., 2022) and the distributional outcomes of anti-inflationary policies (Bolhuis et al., 2022).

There are several ways in which the framework presented here could be expanded in future research. Firstly, by explicitly modelling monetary policy one could compare an inflation targeting central bank with one which takes the distributional consequences into account. Secondly, a more direct treatment of inflation expectations could be added, e.g. by allowing for adaptive expectations along the lines of Hein and Stockhammer (2010) or Hein (2023). Thirdly, workers real wage targets could be endogenised to react to the state of the labour market. This requires a careful analysis of how quickly social norms around wages change and how sensitive wage demands are to the state of the economy. Fourth, the model could be extended by applying an agent-based household and firms sector (e.g. Caiani et al., 2016; Reissl, 2020). This extension could be fruitful in order to analyse the heterogeneity in firm profitability at a more granular level, including, for example, potential changes in profit margins of firms providing luxury goods or consumer staples.

CRediT authorship contribution statement

Rafael Wildauer: Conceptualization, Methodology, Software, Data curation, Writing – original draft, Writing – review & editing. **Karsten Kohler:** Conceptualization, Methodology, Software, Data curation, Writing – original draft, Writing – review & editing. **Adam Aboobaker:** Conceptualization, Methodology, Data curation, Writing – original draft, Writing – review & editing. **Alexander Guschanski:** Conceptualization, Methodology, Data curation, Writing – original draft, Writing – review & editing.

Appendix A. Corporate income taxation and lump sum transfers

This section formally introduces of a corporate income tax on profits in sector 1 (the energy sector) by applying a proportional tax on the sector's nominal profits ($\Pi_{1,n}$). Therefore nominal corporate income tax receipts (T_n) from sector 1 are given by:

$$T_n = t_1 \Pi_{1,n} \tag{A.1}$$

$$\Pi_{1,n} = p_1 Y_1 h_1 = p_1 Y_1 \left(1 - \frac{w_1}{v_1 p_1}\right), \tag{A.2}$$

where t_1 is the tax rate on sector 1 profits. The government uses these tax receipts and redistributes them as a lump sum payment to workers (for example through an energy bill support scheme). As a result, the consumption function and equilibrium nominal output become:

$$C_n = W_n + sT_n + (1-s)\Pi_n. \tag{A.3}$$

$$Y_n^* = \frac{X_n}{s}\left(h - t_1 h_1 \epsilon \left[\delta_2 \gamma \mu^{\gamma-1} + \delta_3(1-\gamma)\mu^{\gamma}\right]\right)^{-1} \tag{A.4}$$

Wage setting changes to:

$$w_{2,t+1} = w_{2,t} + w_{2,t}\left(\phi_2\left[\omega_2^W - \omega_{2,t} - \alpha\frac{T_n}{p_t L_2}\right]\right) \tag{A.5}$$

$$w_{3,t+1} = w_{3,t} + w_{3,t}\left(\phi_3\left[\omega_3^W - \omega_{3,t} - (1-\alpha)\frac{T_n}{p_t L_3}\right]\right), \tag{A.6}$$

where α is the share of tax receipts distributed to sector 2 workers ($1-\alpha$ goes to sector 3 workers) and

$$\frac{T_n}{p_t L_i} = \frac{v_i T_n}{p_t Y_i}. \tag{A.7}$$

All other model equations remain the same.

Appendix B. List of variables and parameters

See Tables B.1–B.3.

Table B.1
Exogenous model parameters.

Parameter	Description
X	autonomous components of demand
s	saving out of profits
δ_i	energy intensity of production
v_i	output per worker
θ_2^T	target mark-up in sector 2
ϵ	real price of energy
ω_1	real consumption wage in the energy sector
ω_i^T	workers' real wage target
ϕ_i	responsiveness of workers to deviations of real wage from target
ψ_i	responsiveness of firms to deviations of profit margin from target
γ	share of sector 2 in nominal final output

Appendix C. Proof of Proposition 2

The Jacobian matrix of the system in (16)–(17) is given by

$$J = \begin{bmatrix} \frac{\partial w_{2,t+1}}{\partial w_{2,t}} & \frac{\partial w_{2,t+1}}{\partial p_{2,t}} \\ \frac{\partial p_{2,t+1}}{\partial w_{2,t}} & \frac{\partial p_{2,t+1}}{\partial p_{2,t}} \end{bmatrix} = \begin{bmatrix} 1 + \hat{w}_2 - \phi_2\omega_2 & \phi_2{\omega_2}^2 \\ \psi_2 & 1 + \hat{p}_2 - \psi_2\omega_2 \end{bmatrix} \tag{C.1}$$

To prove Proposition 2, we need to show two things: firstly, that the system in (16)–(17) is unstable so that prices and nominal wages grow exponentially; and secondly, that prices and nominal wages grow at the same rate, i.e. that there is balanced growth. Mathematically, the first requires the Jacobian matrix to have a dominant eigenvalue that is outside the unit circle, and the second requires all elements of the dominant eigenvector associated with that eigenvalue to be nonzero and of the same sign. In that case, the dominant unstable eigenvalue will drive the dynamics of all state variables of the system such that these variables grow at the same rate, yielding constant and positive ratios between the state variables.

First, we analyse the conditions under which the Jacobian C is likely to have a dominant eigenvector with nonzero elements of the same sign. If the Jacobian matrix is nonnegative ($J \geq 0$), a sufficient condition for balanced growth is that it is irreducible (Szyld, 1985). In this case, by the Perron–Frobenius theorem, the dominant eigenvector of the Jacobian will be everywhere positive (Stachurski and Sargent, 2022, pp. 14–16). However, the Jacobian C will not necessarily be nonnegative as the elements J_{11} and J_{22} may become negative. Thus, irreducibility alone will not strictly guarantee balanced growth. Still, the occurrence of balanced growth is highly likely if the Jacobian matrix is irreducible even if some elements are negative, because then all state variables will feed into each other. Another way of looking at this is that if the Jacobian matrix is irreducible, the associated directed graph of the matrix is strongly connected (Szyld, 1985, p. 1415), i.e. any node that represents an endogenous variable of the system can be reached from any other (see the nodes for w_2 and p_2 in Fig. 2). As all variables feed into each other, they are likely to exhibit the same growth rate.

In the two-dimensional case, irreducibility requires the Jacobian to be non-triangular. Non-triangularity requires the off-diagonal elements of the Jacobian C to be non-zero. With an economically meaningful, i.e. positive, solution for the equilibrium real wage, non-triangularity is satisfied. Using the equilibrium solution for the real wage (22), firms'

Table B.2
List of model variables and equilibria (for the two-sector version).

Variable	Description	Equilibrium expressions
Π	Real profit bill	$\Pi = \frac{X}{s}$
W	Real wage bill	$W = \frac{X}{s}\frac{1-h}{h}$
C	Real aggregate consumption	$C = \frac{X}{s}\frac{1-sh}{h}$
Y_1	Real intermediate good production	$Y_1 = \frac{\delta X}{sh}$
h	Profit share in aggregate	$h = 1 - \delta\frac{\omega_1}{v_1} - \frac{\omega_2}{v_2}$
h_1	Profit share in sector 1	$h_1 = 1 - \frac{\omega_1}{v_1\epsilon}$
h_2	Profit share in sector 2	$h_2 = 1 - \frac{\omega_2}{v_2(1-\delta\epsilon)}$
Y_2^*	Real final output in equilibrium	$Y_2^* = \frac{X}{sh}$
$\hat{p}_2$	Inflation rate in sector 2	$\hat{p}_2 = v_2\psi_2[r_2^T - (1 - \frac{\omega_2}{v_2} - \delta\epsilon)]$
r_1	Profit margin in sector 1	$r_1 = 1 - \frac{\omega_1}{\epsilon v_1} = h_1$
r_2	Profit margin in sector 2	$r_2 = 1 - \frac{\omega_2}{v_2} - \delta\epsilon$
r_2^T	Target profit margin in sector 2	$r_2^T = \frac{\theta_2^T}{1+\theta_2^T}$
ω_2^*	Equilibrium real wage in sector 2	$\omega_2^* = \frac{\phi_2\omega_2^W + \psi_2 v_2(1-r_2^T-\delta\epsilon)}{\psi_2+\phi_2}$

Table B.3
List of model variables and equilibria (for the three-sector version).

Variable	Description	Equilibrium expressions
Y^*	Real aggregate output in equilibrium	$Y^* = \frac{X}{sh}$
Y_1	Real intermediate good output	$Y_1 = [\gamma\delta_2(\mu)^{\gamma-1} + (1-\gamma)\delta_3(\mu)^{\gamma}]Y$
Y_2	Real output in sector 2	$Y_2 = \gamma(\mu)^{\gamma-1}Y$
Y_3	Real output in sector 3	$Y_3 = (1-\gamma)(\mu)^{\gamma}Y$
h	Profit share in aggregate	$h = 1-(1-\gamma)(\mu)^{\gamma}(\frac{\omega_3}{v_3}) - \gamma(\mu)^{\gamma-1}\frac{\omega_2}{v_2} -$ $[\gamma\delta_2(\mu)^{\gamma-1} + (1-\gamma)\delta_3(\mu)^{\gamma}](\frac{\omega_1}{v_1})$
h_1	Profit share in sector 1	$h_1 = 1 - (\frac{\omega_1}{\epsilon v_1})$
h_2	Profit share in sector 2	$h_2 = 1 - (\frac{\omega_2}{v_2((\mu)^{1-\gamma} - \epsilon\delta_2)})$
h_3	Profit share in sector 3	$h_3 = 1 - (\frac{\omega_3}{v_3((\mu)^{-\gamma} - \epsilon\delta_3)})$
r_1	Profit margin in sector 1	$r_1 = h_1$
r_2	Profit margin in sector 2	$r_2 = 1 - (\mu)^{\gamma-1}\frac{\omega_2}{v_2} - (\mu)^{\gamma-1}\delta_2\epsilon$
r_3	Profit margin in sector 3	$r_3 = 1 - (\mu)^{\gamma}\frac{\omega_3}{v_3} - (\mu)^{\gamma}\delta_3\epsilon$

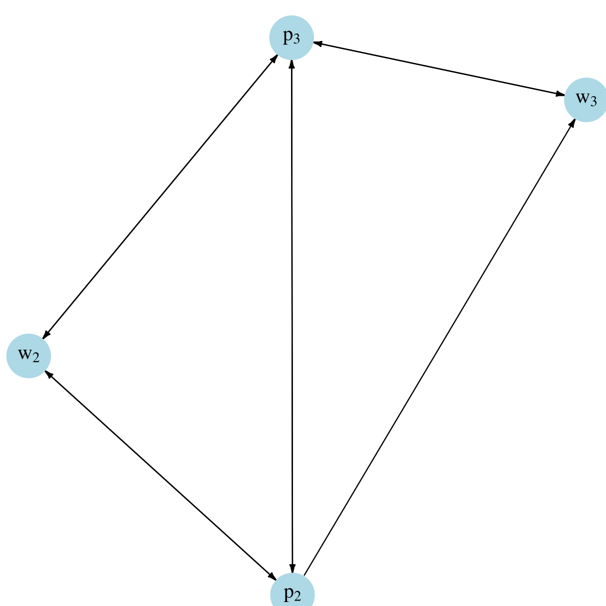

Fig. D.1. Directed Graph of the Jacobian Matrix (D.1).
Notes: Arrows from the state variables to themselves representing the main diagonal of the matrix (D.1) are omitted for clarity.

implicit real wage target $\omega_2^F = v_2\left(\frac{1}{1+\theta_2} - \epsilon\delta\right)$, and imposing $\omega_2^* > 0$ yields the following condition:

$$\phi_2\omega_2^W + \psi_2\omega_2^F > 0. \tag{C.2}$$

Second, we derive the conditions under which the system in (16)–(17) is unstable. A necessary condition for two-dimensional discrete time dynamic systems to be stable is $1 - tr(J) + det(J) > 0$, where $tr(J)$ and $det(J)$ are the trace and determinant of the Jacobian matrix (Medio and Lines, 2003, p. 52). Thus, if $1-tr(J)+det(J) < 0$, the system in (16)–(17) will be unstable. With $\hat{p}_2 = \hat{w}_2$, we have:

$$tr(J) = 2 + 2\hat{w}_2 - \omega_2(\phi_2 + \psi_2)$$
$$det(J) = 1 - \omega_2(\psi_2 + \phi_2) + \hat{w}_2[\hat{w}_2 + 2 - \omega_2(\psi_2 + \phi_2)].$$

From this, we get:

$$1 - tr(J) + det(J) = \hat{w}_2[\hat{w}_2 - \omega_2(\psi_2 + \phi_2)]. \tag{C.3}$$

Using the equation for wage dynamics (16) and the equilibrium solution for the real wage (22) and simplifying yields:

$$1 - tr(J) + det(J) = -\hat{w}_2\left[\frac{\omega_2^W\phi_2^2 + (2\phi_2 + \psi_2)\psi_2\omega_2^F}{\phi_2 + \psi_2}\right]. \tag{C.4}$$

With a positive equilibrium inflation rate $\hat{p}_2 = \hat{w}_2 > 0$, this term is always negative, and the system thus unstable. By (23), the equilibrium inflation rate is positive if $\omega_2^W > \omega_2^F$, which proves Proposition 2.

Appendix D. Analytical discussion of the three-sector model

The Jacobian for the system in (45)–(48) is given by Eq. (D.1) (see Box I), with

$$J_{41} = \frac{\partial p_{3,t+1}}{\partial w_2} = -\frac{ac\frac{\partial h}{\partial w_2}}{(bh+c)^2} = \frac{ac\gamma}{p_2 v_2(bh+c)^2} \tag{D.2}$$

$$J_{42} = \frac{\partial p_{3,t+1}}{\partial p_2} = d\gamma\left(\frac{p_2}{p_3}\right)^{\gamma-1} - \frac{af\frac{\partial h}{\partial p_2} - ah\frac{\partial f}{\partial p_2}}{f^2} \tag{D.3}$$

$$J_{43} = \frac{\partial p_{3,t+1}}{\partial w_3} = \psi_3 - \frac{ac\frac{\partial h}{\partial w_3}}{(bh+c)^2} = \psi_3 + \frac{ac(1-\gamma)}{p_3 v_3(bh+c)^2} \tag{D.4}$$

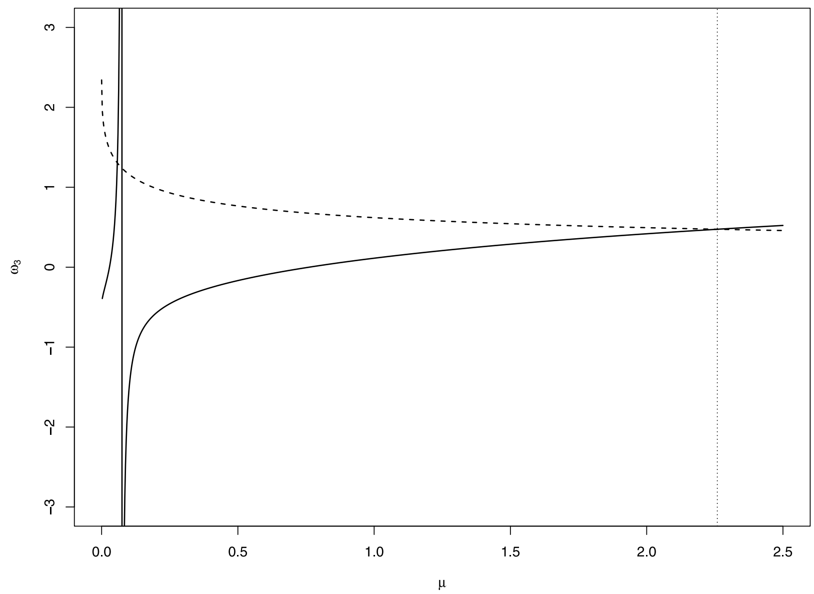

Fig. E.2. Equilibria of ω_3 and μ.
Notes: Based on empirically calibrated parameters reported in Table 1. Dashed line: Eq. (E.4), solid line: Eq. (E.5), vertical dotted line: economically meaningful equilibrium attained in simulation.

$$J(w_2, p_2, w_3, p_3) = \begin{bmatrix} 1 + \hat{w}_2 - \phi_2\omega_2 & \frac{\gamma\phi_2 w_2^2 p_3^{\gamma-1}}{p_2^{\gamma+1}} & 0 & (1-\gamma)\phi_2 w_2^2 \left(\frac{p_3^{\gamma-2}}{p_2^{\gamma}}\right) \\ \psi_2 & 1 - \psi_2 v_2(1 - r_2^T) + \psi_2 v_2 \epsilon_1 \gamma \delta_2 \left(\frac{p_2}{p_3}\right)^{\gamma-1} & 0 & \psi_2 v_2 \epsilon_1 (1-\gamma)\delta_2 \left(\frac{p_2}{p_3}\right)^{\gamma} \\ 0 & \gamma\phi_3 w_3^2 \frac{p_3^{\gamma-1}}{p_2^{\gamma+1}} & 1 + \hat{w}_3 - \phi_3\omega_3 & (1-\gamma)\phi_3 w_3^2 \frac{p_3^{\gamma-2}}{p_2^{\gamma}} \\ J_{41} & J_{42} & J_{43} & J_{44} \end{bmatrix} \quad \text{(D.1)}$$

Box I.

$$J_{44} = \frac{\partial p_{3,t+1}}{\partial p_3} = 1 + d(1-\gamma)\left(\frac{p_2}{p_3}\right)^{\gamma} - \frac{a_2 f_2 \frac{\partial \tilde{h}}{\partial p_3} - a_2 \tilde{h} \frac{\partial f_2}{\partial p_3}}{f_2^2} \quad \text{(D.5)}$$

where: $a = v_3\psi_3 Y_3^P s p_{3,t}$; $a_2 = v_3\psi_3 Y_3^P s$; $b = (1+\beta_0)Y_3^P s$; $c = \beta_1(1-\gamma)X p_{2,t}^{\gamma} p_{3,t}^{-\gamma}$; $c_2 = \beta_1(1-\gamma)X p_{3,t}^{-\gamma}$; $c_3 = \beta_1(1-\gamma)X p_{2,t}^{\gamma}$; $d = \psi_3 v_3 \epsilon_1 \delta_3$; $f = bh^* + c_2 p_{2,t}^{\gamma}$; $f_2 = bh^* + c_3 p_{3,t}^{-\gamma}$; $\tilde{h} = p_{3,t}h^*$; $\frac{\partial f}{\partial p_2} = b\frac{\partial h^*}{\partial p_2} + c_2\gamma p_{2,t}^{\gamma-1}$; $\frac{\partial f_2}{\partial p_3} = b\frac{\partial h^*}{\partial p_3} - c_3\gamma p_{3,t}^{-\gamma-1}$; $\frac{\partial \tilde{h}}{\partial p_3} = h^* + p_3\frac{\partial h^*}{\partial p_3}$. As discussed in Appendix C, for the system to be unstable, the Jacobian matrix needs to exhibit at least one root outside the unit circle. In the two-sector benchmark, instability is the outcome of the interaction between p_2 and w_2, with workers and firms pursing inconsistent real wage targets. In the three-sector extension, this is not necessarily the case anymore as workers target the consumption real wage, whereas firms target the product real wage. However, the interaction between the two subsystems (p_2, w_2) and (p_3, w_3) introduces another potential source of instability. While it is difficult to derive economically meaningful instability conditions, numerical analysis based on the empirically calibrated parameters reported in Section 3 shows that the two subsystems are individually stable while the combined system is unstable.

To show that the state variables are likely to grow at the same rate, we examine whether the Jacobian matrix (D.1) is irreducible. As discussed in Appendix C, irreducibility makes it highly likely that the dominant eigenvector will have nonzero elements of the same sign (although with the presence of negative elements in the Jacobian, there is no guarantee that this will be the case). The directed graph associated with the Jacobian matrix (D.1) is shown in Fig. D.1. It can be seen that the directed graph is strongly connected, i.e. any node can be reached from any other, which means that (D.1) is irreducible (Szyld, 1985, p. 1415). Indeed, the two subsystems (p_2, w_2) and (p_3, w_3) mutually impact each other. As a result, the elements of the dominant eigenvector are likely to be different from zero. If they have the same sign, all variables will grow at the same rate. For the empirically calibrated parameterisation, this is indeed the case.

Appendix E. Equilibria of the three-sector model

Equating the growth rates of wages and prices for each sector in (45)–(46) and (47)–(48) yields:

$$\omega_2 = \frac{c_1 - c_2\mu^{1-\gamma}}{\phi_2 + \psi_2\mu^{1-\gamma}} \quad \text{(E.1)}$$

$$\omega_3 = \frac{c_8 - c_9\mu^{-\gamma} + \frac{c_{10}}{c_{11} + \frac{c_3}{\mu^{\gamma} + c_4 - c_5\omega_3 - c_6\omega_2\mu - c_7\mu}}}{\psi_3\mu^{-\gamma} + \phi_3}, \quad \text{(E.2)}$$

and equating the growth rates of wages in sector 2 and 3 in (45) and (46) yields:

$$\omega_2 = c_{12} + c_{13}\omega_3, \quad \text{(E.3)}$$

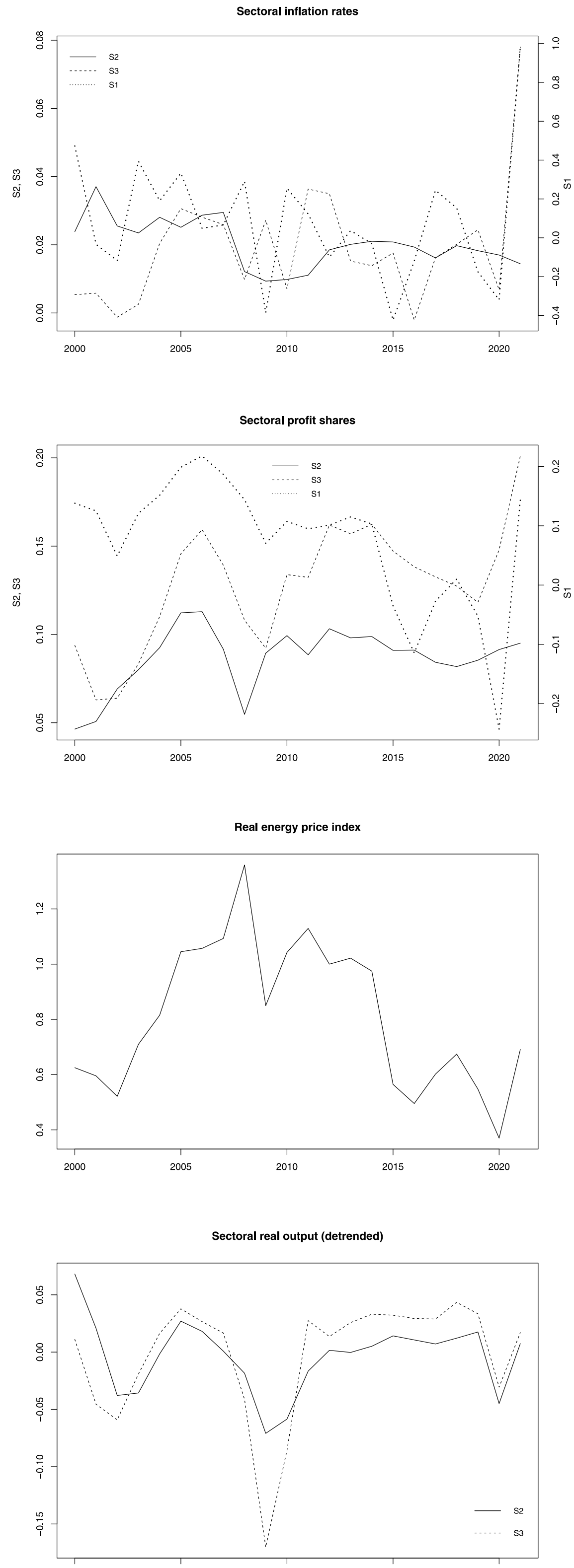

Fig. F.3. Time series used to construct empirical moments.
Notes: S1: sector 1 (energy), S2: sector 2 (services), S3: sector 3 (goods).

where the c_i's are the following exogenous composite parameters:

$$c_1 = \phi_2 \omega_2^W + \psi_2 \upsilon_2 (1 - r_2^T)$$

$$c_2 = \phi_2 \upsilon_2 \delta_2 \epsilon$$

$$c_3 = \frac{\beta_1 (1-\gamma) X}{Y_3^P s}$$

$$c_4 = -\delta_3 (1-\gamma) \left(\frac{\omega_1}{\upsilon_1} \right)$$

$$c_5 = \frac{1-\gamma}{\upsilon_3}$$

$$c_6 = \frac{\gamma}{\upsilon_2}$$

$$c_7 = \delta_2 \gamma \left(\frac{\omega_1}{\upsilon_1} \right)$$

$$c_8 = \phi_3 \omega_3^W$$

$$c_9 = \epsilon \delta_3 \psi_3 \upsilon_3$$

$$c_{10} = \psi_3 \upsilon_3$$

$$c_{11} = 1 + \beta_0$$

$$c_{12} = \omega_2^W - \frac{\phi_3}{\phi_2} \omega_3^W$$

$$c_{13} = \frac{\phi_3}{\phi_2}$$

Combining (E.1) and (E.3) yields:

$$\omega_3 = \frac{c_1 - c_2 \mu^{1-\gamma}}{(\phi_2 + \psi_2 \mu^{1-\gamma}) c_{13}} - \frac{c_{12}}{c_{13}}. \tag{E.4}$$

Combining (E.2), (E.3), and (E.4) yields:

$$\omega_3 = \frac{c_8 - c_9 \mu^{-\gamma} + \frac{c_{10}}{c_{11} + \frac{c_3}{\mu^\gamma + c_4 - \left(\frac{c_1 - c_2 \mu^{1-\gamma}}{\phi_2 + \psi_2 \mu^{1-\gamma}} \right) \left(c_6 \mu + \frac{c_5}{c_{13}} \right) + \frac{c_5 c_{12}}{c_{13}} - c_7 \mu}}}{\psi_3 \mu^{-\gamma} + \phi_3}. \tag{E.5}$$

Eqs. (E.4) and (E.5) are a two-dimensional nonlinear system in ω_3 and μ. While this can be reduced to a single rational function in μ whose roots yield the equilibria, the resulting expression does not admit a clear-cut statement about the possible number of economically meaningful equlibria. Instead, Fig. E.2 plots Eqs. (E.4) and (E.5) for the empirically calibrated parameters reported in Table 1. It can be seen that there are three equilibria. The first two equilibria occur for very small values of μ and values of ω_3 above the real wage target ω_3^W. Thus, these equilibria are inconsistent with a positive equilibrium inflation rate. The economically meaningful equilibrium occurs for $\omega_3^* < \omega_3^W$ and is the one reached in the simulations reported in the main text.

Appendix F. Data for calibration

The energy sector consists of mining (NAICS 21), which is dominated by oil and natural gas extraction. The services sector includes utilities (22), information (51), finance and insurance (52), real estate (53), professional services (54), management of companies (55), administrative and support services (56), education (61), health care (62), arts and entertainment (71), accommodation (72) and other services (81).[29] This represents a narrowly defined services sector which does not include what we call 'goods related' services such as transport or retail. Since these latter sectors would also benefit from a demand shift we included them in a broadly defined goods sector consisting of agriculture (11), construction (23), manufacturing (31–33), wholesale trade (41–42), retail trade (44–45) and transportation and warehousing (48–49). For details see Fig. F.3 and Table F.4.

[29] Numbers in brackets represent the NAICS 2 digit code. Some sector names are abbreviated.

Table F.4
Data definition.

Series	Definition	BEA Table	Notes
Real aggregate output	Log of real gross output, detrended	Value added by industry	Detrended using Hamilton's regression filter
Sector inflation	Annual growth rate of implicit sector deflator	Value added by industry	
Aggregate price index	Deflator of S2 and S3 output	Value added by industry	
Sector profit shares	Corporate profits relative to value added	Table 6.17D	
Real energy price index	Price index of S1 over aggregate price index	Value added by industry	Energy price index was normalised to have mean 0.7 and standard deviation 0.01.

All series except the series on corporate profits are obtained from BEA's GDP by Industry Tables.

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