Carbon Prices and Inflation in a World of Shocks
Systemically significant prices and industrial policy targeting in Germany

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Abstract

Climate change and geopolitical tensions render supply shocks more likely, which can trigger inflation ("shockflation"). Additionally, the EU's reliance upon an emissions trading system as its chief climate mitigation policy can give rise to inflation ("carbonflation"). Through simulations using an input-output price model for Germany, we show that the same systemically significant sectors – those essential for human livelihoods, production and commerce – present points of vulnerability for shockflation and also carbonflation, if carbon markets are the only policy tool deployed to cut emissions. A total of up to 91.3 percent of potential carbonflation can be attributed to just six systemically significant sectors. Our findings remain robust under varying assumptions regarding substitution and passthrough effects. The challenge for policymakers is to design policies that combine transformation with stabilization. Enhancing resilience, dampening price volatility and designing green industrial policies for these key sectors can reduce the macroeconomic risks of both carbonflation and shockflation.

Keywords: inflation, supply shocks, climate change, carbon price policy, economic resilience

JEL codes: C67, E31, E61, Q48, Q58

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1. Introduction

Supply shocks have been widely cited as important drivers of inflation in recent years (Bernanke and Blanchard, 2023; Kilian and Zhou, 2022). Certain sectors have a greater potential to trigger such "shockflation" than others (Weber et al., 2024). Borrowing from the idea of some banks being too important or too connected to fail in the context of financial stability, we consider these sectors as systemically significant (Hockett and Omarova, 2016). The recent bout of shockflation has been unleashed by the emergencies of the COVID-19 pandemic and the Russian attack on Ukraine. However, the climate emergency has also been identified as a trigger for shockflation (Burke et al., 2015; Dell et al., 2012; Kotz et al., 2024; Schnabel, 2022; Solaun and Cerdá, 2019). While climate change poses a major threat to price stability, CO_2 price policies – particularly when they are market-based and volatile as is the case for the key climate mitigation tools in the European Union – can create additional inflationary pressures (e.g., Brand et al, 2023; Hensel et al., 2024; Konradt et al., 2024), which we term "carbonflation". Climate change mitigation policies face challenges in an inflationary environment. If central banks respond to shockflation by raising interest rates and governments resort to fiscal austerity, as seen in the eurozone, there is a risk that decarbonization investments will slow down or even halt due to high upfront capital costs in critical areas like renewable energy (Egli, et al., 2018; Schmidt et al., 2019; Kriwoluzky and Volz, 2023).

In this paper we use input-output simulations to assess which sectors are systemically significant for both shockflation and carbonflation. Our modeling approach is consistent with other input-output studies that trace shock propagation and amplification.[7] We expand on the modeling approach developed for the United States by Weber et al. (2024) to provide a sectoral perspective on inflation risks. While most studies analyze the impact of a shock to a single industry or goods market, we simulate shocks to all sectors of the economy and rank them based on their simulated total inflation impact (direct and indirect).

Germany serves as a particularly interesting case for shockflation in light of the 2022 energy crisis in the wake of the Russian attack on Ukraine. The energy price shock has been the most significant driver of inflation in Germany (Pallotti et al., 2023). Germany is also relevant for carbonflation because, in addition to its national carbon pricing policies, it participates in the European Emissions Trading System (ETS1) and will join the ETS2 starting in 2027, which will replace the national carbon price. The consequences of this transition for price stability are uncertain. Some experts warn that the prices under the ETS2 could be highly

[7] Such studies assess for example the impact of energy price shocks with a focus on the effects on households across different countries (Guan et al., 2023; Zhang et al., 2023); the regressive redistribution triggered by surging energy prices (Ari et al., 2022; Steckel et al., 2022) and carbon prices (Dorband et al., 2019; Feindt et al., 2021; Feng et al., 2010; Labandeira and Labeaga. 1999, 2005; Mardones, 2024; Steckel et al., 2021; Zhang et al., 2019) including the effects of cash transfers (Missbach et al, 2024; Vogt-Schilb, 2019), and analyze the impact of energy prices on global economic stability and growth (Zhao et al., 2023).

volatile, potentially leading to a carbon price shock comparable to the fossil fuel price shock of 2022 (Agora Energiewende und Agora Verkehrswende, 2023; Kalkuhl et al., 2023).

Our paper has three main findings: First, systemically significant sectors for shockflation fall into three categories: essentials for human livelihoods (e.g., food, utilities), essentials for production (e.g., energy inputs), and essentials for commerce (e.g., warehousing and transportation). Five sectors have had an outsized impact on Germany's shockflation following the onset of the Russian war in Ukraine: Oil and Gas; Electricity, Heating, and Cooling; Food, Beverages, and Tobacco; Agriculture; and Coke and Petroleum Products. These sectors were also identified as points of vulnerability for price stability in our analysis using pre-COVID-19 data to determine latent systemic significance. The top sectors with the largest potential and realized inflation impact are robust to a range of assumptions on substitution and passthrough effects.

Second, the sectors with the greatest potential to trigger carbonflation are a subset of those with latent systemic significance for shockflation. Up to 91.3 percent of carbonflation is driven by six sectors: Real Estate Services; Electricity, Heating, and Cooling; Oil and Gas; Land Transport; Coke and Petroleum Products; and Food, Beverages, and Tobacco. These sectors are both points of vulnerability for inflation due to exogenous shocks and main drivers of carbonflation induced by carbon pricing. The link between shockflation and carbonflation is the high price volatility of fossil fuels which is an important driver of shockflation and coincides with the high emissions intensity which determines the relevance of carbon prices.

Third, there is major uncertainty around future levels and volatility of carbon prices and, consequently, the magnitude of carbonflation. Using estimates of carbon prices by Pietzcker et al. (2021) in line with EU emission reduction targets, we find that the cumulative inflation impact from 2023 to 2030 ranges from 3.4 percent (lower bound CO_2 price estimates of EUR 95/tCO_2 for ETS1 sectors and EUR 210/tCO_2 for ETS2) to 7.2 percent (upper bound estimates of EUR 210/tCO_2 for ETS1 sectors and EUR 405/tCO_2 for ETS2). To put this into perspective, when translated into annual inflation rates the simulated carbonflation ranges from 17 percent to 36 percent of the annual ECB inflation target of 2 percent. Importantly, these estimates assume that no measures other than carbon pricing are implemented to meet the emissions targets. Other emissions mitigation measures would likely lower the CO_2 price. Our estimates of carbonflation are consistent with the literature (e.g., Delgado-Téllez et al., 2022; Konradt et al. 2024; Nöh et al. 2020).

The rest of the paper proceeds as follows: In the next section, we introduce our modeling approach. In the third section we identify systemically important prices in the recent German shockflation using both long-run price volatilities and the recent energy crisis to calibrate our simulation of price shocks. In the fourth section, we illustrate the uncertainty around the magnitude of carbonflation and analyze the extent to which carbonflation is driven by systemically important prices in our simulations. The fifth section concludes.

2. Approach to input-output simulations

a. The general model

We implement simulations of the inflation impact of sectoral price shocks using a Leontief price model for the German economy. We consider two kinds of shocks: (1) an exogenous output price change of an individual industry to simulate shockflation, and (2) a CO_2 price policy that increases the costs of production of all industries to simulate carbonflation. Our modeling strategy expands on Weber et al. (2024) by incorporating two new features: First, we directly account for import price changes. Second, we bridge the input-output table with the actual CPI instead of using a synthetic version, thereby improving our measurement of inflation impacts.

The starting point is the basic identity showing that the value of output for each industry is equal to the value of domestically produced inputs, plus the value of imported inputs, plus value added. Value added consists of profits (gross operating surplus), wages (workers' compensations), and net taxes. Equation (1) expresses this identity for all industries with matrix notation:

$$\hat{X}P = \hat{X}A'P + M + V \tag{1}$$

Where $\hat{X}$ is a diagonal matrix of gross output, P the vector of unit prices, A is the matrix of domestic direct requirements, and M and V the vectors of imports of intermediate goods and value added, respectively. Premultiplying both sides of equation (1) by $\hat{X}^{-1}$ and solving for P retrieves the basic equation of the Leontief price model:

$$P = (I - A')^{-1}(m + v) \tag{2}$$

Here, m and v represent vectors of the ratios of imported inputs and value added per unit of output for each sector. Equation (2) shows how the unit prices of all industries depend on each other through their input-output relationships (expressed in matrix A') and the prices of primary inputs (imported inputs and value added). More specifically, matrix $(I - A')^{-1}$ is the transpose of the Leontief inverse matrix and its elements represent the *direct and indirect* requirements of domestic inputs to produce one unit of output for each sector.

b. Exogenous price shocks and inflation impact

To simulate price shocks in individual industries, we set the price of the targeted industry as exogenous. This means the output price is independent of other goods' prices, wages, profits, and import prices.

Additionally, sectors within the categories of "commodities" and "rent" that do not generally follow a cost-plus markup pricing logic, such as Coal, Oil and Gas, Mining and Quarrying, and Real Estate Services, are also set as exogenous in all simulations. Let E represent the subset of endogenous sectors and X the subset of exogenous sectors. We can now write an alternative version of equation (2) as (see derivation and explanation of this equation in the Appendix A.2):

$$P_E = (I - A'_{EE})^{-1}A'_{XE}P_X + (I - A'_{EE})^{-1}(m_E + v_E) \tag{3}$$

Where A_{EE} and A_{XE} are partitions of the original domestic requirements matrix A.[8] This equation shows that endogenous sectors' prices depend on exogenous sectors' prices. Let ΔP_X and ΔP_M represent the price change of the exogenous domestically produced goods and of the imported exogenous goods, respectively. We assume that $\Delta P_X = \Delta P_M$, meaning equal price changes for the same domestic and imported goods.[9] The price change of imported inputs ΔP_M modifies the share of imported inputs in gross output Δm_E (see Appendix A.1 for the mathematical derivation). The prices of endogenous sectors will change according to the following equation:

$$\Delta P_E = (I - A'_{EE})^{-1}A'_{XE}\Delta P_X + (I - A'_{EE})^{-1}\Delta m_E \tag{4}$$

This equation indicates that a change in the domestic and import prices of one of the sectors in the economy generates a price change in the endogenous sectors given by ΔP_E. The element i of this vector shows the percentage change in the price of industry i caused by the price change ΔP_X and the equivalent import price change. But we are interested in deriving a single measure of the inflation a price shock generates. To do so, we calculated a weighted average of the vectors of price changes, termed the "inflation impact". This refers to the price increase of an average national consumption basket brought about by an initial price change. We can divide this total effect into its direct and indirect components. Formally, for an initial shock ΔP_X, we have:

$$IP_{tot} = \textstyle\sum_{i \neq x} w_i \Delta P_E^i + w_X \Delta P_X \tag{5a}$$

[8] The first subindex represents the rows and the second the columns that are kept from the original matrix A.

[9] For our analysis, we are agnostic about the origin of the shock. This no-arbitrage condition implies that the shock could have originated domestically or abroad, but once it happened, domestic and imported prices must move together, so the law of one price holds.

$$IP_{ind} = \sum_{i \neq x} w_i \Delta P_E^i \quad (5b)$$

$$IP_{dir} = w_X \Delta P_X \quad (5c)$$

The subscripts on the left of the equations refer to the total, direct and indirect inflation impact. w_i is the share of industry i in the CPI, and $\Delta P_E{}^i$ is the price change for the endogenous sector i (the subscript x refers to the CPI share of the exogenous industries). This means that our measures of inflation impact can be interpreted as the percentage increase in the CPI induced by a price shock in any particular sector. The direct effect refers to consumers paying more for the final goods produced by the industry where the original price shock occurs. The indirect inflation impact reflects the extent to which other firms use the output of the shocked industry as inputs, which raises their production costs and, consequently, the final price of their products.

The actual price shocks (ΔP_X) we use to simulate the inflation impact of sectoral cost increases and to identify systemically important sectors are:

- Sectoral price volatility from 2000 to 2019 (i.e., the standard deviation of the yearly price changes in this time period), capturing the latent tendency of prices to move in a sector.
- The annual price change 2021 Q3 - 2022 Q3 (i.e., the peak price increases following the onset of the Russian war against Ukraine).

c. Carbon price

To simulate the inflation impact of a carbon price policy, we calculate the vector of the carbon price paid per unit of output for each industry (τ) by applying the carbon price $\hat{\theta}$ (a diagonalized vector with the price of a unit of CO_2 emitted per industry) to the carbon intensity vector (c):

$$\tau \ = \hat{\theta}\ c \quad (6)$$

We partition τ into endogenous sectors (τ_E) and exogenous sectors (τ_X), and add τ_E and τ_X to their corresponding primary cost vector (valued added plus imports). We assume that price changes for domestic goods are equivalent to those for imported goods, resulting in a change in the share of imported inputs in gross output. However, only a portion of imported inputs is affected by carbon price changes, that is, the share of imports originating from other EU Member States. Therefore, we account for the impact of price changes due to carbon prices in ETS1 and ETS2 in other EU Member States that export products to Germany and pass on their price increases. The price change for exogenous sectors (ΔP_X) from carbon pricing is the respective value of τ_X, while the price change for endogenous sectors is given by:

$$\Delta P_E = (I - A'_{EE})^{-1} A'_{XE} \tau_X + (I - A'_{EE})^{-1} (\Delta m_E + \tau_E) \quad (7)$$

Stacking the vectors of price changes (ΔP_E and ΔP_X) results in the final vector of price changes, denoted as ΔP_{CO_2}. The overall inflation impact and the carbon price revenue depend on the carbon price and carbon intensity.[10]

We perform the simulations in a similar way as for the exogenous price changes described in the previous section; simulating the effect of the CO_2 price *one sector at a time*. In each simulation, only one sector pays the respective CO_2 price. This gives us a measure of the inflation impact of the CO_2 price for each sector. As before, we can divide this total sectoral inflation impact into its direct and indirect components. However, an important difference is that we can sum each sectoral inflation impact to obtain the aggregate inflation impact of the CO_2 price policy as a whole. This aggregate result is the same as if we had assumed that each sector pays their CO_2 price simultaneously. This method allows us to estimate the aggregate inflation impact of a CO_2 price policy, and to determine the contribution of each sector to this aggregate inflation.

d. Dynamic substitution effect

So far, we assumed that the production technology remains constant. However, technology upgrading is precisely the purpose of a CO_2 price policy. We therefore relax this assumption and incorporate dynamic substitution effects[11]. The dynamic substitution is achieved by modifying technical coefficients (a_{ij}) from the domestic technical requirement matrix A to reflect a reduction in energy requirements in response to an increase in price. We also assume zero substitution for non-energy inputs (Bun, 2018).

The relative price between energy and the sectoral value added will increase when adding carbon prices. Since value added is exogenous in the baseline input-output price model, this change in the relative price of energy is the change in the energy sector price (defined here as Δp_1). Following Bun (2018) and assuming a scenario of pure technological progress where producers manage to reduce their use of energy without increasing their use of any other input, the effect of the relative increase in the energy price will affect just the technical coefficient (a_{1j}) for energy inputs for any sector j in the following way:

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[10] This baseline model does not account for household carbon emissions leading to an underestimation of the carbon price inflationary impact. To rectify this, we distribute household emissions that are mainly generated due to heating and transportation (private and public) to the sectors where they accrue. We therefore calculate the inflation impact of pricing household emissions independently of our input-output price model as they do not present indirect effects because they do not correspond to inputs to other sectors. Formally, we add the tax revenue per unit of gross output for the three relevant sectors (Coke and Petroleum Products, Electricity, Heating and Cooling and Land transport) stemming from household emissions to the sectoral price changes.

[11] It is inspired by the "induced technical change" first introduced by Hicks (1932), and it is also similar to what Sylos-Labino referred to as "dynamic substitution" (Sylos-Labini, 1988 and 1995)

$$\Delta a_{1j} = -\frac{\sigma_j \, \Delta p_1}{1 + \sigma_j \Delta p_1} a_{1j} \tag{8}$$

Where the parameter σ_j shows how the energy technical coefficient reacts to a change in energy prices. The negative sign of Δa_{ij} indicates that producers manage to reduce their use of energy when energy prices increase. For our analysis, σ_j is the elasticity of substitution parameter calibrated to values from the literature. It is straightforward to calculate ΔA, which is a matrix capturing the changes in the direct technical coefficients. The following equation derives the inflation impact of the CO_2 price policy when we take account of substitution:

$$\Delta P_{CO_2} = L'\Delta l + L'\Delta A'p \tag{9}$$

The first term, $L'\Delta l$ is the inflation impact without substitution: this term is equal to $(I - A')^{-1}\Delta l$, which is equivalent to the right-hand side of equation (2). The second term ($L'\Delta A'p$) represents the pure technological progress (or dynamic substitution) effect. Since all the elements of $\Delta A'$ are either negative or zero, all the elements of $L'\Delta A'p$ will also be negative or zero, meaning that the inflation impact will be lower due to the dynamic substitution effect.

e. Data

To implement our simulations of price shocks and CO_2 price policies for Germany, we aggregate the 2019 input-output table (Destatis, 2023b) to align with emissions data provided by the German Federal Statistical Office (Destatis), resulting in a modified input-output table encompassing 53 sectors. We compile price data from various Destatis sources to match the input-output sectors. For some sectors, there is no direct match. In these cases, we estimate prices by creating a sectoral price index compiled from other relevant sectors. There is some variation between sectors in the coverage of price data across time (see Table B.1 in the appendix).

An important contribution of this paper is simulating the effect of price shocks on the actual CPI. This requires aligning the input-output sectors with the Classification of Individual Consumption by Purpose (COICOP) categories. We connect these two classification systems using the consumption interdependence table (Konsumverflechtungstabelle) for 2019, obtained from Destatis, thereby enhancing the accuracy of our inflation impact estimations by bypassing assumptions about product-commodity relationships (Jacksohn et al., 2023).

We source 2021 greenhouse gas emissions data (measured in CO_2-equivalent) from the environmental economic accounting provided by Destatis (2023a). The table also specifies the sectoral emissions that fall under the ETS1, approximately 40 percent of all emissions in Germany in 2021. However, the Destatis data lacks precise sectoral emissions for the national carbon pricing system. According to the German emission trading authority (DEHSt), another 306 million tons of carbon emissions were priced nationally in the same year (DEHSt, 2023). To distribute these emissions, we follow Öko-Institut (2024) and Agora Energiewende and Agora Verkehrswende (2023), which report the sectoral shares of emissions that fall under the national emission trading system. As these sectors are in the Common Reporting Format (CRF), we employ Eurostat's correspondence table (Eurostat, 2015) to align them with our input-output sectors that are based on Classification of Products by Activity (CPA) categories. Most of these nationally priced emissions are attributed to private households, with the remainder allocated to manufacturing or energy industries. Consequently, some sectors have a share of their emissions priced by the ETS1, another share by the national carbon pricing system. This approach ensures that we closely approximate real-world carbon pricing in Germany while accounting for the majority of emissions that are indeed subject to a carbon price (77 percent of all emissions).

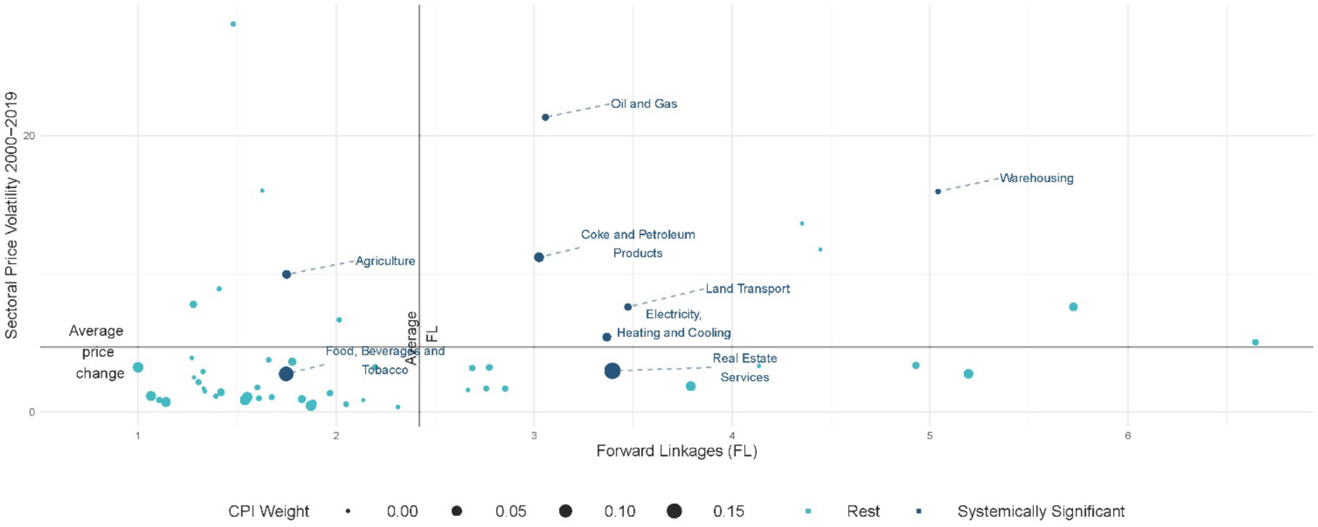
3. Points of vulnerability for "shockflation"

In order to identify the sectors that are systemically significant for price stability in the German economy we report two sets of results in this section. First, we use sectoral price volatilities (from 2000 to 2019) as exogenous price changes and simulate their potential inflation impact. This allows us to rank each sector based on its potential impact on inflation. The sectors at the top of this ranking had the greatest *potential* to generate inflation prior to the recent shockflation episode. In other words, these top-ranked sectors are *latent* systemically significant. Secondly, we calculate the actual price changes observed in the 2022 shockflation at the peak of the energy crisis in the wake of the war in Ukraine. The top sectors of this ranking played a key role in the recent shockflation episode and have *realized* systemic significance based on our simulations. Most of the sectors with latent systemic significance also had realized latent systemic significance.

a. Latent systemic significance

In our model, there are three pathways to systemic significance for inflation: the tendency of prices to move (volatility), the importance of a sector as direct or indirect input for all other sectors (forward linkages), and the weight of a sector's output in personal consumption (weight in the CPI) (see Figure 1 for illustration). These three dimensions jointly determine the inflation impact of a sectoral price shock.

Figure 1: Sectoral Price Volatility vs. Forward Linkages



Notes: The measure of forward linkages of each industry is equal to the sum of the rows of the total domestic requirements matrix, and is given by the x-axis. The average annual price change of each industry between 2000-2019, which we call the "sectoral price volatility" of the industry, is displayed on the y-axis. The position of the horizontal and vertical axes indicate the price volatility of all industries and the average measure of forward linkages of all industries, respectively. Industries identified as systematically significant are colored dark blue and displayed with their description. The seize of the dots indicate each sector's weight in the CPI. The rest is colored light blue. Data sources: destatis Input-Output 2019 tables, destatis price indices.

For the United States, Weber et al. (2024) identify three groups of systemically significant sectors: 1) those that provide essentials for human livelihood such as Food, Housing and Utilities, 2) those that provide essential production inputs including energy like Oil and Petroleum Products, and Chemicals, and 3) those providing the essential infrastructure for commerce like Wholesale Trade. Our findings confirm the existence of these three groups of systemically significant sectors in Germany. The rankings of all sectors based on their simulated inflation impacts are presented in Table B.2. Figure 2 shows the latent systemic significance ranking of all 53 sectors. The top ten ranks stand out for outsized inflation impacts ranging from 0.22 to 0.87 percent. We classify these sectors as having latent systemic significance. They are:[12]

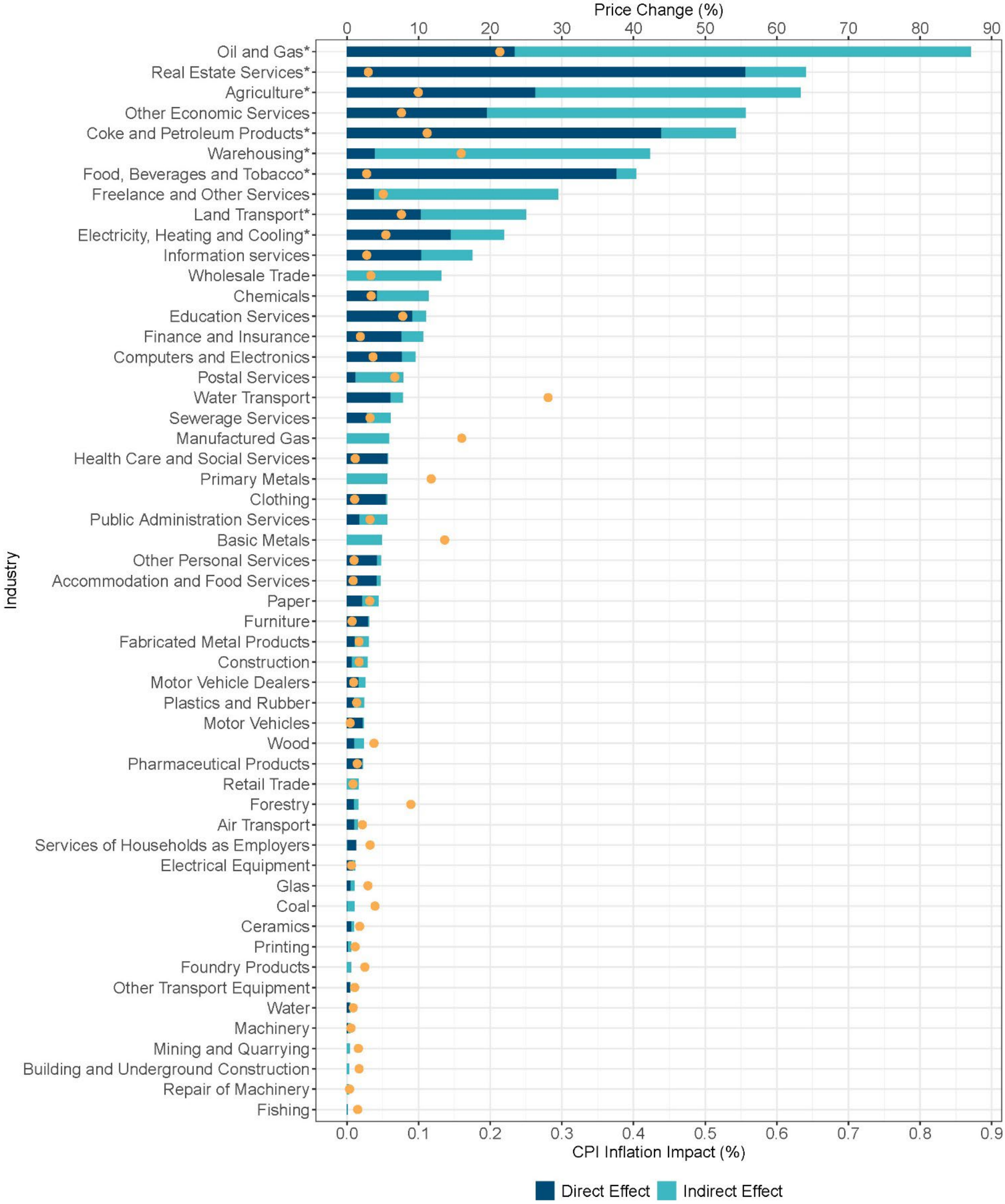
1) *Essentials of human livelihood*: Agriculture; Food, Beverages and Tobacco Products; Real Estate Services; Coke and Petroleum Products; and Electricity, Heating and Cooling (utilities).
   All sectors in this group have large weights in the CPI. Agriculture; Electricity, Heating and Cooling; and Coke and Petroleum Products have above average price volatility reflecting the commodity nature of these sectors. The latter two also have high forward linkages, which

[12] The remaining sectors in the top ten bracket are Other economic services, and Freelance and other services. Both are residual categories that show up in our ranking as they bundle together a set of heterogeneous services that are jointly relatively upstream since all sectors use some services as inputs. As residuals they are not very meaningful economic categories and as labor intensive sectors with little material inputs they are not particularly vulnerable to supply or price shocks. We therefore do not include them in our latently systemically significant category.

highlights their relative importance as inputs into other sectors. The same is true of Real Estate Services, which in Germany includes both residential and commercial housing. Thus, these three sectors also fall into the next group.

2) *Essential production inputs*: Oil and Gas; Coke and Petroleum Products; Electricity, Heating and Cooling (utilities); and Real Estate Services.
   All sectors in this group have above average forward linkages, while all but Real Estate Services also exhibit high price volatility.
3) *Essential infrastructure for commerce*: Warehousing; and Land Transport.
   All sectors in this group play a crucial role as inputs, given that all industries depend on the circulation and transportation of goods. Warehousing, despite a very low CPI weight, hardly stands out for its upstream relevance and price volatility, while Land Transport is rendered systemically significant across all three channels.

Figure 2: CPI Inflation Impact of Sectoral Price Volatility 2000-2019



Notes: The graph shows the results of price-shock simulations for all industries using the Leontief price model. The price shock is the sectoral average price volatility between 2000 and 2019 based on the standard deviation of the yearly price changes. The combined length of the dark blue (direct effect) and light blue (indirect effect) bars represents the overall impact on CPI generated by a price shock of the respective sector. The yellow dot shows the magnitude of the price change. Data sources: destatis Input-Output 2019 tables, destatis price indices.

b. Realized systemic significance

To assess the realized systemic significance in the shockflation of the energy crisis, we simulate the inflation impact based on the annual price changes in the third quarter of 2022, during the peak of the energy shock (see Figure 3) and before the introduction of the European gas price cap and the German gas price brake (Krebs and Weber, 2024; Weber et al., 2023). Here we find five sectors to have an even more outsized inflation impact relative to all other sectors, compared to the ranking for latent systemic significance. These sectors, in order of their ranks are: Oil and Gas; Electricity, Heating and Cooling; Food, Beverages and Tobacco; Agriculture; and Coke and Petroleum Products. All five sectors also exhibit latent systemic significance. It is important to note that the inflation impacts are not precise estimates since we do not account for substitution in this exercise and the simulation is sensitive to assumptions on passthrough.

Unsurprisingly, given the gas price shock, Oil and Gas has by far the largest inflation impact (8.4 percent). Due to Germany's merit-order-pricing in the power market, the prices of electricity correlate strongly with the gas price (BMWK, 2022). As a result, we observe a significant price jump for Electricity, Cooling and Heating, just below that seen in the Oil and Gas and Manufactured Gas sectors.[13] Our analysis, consistent with other studies (e.g. Dao et al, 2023), suggests that energy has been the major driver of the 2022 shockflation. The price increase in Agriculture can also partially be attributed to the rising cost of gas, which is a crucial component in fertilizer production (Adolfsen et al., 2024). In addition, agriculture and food prices have faced an extra shock, due to the market reactions to export blockages in Ukraine (UNCTAD, 2023). The energy and agrofood price shocks created a perfect storm affecting two major points of vulnerability for systemwide price stability.

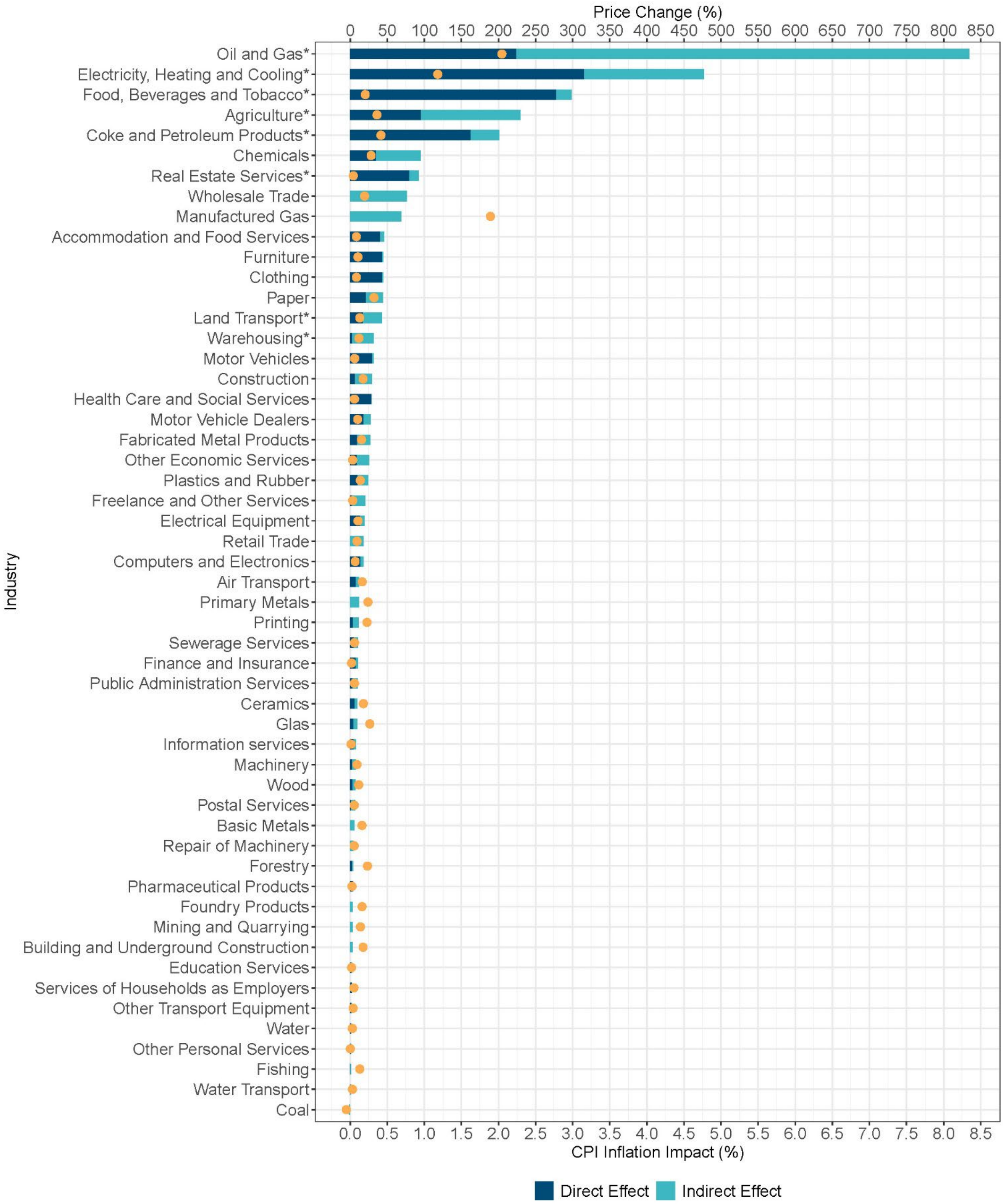
Considering the next five sectors in the ranking, Chemicals and Manufactured Gas prices surged by 50% and 200%, respectively, as prices in both sectors are also linked to gas prices. The gas price explosion moved these sectors up in the ranking compared to latent systemic significance. Chemicals, serving as both a critical production input and an important final consumption good, exhibited relatively stable prices from 2000 to 2019, which meant the sector was not latently systemically significant. Real Estate Services has shown both latent and realized systemic significance. The large increase in Wholesale Trade prices is likely to reflect the price premiums paid in the context of bottlenecks and supply chain issues. Taken together with its high forward linkages, this rendered the sector systemically significant in the 2022 inflation.

In sum, despite truly extraordinary events, our simulations for pre-COVID price volatilities provide a reliable guide to identifying points of vulnerability. All sectors from the first group (Essentials for Human Livelihood) and the second group (Energy Inputs) were in the top-10 for both simulation exercises. Finally,

[13] Note that TTF market prices for gas jumped to 10 times above the long-term price trend (Krebs and Weber, 2024), but our sectoral price index only increased by 200 percent year on year. This is in part because gas and oil prices had already increased substantially in 2021, because overall oil prices rose much less than gas, and since we are using quarterly data rather than the price peak.

within group 3 (Essentials for Commerce), Transportation fell in the ranks, having been surpassed by sectors more directly affected by the gas price shock (i.e., Chemicals, Manufactured Gas) and pandemic-related disruptions (Wholesale Trade).

Figure 3: CPI Inflation Impact of Yearly Price Change 2021 Q3 to 2022 Q3



Notes: The graph shows the results of price-shock simulations for all industries using the Leontief price model. The price shock is the yearly price change from 2021Q3 to 2022Q3. The combined length of the dark blue (direct effect) and light blue (indirect effect) bars represents the overall impact on CPI generated by a price shock of the respective sector. The yellow dot shows the magnitude of the price change. Data sources: destatis Input-Output 2019 tables, destatis price indices.

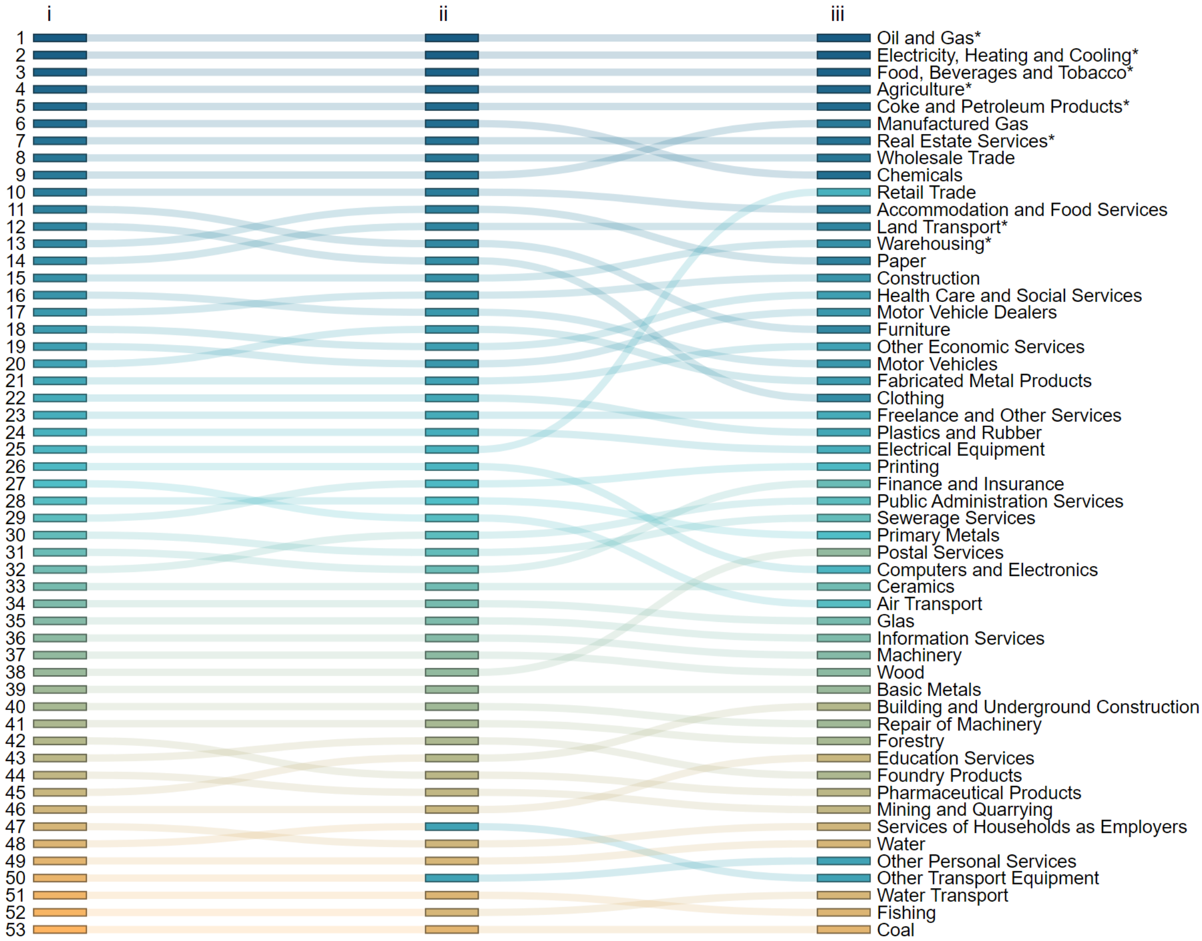
c. Robustness to different passthrough assumptions

In all the simulations we have presented thus far, we have assumed a full cost passthrough, which implies falling profit shares. However, during the energy price shock, many companies managed to protect their margins and some even increased them in response to the cost shock (Adolfsen et al., 2024; Arquié and Thie, 2023; Desnos et al., 2023; Dullien et al. 2023; Hahn 2023, Nikiforos et al., 2024; OECD 2023, Weber and Wasner, 2023, Wildauer et al., 2023). According to the IMF, unlike the inflation that followed the oil shocks of the 1970s – when unit labor costs rose more than unit profits – unit profits accounted for a larger share of inflation during the euro area's 2022 energy crisis (Hansen et al., 2023). We therefore alternate our passthrough assumption in model (ii) and simulate a scenario in which firms maintain constant profit shares despite rising costs. This is a minimal version of so-called sellers' inflation, which does not account for any margin increases (Weber and Wasner, 2023). Note, however, that maintaining constant margins in response to cost shocks results in an increase in unit profits as a matter of accounting (Hahn, 2023). After an initial impulse stage, driven by shocks to systemically significant prices and followed by a second stage of sellers' inflation, where firms protect profit shares, workers may secure wage catch-up after an initial decline in real wages, potentially leading to conflict inflation (Weber and Wasner, 2023). This final stage of wage catch-up was not yet completed in Germany even when inflation was back on target. Meanwhile, we have observed the largest real wage decline in 2022 on record (Krebs and Weber, 2024). To account for the possibility of conflict inflation, we simulate model (iii), where both profit shares remain constant, and wages catch up to restore pre-shock real wages.

Figure 4 presents the rankings for the 2022 shockflation episode using the three different models introduced in the previous paragraph (see Table B.2 in the Appendix for the exact value of the sectoral inflation impact). The top-10 sectors of realized systemic significance remain largely unchanged. The within-group movements are: a decline in Chemicals from six in model i) to nine in model iii), and a rise in Manufactured Gas, from nine in i) to six in iii). The only change in the top 10 happens in model iii) where Retail Trade moves from rank 25 in models i) and ii), to rank 10 in iii) pushing down Accommodation and Food Services. This reflects the importance of Retail trade prices for real wages. A shock to a sector's price will have a relatively larger inflation impact in model iii) when it disproportionately affects the prices of goods that are crucial for workers' consumption baskets. This necessitates a substantial wage adjustment to compensate for the initial loss in purchasing power.

The general pattern is that the only big changes occur between model iii), conflict inflation, on the one hand, and models i) and ii), on the other. But model iii) is the least relevant to the German case. In other words, the most notable ranking shifts occur when real wages are assumed to remain constant which, empirically, has not been the case in the German inflation episode. As shown in Table B.2 in the appendix, conflict inflation leads to a sizable increase in the inflation impact. In contrast, the inflation impact increase in the moderate sellers' inflation specification is considerably smaller.

Figure 4: Inflation Ranks for Simple Cost Passthrough (i), Sellers' Inflation (ii) and Conflict Inflation (iii)



Notes: The sankey diagram shows the ranking of industry's inflation impact across different specifications of the Leontief price model. The left group of nodes presents the rankings for the baseline model (i), the center group of nodes shows the rankings of the profit adjustment model (ii), and the right side depicts the rankings of the wage adjustment model (iii). The lines indicate the change in rankings for each industry. The sankey diagram represents ranking results across models for the annual price change from 2021 Q3 to 2022 Q3. Data sources: destatis Input-Output 2019 tables, destatis price indices.

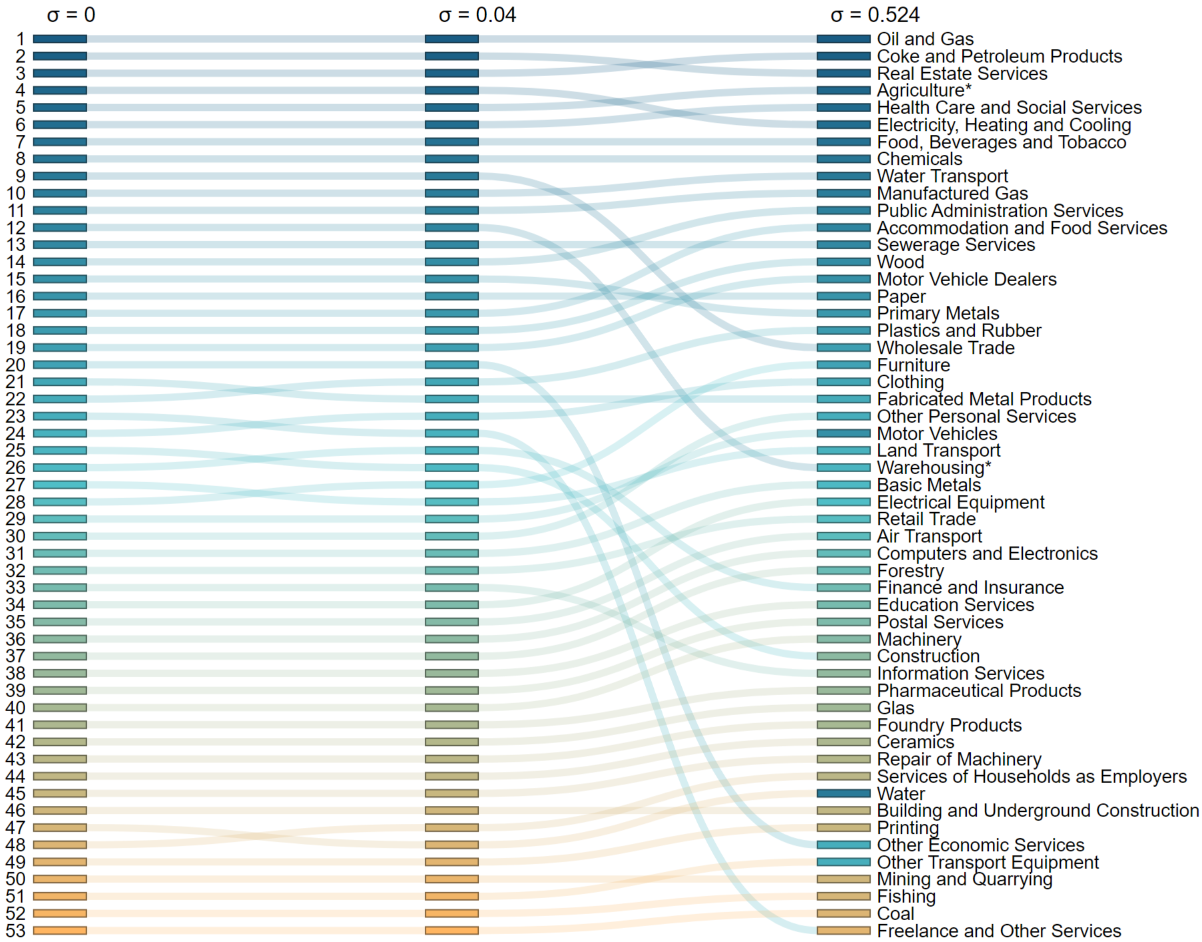
d. Robustness to different substitution assumptions

The ability of firms to substitute gas in the wake of Russia's attack on Ukraine and under the scenario of an immediate gas import embargo has been subject to diverging assessments (e.g. Bachmann et al., 2022; Bundesbank, 2022a, b; Krebs, 2022). The fierceness of the debate among leading economists and the wide variation of estimates indicates that there is a high degree of uncertainty about the elasticity of substitution, at least in the short run. In light of these discussions, our study explores the robustness of identifying realized systemically important sectors by simulating various substitution elasticities. We employ a range of possible substitution elasticities, from a Leontief assumption of complete inelasticity to optimistic scenarios. Specifically, our simulations include a short-term elasticity of substitution of 0.04 following Bachmann et.

al. (2022) and a long-term elasticity of 0.524 following Labandeira et al. (2017) depicted on the left, middle and right sides of the Sankey diagram in Figure 5, respectively. These are pure technological progress substitutions (Bun, 2018).

We assume that the price increase in the industry subjected to the exogenous shock fosters technological progress, which reduces the degree to which other sectors use that sector as an input for their production. The sectoral inflation impact across our different substitution scenarios is reported in Table B.2 in the appendix. Figure 5 illustrates how these varying substitution assumptions affect sectoral rankings. Notably, industries with the largest inflation impact remain mostly stable across scenarios. In other words, even allowing for long-run substitution elasticities does not change these industries' outsized impact on inflation. The only exception is Wholesale Trade, which sees a decline from rank eight to 18 in the long-run technical progress scenario. However, rankings of non-systemically significant sectors show greater variability, particularly when comparing short-run and long-run elasticity of substitution. The Oil and Gas sector remains by far the most systemically significant for inflation under any substitution assumption.

Figure 5: Inflation Ranks for different Substitution Scenarios



Notes: The sankey diagram shows the ranking of industry's inflation across different substitution specifications of the price model. The left group of nodes presents the rankings for the Leontief substitution scenario with an elasticity of $\sigma = 0$, the center group of nodes shows the rankings of the substitution scenario with an elasticity of $\sigma = 0.04$ as considered in Bachmann et al. (2022), and the right side depicts the rankings of the long-run substitution scenario with $\sigma = 0.524$ form the literature (Labandeira et al., 2017). The lines indicate the change in rankings for each industry. The Sankey diagram represents ranking results across substitution scenarios for the annual price change from 2021 Q3 to 2022 Q3. Data sources: destatis Input-Output 2019 tables, destatis price indices, elasticities of substitution from Bachmann et al. (2022) and Labandeira et al. (2017).

4. "Carbonflation" and systemically significant prices

In this section, we illustrate the uncertainty about future carbon prices in Europe and as a result also about the overall magnitude of carbonflation. We identify the most important sectors for carbonflation – that is inflation induced by increases in carbon prices. These sectors are a subset of the systemically significant sectors for shockflation. We show that the overlap of systemically significant prices for carbonflation and shockflation can be explained by the strong relation between emission intensity and price volatility.

a. Uncertain carbon prices

A key instrument in Europe's decarbonization strategy is cap-and-trade. This means that carbon prices are market prices that fluctuate with the demand and supply of emissions certificates where both sides are to some extent steered by policy. The ETS1 has covered an increasing number of sectors (see Table B.3 in the Appendix for sectoral coverage). How emission targets outside the ETS1 are met is currently up to the Member States. Germany largely relies on a parallel, national emissions trading system but with fixed prices that gradually increase until 2025. In 2026, the price is allowed to float between 55 EUR/tCO_2 and 65 EUR/tCO_2. In 2027, the German national system will be merged with the new ETS2. The transition could result in a sudden, large carbon price increase. Some studies warn that this could reach magnitudes comparable to the price shock during the 2022-3 energy crisis after accounting for the price dampening effects of the energy price brakes for final users (Bayer and Bachmann, 2023; Dullien et al., 2024; Kalkuhl et al., 2023).

Models deliver a wide range of possible future carbon prices. For example, Pietzcker et al. (2021) use the REMIND-EU Integrated Assessment Model, to estimate carbon price levels in line with the EU's 2030 targets assuming that emission pricing is the only new climate policy. They posit a price range reflecting scenarios from optimistic to pessimistic. Carbon prices are estimated for the year 2030 and may gradually increase or may jump until then. Their estimates vary by around 100 percent depending on the scenario assumptions: For the ETS1, CO_2 price estimates range between EUR/tCO_2 95 and EUR/tCO_2 210, and for the ETS2 between EUR/tCO_2 210 and EUR/tCO_2 405. Note that the ETS1 price was already EUR/tCO_2 83.5 on average in 2023. The assumption that makes the greatest difference for their CO_2 price estimates is on the pace of market ramp-up. The faster and smoother the ramp-up of markets for new technologies such as electric vehicles and renewable energy, the lower the CO_2 prices needed to achieve an emissions reduction target. Conversely, factors that impede a fast market ramp up – for instance high interest rates – can result in higher carbon prices for the same emissions reduction.

For our carbonflation simulation we use Pietzker et al.'s (2021) carbon price estimates for 2030 and assume a linear increase of CO_2 prices for the ETS1 sectors starting from the 2023 level following a recent IMF study (Konradt et al., 2024). Overall, the pessimistic scenario is the best fit with the actual carbon prices in 2022 and 2023 when using such a linear extrapolation of prices from 2021 to 2030 but it would still have underestimated the actual prices in 2022 by Euro/tCO_2 8.6 and overestimated those in 2023 by Euro/tCO_2 5.96. Until 2026, we use the fixed prices of the national carbon price system in Germany for the ETS2 sectors. For the start of the ETS2 in 2027, we follow Kalkuhl et al. (2023) and assume a price jump. Figure 6a) plots these price paths.

b. Carbonflation risk

If market participants can pass on carbon prices, a carbon price policy can generate inflation (Delgado-Téllez et al., 2022; Konradt et al., 2024; Nöh et al., 2020; UNEP and NIESR, 2022). But the degree of carbonflation is even more difficult to pin down than future carbon prices. In addition to the uncertainty around the carbon price increases, there is uncertainty around passthrough and substitution effects. Furthermore, cumulative carbonflation can vary widely depending on carbon price volatility, if carbon price passthrough is asymmetric – the well-known phenomenon of rockets-and-feathers. To capture the range of possible carbonflation over time a dynamic modeling approach would be required. For simplicity, here we only focus on the variation in carbonflation from different carbon prices which already leads to a wide variation in carbonflation.

On passthrough, we assume that firms keep their margins constant in response to the increased cost of emissions (see 3.c.).[14] We do not include any wage adjustments to protect real wages making the optimistic assumption that there could be a potential climate cash transfer ("Klimageld"). We keep the weighting of different sectors in the CPI constant. We attribute the household emissions to the sectors Land Transport, Coke and Petroleum Products and Electricity, Heating and Cooling based on Öko-Institut (2024) and Agora Energiewende and Agora Verkehrswende (2023). Note that we do not simulate carbon pricing under the Carbon Border Adjustment Mechanism which takes effect in 2026. We do, however, include price changes of imports that come from other EU Member States due to their participation in both the ETS1 and the ETS2.

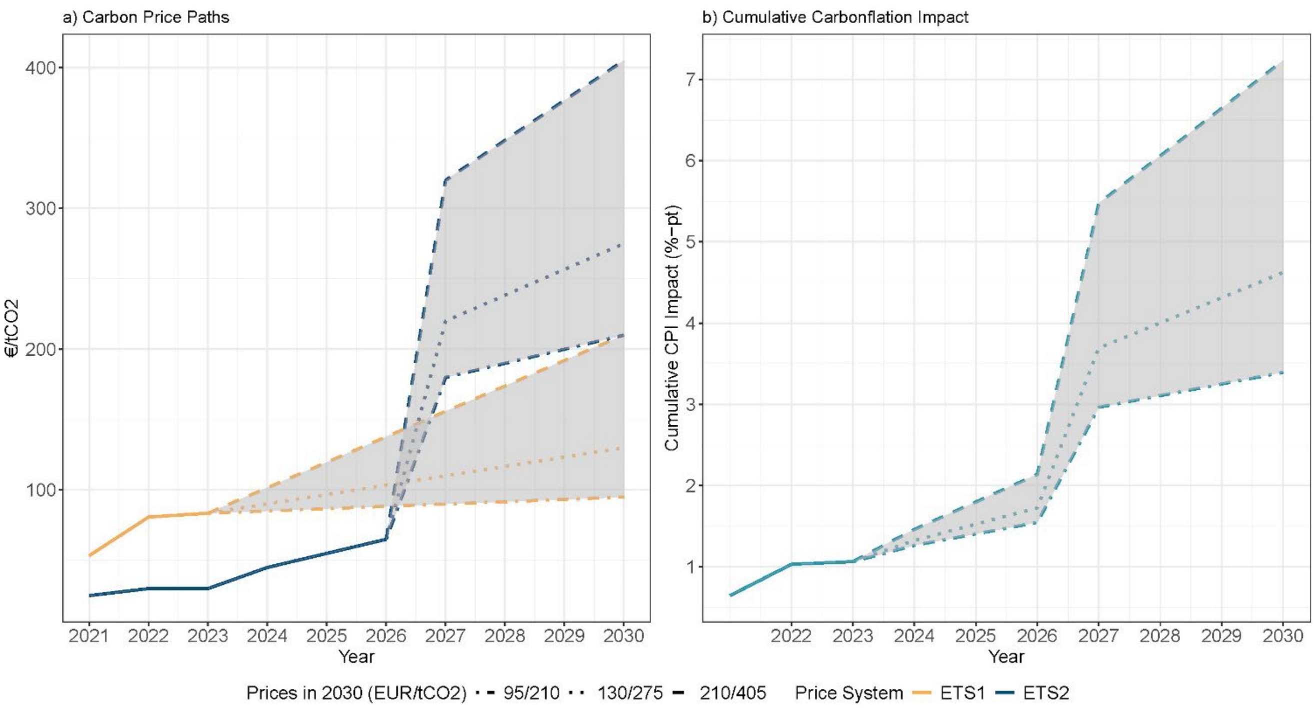
Our simulations are based on the assumption that carbon price policy works as intended:[15] Carbon prices stimulate substitution away from the use of emission-intensive goods and services. Following Konradt et al. (2024), we assume substitution through technological progress using the same elasticities. In response to

[14] The exception is for the firms in the sectors that presented a negative operating surplus for some sectors. Those sectors appear in the same way as in the benchmark model.

[15] This might not be the case, for example, if firms pass on the price increases instead of updating their technology (Desnos et al., 2023).

the carbon price signal, companies in all sectors are assumed to switch to more efficient technologies that produce the same output with less emission-intensive inputs.

Figure 6: Carbon Price Paths and Cumulative Carbonflation Impact



Notes: Panel a) shows carbon price paths from 2021 to 2030. From 2021 to 2023, ETS1 prices are the actual averaged yearly prices calculated by the authors based on ICAP (2024). Prices for the ETS2 sectors follow the fixed prices of the German national carbon price system until 2026. Target carbon prices in 2030 are based on Pietzcker et al. (2021). The lower bound carbon prices are 95 EUR/tCO_2 for the ETS1 sectors, and 210 EUR/tCO_2 for the ETS2 sectors; the moderate carbon prices are 130 EUR/tCO_2 and 275 EUR/tCO_2; and the upper bound carbon prices are 210 EUR/tCO_2 and 405 EUR/tCO_2 respectively. Panel b) shows the simulated cumulative total inflation impact that corresponds to the price paths in panel a). Data sources: destatis Input-Output 2019 table, carbon prices from Pietzcker et al. (2021), ETS prices form ICAP (2024).

The main result from our carbonflation simulation as displayed in Figure 6b) is: There is major uncertainty around the inflationary impact of carbon pricing discerning from the large variation in required carbon price levels alone. The cumulative inflation impact across our three scenarios ranges from 3.4 percentage points in the most optimistic scenario that includes lower bound CO_2 prices to 7.2 percentage points in the more pessimistic scenario with the upper bound carbon price estimate. This translates into an average annual carbonflation that increases inflation by 0.34 percentage points to 0.72 percentage points. Hence, carbonflation could range from 17 percent to 36 percent of the annual ECB inflation target of 2 percent. From 2026 to 2027 a jump in inflation occurs since we assume a price shock with the transition to the ETS2 (see Figure 6b). In that year, the simulated carbonflation ranges from 1.41 percentage points to 3.34 percentage points. In other words, carbonflation alone would amount to 70 percent to 167 percent of the ECB inflation target. In reality, carbon prices formed in an emissions trading system are volatile, which means that the annual carbonflation estimates based on smooth price paths presented here might well underestimate actual carbonflation.

Our carbonflation estimates are consistent with the literature accounting for modeling choices. For a slightly shorter period and with a price increase of 112 EUR/tCO_2, Konradt et al. (2024) find a cumulative CPI impact for the Euro area between 1.8 percentage points and 3.7 percentage points using an input-output approach, with variation depending on assumptions about passthrough. Another estimate for annual carbonflation in the Euro area based on 2030 carbon prices of 120 EUR/tCO_2 and 200 EUR/tCO_2, is 0.15 percentage points and 0.4 percentage points, respectively (Delgado-Téllez et al., 2022). Nöh et al. (2020) project a slightly larger cumulative CPI impact for the national carbon price in Germany. Using a German income and consumption survey, they examine price changes within households' consumption baskets and find an average annual CPI increase of 0.43 percentage points.[16] In comparison, our largest simulated annual carbonflation impact is 0.36 percentage points in the same period that includes both emission trading systems. However, the authors stress the possibility of double-counting indirect effects, potentially overlapping with ETS1 emissions in their analysis. Additionally, unlike our analysis, Nöh et al. (2020) do not account for substitution effects, which may explain the difference between the CPI impacts.

c. Systemically significant prices for carbonflation

The literature on carbonflation has so far focused on the total inflation impact of carbon price policies. Our modeling approach allows an analysis of which sectors matter most for carbonflation. In principle, there is a wide spectrum of possible climate mitigation policies ranging from relying exclusively on carbon pricing to choosing non-price-based policies such as investment programs, regulation, standards, behavioral norms, or a policy mix that combines carbon pricing and non-price measures (Grubb et al., 2023). Targeting non-price-based policies to sectors that have the greatest potential contribution to carbonflation can help reduce the uncertain inflationary effects from carbon pricing.

To identify systemically significant prices for carbonflation we proceed in the same way as for shockflation. We calculate the carbonflation impact of a CO_2 price applied *to one industry at a time* and rank sectors according to this carbonflation impact. Adding up all the sectoral carbonflation impacts amounts to the same as simulating the effect of a CO_2 price for all industries simultaneously. Therefore – unlike for shockflation – we can also determine the share that any one sector accounts for in total carbonflation.

We first simulate a potential carbon price shock in 2027 which presents the most immediate risk of carbonflation. A linear projection from the actual ETS1 price in 2023 to Pietzcker et al.'s (2021) price estimates for 2030 results in an almost flat curve for the lower bound prices, which is not plausible given the European emission reduction targets that are meant to be achieved by carbon prices alone. To simulate two plausible magnitudes of shocks, we take the middle and upper bound carbon price increases for the ETS2 sectors from 2026 to 2027 as depicted in Figure 6a), i.e. Euro/tCO_2 155 and Euro/tCO_2 255

[16] Own calculation based on the author's total inflation impact of 2.6 percentage points during a period of six years between 2021 and 2026.

respectively. For ETS1 sectors, we take the projected middle and upper price bound for 2026 and assume that the price increase to 2027 is in line with the annual price volatility in 2020-2023 when the current ETS1 configuration has been in operation. This gives us carbon price changes of Euro/tCO_2 13 and 17.

Figure 7a) and c) show our sectoral carbonflation rankings for the two magnitudes of carbon price shocks. The length of the bar represents the change in the CPI in the respective industry. The dot represents the magnitude of the change in sectoral prices caused by a carbon price change. As before, the direct effect captures the change in the CPI due to the price change in the industry that pays the increased CO_2 price, and the indirect impact captures the price changes that follow in all other industries. Note that the relatively small indirect effects compared to shockflation are due to the fact that we only simulate the EU internal carbon price changes, while some key upstream inputs such as oil and gas are largely imported.

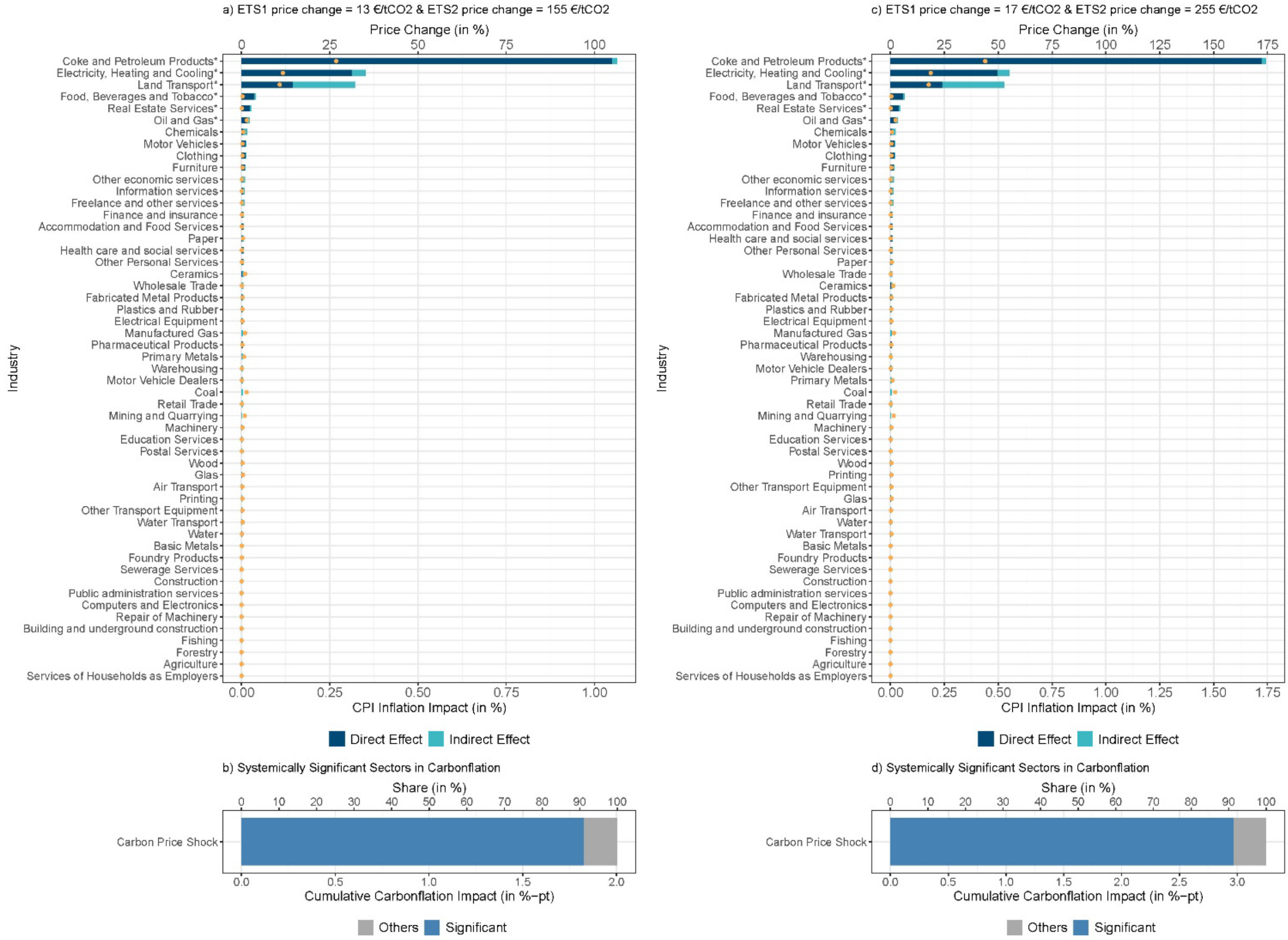
We find that in the simulation of carbon price shocks three sectors have an outsized impact on carbonflation: Coke and Petroleum Products; Electricity, Heating and Cooling and Land Transport. All three sectors will also be part of the ETS2, explaining their top ranks in this simulation. As discussed, these sectors include household emissions, thus intensifying the overall inflation impact of these sectors. The next three sectors are: Food and Tobacco Products, Real Estate Services, and Oil and Gas - which are also systemically significant in our shockflation scenario. Jointly the six sectors account for 91.1 percent and 91.3 percent of the total carbonflation increase of 2 and 3.25 percentage points. If we consider the larger carbon price shock, the Coke and Petroleum Products sector alone induces an inflation increase of almost 1.75 percentage points, 87.5 percent of the annual inflation target.[17]

The price jump in 2027 affects the ETS2 sectors more than the ETS1 sectors. To assess which sectors are systemically significant for carbonflation in the medium run, we use the increase from the 2023 carbon price levels to the projected 2030 prices for the next simulation (Figure 8). We find that the same six sectors as in the simulation of the 2027 carbon price shock exercise the largest carbonflation impact. Jointly these six sectors account for 90.3 percent and 89.3 percent of the total carbonflation of 3.5 and 6 percentage points, respectively. All six sectors are also systemically significant for shockflation. These six sectors should be a prime focus for policy makers who wish to contain inflation risks.[18]

[17] Some energy intensive industries like Primary metals or Foundry products are relatively low in the ranking since they have a low weight in the CPI and the indirect effect of these sectors is small because large shares of their outputs are inputs into their own sector.

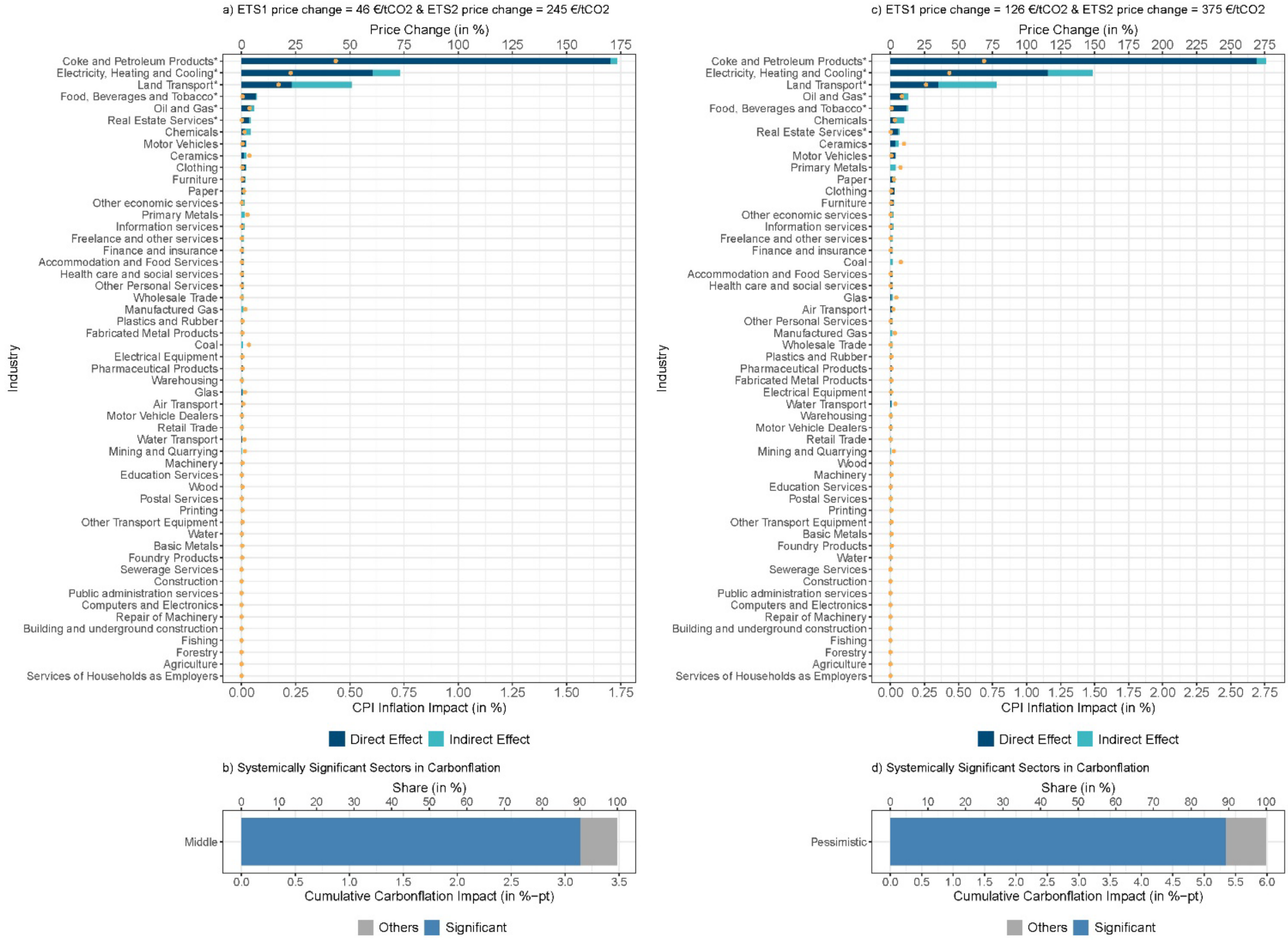
[18] It is important to note that carbon pricing creates tax revenue for governments; an important economic policy issue is the debate on what to do with such revenues. Some options could reduce inflation, such as financing infrastructure, subsidizing green technologies, and cutting taxes. Other possible policies deal with the consequence of inflation, such as lump-sum transfers to low-income households (Wills et al., 2022). Since we are not discussing those alternative recycling schemes and their outcomes, we present the maximum inflationary impact here as a cautionary tale of the worst possible scenario.

Figure 7: Sectoral Carbonflation Impact and Share of Systemically Significant Sectors with Carbon Price Shock from 2026 to 2027



Notes: The graph shows the results of our two carbon price shock scenarios using the Leontief price model. Panel a) and b) show the outcome for an ETS1 shock of Euro/tCO_2 13 and an ETS2 shock of Euro/tCO_2 155. Panel c) and d) depict the outcome for an ETS1 shock of Euro/tCO_2 17 and an ETS2 shock of Euro/tCO_2 255. Panel a) and c) show the results for all industries. The combined length of the dark blue (direct effect) and light blue (indirect effect) bars represents the overall impact on CPI generated by a carbon price shock to the respective sector. The yellow dot shows the magnitude of the sectoral price change due to the carbon price shock. The bar plots in panel c) and d) show the total inflation impact of the respective carbon price shock and the share of the systemically significant sectors therein (blue bar).

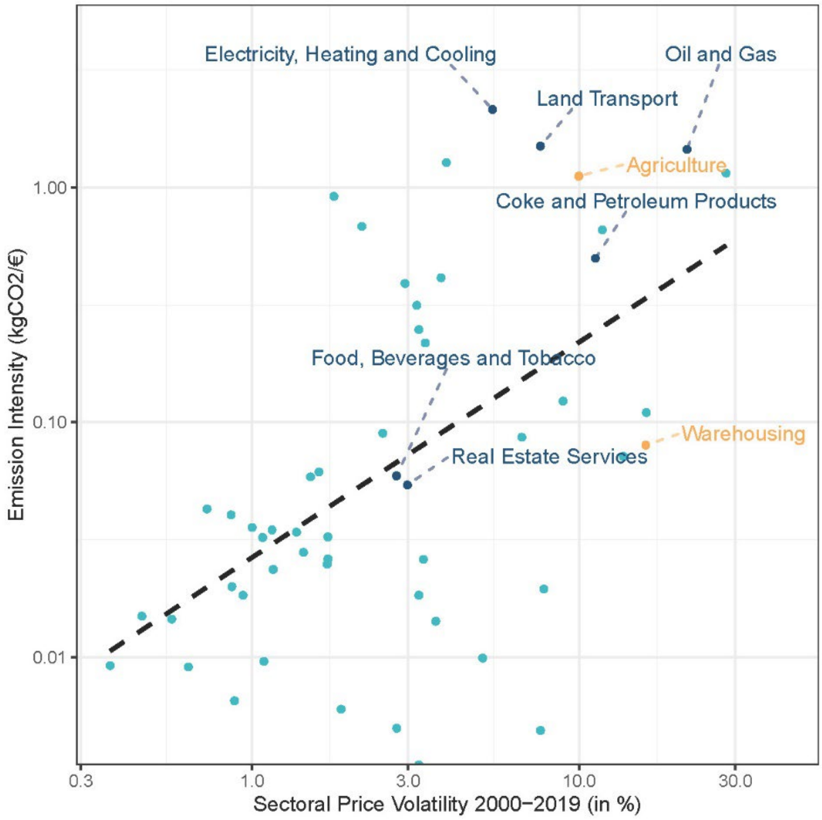
Figure 8: Sectoral Carbonflation Impact and Share of Systemically Significant Sectors, 2023-2030



Notes: The graph shows the inflation impact of linear carbon price increases between 2023 and 2030 using the Leontief price model. Panel a) and b) show the impact for the ETS1 price increase of Euro/tCO_2 46 and the ETS2 price increase of Euro/tCO_2 245. Panels c) and d) depict the outcome for the ETS1 price increase of Euro/tCO_2 126 and the ETS2 price increase of Euro/tCO_2 375. Panel a) and c) show the results for all industries. The combined length of the dark blue (direct effect) and light blue (indirect effect) bars represents the overall impact on the CPI generated by the carbon price increase of the respective sector. The yellow dot shows the magnitude of the sectoral price change due to the carbon price increase. The bar plots in panel c) and d) show the total inflation impact of the respective carbon price increase and the share of the systemically significant sectors therein (blue bar).

The overlap of systemically significant prices for carbonflation and shockflation can be explained by the strong relation between emission intensity and price volatility. Figure 9 illustrates this relation. Fossil fuel prices are among the most volatile prices (Regnier, 2007) and fossil fuel intensity is also correlated with emission intensity. As we have seen, systemic significance for shockflation is determined via three channels, namely weight in CPI, forward linkages, and the magnitude of the price shock. For carbonflation, the latter channel is replaced by the magnitude of the carbon price increase which reflects the sectoral emission intensity. Electricity, Heating and Cooling; Coke and Petroleum Products; Oil and Gas are important for carbonflation due to their emissions intensity, centrality as production inputs (ranks 12 to 14 of all sectors in terms of forward linkages) and relatively high weights in the CPI. In contrast, the Real Estate Services sector enters the top ranks due to its importance as a production input (rank 11 in terms of forward linkages) and its high weight in consumer baskets which means that even smaller policy-induced price changes have a large impact on the CPI. Land transport ranks high due to its high emission intensity and centrality as a production input (rank 10 in terms of forward linkages).

Figure 9: Emission Intensity vs. Sectoral Price Volatility



Notes: The figure plot displays the correlation between emission intensity (kgCO_2/€) and sectoral price volatility (in percent). The dark blue points are sectors that are systemically significant for both shockflation and carbonflation. The yellow dots are systemically significant for shockflation only. The turquoise points are all other sectors. The figure is in log-log scale. Source: destatis environmental economic accounting, own calculation, destatis price indices.

5. Conclusion

We use a Leontief price model to determine sectors that present points of vulnerability for overall price stability. This simulation approach enables us to investigate the propagation of exogenous prices shocks and carbon prices through the economy via input-output linkages. Our analysis yields two main findings. First, near-term carbon prices, and hence the magnitude of carbonflation, could potentially reach levels that challenge monetary stability – even without accounting for the CBAM. Simulated annual carbonflation ranges from 0.34 percentage points with moderate, linear price increases to 3.25 percentage points for a potential carbon price shock in 2027. Second, six sectors are systemically significant for both shockflation and carbonflation (see Table B.4 in the Appendix). Together, these six sectors – Electricity, Heating and Cooling; Coke and Petroleum Products; Oil and Gas; Real Estate Services; Food and Tobacco Products;

and Land Transport – account for up to 91.3 percent of total carbonflation. Simply put, the key to preventing both shockflation and carbonflation lies in the energy, housing, food, and transportation and logistics sectors. All inflation outcomes are characterized by a high uncertainty. Even the most pessimistic scenario can turn out to be too optimistic, which was in fact already the case for carbon price projections in 2022-2023. If in addition to the prevailing trends major climate and geopolitical shocks destabilize supply chains in ways that further constrain the market ramp-up for key transition technologies while triggering shockflation to which the ECB reacts with renewed interest rate hikes, we might well see even higher carbon prices and carbonflation.

This paper contributes to the ongoing discussions about the inflationary pressure originating from energy prices shocks and carbon prices adding a specific sectoral view to the discussion. From a policy perspective, concentrating transition and resilience efforts on the systemically significant sectors identified in this study would go a long way in mitigating both shockflation and carbonflation. Today's macroeconomic stabilization regime relies on interest rate hikes and fiscal tightening in response to inflation, effectively pushing down the entire economy in response to sectoral price increases while rendering the investments necessary for resilience and decarbonization more expensive.

A new policy toolbox is needed for systemically significant sectors to contain inflation risks in a world of shocks and under the imperative of climate change mitigation (van't Klooster and Weber, 2024). The new approach should focus on preventing and containing price spikes in sectors crucial for system-wide price stability.

One instrument in achieving these goals is public buffer stocks (Weber and Schulken, 2024). These can be both physical (buying, storing, and selling actual commodities) and virtual (counter-cyclical open market operations in commodity futures markets (von Braun and Torero, 2009; Hockett and Omarova, 2016). Buffer stocks can keep critical prices within a certain range and serve as an industrial policy tool by guaranteeing markets and setting incentives through public procurement.

A second pillar in achieving price stabilization and the green transformation is industrial policy. Its potential to contain carbonflation while reducing the vulnerability to shockflation should be added to the advantages economists attribute to industrial policy (Chang and Andreoni, 2020; Rodrik, 2015). Substantial investments are needed to build renewable energy systems, decarbonize transportation, retrofit housing, and green the food system. States can successfully induce sectoral technological change (Meckling and Nahm, 2018). The build out of new technologies are not merely a market failure issue to be corrected with a carbon price. After all, uncertainties about carbon prices can in fact hinder decarbonization investments (Fuchs et al, 2024). Technological change instead requires market creation and shaping, necessitating public investment (Mazzucato and Semieniuk, 2017). Conditionalities, regulation, and standard-setting for systemically significant sectors are essential tools to complement public investments (Mazzucato and Rodrik, 2023).

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Appendix

Appendix A. Mathematical derivations

A.1 Derivation of import shock

For all the simulations in which we assume an exogenous price shock to a single industry, we also assume that there is an equivalent shock to the import price of such an industry. That is, if there is an exogenous price increase ΔP_X, then we assume an equivalent import price shock, ΔP_M. We refer to this as the non-arbitrage assumption, meaning that the shock does not generate a difference between the domestic and the international price of goods. The next issue is to explain how does ΔP_M impact the costs of industries.

Consider A_M, which is the direct import requirements matrix. Its element α_{ij} represents how much imports of industry j are necessary to produce a unit of sector i. Vector m, the share of imported inputs in gross output, is equal to the sum of the columns of A_M.

Now assume there is a 10 percent increase in the price of imported good 1 (the column-vector ΔP_M will have a zero for all prices that remain constant). This means that every sector will pay 10 percent more for its imports of good 1. We can represent this last proposition by multiplying the first row of matrix A_M by 1.1. Hence, when we add the columns of this modified A_M, we will get a new vector Δm, which represents the new share of imported inputs in gross output that follows from an import price shock to good 1. As we said before, all our simulations with exogenous price shocks implement the assumption that $\Delta P_X = \Delta P_M$, which just means that the price increase is the same for domestically produced as for the imported good.

A.2 Derivation of price change equation with exogenous sectors

Equation (4) shows how the price of all endogenous sectors change when there is an exogenous price shock to one or more sectors in the economy, which impacts both their domestic and imported price by the same amount. The derivation is identical to Weber et. al (2024), which is itself based on Valadkhani and Mitchell (2002).

Equation (4) can be expressed in the following way:

$$\begin{bmatrix} P_X \\ P_E \end{bmatrix} = \begin{bmatrix} A'_{XX} & A'_{EX} \\ A'_{XE} & A'_{EE} \end{bmatrix} \begin{bmatrix} P_X \\ P_E \end{bmatrix} + \begin{bmatrix} v_X \\ v_E \end{bmatrix} + \begin{bmatrix} m_X \\ m_E \end{bmatrix} \tag{A1}$$

All the elements of this equation represent *partitions* or subsets of the original vectors and matrices P, A, v and m. The criterion to divide them is the exogeneity and endogeneity of sectors. Particularly, X represents the set of exogenous sectors, and E that of endogenous sectors. The partition for P, v and m is straightforward. For example, if the exogenous sectors are $X = 1,2$, then P_X, v_X and m_X will be the first two elements of their corresponding original vector. For the partitions of A, the first subindex represents the rows and the second the columns, so that, for example, A'_{XE} would consist of the first two rows of matrix A (the exogenous sectors), and all but the first two columns of matrix A (all the endogenous sectors). Then, solving the multiplication in the first term of equation (A1), and focusing exclusively on the bottom element (the prices of endogenous sectors), we get:

$$P_E = A'_{XE}P_X + A'_{EE}P_E + v_E + m_E \tag{A2}$$

Then solving for P_E will retrieve equation (3) in the main text, and then expressing everything in terms of changes Δ results in equation (4). Notice that the term Δm_E in equation (4) is calculated as we explain in the previous section of the appendix.

Appendix B. Additional tables

Table B.1: Sectoral Descriptions

CPA	Description	Price Category	Price Quality	Period
01	Agriculture	Producer Price Agriculture	very good	2000-2022
02	Forestry	Producer Price Forestry	very good	2000-2022
03	Fishing	Consumer Price	sufficient	2000-2022
05	Coal	Producer Price Industry	good	2010-2022
06	Oil and Gas	Producer Price Industry	very good	2000-2022
07-09	Mining and quarrying	Producer Price Industry	very good	2000-2022
10-12	Food, beverages and tobacco	Producer Price Industry	very good	2000-2022
13-15	Textiles	Producer Price Industry	very good	2000-2022
16	Wood	Producer Price Industry	very good	2000-2022

17	Paper	Producer Price Industry	very good	2000-2022
18	Printing	Producer Price Industry	very good	2000-2022
19	Coke and petroleum products	Producer Price Industry	very good	2000-2022
20	Chemicals	Producer Price Industry	very good	2000-2022
21	Pharmaceutical products	Producer Price Industry	very good	2000-2022
22	Plastics and rubber	Producer Price Industry	very good	2000-2022
23.1	Glas	Producer Price Industry	very good	2000-2022
23.2-23.9	Ceramics	Producer Price Industry	very good	2000-2022
24.1-24.3	Primary metals	Producer Price Industry	very good	2000-2022
24.4	Basic metals	Producer Price Industry	very good	2000-2022
24.5	Foundry products	Producer Price Industry	very good	2000-2022
25	Fabricated metal products	Producer Price Industry	very good	2000-2022
26	Computers and electronics	Producer Price Industry	very good	2000-2022
27	Electrical equipment	Producer Price Industry	very good	2000-2022
28	Machinery	Producer Price Industry	very good	2000-2022
29	Motor vehicles	Producer Price Industry	very good	2000-2022
30	Other transport equipment	Producer Price Industry	very good	2000-2022
31-32	Furniture	Producer Price Industry	very good	2000-2022
33	Repair of machinery	Producer Price Industry	good	2010-2022
35.1, 35.3	Electricity, heating and cooling	Producer Price Industry	good	2010-2022
35.2	Manufactured Gas	Producer Price Industry	very good	2000-2022
36	Water	Producer Price Industry	very good	2000-2022
37-39	Sewerage services	Calculated based on Producer Price Services	sufficient	2000-2023
41-42	Building and underground construction	Calculated based on Construction Industry Price	sufficient	2000-2022

43	Construction	Calculated based on Construction Industry Price	sufficient	2000-2022
45	Motor vehicle dealers	Retail Price	very good	2000-2022
46	Wholesale trade	Wholesale Price	very good	2000-2022
47	Retail trade	Retail Price	very good	2000-2022
49	Land transport	Producer Price Services	very good	2006-2022
50	Water transport	Producer Price Services	very good	2006-2022
51	Air transport	Producer Price Services	sufficient	2015-2022
52	Warehousing	Producer Price Services	very good	2006-2022
53	Postal services	Producer Price Services	very good	2006-2022
I	Accommodation and food services	Consumer Price	sufficient	2000-2022
J	Information Services	Producer Price Services	very good	2006-2022
K	Finance and Insurance	Consumer Price	sufficient	2000-2022
L	Real estate services	House Price Index	sufficient	2005-2022
M	Freelance and other Services	Producer Price Services	very good	2006-2022
N	Other Economic Services	Producer Price Services	very good	2006-2022
O	Public Administration Services	Calculated based on Producer Price Services	sufficient	2000-2023
P	Education services	Consumer Price	sufficient	2000-2022
Q	Health Care and Social Services	Consumer Price	sufficient	2000-2022
R-01	Other personal services	Calculated based on Consumer Price	sufficient	2000-2023
PRIVAT HH	Services of households as employers	Calculated based on Producer Price Services	sufficient	2000-2023

Notes: The statistical classification of products by activity (CPA) is the classification of products at the level of the EU. The price category summarizes the subcategories the prices are sourced from. Whenever there was no matching price data for a sector, we calculated prices for this particular sector based on weighted averages of prices from other sectors. The price quality shows the author's assessment of the quality of the data in terms of matching between the input-output table and the price data. Generally, price data's quality is high when original data directly matches input-output sectors without further adjustments. Data spanning from 2000 to 2022 for industrial products and from 2006 to 2022 for producer prices in services is considered very good. Shorter time frames indicate good quality, while individually calculated or non-producer prices have sufficient quality. Whenever only monthly price data is available it is converted into quarterly data via averaging.

Table B.2: Inflation Impact across different Scenarios

CPA	Description	Period of Price Change	Yearly Price Change (percent)	CPI Impact Model i	CPI Impact Model ii	CPI Impact Model iii	CPI Impact Model i, σ=0.524	CPI Impact Model i, σ=0.04	Rank Forward Linkages	Weight in CPI	Rank CPI Impact
01	Agriculture	2000-2019	9.97	0.63	0.65	0.73	-0.35	0.52	30	0.03	3
		2021 Q3 - 2022 Q3	36.14	2.30	2.34	2.66	0.91	2.13	30	0.03	4
02	Forestry	2000-2019	8.92	0.02	0.02	0.02	-0.01	0.01	41	0.00	38
		2021 Q3 - 2022 Q3	23.45	0.04	0.05	0.06	0.01	0.04	41	0.00	43
03	Fishing	2000-2019	1.51	0.00	0.00	0.00	-0.01	0.00	43	0.00	53
		2021 Q3 - 2022 Q3	13.02	0.01	0.01	0.01	0.00	0.01	43	0.00	51
05	Coal	2000-2019	3.93	0.01	0.01	0.02	-0.02	0.01	49	0.00	45
		2021 Q3 - 2022 Q3	-5.09	-0.01	-0.02	-0.02	-0.04	-0.02	49	0.00	53
06	Oil and Gas	2000-2019	21.35	0.88	0.93	1.01	0.87	0.88	13	0.01	1
		2021 Q3 - 2022 Q3	204.61	8.41	8.91	9.70	8.37	8.41	13	0.01	1
07-09	Mining and quarrying	2000-2019	1.60	0.01	0.01	0.01	-0.10	-0.01	19	0.00	46
		2021 Q3 - 2022 Q3	13.97	0.05	0.06	0.06	-0.07	0.04	19	0.00	41
10-12	Food, beverages and tobacco	2000-2019	2.76	0.40	0.41	0.50	0.15	0.38	31	0.14	7
		2021 Q3 - 2022 Q3	20.42	2.99	3.02	3.68	2.66	2.95	31	0.14	3

13-15	Textiles	2000-2019	1.08	0.06	0.06	0.05	0.03	0.05	37	0.05	25
		2021 Q3 - 2022 Q3	8.53	0.45	0.45	0.39	0.42	0.44	37	0.05	14
16	Wood	2000-2019	3.78	0.03	0.03	0.03	-0.07	0.02	33	0.00	32
		2021 Q3 - 2022 Q3	11.61	0.08	0.09	0.10	-0.03	0.07	33	0.00	38
17	Paper	2000-2019	3.19	0.04	0.05	0.06	-0.15	0.02	18	0.01	29
		2021 Q3 - 2022 Q3	32.15	0.45	0.48	0.61	0.16	0.41	18	0.01	12
18	Printing	2000-2019	1.15	0.01	0.01	0.01	-0.12	-0.01	42	0.00	47
		2021 Q3 - 2022 Q3	22.77	0.12	0.14	0.22	-0.05	0.10	42	0.00	30
19	Coke and petroleum products	2000-2019	11.21	0.55	0.58	0.70	0.37	0.53	14	0.04	5
		2021 Q3 - 2022 Q3	41.48	2.04	2.15	2.58	1.78	2.01	14	0.04	5
20	Chemicals	2000-2019	3.38	0.12	0.13	0.13	-0.11	0.09	5	0.01	14
		2021 Q3 - 2022 Q3	28.27	0.98	1.08	1.11	0.66	0.94	5	0.01	6
21	Pharmaceutical products	2000-2019	1.44	0.02	0.02	0.03	0.02	0.02	40	0.02	36
		2021 Q3 - 2022 Q3	2.48	0.04	0.04	0.05	0.03	0.04	40	0.02	44
22	Plastics and rubber	2000-2019	1.37	0.03	0.03	0.03	-0.21	0.00	25	0.01	33
		2021 Q3 - 2022 Q3	13.66	0.26	0.29	0.31	-0.03	0.22	25	0.01	22
23.1	Glas	2000-2019	2.93	0.01	0.01	0.02	-0.02	0.01	45	0.00	44
		2021 Q3 - 2022 Q3	26.56	0.10	0.11	0.14	0.05	0.09	45	0.00	35
	Ceramics	2000-2019	1.78	0.01	0.02	0.02	-0.08	0.00	36	0.00	41

23.2-23.9		2021 Q3 - 2022 Q3	17.86	0.12	0.15	0.20	0.01	0.11	36	0.00	29
24.1-24.3	Primary metals	2000-2019	11.76	0.07	0.08	0.09	-0.03	0.05	6	0.00	19
		2021 Q3 - 2022 Q3	24.07	0.13	0.16	0.18	0.02	0.12	6	0.00	27
24.4	Basic metals	2000-2019	13.65	0.05	0.06	0.07	-0.02	0.04	7	0.00	26
		2021 Q3 - 2022 Q3	16.01	0.06	0.07	0.08	-0.01	0.05	7	0.00	40
24.5	Foundry products	2000-2019	2.51	0.01	0.01	0.01	-0.08	0.00	47	0.00	48
		2021 Q3 - 2022 Q3	16.12	0.04	0.04	0.05	-0.06	0.03	47	0.00	45
25	Fabricated metal products	2000-2019	1.70	0.03	0.04	0.05	-0.31	-0.01	15	0.01	30
		2021 Q3 - 2022 Q3	15.38	0.30	0.34	0.41	-0.12	0.25	15	0.01	18
26	Computers and electronics	2000-2019	3.64	0.10	0.10	0.09	0.00	0.09	29	0.02	16
		2021 Q3 - 2022 Q3	6.82	0.18	0.19	0.17	0.08	0.17	29	0.02	26
27	Electrical equipment	2000-2019	0.64	0.01	0.01	0.02	-0.09	0.00	26	0.01	42
		2021 Q3 - 2022 Q3	10.61	0.20	0.23	0.26	0.08	0.19	26	0.01	24
28	Machinery	2000-2019	0.57	0.01	0.01	0.01	-0.11	-0.01	23	0.00	51
		2021 Q3 - 2022 Q3	9.36	0.09	0.10	0.11	-0.05	0.07	23	0.00	37
29	Motor vehicles	2000-2019	0.46	0.02	0.02	0.03	-0.03	0.02	27	0.05	35
		2021 Q3 - 2022 Q3	6.13	0.32	0.32	0.44	0.26	0.31	27	0.05	17
30		2000-2019	1.09	0.01	0.01	0.01	-0.01	0.00	32	0.00	49

	Other transport equipment	2021 Q3 - 2022 Q3	4.02	0.02	0.02	0.02	0.00	0.02	32	0.00	47
31-32	Furniture	2000-2019	0.73	0.03	0.03	0.03	0.01	0.03	50	0.04	31
		2021 Q3 - 2022 Q3	10.56	0.45	0.45	0.49	0.42	0.45	50	0.04	13
33	Repair of machinery	2000-2019	0.37	0.00	0.00	0.00	-0.26	-0.03	20	0.00	52
		2021 Q3 - 2022 Q3	5.57	0.05	0.06	0.07	-0.23	0.02	20	0.00	42
35.1, 35.3	Electricity, heating and cooling	2000-2019	5.43	0.23	0.24	0.37	-0.33	0.16	12	0.03	10
		2021 Q3 - 2022 Q3	118.13	4.94	5.27	8.14	3.22	4.68	12	0.03	2
35.2	Manufactured Gas	2000-2019	16.03	0.06	0.07	0.16	-0.11	0.04	34	0.00	22
		2021 Q3 - 2022 Q3	189.16	0.73	0.87	1.93	0.06	0.61	34	0.00	9
36	Water	2000-2019	0.88	0.01	0.01	0.01	-0.04	0.00	51	0.00	50
		2021 Q3 - 2022 Q3	2.99	0.02	0.02	0.03	-0.03	0.01	51	0.00	49
37-39	Sewerage services	2000-2019	3.24	0.06	0.07	0.10	-0.28	0.02	16	0.01	21
		2021 Q3 - 2022 Q3	5.82	0.11	0.12	0.19	-0.24	0.07	16	0.01	34
41-42	Building and underground construction	2000-2019	1.71	0.01	0.02	0.02	-0.22	-0.02	44	0.00	43
		2021 Q3 - 2022 Q3	17.47	0.12	0.16	0.22	-0.18	0.08	44	0.00	32
43	Construction	2000-2019	1.71	0.06	0.08	0.11	-1.03	-0.06	17	0.00	23
		2021 Q3 - 2022 Q3	17.47	0.61	0.80	1.09	-0.77	0.45	17	0.00	10
45		2000-2019	0.94	0.03	0.03	0.05	-0.28	-0.01	28	0.02	34

	Motor vehicle dealers	2021 Q3 - 2022 Q3	10.13	0.28	0.29	0.49	-0.08	0.24	28	0.02	20
46	Wholesale trade	2000-2019	3.34	0.14	0.16	0.30	-1.33	-0.03	8	0.00	12
		2021 Q3 - 2022 Q3	19.43	0.81	0.95	1.74	-1.05	0.59	8	0.00	8
47	Retail trade	2000-2019	0.86	0.02	0.02	0.08	-0.68	-0.06	22	0.00	37
		2021 Q3 - 2022 Q3	9.34	0.19	0.22	0.91	-0.61	0.10	22	0.00	25
49	Land transport	2000-2019	7.61	0.26	0.29	0.47	-0.43	0.18	10	0.01	9
		2021 Q3 - 2022 Q3	13.01	0.44	0.49	0.81	-0.31	0.35	10	0.01	15
50	Water transport	2000-2019	28.08	0.08	0.09	0.16	0.06	0.08	39	0.00	18
		2021 Q3 - 2022 Q3	3.21	0.01	0.01	0.02	-0.01	0.01	39	0.00	52
51	Air transport	2000-2019	2.17	0.02	0.02	0.02	-0.05	0.01	46	0.00	39
		2021 Q3 - 2022 Q3	16.42	0.12	0.13	0.17	0.04	0.11	46	0.00	31
52	Warehousing	2000-2019	15.97	0.44	0.52	0.77	-0.59	0.32	4	0.00	6
		2021 Q3 - 2022 Q3	11.93	0.33	0.39	0.57	-0.64	0.21	4	0.00	16
53	Postal services	2000-2019	6.68	0.08	0.10	0.18	-0.32	0.04	24	0.00	17
		2021 Q3 - 2022 Q3	5.61	0.07	0.08	0.15	-0.32	0.02	24	0.00	39
I	Accommodation and food services	2000-2019	0.87	0.05	0.05	0.09	-0.04	0.04	38	0.05	28
		2021 Q3 - 2022 Q3	8.46	0.46	0.48	0.88	0.37	0.45	38	0.05	11
J		2000-2019	2.77	0.18	0.20	0.29	-0.66	0.09	3	0.04	11

	Information Services	2021 Q3 - 2022 Q3	1.29	0.09	0.10	0.13	-0.74	-0.01	3	0.04	36
K	Finance and Insurance	2000-2019	1.87	0.13	0.15	0.24	-0.82	0.02	9	0.04	13
		2021 Q3 - 2022 Q3	1.92	0.13	0.15	0.25	-0.82	0.03	9	0.04	28
L	Real estate services	2000-2019	2.99	0.64	0.66	1.17	-0.38	0.53	11	0.19	2
		2021 Q3 - 2022 Q3	4.30	0.92	0.95	1.68	-0.12	0.81	11	0.19	7
M	Freelance and other Services	2000-2019	5.07	0.36	0.44	0.56	-1.68	0.13	1	0.01	8
		2021 Q3 - 2022 Q3	3.52	0.25	0.30	0.39	-1.74	0.03	1	0.01	23
N	Other Economic Services	2000-2019	7.62	0.60	0.70	1.01	-1.25	0.39	2	0.03	4
		2021 Q3 - 2022 Q3	3.49	0.28	0.32	0.46	-1.46	0.08	2	0.03	21
O	Public Administration Services	2000-2019	3.24	0.06	0.08	0.11	-0.44	0.01	21	0.01	20
		2021 Q3 - 2022 Q3	5.82	0.12	0.14	0.20	-0.41	0.05	21	0.01	33
P	Education services	2000-2019	7.80	0.12	0.12	0.22	0.00	0.10	48	0.01	15
		2021 Q3 - 2022 Q3	1.98	0.03	0.03	0.06	-0.08	0.02	48	0.01	46
Q	Health Care and Social Services	2000-2019	1.16	0.06	0.06	0.11	0.05	0.06	52	0.04	24
		2021 Q3 - 2022 Q3	5.82	0.29	0.29	0.54	0.28	0.29	52	0.04	19
R-01	Other personal services	2000-2019	1.00	0.05	0.05	0.09	-0.15	0.03	35	0.00	27
		2021 Q3 - 2022 Q3	0.31	0.02	0.02	0.03	-0.18	-0.01	35	0.00	50
		2000-2019	3.24	0.01	0.01	0.03	0.01	0.01	53	0.05	40

PRIVATHH	Services of households as employers	2021 Q3 - 2022 Q3	5.20	0.02	0.02	0.04	0.02	0.02	53	0.05	48

Notes: The statistical classification of products by activity (CPA) is the classification of products at the level of the EU. The description gives the corresponding name. The period of price change includes the average price changes per sector between 2000 and 2019 based on the standard deviation of the yearly price changes. The other period gives the yearly sectoral price changes from the third quarter of 2021 to the third quarter of 2022, that is the peak of the energy crisis in Germany. The yearly price change includes each sector's price change in the respective period in percent. Each sector's CPI impact is displayed across models with different pass-through assumptions, that is the baseline model i, model ii with constant profit share, and model ii with constant profit share and constant real wages, as well as with the different elasticities of substitution. In addition, each industry's ranking among the 53 sectors in terms of forward linkages is provided, as is the sectors' ranking in terms of the overall inflation impact for the price shock model

Table B.3: Inflation Impact across different Carbon Price Scenarios

Sector	Optimistic Scenario	Middle-of-the-Road Scenario	Pessimistic Scenario	Price System
Agriculture	0.00	0.00	0.00	none
Forestry	0.00	0.00	0.00	none
Fishing	0.00	0.00	0.00	none
Coal	0.01	0.01	0.02	ETS1 / ETS2
Oil and gas	0.07	0.10	0.17	ETS1 / ETS2
Mining and quarrying	0.00	0.00	0.01	ETS1 / ETS2
Food, beverages and tobacco	0.07	0.10	0.15	ETS1 / ETS2
Clothing	0.02	0.02	0.03	ETS1 / ETS2
Wood	0.00	0.00	0.01	ETS1 / ETS2
Paper	0.02	0.03	0.05	ETS1 / ETS2
Printing	0.00	0.00	0.00	ETS1 / ETS2
Coke and petroleum products	1.55	2.06	3.11	ETS1 / ETS2
Chemicals	0.06	0.08	0.14	ETS1 / ETS2
Pharmaceutical products	0.01	0.01	0.01	ETS1 / ETS2
Plastics and rubber	0.01	0.01	0.01	ETS1 / ETS2
Glas	0.01	0.01	0.02	ETS1
Ceramics	0.03	0.05	0.09	ETS1
Primary metals	0.02	0.03	0.05	ETS1
Basic metals	0.00	0.00	0.00	ETS1
Foundry products	0.00	0.00	0.00	ETS1
Fabricated metal products	0.01	0.01	0.01	ETS1 / ETS2
Computers and electronics	0.00	0.00	0.00	ETS1
Electrical equipment	0.01	0.01	0.01	ETS1 / ETS2
Machinery	0.00	0.00	0.01	ETS1 / ETS2
Motor vehicles	0.02	0.03	0.04	ETS1 / ETS2

Other transport equipment	0.00	0.00	0.00	ETS1 / ETS2
Furniture	0.01	0.02	0.03	ETS1 / ETS2
Repair of machinery	0.00	0.00	0.00	ETS1
Electricity, heating and cooling	0.83	1.18	1.94	ETS1 / ETS2
Manufactured gas	0.01	0.01	0.02	ETS1 / ETS2
Water	0.00	0.00	0.00	ETS1 / ETS2
Sewerage services	0.00	0.00	0.00	ETS1
Building and underground construction	0.00	0.00	0.00	ETS1
Construction	0.00	0.00	0.00	ETS1
Motor vehicle dealers	0.00	0.01	0.01	ETS2
Wholesale trade	0.01	0.01	0.01	ETS1 / ETS2
Retail trade	0.00	0.00	0.01	ETS2
Land transport	0.44	0.57	0.84	ETS1 /ETS2
Water transport	0.01	0.01	0.01	ETS1
Air transport	0.01	0.01	0.02	ETS1
Warehousing	0.01	0.01	0.01	ETS1 / ETS2
Postal services	0.00	0.00	0.00	ETS2
Accommodation and food services	0.01	0.01	0.02	ETS2
Information services	0.01	0.01	0.02	ETS2
Finance and insurance	0.01	0.01	0.02	ETS2
Real estate services	0.04	0.05	0.07	ETS1 / ETS2
Freelance and other services	0.01	0.01	0.02	ETS1 / ETS2
Other economic services	0.01	0.02	0.03	ETS1 / ETS2
Public administration services	0.00	0.00	0.00	ETS1
Education services	0.00	0.00	0.00	ETS1 / ETS2
Health care and social services	0.01	0.01	0.02	ETS1 / ETS2
Other personal services	0.01	0.01	0.02	ETS2

Services of households as employers	0.00	0.00	0.00	none

Notes: The table shows the results for each sector's CPI impact across different carbon pricing models from 2023 to 2030. The most optimistic scenario includes lower bound carbon prices of 95 EUR/tCO_2 for the ETS1 sectors, and 210 EUR/tCO_2 for the ETS2 sectors, the middle scenario entails carbon prices of 130 EUR/tCO_2 for the ETS1 sectors, and 275 EUR/tCO_2 for the ETS2 sectors, the most pessimistic scenario is calculated based on upper bound carbon prices of 210 EUR/tCO_2 for the ETS1 sectors and 405 EUR/tCO_2 for the ETS2 sectors.

Table B.4: Systemically significant sectors for shockflation and carbonflation

Sector	SSS for Shockflation (inflation impact)	SSS for Carbonflation (inflation impact)	Weight in CPI	Forward linkages (rank)	Price volatility (rank)	Emission intensity (rank)
Electricity, Heating and Cooling	latent (0.2%) realized (4.8%)	Cumulative 2030 (0.83% - 1.94%) 2027 carbon price shock (0.26% - 0.55%)	0.027	12	14	1
Oil and Gas	latent (0.8%) realized (8.3%)	Cumulative 2030 (0.07% - 0.17%) 2027 carbon price shock (0.02% - 0.03%)	0.011	13	2	3
Coke and Petroleum Products	latent (0.5%), realized (2%)	Cumulative 2030 (1.56% - 3.11%) 2027 carbon price shock (0.79% - 1.74%)	0.039	14	7	10
Real Estate Services	latent (0.6%), realized (0.9%)	Cumulative 2030 (0.04% - 0.07%) 2027 carbon price shock (0.02% - 0.05%)	0.186	11	25	23

Food, Beverages and Tobacco	latent (0.4%), realized (3%)	Cumulative 2030 (0.07% - 0.15%) 2027 carbon price shock (0.03% - 0.06%)	0.136	31	28	24
Land Transport	latent (0.3%), realized (0.43%)	Cumulative 2030 (0.44% - 0.85%) 2027 carbon price shock (0.24% - 0.52%)	0.014	10	12	2
Agriculture	latent (0.6%), realized (2.3%)	No	0.026	30	8	6
Warehousing	latent (0.4%), realized (0.3%)	No	0.002	4	4	20

Notes: The table shows the results for our systemically significant sectors. Columns 2 and 3 show the sectors' impact on shockflation (latent and realized) and carbonflation (both cumulative and carbon price shocks). Column 4 provides the CPI weight of the sectors, calculated based on each sector's weight in the consumption interdependence table ("Konsumverflechtungstabelle") and the corresponding weight of each category in the CPI. Columns 5 to 7 display the sectors' ranks in forward linkages, price volatility between 2000 and 2019, and emission intensity. Authors' own calculation.