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Stress-testing Inflation Exposure: Systemically significant prices and asymmetric shock propagation in the EU[☆]

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ABSTRACT

This paper documents asymmetries in price shock exposure for the EU, EU core and periphery within the global production network. Building on the foundational work of Weber et al. (2024a), we run a cost-push stress-test using data from the World Input Output Database to estimate a region's exposure to globally originating and propagating price shocks. We confirm the existence of systemically significant sectors which dominate the overall price level. While the final goods price effects of various sectors are significant, about half are the result of higher-order propagation. This indirect effect is even larger for peripheral countries. Tracing disaggregated shock trajectories uncovers that price volatility originating in core and non-EU countries impacts the peripheral countries more than vice versa. Simultaneously, our method of recovering consumption substitution effects shows that substitution is more limited in the European periphery. The stark asymmetries in exposure have profound implications for fiscal and monetary policy.

1. Introduction

In a globally integrated economy, hardly any region can avoid economic exposure to shocks such as the Covid-19 pandemic or the recent geopolitical conflicts. Yet, the level of exposure may vary substantially depending on the region and type of shock (Chakraborty et al., 2024). This paper aims to uncover latent asymmetries in price shock exposure for the EU, EU core and periphery within the global production network.[1] Building on the foundational work of Weber et al. (2024a), we run a cost-push stress-testing exercise using data from the World Input Output Database to identify a regions' exposure to globally originating and propagating price shocks. Consistent with Weber et al.'s (2024a) findings for the United States, we find a small subset of systemically significant sectors to dominate the price volatility in the EU, EU periphery and EU core. While for most of these sectors, the direct effect of a shock on its respective final goods' prices is substantial, close to half of the total price volatility in our model results from higher-order propagation within the production network. Breaking down the geographical component of price volatility exposure, we show that the indirect propagation effect is larger for peripheral countries. By tracing individual shock trajectories, we find that price volatility propagating from the EU core to the periphery has substantially more impact than vice versa. Moreover, our model suggests that peripheral countries import substantially more price volatility from outside the EU, which suggests them to be more exposed to world market prices. To recover consumption substitution effects, we suggest a decomposition based on Olley and Pakes (1996) and find that while consumers in the EU core are able to partially substitute away from more volatile sectors, consumers in peripheral countries are not. We also suggest a formal operationalization for the existence of systemically significant prices, utilizing the mathematical properties of power law distributions. Our results show that the overall price impact of the most important sectors is well described by a power law distribution with a tail exponent smaller than 2. Therefore, the idiosyncratic destinies of these systemically significant

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[1] We decided to include Great Britain in our analysis because of its economic importance and extensive trade relationship with EU countries. For the sake of brevity, we use the acronym EU to refer to the EU countries at the final year of our sample in 2014, thus including Great Britain.

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sectors indeed drive aggregate fluctuations of the synthetic CPIs in our model. Finally, a power series approximation allows us to trace the diffusion of shocks by documenting round-to-round effects. Notably, we are able to derive all our results from an in-sample of years with relatively low inflationary pressure and thus overcoming a notorious challenge for stress-tests (Borio et al. 2014).

The remainder of this paper is organized as follows: Section 2 places our findings within the body of related literature. In Section 3, data and methodology of the stress-test are presented. Section 4 showcases our findings, while Section 5 discusses our results. Section 6 concludes and points to some avenues for further research.

2. Related literature

Our project relates to several strands of research, some of which sparked (renewed) interest in the wake of the latest supply chain disruptions. Namely, we add to a neglected perspective of the latest calls to stress-test production networks by uncovering the latent inflation exposure in the global production network using an input-output (IO) stress-test framework. Moreover, our work supports efforts to decipher the underlying dynamics of what is widely considered a cost-push inflation resulting from a mixture of recent supply-side shocks. Thirdly, we add to the understanding of differing regional exposures manifested in heterogeneous dependencies between regions.

In the post-Lehman world, stress-tests were soon regarded as a viable tool for authorities to simulate pressure on the financial system and played a crucial role in restoring confidence in the financial system (Herring and Schuermann, 2022). By now, stress-tests are considered indispensable and their much-needed improvement has been prioritized by authorities and researchers alike (Aikmann et al., 2023). Lately, calls to establish macroprudential stress-tests also for supply chains became more prominent (Baldwin and Freeman, 2022; Miroudot, 2020). Naturally, input-output (IO) models which have commonly been used to conduct disaster impact analysis provide a sensible starting point.[2] As a prominent example, Carvalho et al. (2021) investigate the Great East Japan Earthquake of 2011 and document the relevance of IO linkages in propagating this shock. Closer to an actual stress-test are the works of Diem et al. (2022) and Chakraborty et al. (2024). The authors of the former paper propose and test a novel measure of economic systemic risk of firms in the Hungarian production network. The latter paper shows that richer countries expose poorer countries to significantly more systemic risk than vice versa. Finally, the foundational work of Weber et al. (2024a), unveiled the need to expand the supply-side stress-test call to also assess potential inflation exposure. Challenging the conventional understanding of inflation as an aggregate phenomenon, the authors show, a set of few sectors – so-called systemically significant prices[3] – to be the main driver of the overall price level in the US.[4] Moreover, their research suggests that these systemically significant prices could be identified before critical disruptions occur, opening up a broad policy space to address future cost-push shocks (van't Klooster and Weber, 2024). Weber et al.'s (2024a) IO price model framework, which builds upon the foundational work of Leontief and its application in Valadkhani and Mitchell (2002), has since been successfully applied to disentangle the latest inflationary dynamics (see e.g. Goldztejn, 2024 for the French case), simulating scenarios of carbon price inflation (Weber et al., 2024b) or decomposing the asymmetric effects of cost-push shocks on different income groups in the EU (Ipsen and Schulz, 2024; Schulz and Ipsen, 2024). This paper again builds upon this framework to study the geographical dimension of cost-push inflation exposure faced by different regions within the European Union.

Extending Weber et al. (2024a), we embed our stress-test exercise in a global context. Naturally, not only the interconnectedness of firms and sectors within a given economy is of relevance to understand output and inflation dynamics, but also the cross-border linkages to the world economy. Borio and Filardo (2007) find, for example, that the influence of global factors on inflation in OECD countries has been growing over time, particularly since the 1990s due to the increased integration of the world economy. However, it is also insufficient to merely contrast exposure of the EU vis-à-vis non-EU-countries. Given the regional heterogeneity within the EU, a comprehensive analysis of inflation exposure for the EU must also examine latent internal asymmetries in exposure.

As several studies have shown, these asymmetries can be substantial. Bayoumi and Eichengreen (1992) provide evidence for the existence of a core-periphery pattern for 11 EU countries and find that, while comparable shocks occur in the core, these are more asymmetric for peripheral countries. Chakraborty et al. (2024), tracing global asymmetries in systemic risk exposure, also identify asymmetries within the EU. Gräbner et al. (2020a, 2020b) again find patterns of asymmetries such as a core-periphery structure for different EU countries.

Fig. 1 shows that such a core-periphery structure is also clearly visible in the EU production network (as of 2014). This highlights the need to not only consider the exposure of EU vis-à-vis non-EU countries but also asymmetric price shock exposure *within* the EU. Sectors are represented by dots, while links between dots capture trade relationships of >385 million USD (smaller links have been omitted for visibility reasons). Clusters (colors) are identified using the Louvain method for community detection and indicate sets of sectors with increased trade relationships. The upper right corner shows a part of the network at further granularity with sector labels according to the ISIC Rev. 4 classification.

Therefore, the analytical perspective of a core-periphery structure is used in this study to analyze the geographical asymmetries in inflation exposure in the EU. Historically, the distinction between core (or center) and periphery first gained recognition through the work of dependency theorists. The classical Keynesian view espoused by Pasinetti (1983, chp. 11) argues that proportional differences in national income between countries manifest themselves into structurally different consumption baskets based on a hierarchy of needs, with essential goods being at the top of the hierarchy. This line of argument resembles a major hypothesis of dependency theorists (Harvey et al., 2010) who argue that substitutability is much more limited for these essential goods, rendering consumers in low-income countries more exposed to world market prices. We explore the consequences of this presumed differential substitutability between core and periphery as one building-block of our stress-test. A second key hypothesis of dependency theorists relates more directly to the IO structure on which our stress-test is based. It follows the canonical definition of dos Santos (1970, p. 231) describing dependency as "a situation in which the economy of certain countries is conditioned by the development and expansion of another". This definition focuses on the notion of asymmetry - the core affects the periphery much stronger than the other way round. We therefore conjecture that inflation spill-overs from the core to the periphery are quantitatively much more relevant than vice versa, in line with this oft-cited definition of dependency.

Consequently, building on the core-periphery dichotomy enables us to uncover asymmetric shock trajectories and contrast heterogeneous vulnerabilities due to regional differences in price volatility and

[2] See Galbusera and Giannopoulos (2018) for an overview.

[3] The concept of systemically significant prices was first put forward by Hockett and Omarova (2016).

[4] The insight that shocks of heterogenous origins can trigger aggregate fluctuations in the presence of strongly asymmetric intersectoral IO linkages – as found in empirical production networks – has been increasingly considered following the initial work by Acemoglu et al. (2012). However, expanding this notion to the realm of inflation is in marked contrast to the conventional wisdom of both the Monetarist and New Keynesian approaches that inflation should be understood as an aggregate phenomenon (Galbraith, 2023). Yet, recent theoretical papers in the New Keynesian tradition also implicitly recognize the existence of systemically significant prices by showing that relative price movements might affect aggregate inflation (Afrouzi et al., 2024).

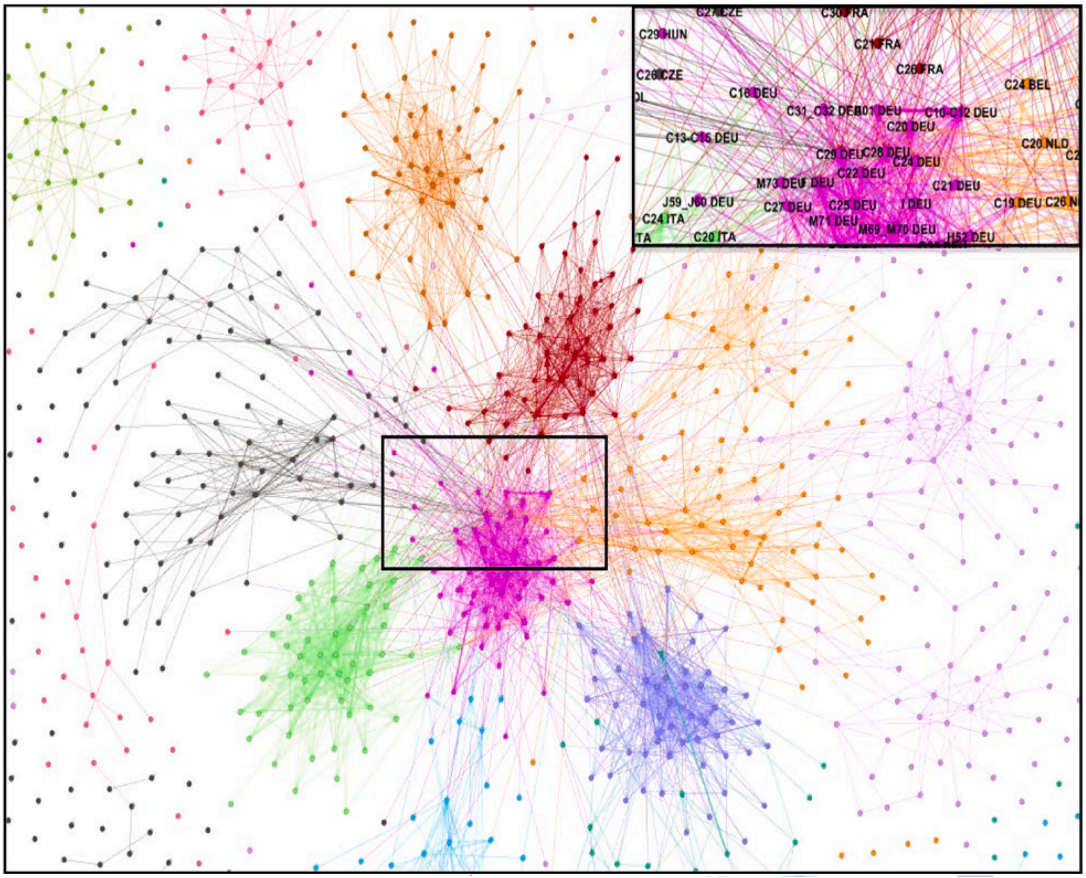

Fig. 1. Snapshot of the EU production network in 2014 based on World Input Output Database. Nodes (dots) represent sectors, edges (links) represent trade relationships of >385 million USD (smaller edges omitted for visibility reasons). Different colors indicate sectorial clusters of increased trade (identified using the Louvain method of community detection). Upper right panel magnifies the image detail, showing sector specifications according to ISIC Rev. 4. The network displays a clear core-periphery structure.

elasticities of substitution vis-à-vis non-EU-countries but also within the EU.

3. Data and methodology

For our empirical application, we use the World Input Output Database (WIOD). The WIOD provides annual panel IO data for the years 2000 until 2014, covering 43 countries with 56 sectors each, following the ISIC Rev. 4 classification (Timmer et al., 2015). These countries account for >85 percent of world GDP, offering an excellent representation of worldwide intermediate goods flows. The remainder of world economic activity is accounted for in a residual fictitious entity called "Rest of the World" (ROW). We use the most recent data from 2014 as a basis for the production network. Input price index data is taken from the WIOD's Socio-Economic Accounts over the years 2000 – 2014 to calculate the price shocks in the model. The consumption shares are based on the values of final use for individual consumption in the EU, EU core and periphery. We therefore allow for shock propagation of producer prices through worldwide supply chains, while focusing only on the implied CPI volatility for the respective European consumers. This contrasts with the approach within the paper by Weber et al. (2024a) who use national IO tables and consequently do not take shock transmission through global supply chains into account. A direct corollary to that is that Weber et al. likely underestimate the total impact of price shocks.

As for the model, we utilize the structure of the global production network to analyze the propagation of price shocks. Intuitively, different sectors are woven into a production network via their input and output linkages in their production processes of complex goods and services. IO models build on these inter-linkages by formulating a system of linear equations that describe the functional dependencies emerging from products flowing between sectors. Accordingly, these models can be used to analyze the propagation of shocks in this production network (Leontief, 1986; Miller and Blair, 2009). We build our stress-test exercise on the standard Leontief price model as has been used by Valadkhani and Mitchell (2002) and Weber et al. (2024a). The derivation of the IO price model can be found in Appendix A.

In our stress-test exercise, we expose every sector of our global production network to an individually empirically validated price shock. This shock in turn ripples through the production network, eventually reaching consumers final consumption and therefore impacting the overall consumer price level. As in Weber et al. (2024a), we compute the individual shocks as the standard deviation of the yearly logarithmic price changes $\%\Delta P$ for every sector$_x$ in our observation period according to (1). We use price volatility since large price fluctuations impede predictability in economic decision-making and hence play a crucial role in the functioning of production networks and for household consumption (Damjanovic and Nolan, 2010).[5]

$$\Delta P_x^{P_{t_0,t_1}} = \sqrt{\frac{1}{T}\sum_{t=t_0}^{t_1}\left(\%\Delta P_t^x \quad \%\Delta P_{t_0,t_1}^{\bar{x}}\right)^2} \tag{1}$$

[5] We do check the robustness of our results for stress scenarios based on the mean price growth, as this is another important aspect of price changes. Our results are not materially sensitive to this alternative specification.

Sectors experiencing more volatile price fluctuations will thus be exposed to a larger shock in our stress-test than relatively less volatile sectors. This approach considers the heterogeneous nature of price formations within different sectors.

As we show in Appendix A, the Leontief price model captures the following relationship

$$\Delta P_E = (I - A'_{EE})^{-1} A'_{XE} \Delta P_x \tag{2}$$

where ΔP_E measures the price volatility in the endogenous sectors induced by the price shock ΔP_x in the exogenous sector. In the next step, we introduce the sector-level shares of household consumption. We use three different sets of sector-level consumption shares corresponding to three different synthetic CPIs: One for the EU as a whole, one for the EU core countries and one for the EU periphery countries. Our categorization of core and periphery countries follows the standard definition within the literature (Gräbner et al., 2020a). While the classification by Gräbner et al. (2020a) is based on a multidimensional methodology, it is also consistent with our major argument grounded in differences of average incomes: The GDP per capita in each core country is higher than in each peripheral country, with the cut-off point being between Italy with the lowest value in the core (34,460 USD per capita in 2010 dollars, as of 2014) and Malta (30,917 USD per capita) with the highest value in the periphery.[6]

$$c_{core} = \{AUT, BEL, DNK, FIN, FRA, GER, GBR, ITA, IRL, LUX, NLD, SWE\}$$

$$c_{periphery} = \{BGR, CYP, CZE, ESP, EST, GRE, HRV, HUN, LVA, LTU, MLT, POL, PRT, ROU, SVK, SVN\}$$

Note that the consumption shares are the only variable that is varied for our analysis of the EU, EU core and periphery setup, respectively. The sector-level shocks as well as the links and weights of the global production networks remain the same for each of the three analyses. Per construction, differences in implied CPI volatility can therefore only emerge from variation in consumption behavior between regions. Every disparity in the inflation exposure of EU, EU core and periphery is thus to be found in differences in the quantity and type of their consumption.

Having introduced the consumption shares, we are able to decompose (2) into

$$\pi^{direct} = c_x \Delta P_x \tag{3}$$

$$\pi^{indirect} = \sum_{i \neq x} c_i \, \Delta P_i \tag{4}$$

and

$$\pi^{total} = c_x \Delta P_x + \sum_{i \neq x} c_i \, \Delta P_i. \tag{5}$$

Eq. (3) describes the volatility effect on the synthetic CPI that results from the price shock to final demand in the exogenously shocked sector. Eq. (4) captures the higher-order propagation effects of this price shock due to the sector's IO linkages to other sectors and the affected final demand within these other sectors. Eq. (5) finally gives us the total implied CPI volatility induced by the shock. If we sum over each

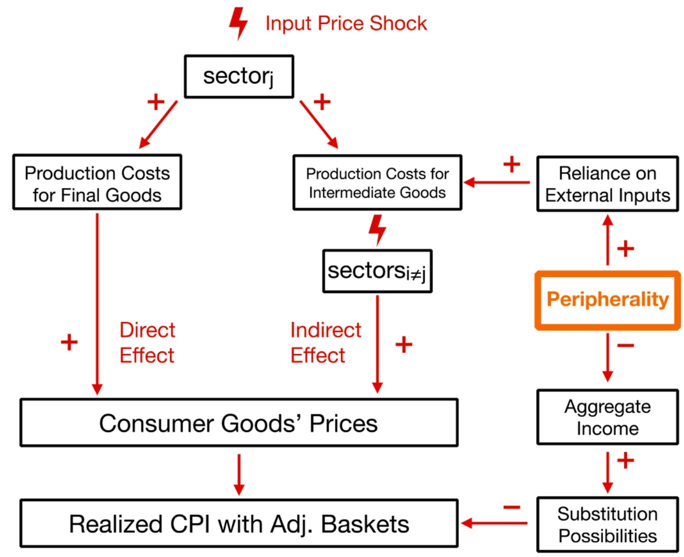

Fig. 2. Hypothesized exposure channels and mechanisms of our stress-test framework.

equation, we get the direct, indirect and total price volatility in a region that was induced by our stress-test.

Note, that the Leontief price model used for the stress-test assumes a 1:1 cost pass-through by each sector to either its customer sector or to final consumption. Therefore, the model overestimates price shock propagation where sectors find ways of substitution or function as a "price sink".[7] While the issue of substitutability is a well-known limitation of (Leontief) IO models,[8] recent history has shown illustratively for the cases of semi-conductors and gas, that substitution can prove difficult in the short-run, which is the focus of our stress-testing exercise.[9] Backing this argument, research on firm-level cost pass-through suggests that firms completely pass-through sectoral cost shocks (Duprez and Magermann, 2018). Finally, a stress-test of inflationary exposure naturally aims to understand the upper bound of a potential adverse stress scenario. Accordingly, the Leontief price model seems to be an adequate choice to model cost-push stress scenarios on a sectoral level. Since pass-through is assumed and not calibrated, this exercise should not be interpreted as a prediction or reproduction of realized CPI volatilities, but as a stress-test used to identify and rank potential

[6] See Appendix B for a list with full country names. This categorization leaves us with a ratio of core to peripheral sectors of 3:4. Where appropriate, we offset this imbalance by a normalization to facilitate comparability between regions. The procedure is detailed in Appendix C.

[7] The estimation bias could in principle work also towards underestimation. Imagine for example sectors raising prices disproportionately compared to their risen input costs.

[8] Weber et al. (2024) relax this assumption by extending their baseline model to capture conflict inflation in form of constant profit shares and constant real wages, respectively. Crucially, the systemic significance of sectors is not affected in either scenario. The simulations, however, point to important implications of the distributional consequences of cost-push shocks. Due to limitations of the dataset, we are unable to reproduce these additional simulations, since the WIOD does not provide data on nominal wages and profits for the "Rest of the World" category. However, Ipsen and Schulz (2024) as well as Schulz and Ipsen (2024) address distributional aspects of cost-push inflation based on a similar framework to Weber et al. (2024a) and the present paper.

[9] Even accounts like Bachmann et al. (2024) criticizing the assumptions of Leontief-type models acknowledge that substitution takes time and the elasticity of substitution is likely very low in the short run.

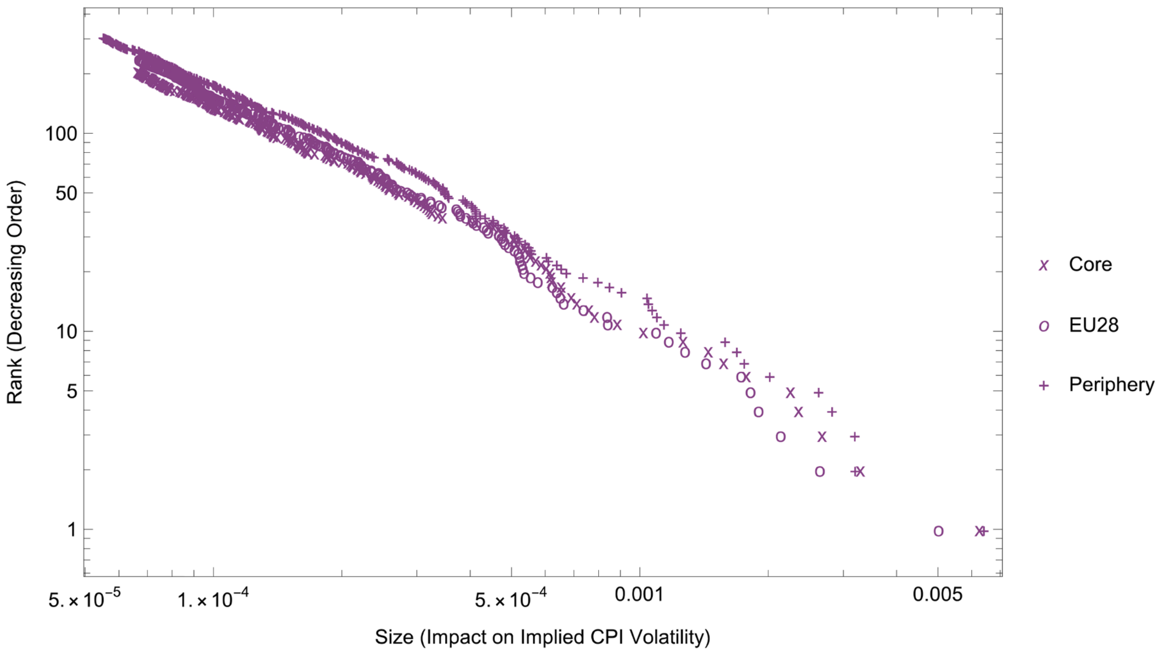

Fig. 3. Rank of sectors according to their impact on implied CPI volatility in decreasing order against their impact on a double-logarithmic scale for three different regions. Threshold for the minimum of the power law determined by the method of Clauset et al. (2009). Approximately linear in behavior in all cases indicates power law upper tails.

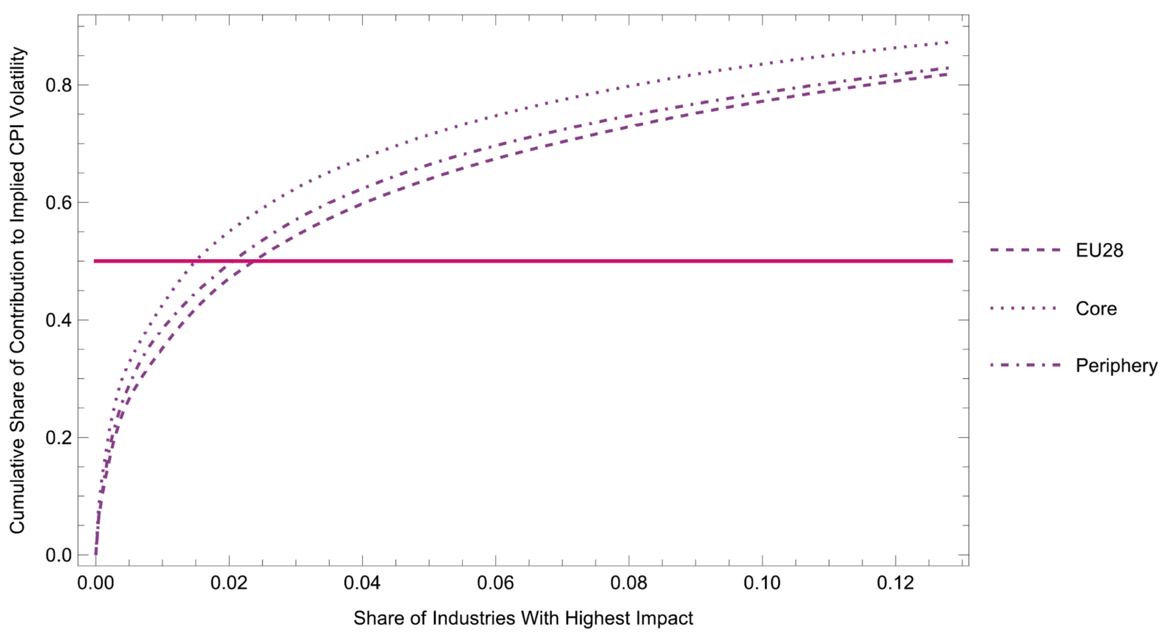

Fig. 4. Share of industries needed to reach a certain cumulative impact on the consumer price level for EU, EU core and periphery specification, respectively. Horizontal line showing 50 percent threshold.

exposures to price volatilities following a stress scenario.

Fig. 2 summarizes the hypothesized channels of our stress-testing exercise. Sectoral cost-push shocks affect the costs of final goods producers directly and in this way the synthetic CPIs via the consumption share vector. Since the input price index of a given sector also enters as input prices for other sectors, the production network amplifies the cost effect. In both regards, peripherality crucially mediates the effect: Consumers in the periphery have lower income and thus cannot substitute away from especially volatile goods. Additionally, peripheral producers are also relatively more reliant on imports of intermediate goods, rendering them particularly vulnerable to volatility in global markets, i.e., the core and the rest of the world.

Adding to Weber et al.'s (2024a) approach, we propose a formal operationalization of the concept of systemically significant prices for our dataset.[10] We take "systemically significant" to mean that the behavior of the aggregate ("system") is driven by a few "significant"

[10] We employ the method of Clauset et al. (2009) to determine the minimal threshold of the power law distribution.

components of the aggregate. To operationalize this concept, we leverage the properties of the power law distribution that governs the sectoral inflation impacts for all geographical disaggregations. While top observations might dominate aggregate statistics for other distributional forms (such as a log-normal distribution with high variance), this distributional functional form of a power law has the advantage that the inequality or concentration in the tail can be conveniently summarized by the tail exponent α. If this α is below two, the underlying distribution has infinite variance and continuing to sample from this population lets the sample variance increase without bounds. More pertinently, for such a distribution, the maximum sample observation almost entirely determines other summary statistics, especially its mean and, consequently, total value (Schulz and Milaković, 2023).[11] Thus, for a power law distribution with a tail exponent below two, aggregates are indeed driven by the top "significant" observations.

4. Results

Fig. 3 documents the existence of systemically significant prices in the EU, EU core and periphery based on our power-law methodology.[12] It plots the sectoral ranks against the sector's total impact on aggregate CPI volatility with rank one showing the most impactful sector. All three regions display approximately linear behavior on a double-logarithmic scale, indicating that inflationary impacts are well described by a power law distribution. Estimating their tail exponents via maximum likelihood furthermore shows that all three spatial levels exhibit heavy upper tails with tail exponents below two and close to one: 1.10 (EU), 1.04 (EU core) and 1.00 (EU periphery). Therefore, we find that there indeed exist systemically significant prices across all considered regional disaggregations. The origins of this power law-like behavior are unclear, though. Typically, generating mechanisms build on a variant of stochastically multiplicative growth (Gabaix, 2009). For our case of inflationary impacts, this mechanism appears unlikely to be at play here.

To gauge the highly asymmetric impact of different sectors apart from this distributional regularity, we plot the cumulative impact of these sectors in Fig. 4. It shows the share of industries needed to reach a certain threshold of cumulative impact on the synthetic consumer price levels of each region. We see that in our model around two percent of industries with the highest impact account for 50 percent of the total contribution to CPI volatility in the EU28. Moreover, it shows that sectoral impacts in the core are even more asymmetric with fewer sectors driving the aggregate volatility of the synthetic CPIs compared to the periphery.[13]

Figs. 5-7 take a closer look at the ten most significant sectors for the synthetic EU, EU core and periphery CPIs.[14] The bars can be read as: How much does the stress scenario (historical input price volatility) in sector_j of country_c affect the synthetic CPI of the EU, EU core and periphery? For the EU, sectors related to real estate activities, energy supply and production as well as financial services build the set of systemically significant prices. Comparing the EU core and periphery, there appear to be both structural similarities and differences in the composition and ranking of the most significant sectors. On the one hand, we find sectors of real estate activities, energy provision, financial services but also food manufacturing in both sets of systemically significant prices. On the other hand, there appear structural differences with the core being disproportionally affected by shocks in real estate activities while the periphery appears disproportionally exposed to sectors related to energy supply and production. Unsurprisingly, the respective largest economies constitute a disproportionate fraction of the set of systemically significant prices since the largest share of consumption happens within countries. Yet, in some cases, the list also reflects country-level idiosyncrasies driving up sectoral volatility. For example, the housing boom of the 2000s in the Netherlands increased the volatility of the Dutch real estate sector, even though the Dutch consumers only contribute little to overall consumption expenditures in the EU and the core countries. Similarly, the high volatility of the Polish manufacture of coke and refined petroleum sector reflects the geopolitical tensions and resulting price volatility of crude oil of this period.

To better understand the structural similarities and differences between EU core and periphery, Figs. 8-10 report the ten most important sector *classes* for the EU, EU core and periphery. These account for nearly 60 percent of implied CPI volatility in the respective regions. The bars give the sum of the direct and indirect CPI volatility in a region, induced by price shocks in a sector class.[15] The first bar in Fig. 8 can be read as follows: If every "Real estate activities" sector in our dataset (one for each of the 43 countries in the WIOD) would experience its average price volatility, the implied CPI impact for the EU consumers would be around 1.5 percent, with only a minor role for propagation effects (indirect effect). As such, it is ranked highest both in the EU and EU core. This picture changes for the synthetic CPI of EU periphery countries. Here, the sector of "Manufacturing of coke and refined petroleum products" is at the top. Naturally, the higher-order propagation effects for this sector class are substantially greater than for real estate activities.

Despite these differences, there again appear to be striking regularities in the set of systemically significant prices: the EU core and periphery share eight out of the ten most significant sector classes (though their relative importance differs).[16] In line with this observation, there exists a substantial overlap with the systemically significant prices identified by Weber et al. (2024a) for the United States[17] and, less

[11] To further illustrate this point, we conducted simulations for populations sampled from power laws with different tail exponents and calculated correlations between the sample mean and maximum values. For the empirically relevant parameter ranges, we find that there is almost a perfect correlation for all measures of association. The relevant simulation outcomes can be found in Appendix D.

[12] The code and a link to the publicly available data to reproduce the results of this paper can be found at https://github.com/ip5490/Stress-testing-Inflation-Exposure.

[13] The attentive reader might wonder why, in Figure 4, the impact of core sectors is more asymmetric than for the peripheral sectors, even though the concentration within the power law tail in the periphery is higher (indicated by a lower estimated tail exponent). This is due to the fact that the gap in total impact *between* the power law and non-power law segments of the core estimates is higher than for the periphery, more than compensating for the higher concentration *within* the power law segment for the peripheral estimates.

[14] Appendix E provides tables including the effect sizes and sector-level average price volatilities that function as the stress scenarios.

[15] A sector class simply represents the set of every national sector in this class (sector_j in Brazil, France, Hungary, etc.). Therefore, each bar shows the implied CPI volatility in a region that emerges if every national sector of this class is shocked with its average price volatility.

[16] These are "Real estate activities", "Manufacturing of coke and refined petroleum products", "Manufacturing of food products", "Electricity, gas, steam and air conditioning supply", "Crop and animal production, hunting and related service activities", "Wholesale trade, except of motor vehicles and motorcycles", "Financial service activities, except insurance and pension funding", "Manufacture of chemicals and chemical products".

[17] These are "Petroleum and coal products," "Oil and gas extraction," "Farms," "Food and beverage and tobacco products," "Chemical products," "Housing," "Utilities," and "Wholesale trade" (Weber et al., 2024a). While, due to differences in the classification, a one-to-one mapping to our results is not possible, the significant overlap is nevertheless apparent.

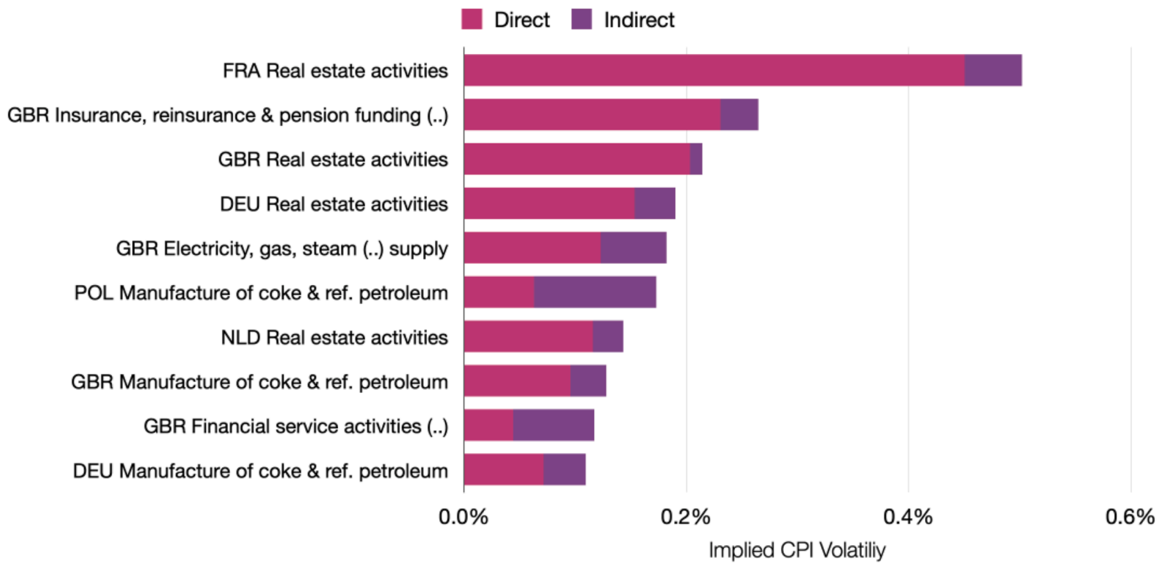

Fig. 5. Implied CPI volatility induced by the ten most impactful national sectors for the EU (decreasing order). The total effect can be decomposed into the direct effect (magenta) on the synthetic CPI and the indirect effect (purple), i.e. the higher-order propagations.

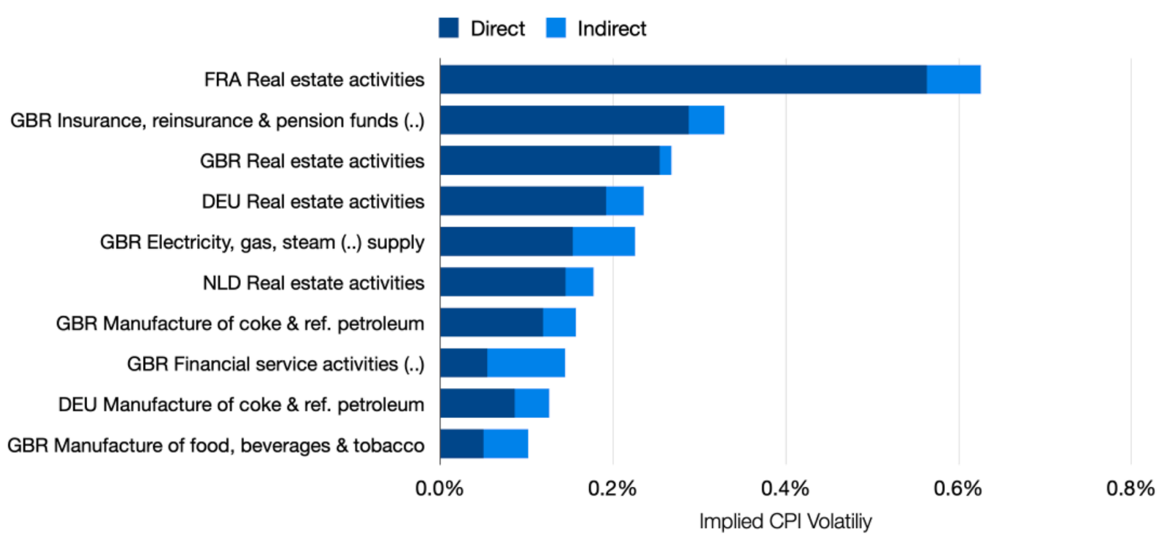

Fig. 6. Implied CPI volatility induced by the ten most impactful national sectors for the EU core (decreasing order). The total effect can be decomposed into the direct effect (darker blue) on the synthetic CPI and the indirect effect (lighter blue), i.e. the higher-order propagations.

surprisingly, also with the systemically significant prices for Germany (Weber et al., 2024b)[18] and France (Goldztejn, 2024)[19]

In general, the classes of real estate activities, food production as well as raw materials in the form of energy supply appear as systemically significant across all extant studies. Real estate sectors mostly matter because of their direct impact, while the sectors qualifying as energy suppliers also matter through their indirect effect i.e. their pivotal role for other sectors in the production process (Usman et al., 2024). These results indicate that either size understood as share in total consumption or centrality in the form of supplying essential (agriculture) or universal (energy) inputs may render a sector systemically significant, rather than merely considering its unweighted volatility itself.

Table 1 and 2 further decomposes the geographical asymmetries in price volatility in the EU periphery vis-à-vis the core: While the EU core experiences 4.40 percentage points of direct and 3.41 percentage points of indirect effects, accumulating to 7.81 percentage points in total, the periphery is exposed to 5.35 percentage points of direct and 4.64 percentage points of indirect effects, accumulating to 9.99 percentage points.

Therefore, the indirect effect makes up a higher share of the total inflation exposure for peripheral countries compared to the core. Considering the volatile price formation in raw material sectors, the difference in the importance of raw materials between EU core and

[18] The ten most important sectors (as of 2019) are identified to be: "Electricity, Heating and Cooling", "Land Transport", "Freelance and Other Services", "Food, Beverages and Tobacco", "Warehousing", "Coke and Petroleum Products", "Other Economic Services", "Agriculture", "Real Estate Services" and "Oil and Gas" (Weber et al., 2024b).

[19] These are "Coking and refining", "Real Estate Activities", "Trade", "Manufacture of food, beverages and tobacco products", "Agriculture, forestry and fisheries", "Finance and Insurance Activities", "Production and distribution of electricity, gas, steam and air conditioning", "Telecommunications", "Transport and storage", "Legal, accounting, management, architecture, engineering, control and technical analysis activities". While again, a one-to-one mapping to our results is not possible, the significant overlap is apparent.

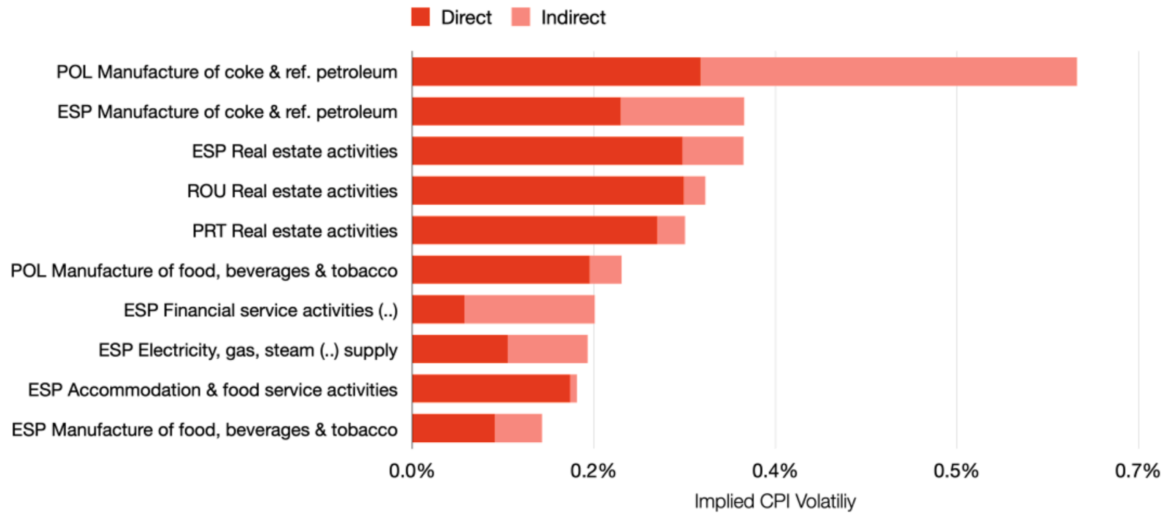

Fig. 7. Implied CPI volatility induced by the ten most impactful national sectors for the EU core (decreasing order). The total effect can be decomposed into the direct effect (darker red) on the synthetic CPI and the indirect effect (lighter red), i.e. the higher-order propagations.

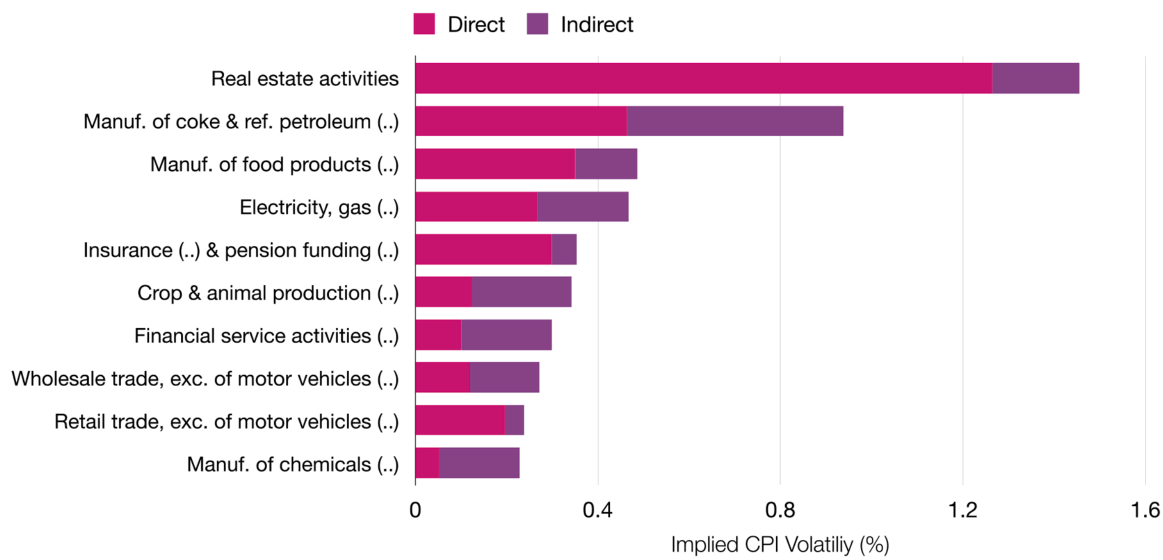

Fig. 8. Summed CPI volatility induced by the ten most impactful sector classes for the EU (decreasing order). The total effect can be decomposed into the direct effect (magenta) on the CPI and the indirect effect (purple), i.e. the higher-order propagations.

periphery at least partially explains the greater volatility in the periphery. According to Herman Daly's 'inverted pyramid', this higher volatility stems from the position of raw materials and energy at the outset of the production process (Cahen-Fourot et al., 2020).

A greater dependence on raw materials naturally suggests a more exposed position in world markets. We see this hypothesis confirmed when illustrating the price shock trajectories (Fig. 11). The EU periphery imports 1.02 percentage points of its inflation exposure from sectors located in countries outside the EU, while it is only 0.80 percentage points for the EU core. In addition to that, peripheral countries also bear a greater inflation exposure vis-à-vis core countries. While core countries face an exposure of only 0.37 percentage points from peripheral countries, price volatility diffusing from core sectors to the periphery is more than three times this size (1.29 percentage points). Conversely, while it is the upstream sectors of raw materials exposing peripheral countries to price volatility, it is the higher dependence on down-stream sectors such as real estate activities that seem to prevent the EU core from importing a similar share of volatility. These findings, based on a very different dataset, are in line with results from Joya and Rougier (2019) and Chakraborty et al. (2024) who find lower-income countries to be more exposed to supply-chain risk from outside their region compared to higher-income countries.

The results from recovering consumption substitution effects (6) shed more light on the asymmetric inflation exposure.[20] Consumers in the peripheral countries seem to be at the mercy of price volatilities, while consumers in the core countries are better able to substitute away from increasingly volatile prices. More formally, the cross-sectional covariance between consumption shares and price volatilities is virtually non-existent for the periphery (0.05 percentage points), while it is significantly negative for the core (−0.89 percentage points). The mean price volatility $\overline{\pi}$ is 5.3 percentage points.

$$\pi^{direct} = \overline{\pi} + (N - 1)\cdot cov(c_x, \Delta P_x) \quad (6)$$

Finally, Figs. 12 and 13 show the round-to-round decomposition for

[20] This decomposition holds, since consumption shares c sum to one (Olley and Pakes, 1996).

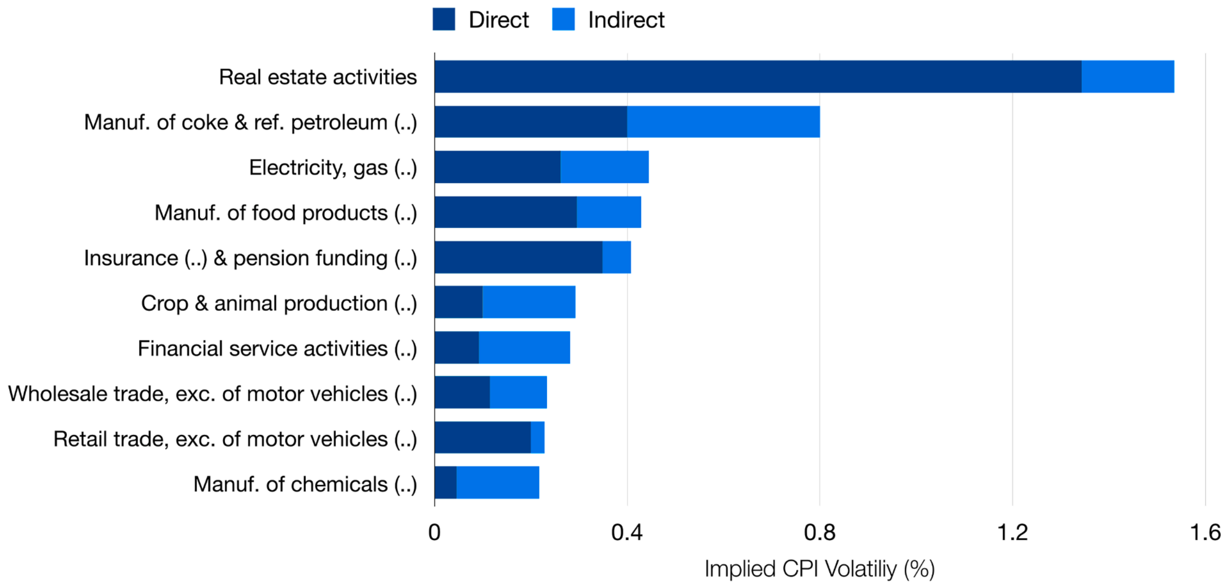

Fig. 9. Summed CPI volatility induced by the ten most impactful sectors for the EU core (decreasing order). The total effect can be decomposed into the direct effect (darker blue) on the CPI and the indirect effect (lighter blue), i.e. the higher-order propagations.

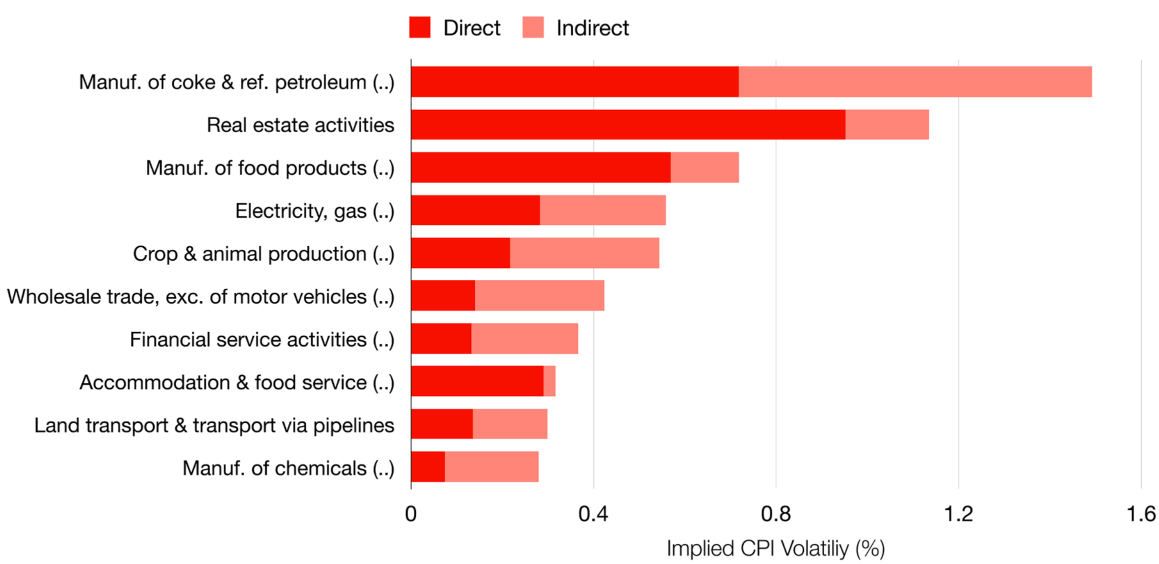

Fig. 10. Summed CPI volatility induced by the ten most impactful sectors for the EU periphery (decreasing order). The total effect can be decomposed into the direct effect (darker red) on the CPI and the indirect effect (lighter red), i.e. the higher-order propagations.

Table 1
Inflation exposure in percentage points for the core vis-à-vis core, periphery and non-EU countries. Decomposed into direct, indirect and total effect. Consider, for example, the first cell in the first row: The direct effect of shocks diffusing from core sectors accounts for 4.13 percentage points of inflation impact in the core. The ratio of sectors in the core and peripheral countries are normalized to a 1:1 ratio to prevent under-/overestimation by differing numbers of sectors.

Effects	Core to Core (%)	Periphery to Core (%)	non-EU to Core (%)	Sum (%)
direct	4.13	0.11	0.16	4.40
indirect	2.51	0.26	0.64	3.41
total	6.64	0.37	0.80	7.81

Table 2
Inflation exposure in percentage points for the periphery vis-à-vis core, periphery and non-EU countries. Decomposed into direct, indirect and total effect.

Effects	Periphery to Periphery (%)	Core to Periphery (%)	non-EU to Periphery (%)	Sum (%)
direct	4.80	0.37	0.18	5.35
indirect	2.88	0.92	0.84	4.64
total	7.68	1.29	1.02	9.99

the two most relevant cases of the sector classes “Real Estate Activities” (top) and “Manufacturing of Coke and Refined Petroleum” (bottom), respectively. Round 0 marks the direct effect a sector causes, when confronted with our stress scenario. Round 1 to 10 show the cumulative indirect effects adding to the direct effect of round 0. We see that there exist sizable intersectoral and geographical differences in the round-to-round effects. The decomposition also shows the bulk of higher-order effects to be limited to the first five to six rounds. This implies that price shocks mostly diffuse within a small number of sectors and thus display rather short path-lengths. These results are valuable in and of

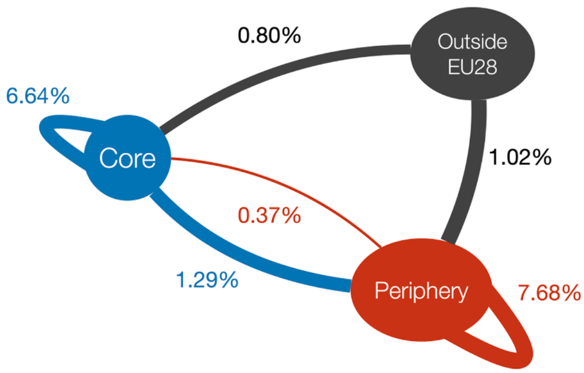

Fig. 11. Paths of price volatilities originating in EU core, periphery and outside EU28 countries, respectively.

itself, however, also shield our analysis against the critique of Leontief IO models unrealistically considering an infinite number of adjustment rounds, or, equivalently, that all adjustments happen instantaneously neglecting historical time in the basic model mechanism (for a related criticism of comparative statics and historical time, cf. Robinson, 1980).

Overall, peripheral countries seem to be confronted with a significantly greater inflation exposure due to their greater reliance on raw materials and dependence on core and outside-EU sectors. Part of this exposure is attributable to differences in the production regime. However, and in line with the reasoning of Pasinetti (1983), we show that a substantial share of exposure stems from differences in the ability to substitute away from volatile sectors.

5. Discussion

As key inflation propagators, the identified systemically significant prices present risks that need to be addressed by administrations of national and supranational levels. Our simulation results suggest that about two percent of sectors generate more than half of the total inflation exposure.

Weber and Wasner (2023) and in more detail van't Klooster and Weber (2024) discuss several levers to decrease and manage exposure against systemically significant prices and cost-push inflation more generally: First, improving the monitoring of exposures, which hinges on the quality, granularity and timeliness of available data, is a key aspect of preparing for future stress scenarios. The recent upheavals caused by semi-conductor shortages have shown that the identification of systemically significant prices should not stop at the sectoral level but needs to examine the firm- and product-level as well. Second, improved competition policy might reduce pass-through in sectors that profit from (temporary) bottlenecks. Third, the implementation of buffer stocks for systemically significant prices – in analogy to the Basel III framework for banks that also includes stress-testing – could not only decrease pressure on prices in times of stress but go well beyond by ensuring production and supply of essentials. Furthermore, the authors discuss the taxation of windfall profits and strategic price controls as potential measures. Baldwin and Freeman (2022) articulate similar considerations, including supply diversification and reshoring, and emphasize the role of public regulatory responsibility in cases where public harm needs to be prevented.

Our results show that this discussion also needs to consider the asymmetric exposures faced within the EU, with the EU periphery being subject to a set of key constraints. Naturally, the exposure of peripheral countries is linked to their lower average income, which in turn limits their capability for consumption substitution. This points to an appropriate fiscal transfer scheme on the national (and supranational) level, but also to targeted regional development strategies to facilitate European cohesion. These should not only take the path-dependent nature of economic development into account (Deegan et al., 2021), but also aim to reduce exposure. Next, we find that peripheral price volatility depends strongly on the core and the rest of the world. This means that policymakers in the peripheral countries are less capable of controlling these largely external sources of disturbances. Building technological capabilities, especially in renewable energies, could reduce their dependence on volatile imports of fossil fuels and hence decrease inflation exposure. A final challenge for mitigation policies are differences in the sectoral composition, that drive the response to cost-push shocks. We find the total impact of industries to be more concentrated in the core compared to the periphery. Thus, policy and costly supervision in the periphery needs to cover more sectors. Qualitatively, the most significant drivers of inflation exposure in the core are the various real estate sectors, while it is sectors related to energy production and raw materials in the periphery. Since monetary policy is highly

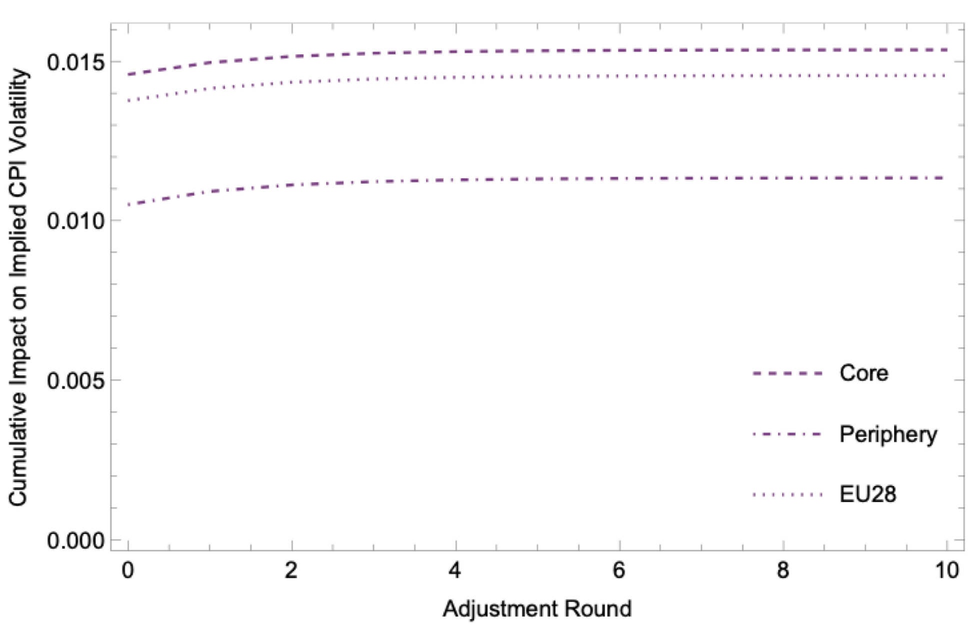

Fig. 12. Round-to-round approximation for "Real Estate Activities". Round 0 shows the direct effect. Round 1 to 10 showing the cumulative indirect effects adding to round 0 (decimal values).

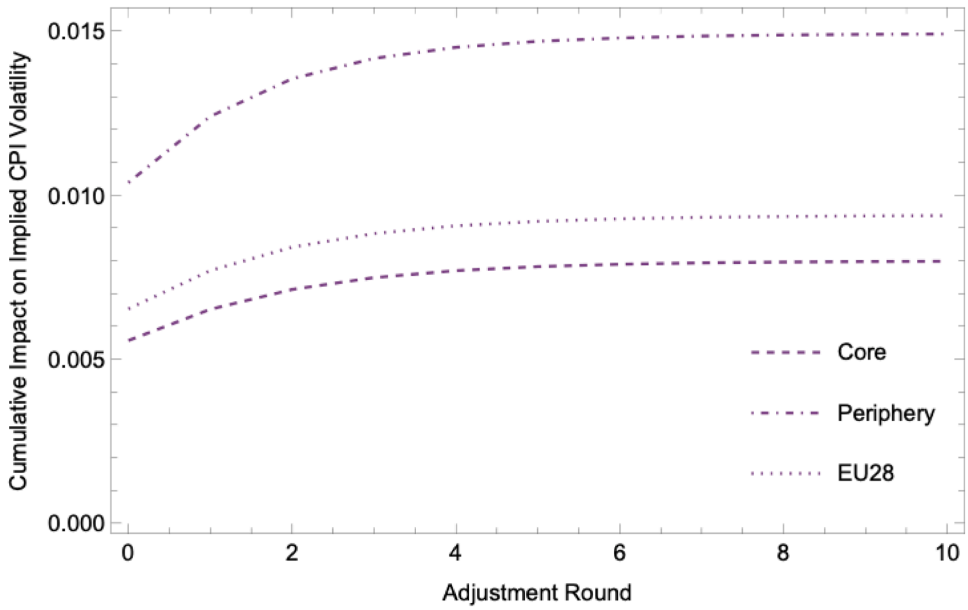

Fig. 13. Round-to-round approximation for "Manufacturing of Coke and Refined Petroleum". Round 0 shows the direct effect. Round 1 to 10 showing the cumulative indirect effects adding to round 0 (decimal values).

asymmetric in its impact both on the regional and the sectoral level, a common monetary policy as in the Eurozone might therefore cause further divergence of core and periphery (Beraja et al., 2018; Carlino and DeFina, 1998; Peersman and Smets, 2005). In particular, there exists evidence that monetary policy is more effective in curbing the price volatility of residential investment (Enders and Ma, 2011). Given that the real estate sector dominates the synthetic CPI of the core but only to a lesser extent the synthetic CPI of the periphery, monetary policy might thus only further the volatility differential between core and peripheral countries, calling for counteracting fiscal measures both on the national and supranational level.

6. Conclusion

Our paper provided a stress-test for inflation exposure explicitly accounting for amplification in production networks. Applying data from the World Input Output Database to a Leontief price model, we confirmed the existence of systemically significant sectors for synthetic CPIs of the EU, EU periphery and core. Adding to Weber et al. (2024a), we suggest a new approach to operationalize the existence of systemically significant prices based on the mathematical properties of power law distributions. Documenting several dimensions of sectoral and spatial heterogeneity, we hope to aid policy to enhance European inflation resilience by highlighting potential levers for which targeted policies could disproportionately affect aggregate outcomes. Theoretically, our results imply that the notion of inflation as a purely aggregate phenomenon underlying much of orthodox macroeconomics is too simplistic and ignores the role of systemically significant prices and shock propagation within production networks.

Yet, our simulation also has several limitations, essentially due to the lack of more current and granular data: The data does not cover the most recent period of high inflation and is highly aggregated on a country level. Since we do not have consumption microdata, we implicitly employ the fiction of a representative consumer for a region and only consider shares in the total consumption of said region. This prevents us from examining the effects of cost-push shocks along the personal income distribution, which are arguably even more important for policy (see Schulz and Ipsen, 2024). Also, as Weber and Schulz, 2025 show, core-periphery patterns are more prevalent on the much more granular county level, which, with the appropriate data, calls for an even more granular study of the spatial propagation of cost-push shocks. Finally, the Leontief price model implicitly makes strong assumptions about substitutability along the supply chain, rendering our simulation results upper-bound estimates. We aim to address these issues in further research, investigating country-specifics as a first step, and augment our propagation model with a modified Leontief production function that partially allows for input substitution (Pichler et al., 2022). Notwithstanding these limitations, our paper provides a first stress-test for inflation exposure in supply chains that takes spatial heterogeneities seriously and can be straightforwardly applied and extended to other scenarios.

CRediT authorship contribution statement

Leonhard Ipsen: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Armin Aminian:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Conceptualization. **Jan Schulz:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Data curation, Conceptualization.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.strueco.2025.05.010.

Data availability

The data and code is uploaded to a GitHub repository, as indicated in the manuscript.

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