The (Dis-)Equalizing Effects of Production Networks

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Working Paper No. 195

May 2024

BAMBERG ECONOMIC RESEARCH GROUP

BERG Working Paper Series

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ISBN 978-3-949224-16-4

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The
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Production Networks

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Abstract

We suggest and empirically substantiate that the global production network constitutes an important variable for inflation inequality, as it modulates the impact of cost-push shocks on households. For most price shocks, the production network reduces inflation inequality, however, at the expense of lower-income households. Introducing a synthetic Consumer Price Index indicates lower-income households to be at the losing end of the overall effect of supply-side price shocks.

Keywords: Inequality, Inflation, Input-output Analysis, Europe

Declarations of interest: none

Acknowledgements: We thank Frank Westerhoff, Georg Maxton and the participants of the meeting of the Keynes Society in Bamberg in 2024 for valuable comments at crucial junctions of this investigation. Funding by the Hans-Böckler-Foundation through grant PK045 is gratefully acknowledged.

1. Introduction

Do production networks amplify income-dependent inflation inequality? And if so, who is paying for it? To answer this, we simulate sector-level price shocks in the global production network and investigate the income-dependent exposure of households in 21 EU countries to these shocks. Our results show that for most price shocks, the production network actually dampens inflation inequality across income quintiles. However, more often than not, it does so at the expense of lower-income households.[1] Considering the sectors' shares in a synthetic Consumer Price Index indicates that lower-income households are also disproportionally exposed to the overall effects of price shocks in our model. This study aims to contribute a missing piece to the heavily contested literature on the nexus of inflation and income inequality (Garcimartín et al., 2021).

2. Data

We base our analysis on three different datasets: First, we use the World Input Output Database (WIOD) to inform our global production network (as of 2014), the sector-specific price shocks (2000 - 2014) as well as the shares of final demand of a country$_i$ in sector$_a$ of country$_c$ (as of 2014) (Timmer et al., 2014). It has been shown, that the global sector-level production network evolves rather incrementally (McNerney et al., 2022), which makes this dataset, even though outdated, a reasonable proxy for our analysis. Crucially, this setup allows price shocks to originate and propagate globally. Note that relying only on the final demand shares of the WIOD would be equivalent to assuming one representative household in each country. We thus introduce a second dataset that gives us sector-level data on consumption by purpose expenditure shares for income quintiles Q1 (low) to Q5 (high). The latest data available includes data for 21 EU countries[2] for the year 2020 (Eurostat 2021b). Since the COICOP data follows a different classification than the WIOD (COICOP versus ISIC Rev. 4), we rely on bridging matrices provided by Cai and Vandyck (2020) to offset the *expenditures by income shares* with the *final consumption shares* of the WIOD. Doing so gives us the consumption share$_{q,i,a,c}$ – the share of consumption expenditure of a respective income quintile$_q$ of country$_i$ in sector$_a$ of country$_c$. Country$_i$ corresponds to a country in the set of the 21 EU countries in the Eurostat sample, while country$_c$ corresponds to a country in the set of 43 countries sampled in the WIOD. Sector$_a$ corresponds to one of the 56 sector classes sampled in the WIOD. Finally, to analyze the sector-level elasticities of inflation exposure with

[1] In our study, inflation inequality refers to any situation, where the impact of inflation on different income groups is asymmetric. The production network might dampen or amplify this asymmetry. By contrast, we refer to an equalizing (disequalizing) effect, whenever inflation affects richer (poorer) households disproportionately.

[2] The countries are Austria, Belgium, Bulgaria, Croatia, Cyprus, Denmark, Estonia, Germany, Greece, France, Hungary, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Romania, Slovenia, Slovakia and Spain.

respect to income, we use 2020 mean absolute income values for the income quintiles of the 21 EU countries (Eurostat, 2021a).[3]

3. Empirical Strategy

For our empirical analysis, we set up a Leontief price model based on Weber et al. (2024). We present the derivation of the model in Appendix A. The basic mechanism works as follows: sector$_a$ in country$_c$ is exposed to its average input price shock, which we compute as the mean logarithmic differences of its input prices from 2000 - 2014. This price shock propagates linearly downstream and reaches households either directly through increased prices for final goods or indirectly via the production network effect of increased prices for intermediate goods. Note the straightforward economic interpretation: The *direct* effect gives the effect of a price shock to a sector as if there was no production network appended to it. The *indirect* effect indicates exclusively the additional effect of the price shock propagating in the production network – the production network effect. Together they give the *total* effect of a price shock to a sector on a given country-income pair. In our model, every price shock reaches and is fully absorbed by households eventually. While ruling out substitution on the household level is an unrealistic assumption, it is not obvious whether we over- or underestimate inflation inequality in doing so. One reason is that, as the price of a good rises, its relative share in the total expenditures does too, which is akin to a negative substitution effect. Kaplan and Schulhofer-Wohl (2017) is one of several studies that finds such a negative substitution for a significant share of households.

Since the final consumption shares differ across countries and income quintiles, the exposure of households to individual sectors is asymmetric. We repeat this exercise for every sector in our global production network and with every one of the 21×5 country-income pairs on the receiving end. By the end, we have simulated every direct and indirect effect of an average price shock in every sector of all countries$_c$ on all income quintiles$_q$ in all countries$_i$. This allows us to tackle our initial research questions. Using the log-log-regression equation in (1), we estimate how the exposure towards a sector class changes with respect to income. Namely, we use the logarithmic effect $log(E) \in \{\text{Direct Effect, Indirect Effect, Total Effect}\}$ of sector$_a$ as our dependent variable and the logarithmic average absolute income of quintile$_q$ of country$_i$, $log(Y_{q,i})$, as our independent variable. δ_i is a dummy variable that accounts for country-level fixed effects while $\epsilon_{a,q,i}$ represents an error term.

$$log(E_{a,q,i}) = \beta_{0,a} + \beta_{1,a} log(Y_{q,i}) + \delta_i + \epsilon_{a,q,i} \tag{1}$$

[3] As we lack data for the mean absolute income of Q5, we use the following classification: Q1 corresponds to the value of the first percentile, Q2 corresponds to the 20th percentile, up to Q5 which corresponds to the 80th percentile.

A negative elasticity coefficient $\beta_{1,a}$ indicates that the inflation exposure of households towards this sector class is reduced with increasing income. The opposite is true for a positive coefficient. Each coefficient corresponds to the percentage change in exposure to a sector following a one percent increase in income. An exemplary question would be: How does the exposure to the 'Fishing & Aquaculture' sector change with income? To answer this, we would consider the effects of all the 'Fishing & Aquaculture' sectors on all country-income pairs and estimate an elasticity coefficient with country-level fixed effects.

4. Results

Figure 1 presents the sector-level estimates (points) as well as the 95 percent confidence interval (whiskers) for the direct, production network and total effect. Note, that we have fewer sectors in the direct effect estimates than in the indirect effect estimates. This is due to zero or negative values in some instances of the direct effects of these sectors, which leads to the exclusion from our log-log regression.

The production network appears to dampen inflation inequality across income quintiles for most price shocks as we find significantly more heterogeneity in the direct effect estimates than in the production network effect estimates. This suggests that shocks tend to propagate from sectors with larger income-dependent consumption differences to sectors with less heterogeneity. Put differently, the production network "pushes" the estimates closer to the zero line, which marks no income dependence in the inflation exposure towards a sector. Recall, that this does not yet tell us whether the production network effect is equalizing or disequalizing. In *absolute* terms, the production network appears to have an equalizing effect: Most indirect effect estimates are significantly positive. However, for most sectors, the indirect effect estimates are substantially smaller than the direct effect estimates. Thus, they are affecting lower-income households *relatively* more than the direct effect estimates. Consequently, the production network dampens inflation inequality but does so to the detriment of poorer households.

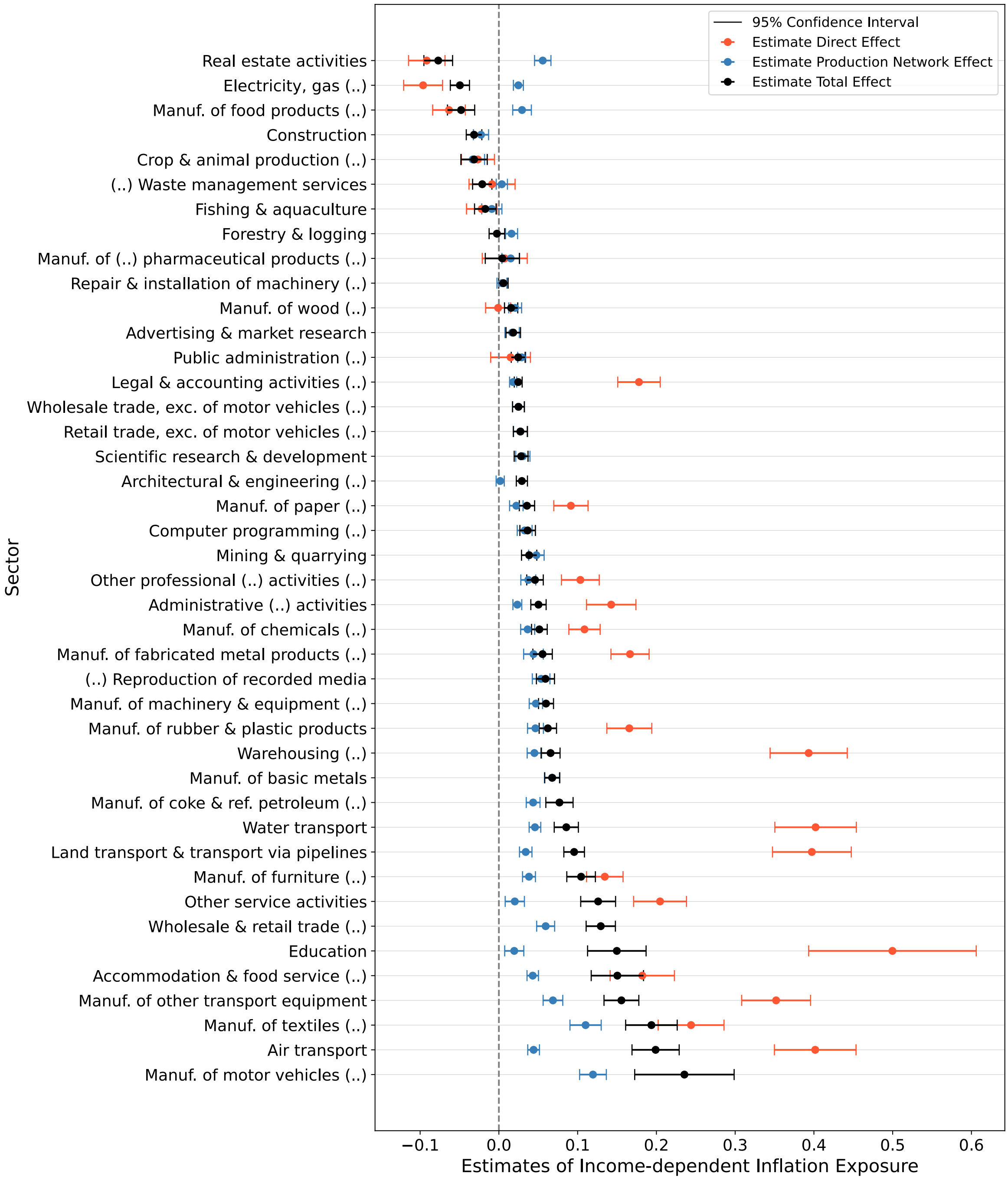

Fig. 1. Direct, production network and total effect elasticity estimates (points) and 95 percent confidence intervals (whiskers) for income-dependent inflation exposure to a given sector class. A positive (negative) estimate reflects increasing (decreasing) exposure with increasing income.

Does this mean that, in absolute terms, higher-income households are disproportionally exposed to both the direct and production network effect of supply-side price shocks? Not necessarily, as we are yet to consider the absolute expenditure weights in sectors – akin to a Consumer Price Index (CPI). Conveniently, the total effect share of a sector class can be seen as a reasonable first-order approximation of its share in a synthetic CPI. We can thus easily compare the effect share of inequality enhancing sectors (the ones with negative estimates) in our synthetic CPI to the effect share of inequality reducing sectors (the ones with positive estimates). We compute these for the direct, indirect, and total effect as

$$\frac{\sum_{i=1}^{I}\sum_{q=1}^{Q}\text{effect inequality enhancing (reducing) sectors}}{\sum_{i=1}^{I}\sum_{q=1}^{Q}\text{effect all sectors}}. \quad (2)$$

We normalize the shares to one since we omitted insignificant estimates as well as some sectors in the log-log-regression due to zero values. As Table 1 confirms, higher-income households are, in absolute terms, significantly more exposed to the production network effect, with 87 percent of the average *indirect* effect stemming from inequality reducing sectors. However, even though there are only five inequality enhancing sectors for the *direct* effect, these account for 83 percent of the overall *direct* inflation exposure of households. In total, lower-income households are in fact slightly more exposed to the total effect of price shocks as the last column shows.

Table 1

	Average Direct Effect Share (%)	Average Indirect Effect Share (%)	Average Total Effect Share (%)
Inequality Enhancing Sectors	0.83	0.13	0.52
Inequality Reducing Sectors	0.17	0.87	0.48
Sum	1.00	1.00	1.00

5. Conclusion

In this paper, we have shown that the global production network is a relevant variable when analyzing income-dependent inflation inequality. Our findings indicate a dampening production network effect on inflation inequality, mostly, however, to the detriment of poorer households. A synthetic CPI furthermore suggests that these households are also disproportionally exposed to the overall effect of the larger share of price shocks in our model. As geopolitical and ecological crises deepen, more supply-side price shocks can be expected. Implementing supply-side stress-tests based on a model similar to ours could inform preemptive or at least timely measures by estimating the distributional consequences as well as pinpointing sector- and country-level exposures.

References

Cai, M., & Vandyck, T. (2020). Bridging between economy-wide activity and household-level consumption data: Matrices for European countries. *Data in Brief*, *30*, 105395.

Duprez, C., & Magerman, G. (2018). *Price Updating in Production Networks* (Working Paper Research 352). National Bank of Belgium.

Eurostat (2021a). *Distribution of income by quantiles* [Data set]. https://ec.europa.eu/eurostat/databrowser/view/ilc_di01/default/table?lang=en&category=livcon.ilc.ilc_ip.ilc_di

Eurostat (2021b). *Structure of consumption expenditure by income quintile and COICOP consumption purpose* [Data set]. https://ec.europa.eu/eurostat/databrowser/view/hbs_str_t223/default/table?lang=en&category=livcon.hbs.hbs_struc

Garcimartín, C., Astudillo, J., & Martínez, A. (2021). Inflation and income distribution in Central America, Mexico, Panama, and the Dominican Republic. *Review of Development Economics*, *25*(1), 315–339.

Kaplan, G., & Schulhofer-Wohl, S. (2017). Inflation at the household level. *Journal of Monetary Economics*, *91*, 19-38.

McNerney, J., Savoie, C., Caravelli, F., Carvalho, V. M., & Farmer, J. D. (2022). How production networks amplify economic growth. *Proceedings of the National Academy of Sciences*, 119(1), e2106031118.

Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R., & De Vries, G. J. (2015). An illustrated user guide to the world input–output database: the case of global automotive production. *Review of International Economics*, *23*(3), 575-605.

Weber, I. M., Lara Jauregui, J., Teixeira, L., & Nassif Pires, L. (2024). Inflation in times of overlapping emergencies: Systemically significant prices from an input–output perspective. *Industrial and Corporate Change*, *33*(2), 297-341.

Appendix A

The fundamental principle of the Leontief price model is shown in equation (i) which states that the price P_j of sector$_j$ is dependent on the prices of inputs $P_{i \neq j}$ times the technical coefficients a_{ij} plus the value added V_j.[4] The technical coefficient a_{ij} is the ratio of value of inputs from sector$_i$ to the overall value of sector$_j$ output.

$$P_j = a_{1j}\, P_1 + \ldots + a_{ij}\, P_i + \ldots + a_{nj}\, P_n + V_j \tag{i}$$

As Input-Output tables report production values in currency units and do not differentiate between quantities and prices, the output of each sector is normalized, so that the above equation gives the price per unit of output. Accordingly, price changes are to be interpreted as percentage changes. Introducing n sectors, this can be written as a system of linear equations, which, in matrix notation, gives

$$\begin{bmatrix} P_1 \\ P_2 \\ \vdots \\ P_n \end{bmatrix} = \begin{bmatrix} a_{11} a_{21} & \cdots a_{n1} \\ a_{12} a_{22} & \cdots a_{n2} \\ \vdots \; \vdots & \ddots \; \vdots \\ a_{1n} a_{2n} & \cdots a_{nn} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ \vdots \\ P_n \end{bmatrix} + \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{bmatrix} \tag{ii}$$

or

$$P \; = A'\, P + v \tag{iii}$$

We use the transpose of the technical coefficient matrix A, since we assume shocks to propagate downstream. To simulate a price shock to a given sector, we have to set the respective sector exogenous which splits (iii) into

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

[4] This section is based on Valadkhani and Mitchell (2002) and Weber et al. (2024). Note, that our data comprises global trade, thus imports are broken down to individual sector-level inputs and do not explicitly show up in the derivation.

where P_E and P_X are the price vectors of the endogenous and exogenous sectors, respectively. Since we determine P_X exogenously this reduces to

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

where $A'_{XE}P_X$ represents the dependence of prices in endogenous sectors on the price in the exogenous sector, while $A'_{EE}P_E$ represents the dependence of prices in endogenous sectors on each other. Solving for P_E yields

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

by ruling out changes in the quantity of inputs, the price change in the endogenous sectors, following a change in prices in the exogenous sector ΔP_x is given by

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

which represents the core of our model. Finally, we have to introduce expenditure shares, where $es_{x,q,i}$ is the expenditure share of quintile$_q$ of country$_i$ in the exogenous sector$_x$ and $es_{b,q,i}$ is the expenditure share of quintile$_q$ of country$_i$ in the respective endogenous sector $b \neq x$. It follows, that the direct effect of a price change in the exogenous sector, that is the effect without considering propagation in the network, is given by (viii), while the indirect effect, that is the isolated production network effect, is given by (ix). Equation (x) gives the total effect of a price change in sector$_x$ which is the sum of the direct and indirect effect.

$$\Delta\pi_{Q,I}^{direct} = es_{x,q,i}\Delta P_X \tag{viii}$$

$$\Delta\pi_{Q,I}^{indirect} = \sum_{b \neq x} es_{b,q,i}\, \Delta P_E^b \tag{ix}$$

$$\Delta\pi_{Q,I}^{total} = es_{x,q,i}\Delta P_X + \sum_{b \neq x} es_{b,q,i}\, \Delta P_E^b \tag{x}$$

References

Valadkhani, A., & Mitchell, W. F. (2002). Assessing the impact of changes in petroleum prices on inflation and household expenditures in Australia. *Australian Economic Review*, *35*(2), 122-132.

Weber, I. M., Lara Jauregui, J., Teixeira, L., & Nassif Pires, L. (2024). Inflation in times of overlapping emergencies: Systemically significant prices from an input–output perspective. *Industrial and Corporate Change*, *33*(2), 297-341.

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