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Niklas Geyer BSC

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Abstract

Englisch / English

We simulate sector specific price shocks and assess their impact on aggregated price levels such as the Consumer Price Index (CPI), Producer Price Index (PPI) and Import Price Index (IPI). Data is mainly provided by the Word Input-Output Database (WIOD) which covers 28 EU countries and 15 other major countries in the world for the year 2014. We find large differences in the price impact of individual industries on aggregated price levels, with the industry “Electricity & Gas” demonstrating the by far most substantial impact. The industries with the highest aggregated price impact can broadly be grouped into energy supply, necessities of life and essential production inputs. Furthermore, we simulate price shocks for different inflation periods, observing that industries with the largest impact on aggregated prices remain relatively constant. Similar results have been found for the US. Furthermore, we use monthly price data of industries, which are trading with gas, petroleum, or oil for the period January 2021 to February 2023 to simulate gas price shocks and determine their impact on the CPI, PPI and IPI. Subsequently, we compare the simulations with their real indices and find that especially changes in the price levels for the CPI and IPI can be explained very well by these simulations. Finally, we construct a counterfactual scenario where we assume that Austria is economically self-sufficient, to assess, to what extent price increases in Austria are imported. Depending on the scenario, we find an average price impact of 0,7 % to 1,4 % for the CPI and of 2,2 % to 3,2 % for the PPI due to imports.

Deutsch / German

Wir simulieren sektorspezifische Preisschocks und berechnen ihre Auswirkungen auf aggregierte Preisniveaus wie den Verbraucherpreisindex (VPI), den Produzentenpreisindex (PPI) und den Importpreisindex (IPI). Die Daten stammen hauptsächlich aus der Word Input-Output Database (WIOD), die 28 EU-Länder und 15 weitere wichtige Länder der Welt für das Jahr 2014 abdeckt. Es lassen sich große Unterschiede in den Preisauswirkungen einzelner Branchen auf das aggregierte Preisniveau beobachten, wobei die Industrie „Elektrizität & Gas“ den bei weitem größten Einfluss auf das Preisniveau aufweist. Die Branchen mit den höchsten aggregierten Preisauswirkungen lassen sich grob in die Bereiche Energieversorgung, lebensnotwendige Güter und wesentliche Produktionsfaktoren einteilen. Des Weiteren simulieren wir Preisschocks für verschiedene Inflationsperioden, wobei zu beobachten ist, dass Industrien mit den größten Auswirkungen auf aggregierte Preise konstant bleiben. Ähnliche Ergebnisse wurden auch für die USA gefunden. Außerdem verwenden wir monatliche Preisdaten, für den Zeitraum Jänner 2021 bis Februar 2023, von Branchen, die mit Gas, Erdöl oder Öl handeln, um Gaspreisschocks zu simulieren und ihre Auswirkungen auf den VPI, den PPI und den IPI zu ermitteln. Anschließend vergleichen wir die Simulationen mit den realen Indizes und stellen fest, dass insbesondere die Veränderungen der Preisniveaus für den VPI und den IPI sehr gut durch diese Simulationen erklärt werden können. Abschließend konstruieren wir ein kontrafaktisches Szenario, in dem davon ausgegangen wird, dass Österreich wirtschaftlich autark ist, um zu beurteilen, inwieweit Preissteigerungen in Österreich importiert werden. Je nach Szenario ermitteln wir einen durchschnittlichen Preiseinfluss von 0,7 % bis 1,4 % für den VPI und von 2,2 % bis 3,2 % für den PPI aufgrund von Importen.

Content

1.Introduction

In recent years, Europe, like many other regions in the world, has faced significant economic challenges. The by far most pressing issue in the past two years was the rise in inflation rates. The most dominant economic issue covering media, politics and academia has been the sharp rise in prices starting in the energy sector and finally transmitting through to all other sectors which are relevant for final consumers. Especially in Austria, discussions have been very much focused to what extent current price increases are imported and whether it would have been possible to avoid such sharp price increases. Simulations have shown that a 10% rationing of gas supply would lead to a decrease in the gross value added by about 1,2% for Austria, which means the second highest decrease in the Euro area. (Gunnella et al., 2022)

The strong price increase in the energy sector and the resulting price changes in the overall price level shows that the global economy is a complex system of interdependent industries. As prices rise in some industries, the cost of producing goods and services increases, and costs are ultimately passed on to consumers in the form of higher prices. The impact of these shocks on the economy can be significant, particularly for small countries like Austria relying heavily on imports.

The question of how shocks in one sector are related to price changes in others is of great importance for policymakers and businesses alike. Most recent empirical studies use probabilistic approaches to investigate the relationship between price shocks in certain industries or commodities and their impact on the general price level. For example, Messner et al. (2023) uses a small-scale Bayesian vector autregressive (BVAR) model simulating shocks for different upstream and intermediate industries in the Euro area, finding an impact of 0.3 to 1.1 percentage points on headline inflation depending on the shocked industry. Similar results have been found by using local projection methods for 46 countries covering the time February 1992 to December 2021. (Carrière-Swallow et al., 2022)

An alternative analytical tool for gaining insights into the interdependent relationships of industries is an Input-Output analysis. This type of analysis can help understanding the complex interdependencies of different industries and how changes in one sector can affect others. Through this approach, price shocks in different industries can be simulated and the impact on other industries and the economy as a whole calculated.

An Input-Output analysis explores, how the costs of inputs from different industries, including labour and capital, are consumed in the production process, and used to produce goods and services.

To analyse price shocks through a system of interconnected industries the Leontief Price model is known to be the first attempt. (Leontief, 1937) (Sharify and Sancho, 2010) When a price shock occurs in one industry, such as the gas industry, it can have cascading effects throughout the entire economy. The Leontief price model has the core premise "… *that the whole of the economy is a vast cross-sectoral network of cost-price linkages.*" (Weber et al., 2022) By simulating these shocks and assuming a full pass-through rate, a price impact on other industries and the overall economy can be calculated.

Since a Leontief Price model can be used to investigate the direct and indirect price impact of a certain industry on all other industries in an economy, the model has been widely used for various countries and simulations. For example, to investigate the impact of corporate income taxes in the US and Canada (Melvin, 1979), for indirect tax policies in Poland (Boratyński, 2002), for observing the overall price impact of a 100% price increase in "Petroleum and coal products" in Australia (Valadkhani and Mitchell, 2002), to simulate the inflationary effect of a doubling of energy prices in Turkey and four EU member countries (Aydoğuş, 2007) as well as for China to investigate the impact of imported oil-price shocks on the general consumer price level (Wu, et al., 2012) and also to identify systemically significant industries for price stability in the US. (Weber et al., 2022)

The above-mentioned papers are solely relying on national Input-Output data and treat foreign price shocks as imports. However, by using data from the World Input Output Database (WIOD), it is possible to simulate price shocks on a global scale. With WIOD's comprehensive coverage of 56 industries in 27 EU countries and 17 other major countries including the "Rest of the World" (ROW), it is well-suited to explore the impact of global price shocks.

More recently the WIOD has been used to simulate worldwide hypothetical inflation shocks and compute how they propagate across countries, finding that a raise in inflation by 1% in all countries in the world other than the one under observation increases domestic inflation by 0.19% and by well over 0.3% in some small open economies. (Auer et al., 2018)

Furthermore, the data set has been used for constructing agent-based models in a small open economy (Poledna et al., 2023) as well as for dynamic macroeconomic and trade models. (Kratena et al., 2017) (Baqaee and Farhi, 2022)

Overall, the rise in inflation rates in Europe has raised many questions about the relationship between different sectors of the economy. By performing an Input-Output analysis and using data from sources like the World Input Output Database, one can gain valuable insights into these relationships and better understand the impact of price increases on the economy.

The work is structured in the following way. First, we introduce Input-Output tables with a particular emphasis on the Leontief price model and the WIOD. Secondly, we derive the Leontief price model based on the WIOD, to investigate how a price shock to a particular industry can cascade through an economic system and lead to price increases in the economy.

Subsequently, we simulate industry specific price shocks covering three different inflationary periods. The first one reflects the calm inflationary period before 2020 where the industries average price volatility from 2000 to 2019 is used as simulated price shocks and the industries influence on overall prices in Austria is observed. Then, the same analysis is undertaken with price shocks covering the period 2020/Q4 to 2021/Q4 to investigate whether the most influential industries with regards to price increases has changed during the post shutdown COVID-19 pandemic. In the third scenario, price shocks are introduced covering the period 2021/Q4 to 2022/Q4 to investigate whether the most significant industries have changed due to sector specific price changes starting with the Ukraine war.

Obtaining the results for the three inflationary periods it becomes evident that the industries which have the highest impact on aggregated price levels remain largely constant confirming the results found by Weber et al. (2022) for the US. Differences in the findings for the US and Austria can primarily be attributed to the use of a different data set. The industries with the highest aggregated price impact can broadly be grouped into energy supply, necessities of life and essential production inputs for Austria as well as for the US.

Furthermore, we obtain monthly price changes for the period January 2021 to February 2023 for industries which trade with gas, petroleum or oil and use these price changes as shocks to simulate on how gas price shocks have affected the overall price level in the economy. For an empirical validation we compare the resulting price increases with the monthly price changes for different indices such as the Consumer Price Index (CPI), Producer Price Index (PPI) and the

Import Price Index (IPI) and investigate whether the simulations can match the price changes in the above-mentioned indices.

We find that price changes in the CPI and IPI can very well be approximated by our simulations. For the CPI, using the period January 2021 to September 2022, we calculate an average inflation impact of 5,3 % and observe an average price change of 5,3 % for the real CPI in Austria as well. After the period, the model fails in explaining price increases in the real CPI in Austria. Similarly, for the IPI, we calculate an average price impact of 15,7 % and observe a price change of 17,6 % for the real IPI in Austria. However, upon examination, we ascertain that the model specification for the PPI fails in explaining changes in the real PPI for Austria. Comparing the calculations of the input output analysis for the PPI with the real PPI, we find an average overestimation of 15,2 percentage points for the period January 2021 to February 2023.

Comparing certain calculated aggregated price impacts to price changes found in other paper, we find mostly similar results. For example, simulating a 100% increase in energy prices for Germany, the Netherlands, Portugal, Hungary and Turkey would lead to a price increase "…*in consumers' prices ranging between 2,8 and 8,6 percent among countries",* (Aydoğuş, 2007) or for China where a doubling of oil prices would lead to"… *a 4,9% increase in general consumer price level"* (Wu et al., 2012), we find for a comparable shock scenario a price increase of 5 to 6% for Austria.

Results for Australia are indicating that a 100% price increase in "Petroleum and coal products" would lead to a 2,5% or 1,8% increase in the CPI, depending on the data set used (Valadkhani and Mitchell, 2002), we find that a 100% global price increase in the industry "Manufacture of coke and refined petroleum products" would lead to a 2,8% increase in the CPI for Austria.

Differences can be found when comparing the results to Schneider (2023) done for Austria as well, where he calculates *"… an increase in consumer prices by 25,6% between January 2021 and November 2022 …"* (Schneider, 2023) and an overestimation in the real CPI for Austria of 9,8 percentage points. We find for the same period a maximum calculated price increase in consumer prices of 10,7%. These discrepancies can most likely be attributed towards three factors: In the paper, by Schneider (2023), national data sources are primarily used for calculating price changes in the energy sector, with maximum price changes ranging from +96% for oil to +1124% for gas. However, we used data from EUROSTAT leading to a price change in energy related sectors with a maximum of +194% for "Electricity & Gas" and +219% for "Mining and Quarrying", resulting in higher sectoral shock scenarios in Schneider (2023) and finally in higher simulated Consumer Prices. Furthermore, the paper assumes a nominal increase in wages for the energy sector of +7% while we assumed that wages stay constant. Finally, Schneider (2023) assumes an increase in profits by +150% between January 2021 and November 2022 relying on balance sheet data of the two main energy providers in Austria, meanwhile we assume, that firms can adjust their profits in proportion to the price shock.

Finally, we investigate to what extent these price changes are imported by constructing a counterfactual scenario where we assume that Austria is a completely self-sufficient economy with no economic relations to other countries.

Depending on the scenario, we find an average price impact of 0,7 % to 1,4 % for the CPI and of 2,2 % to 3,2 % for the PPI due to imports.

2.Input-Output models and the WIOD

The foundation of Input-Output models, developed by Leontief, builds upon the work done by Mitchell (1913) and Mills (1927), which were investigating the relationship between relative prices and the overall price level. These findings serve as a foundation to generate a network where "*… the prices ruling at any given time for the infinite variety of commodities, services, and rights which are being bought and sold constitute a system. That is, these prices are so related to each other as to make a regular and connected whole*." (Mitchell, 1913) Hence, the premise is, that the economy as a whole can be reflected by transactions from one industry to another industry, which in total shows an interdependent network of industries and regions. Originally, Leontief developed the Input-Output model to reflect transactions in physical units. (Leontief, 1937; Miller and Blair, 1982) However, Input-Output tables are nowadays mostly carried out to reflect transactions in monetary terms. This interrelated network can thus take up the following form:

Table 1: World Input-Output Database (WIOD)

	Industry	Industry 1	…	Industry 56	Final consumption expenditure by households & government	…	Gross fixed capital formation
Industry	Country	AUS	…	ROW	AUS	…	ROW
Industry 1	AUS	z_{11}	…	$z_{2464,1}$	F_1	…	C_1
Industry 2	AUS	z_{12}	…	$z_{2464,2}$	F_2	…	C_2
Industry 3	AUS	z_{13}	…	$z_{2464,3}$	F_3	…	C_3
…	…	…	…	…	…	…	…
Industry 54	ROW	$z_{1,2462}$	…	$z_{2464,2462}$	F_{2462}	…	C_{2462}
Industry 55	ROW	$z_{1,2463}$	…	$z_{2464,2463}$	F_{2463}	…	C_{2463}
Industry 56	ROW	$z_{1,2464}$	…	$z_{2464,2464}$	F_{2464}	…	C_{2464}
Z	TOT	Z_1	…	Z_{2464}	F_T	…	C_{tot}
TXSP	TOT	$TXSP_1$	…	TXSP_{2464}	$\mathrm{TXSP}_{\mathrm{HH,G}}$	…	$TXSPC$
V	TOT	V_1	…	V_{2464}		…	
TM	TOT	TM_1	…	TM_{2464}	$TM_{HH,G}$	…	TM_C
Output	TOT	X_1	…	X_{2464}		…	

Source: World Input-Output Database (WIOD) – (Dietzenbacher et al., 2014)

The above table shows the interrelated structure of the World Input-Output Database (WIOD). The WIOD consists of 56 industries and 44 countries including one country representing the rest of the world (ROW). Therefore, there are in total 2464 interdependent industries. $z_{i,j}$ shows the intermediate production stream from industry j to industry i. For example, $z_{1,1} = 12.924.000.000$ means that goods with a worth of 12,9 bn of US $ are supplied from Industry 1 ("Crop and animal production, hunting and related service activities") in Australia to the same Industry in Australia as an input. Consequently, $z_{2464,1} = 112.000.000$ means that goods with a worth of 112 Mio of US $ are supplied from Industry 1 in Australia to Industry 56 ("Activities of extraterritorial organizations and bodies") in the ROW. X_1 are the sum of all intermediate inputs needed by industry 1 in Australia. $TXSP_1$ are taxes less subsidies on products payed by industry 1, V_1 is the value added by industry 1 and consists of profits and wages generated by industry 1, TM_1 are the international transport margins of industry 1 and $Output_1$ is the total output of industry 1, all for Australia. The same Input-Output structure is given for all 56 industries in all 44 countries. Finally, $\mathrm{F_j}$ shows the aggregated final consumption of households and government of industry j[1], while C_{j} indicates the aggregated gross fixed capital formation of industry j.

2.1 Leontief Price Model

In the model the value of any worldwide industry's total output consists of the value of its global inputs plus the total value added, taxes less subsidies on products and international transport margins. Hence the value of the total output for industry j is given by,

$$x_j = \sum_{i=1}^{n} z_{ij} + v_j + \mathrm{txsp}_j + \mathrm{t}m_j$$

or

$$X^t = i^t Z + V^t + TX^t + TM^t$$

where Z is the 2464×2464 intermediate matrix and $i = [1, \dots, 1_n]$ an identity vector, $\mathrm{V^t}$ describes a vector of value added, $\mathrm{TX^t}$ is a vector of the value for taxes less subsidies on products and $\mathrm{TM^t}$ is a vector of the value for international transport margins. Z is multiplied with $\hat{X}^{-1}$ which is a diagonal matrix with total output in the diagonal and 0 in the off-diagonal.

[1] For illustrative purposes the final consumption of households and government in the above table are shown together. However, in the WIOD both categories are separated.

$$\mathrm{A} = \hat{X}^{-1}\mathrm{Z}$$

We divide each element z_{ij} by the respective total output of industry j. Hence, we get matrix A, which shows the proportion of each input industry needed to produce one good in output industry j. Matrix A is also called a "*matrix with global direct technical coefficients.*" (Leontief, , 1986)

The following simplified example of matrix A shows only two interdependent industries, namely industry 1 and industry 2, $a_{11} = 0.3$ and $a_{21} = 0.7$ means that industry 1 needs 0.3 inputs of industry 1 and 0.7 inputs of industry 2 to produce one unit of output. Subsequently, industry 2 needs 0.4 inputs of industry 1 and 0.6 inputs of industry 2 to produce one unit of output.

$$A = \begin{bmatrix} 0.3 & 0.4 \\ 0.7 & 0.6 \end{bmatrix}$$

We can then rearrange the previous formula for A and substitute for Z and post multiplying by $\hat{X}^{-1}$ and we get,

$$X^t\hat{X}^{-1} = i^t\mathrm{A}\hat{X}\hat{X}^{-1} + V^t\hat{X}^{-1} + \mathrm{T}X^t\hat{X}^{-1} + \mathrm{T}M^t\hat{X}^{-1}$$

$$or$$

$$i^t = i^tA + v^t + tx^t + tm^t$$

The right side of the above equation *"is the cost of inputs per unit of output. Output prices are set equal to total cost of production…"* (Miller and Blair, 1982). Hence, we have that each price equals to 1, for the left side of the equation. The above formula shows the unique measurement units in the base year table. Hence, *"… amounts that can be purchased for 1 $."* (Miller and Blair, 1982) We can denote the vector $i^t = [1, \dots, 1_n]^t$ as the vector with base year index prices $p^t = [p_1, \dots, p_n]$.

Then the price model is given by,

$$p^t = p^tA + v^t + tx^t + tm^t$$

or after transposing the above formula we get,

$$P = A^tP + v + tx + tm$$

To simulate a price shock, we must set the sector where the shock occurs as exogenous. Hence this sector is not affected by the cascading effect of price increases by other industries. This serves as inputs for the endogenous sectors. We can separate the above equation into the exogenous components denoted by X and their endougenous components denoted by E. Separating the above formula, we get,

$$\begin{bmatrix} P_X \\ P_E \end{bmatrix} = \begin{bmatrix} A^t_{XX} & A^t_{EX} \\ A^t_{XE} & A^t_{EE} \end{bmatrix} \begin{bmatrix} P_X \\ P_E \end{bmatrix} + \begin{bmatrix} v_X \\ v_E \end{bmatrix} + \begin{bmatrix} tx_X \\ tx_E \end{bmatrix} + \begin{bmatrix} tm_X \\ tm_E \end{bmatrix}$$

For P_X, v_X, tx_X and tm_X the corresponding subindex X is indicative of the price index, value added, taxes less subsidies and international transport margins for the exogenous industries and subindex E indicates the same variables for the respective endogenous industries.

Matrix A is partitioned into 4 parts. If we assume that n industries are exogenous (hence shocked) and m industries are endogenous, we get 4 sub-matrices with the following dimensions:

- A^t_{XX} contains the direct input requirements from the exogenous industries to the exogenous industries and has the dimension $\mathrm{n} \times \mathrm{n}$
- A^t_{EX} contains the direct input requirements from the endogenous industries to the exogenous industries and has the dimension $\mathrm{n} \times \mathrm{m}$
- A^t_{XE} contains the direct input requirements from the exogenous industries to the endogenous industries and has the dimension $\mathrm{m} \times \mathrm{n}$
- A^t_{EE} contains the direct input requirements from the endogenous industries to the endogenous industries and has the dimension $\mathrm{m} \times \mathrm{m}$

Hence, for determining how an exogenous price shock P_X affects the endogenous prices P_E we only need the second row of the above formula, since the other relationships explained within matrix A, namely A^t_{XX} and A^t_{EX}, are not affecting P_E.

Thus, by solving the above equation P_E can be explained by the below relationship:

$$P_E = (I - A^t_{EE})^{-1} A^t_{XE} P_X + (I - A^t_{EE})^{-1}(v + tx + tm)$$

In the formula above P_E and P_X are vectors of prices for the the endogenous and exogenous sectors.

The above formula shows that the total price change in ΔP_E will depend on two factors: On the magnitude of the price shock in ΔP_X, and the Input-Output relationship between the sectors, which are captured by $(I - A_{EE}^t)^{-1} A_{XE}^t$:

$$\Delta P_E = (I - A_{EE}^t)^{-1} A_{XE}^t \Delta P_X$$

ΔP_E^i can be interpreted as the percent change in sector i due to an exogenous price change ΔP_X . To calculate the overall impact on different measures of price increases, which follows from the price change ΔP_X, we aggregate the price change in each sector for ΔP_X and ΔP_E^i. By using the household consumption shares of each industry, a *"synthetic CPI"* can be produced.[2] Furthermore, we use the weights given to each industry for the producer price index (PPI) and import price index (IPI) provided by STATISTIK AUSTRIA to simulate price changes in the PPI and IPI (STATISIK AUSTRIA, 2023). The price impact is given by the total price impact (PI_{tot}), which is composed of a direct price impact (PI_{dir}) and an indirect price impact (PI_{indir}). The weight for each industry is given by c_i. If we assume that only one industry j is set exogenous and the weight for this industry is given by c_j, we get:

$$PI_{dir} = c_j \Delta P_X^j$$

$$PI_{indir} = \sum_{i \neq j} c_i \Delta P_E^i$$

$$PI_{tot} = \sum_{i \neq j} c_i \Delta P_E^i + c_j \Delta P_X$$

From the above equations, the direct price impact (PI_{dir}) follows from the weighted exogenous price change $c_j \Delta P_X^j$. In case of more than one exogenous industry the weighted sum $\sum_{j \neq i} c_j \Delta P_X^j$ would be needed to assess the direct price impact. The indirect price impact is given by the weighted sum $\sum_{i \neq j} c_i \Delta P_E^i$ following from the exogenous price change ΔP_X^j. The sum of both price changes constitutes the total price change PI_{tot}.

It must be pointed out that, *"…the simulated inflation impacts of sector specific shocks do not present a prediction in any strict sense"*. (Weber et al., 2022) In the following chapter we conduct a simulation experiment. Similarly, to the simulation of Leontief, where he calculated price increases due to a 10% increase in wages. He concluded that *"… it simply describes the*

[2] See (Valadkhani and Mitchell, 2002) and (Weber et al., 2022)

probable results of an artificial experiment, an experiment that nevertheless might contribute to realistic understanding of the actual happenings and to a reasonable appraisal of various practical and impractical alternatives …", (Leontief, 1986) we simulate a price change for each sector and observe the inflationary impact (PI_{dir}, PI_{indir}, PI_{tot}) this sector has. The following main chapter builds a framework, for trying to answer the following questions:

- Which industries are the most important for overall price increases?
- Have these industries changed for different inflationary periods?
- Are these industries differing across countries?
- What are the channels through which an industry has a high influence on overall price increases?

2.2 Leontief Price Model with Profit adjustment

The model derived in chapter 2.1 assumes that nominal wages and profits are staying constant. Hence, we assume a real profit and wage loss. However, it is reasonable to assume that firms at least are trying to adapt their profits accordingly to the increase in prices. For the case of an increase in input prices, this would mean a nominal increase in profits, which would set out another cascading effect of price increases throughout the economic system. It is similarly sensible to assume that earner of wages would try to fight at least for some of their real loss in wages due to the price increases by demanding an increase in nominal wages. This has been done by Rowthorn (1977) and Weber et al. (2022). In this section we shortly derive the model with profit adjustment.[3]

Once more, within the model framework, the value of any worldwide industry's total output consists of the value of its global inputs plus the total value added, taxes less subsidies on products and international transport margins.

$$X^t = i^t Z + V^t + TX^t + TM^t$$

where Z is the intermediate matrix and $i = [1, \dots, 1_n]$ an identity vector, V^t describes a vector of value added, TX is a vector of the value for taxes less subsidies on products and TM is a vector of the value for international transport margins. Since V^t is the sum of wages and profits

[3] Due to potential issues inherent in Input-Output tables covering the whole world and creating price shocks including wage adjustments, like it has been done by Rowthorn (1977) and Weber et al. (2022), we have refrained from including them in the work.

for each industry in each country denominated in US$[4], we must split up V^t into V_π^t and V_w^t (Bulmer-Thomas, 1982). When splitting up V^t we get,

$$X^t = i^t Z + V_\pi^t + V_w^t + TX^t + TM^t$$

Where V_π^t is a vector of profits earned in each country and industry and V_w^t a vector of wages earned in each country and industry.

When we multiply Z and V_π^t with $\hat{X}^{-1}$, which is a diagonal matrix with total output in the diagonal and 0 in the off-diagonal, we get,

$$\mathrm{A} = \hat{X}^{-1}\mathrm{Z}$$

$$\text{and}$$

$$A_\pi = \hat{X}^{-1}V_\pi^t$$

where we divide each element z_{ij} by the respective total output of industry j and we divide V_π^t by the respective total output of each industry in each country. Hence, we get a diagonal matrix A_π, where every element in the diagonal shows the ratio of profits to the value of total output for each industry in each country.

We can then rearrange the previous formula for A and substitute for Z and post multiplying by $\hat{X}^{-1}$ and we get,

$$X^t\hat{X}^{-1} = i^t\mathrm{A}\hat{X}\hat{X}^{-1} + i^t A_\pi \hat{X}\hat{X}^{-1} + V_w^t\hat{X}^{-1} + \mathrm{T}X^t\hat{X}^{-1} + \mathrm{T}M^t\hat{X}^{-1}$$

$$or$$

$$i^t = i^t A + i^t A_\pi + v_w^t + tx^t + tm^t$$

The right side of the above equation is again *"… the cost of inputs per unit of output …"* (Miller and Blair, 1982). We can again denote the vector $i^t = [1, \ldots, 1_n]^t$ as the vector with base year index prices $p^t = [p_1, \ldots, p_n]$.

The new price model is then given by,

$$p^t = p^t A + p^t A_\pi + v_w^t + tx^t + tm^t$$

or after transposing the above formula we get,

[4] Profits in USD can be derived with the WIODs Socio Accounts. Where profits are denoted by "Capital compensation (in millions of national currency)" (Dietzenbacher et al., 2014)

$$P = A^t P + A_\pi^t P + v_w + tx + tm$$

We can separate the above equation into the exogenous components denoted by X and their endougenous components denoted by E:

$$\begin{bmatrix} P_X \\ P_E \end{bmatrix} = \begin{bmatrix} A_{XX}^t & A_{EX}^t \\ A_{XE}^t & A_{EE}^t \end{bmatrix} \begin{bmatrix} P_X \\ P_E \end{bmatrix} + \begin{bmatrix} A_{\pi,XX}^t & 0 \\ 0 & A_{\pi,EE}^t \end{bmatrix} \begin{bmatrix} P_X \\ P_E \end{bmatrix} + \begin{bmatrix} v_{w,X} \\ v_{w,E} \end{bmatrix} + \begin{bmatrix} tx_X \\ tx_E \end{bmatrix} + \begin{bmatrix} tm_X \\ tm_E \end{bmatrix}$$

The newly derived element $v_{w,X}$ shows the nominal wages divided by the value of output of the industries and countries which are exogenous, $v_{w,E}$ shows the nominal wages divided by the value of output of the industries which are endogenous. $A_{\pi,XX}^t$ contains the profit to output ratio for the exogenous industries and $A_{\pi,EE}^t$ the ratio for the endogenous industries.

Similarly, to the previous chapter, for determining how an exogenous price shock P_X affects the endogenous prices P_E, we only need the second row of the above formula.

Thus, by solving the above equation P_E can be explained by the below relationship:

$$P_E = \left(I - A_{EE}^t - A_{\pi,EE}^t\right)^{-1} A_{XE}^t P_X + \left(I - A_{EE}^t - A_{\pi,EE}^t\right)^{-1} (v + tx + tm)$$

The above formula shows that the total price change in ΔP_E does not only depend on the magnitude of the price shock in ΔP_X, and the Input-Output relationship between the sectors, which is captured by $(I - A_{EE}^t)^{-1} A_{XE}^t$, it depends as well on the profit structure which is captured by $A_{\pi,EE}^t$:

$$\Delta P_E = \left(I - A_{EE}^t - A_{\pi,EE}^t\right)^{-1} A_{XE}^t \Delta P_X$$

The aggregation of the price vectors ΔP_E and ΔP_X is then the same as in the price model without profit adjustment.

2.3 Leontief Price Model only for Austria - Counterfactual scenario

In the past three years a discussion evolved in the wake of the increasing prices, to what extent price increases are imported. To gain clarity in this discussion we can also use a different derivation of the Leontief Price Model where we assume, everything else constant, that Austria is a completely self-sufficient country with no economic relations to any other country. By doing so, the below formula for a price shock, derived in chapter 2.1, remains the same and only the size of the matrices is changing.

$$P_E = (I - A_{EE}^t)^{-1} A_{XE}^t P_X + (I - A_{EE}^t)^{-1} (v + tx + tm)$$

We have, for instance, not a matrix $A^t_{n\times n}$, where $n = 2464$ comes from the fact that we have 56 industries times 44 countries in the WIOD, instead we have a matrix $A^t_{56\times 56}$, which only shows the interdependent structure of the Austrian industries among each other.

Similarly for the Leontief Price Model with Profit adjustments, where the formula derived in subchapter 2.2 remains the same,

$$P_E = \left(I - A^t_{EE} - A^t_{\pi,EE}\right)^{-1} A^t_{XE} P_X + \left(I - A^t_{EE} - A^t_{\pi,EE}\right)^{-1} (v + tx + tm)$$

We again select only the interdependencies among industries in Austria. Hence, matrix $A^t_{\pi,EE}$ constitutes a 56×56 matrix as well.

2.4 Summary of different Leontief model specifications

In the following chapter, the focus lies primarily on the investigation of understanding the dynamics of how an industry can have a significant impact on overall prices. For this, we only use the model derived in subchapter 2.1, which constitutes a worldwide model without adjustment of profits.

For chapter 4, we use all the models derived in the subchapters 2.1-2.3, which can be summarized by,

a. Model 1: Worldwide model without adjustment of profits
b. Model 2: Worldwide model with adjustment of profits
c. Model 3: Simulation only for Austria without adjustment of profits (Counterfactual scenario)
d. Model 4: Simulation only for Austria with adjustment of profits (Counterfactual scenario)

3.Systemically significant prices in Austria from 2000 to 2022

In this chapter we present the results of the simulation experiments for Austria. The following section is very closely related to the work of Weber et al. (2022), where similar calculations have been done for the US. In subsection 3.1 we compare the results of the simulation experiment for Austria more closely with the results for the US. We conduct an experiment for three different inflationary episodes. The first episode uses the average price volatility from 2000-2019 of each sector as a price shock[5] and represents the calm inflationary time span. The second, uses the yearly percent price change from 2020/Q4 to 2021/Q4, calculated by $\Delta P_t^j = (P_t - P_{t-1})/P_{t-1}$ as price shocks, where $t = 2021/Q4$ and represents the inflationary episode during the post shutdown COVID-19 crisis. The third one uses the yearly percent price changes from 2021/Q4 to 2022/Q4 as the price shocking scenarios and represents the inflationary episode during the war in Ukraine.[6]

Figure 1 below shows the simulation results for the top 10 industries with the highest inflation impact using a Leontief price model for, a) time span 2000-2019, b) time span 2020/Q4-2021/Q4 and c) time span 2021/Q4-2022/Q4. The blue dot indicates the sectoral price volatility for the different time periods and therefore the simulated price shock for the specific sector. The magnitude of the price shock is given by the upper y-axis. The yellow bar shows the direct inflation impact while the purple bar indicates the indirect inflation impact. Both plots combined are showing the total inflation impact. The magnitude of the inflation impact is given by the lower y-axis.

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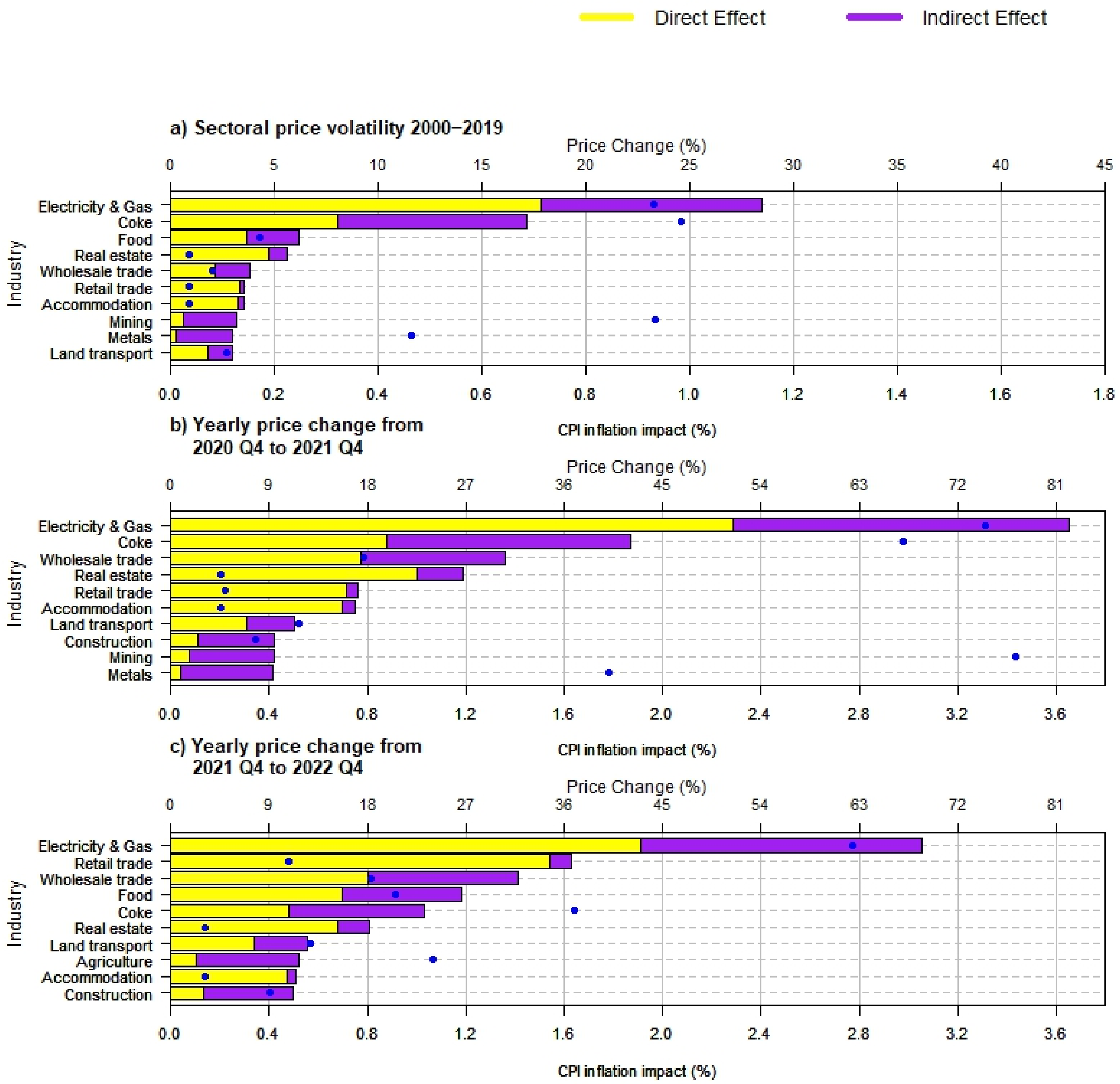
[5] Average sectoral price volatility is calculated by the standard deviation of sector $j's$ yearly percent price change between 2000-2019. Hence, we get,

$$\sigma^{j}_{t_0,t_1} = \sqrt{\frac{1}{T}\sum_{t=t_0}^{t_1}\left(\Delta P_t^j - \Delta P_{t_0,t_1}^{\bar{j}}\right)^2}$$

Where t_0 is the initial date, t_1 the final date, T the number of observations, $\Delta P_t^j = (P_t - P_{t-1}/P_{t-1}$ (percent price change with yearly data) and $\Delta P_{t_0,t_1}^{\bar{j}}$ the average yearly percentage price change between t_0 and t_1. It follows, the higher the standard deviation, the higher the sectoral volatility. Hence, the higher the simulated price shock.

[6] Due to the global scale of the shocks, it is assumed that each industry has the same industry specific price increase. For example, simulating a global price increase of 10% for the industry "Wholesale trade", it is assumed that for each country and the rest of the world the prices in the industry "Wholesale trade" have experienced a price increase of 10%. Furthermore, since no NACE specific price date aggregated for the whole world are existing various other data sources had to be used for constructing the simulated sector specific price shocks. For further information see the Appendix.

Figure 1: Inflation Impact for Austria



The graph shows that the impact on inflation varies greatly from industry to industry. In scenario a), the sector “Electricity & Gas” (NACE D35) shows a price impact of 1.1%, whereas the sector “Manufacture of coke and refined petroleum products” (NACE C19) has a lower price impact of 0.7 % and therefore already 0.4 percentage points smaller. All other eight industries are ranging between 0.1 to 0.2 percent. Comparing the different simulation scenarios, the industries with the highest impact on inflation is staying relatively constant. In all three scenarios the most important sector is “Electricity & Gas” with about a two times higher impact on inflation for scenario b) and c). For the time span covering the COVID-19 episode (scenario b) 9 out of 10 industries are also among the top 10 industries in comparison to the time span covering the sectoral price volatility (scenario a). Similarly, for scenario c), where 8 out of 10 industries are among the top 10 industries in comparison to scenario a).

3.1 Comparison with results for US

Weber et al. (2022) have done almost the same analysis for the US. Methodological differences can be attributed to other data that have been used. While the WIOD constitutes Input-Output data that are covering the whole world, Weber et al. (2022) uses data solely for the US and treats sectors from the rest of the world as Imports. Furthermore, the WIOD covers 56 different industries, while the Input-Output data for the US are covering 71 industries. Furthermore, Weber et al. (2022) uses for scenario c) the yearly price change from Q2 2021 to Q2 2022 while we use for scenario c) the yearly price change from Q4 2021 to Q4 2022. Apart from these differences the same analysis has been done for Austria.

Table 2: Inflation Impact for US

Top 10 industries Weber et al. (2022)			
Rank	**Scenario a)**	**Scenario b)**	**Scenario c)**
1	Petroleum and coal products	Petroleum and coal products	Petroleum and coal products
2	Oil and gas extraction	Oil and gas extraction	Wholesale trade
3	Farms	Wholesale trade	Housing
4	Food and beverage and tobacco products	Chemical products	Utilities
5	Federal Reserve banks, credit intermediation, and related acitivities	Utilities	Oil and gas extraction
6	Chemical products	Food and beverage and tobacco products	Food and beverage and tobacco products
7	Housing	Housing	Farms
8	Utilities	Motor vehicle and parts dealers	Food services and drinking places
9	Wholesale trade	Farms	Chemical products
10	Other retail	Other retail	Truck transportation

The above table shows the top 10 industries ranked by their inflation impact for the different scenarios in the US. The results show a very similar ranking in comparison to Austria, with energy-related sectors such as “Petroleum and coal products” and “Oil and gas extraction” at the top and with sectors like “Food and beverage and tobacco products”, “Wholesale trade”, “Housing and Utilities” in the middle. In principle, the results for the US are similar to Austria.

Differences occur in the magnitude of the inflation impact. For example, the industry with the highest impact for Austria, “Electricity & Gas” (NACE D35), has an impact of 1.1%-3.6% depending on the observed inflation scenario. While for the US the industry with the highest impact, “Petroleum and coal products”, is ranging from 0.4%-1.5%. These differences in the magnitude of the shock have most likely the following two reasons.

First, data for the US are available on a more granular level with regards to sectors related to energy, such as “Petroleum and coal products” or “Oil and gas extraction”, while for Austria similar data are only available on a more aggregated level such as “Electricity & Gas”, “Mining and quarrying” (NACE B) or “Manufacture of coke and refined petroleum products” (NACE C19). Therefore, especially the sector “Electricity & Gas” takes up a higher proportion in other industries (higher number of forward linkages[7]) and makes up a higher proportion in the synthetic CPI as well (higher direct impact). In comparison, the sector “Electricity & Gas” has a forward linkage of about 4,5 while the sector for the industry with the highest inflation impact for the US, “Petroleum and coal products”, has a forward linkage of about 2,2. Furthermore, the proportion in the synthetic CPI for the sector “Electricity & Gas” is in Austria at 3,1% while for the US the sector “Petroleum and coal products” takes up only 1,2%.

Second, since WIOD shows interdependencies for the whole world, global indirect effects are measured as well. For example, simulating how a price increase for the sector “Wholesale trade” affects the overall price level in the US. The price model set up by Weber et al. (2022) calculates how the price increase for the sector “Wholesale trade” only for the US affects the overall price level in the US. However, the price model based on the WIOD would calculate how a worldwide price increase for the sector “Wholesale trade” affects the overall price level in the US. Hence, the inflation impact calculated based on the WIOD should in principle be higher than it is when calculated based on a single country.

[7] Forward linkage (FL) is a measure on how much a certain industry is needed as an input by other industries. The larger the FL, the more the industry is needed as an input by other industries. We calculate the FL as the row sum of the Leontief inverse matrix $\mathrm{L} = (I - A)^{-1}$. It can be interpreted as “… *the amount by which the production of industry i would need to increase in order to allow for a unitary increase in total final demand.*” (Weber et al., 2022)

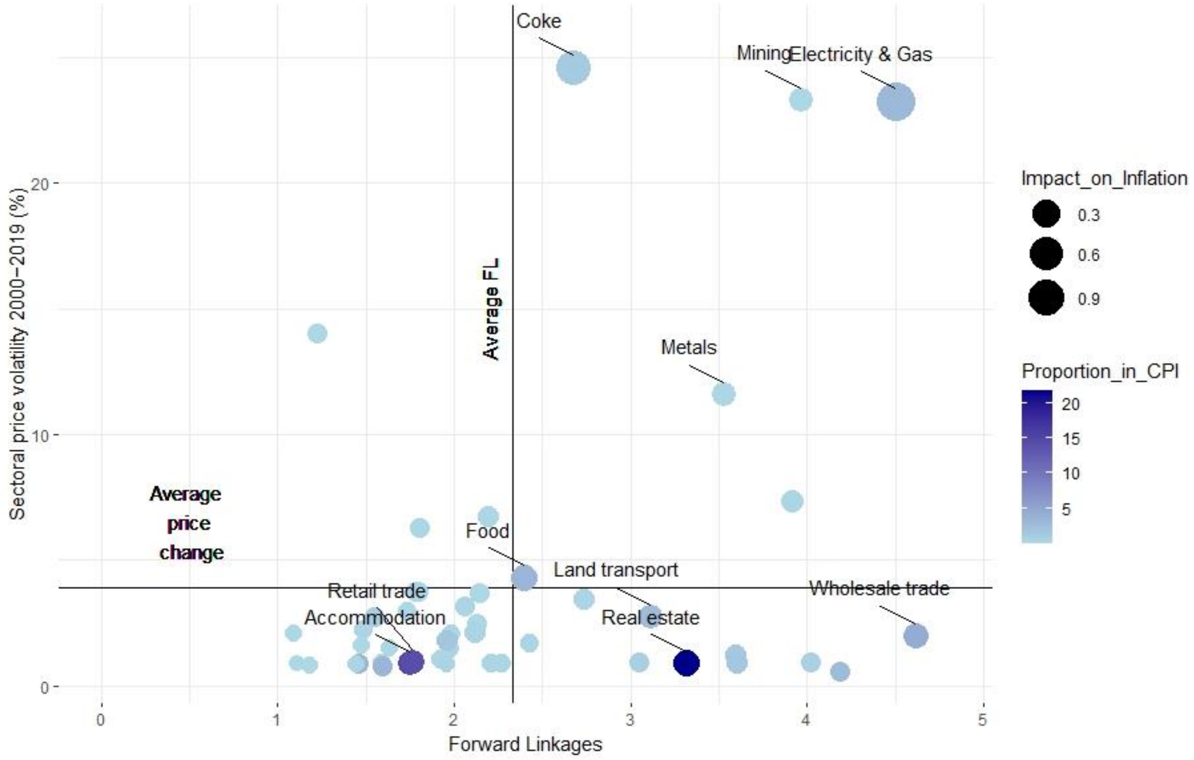
3.2 Channels of inflation impact

The results for Austria and the US are suggesting *"… that there is a group of industries that have a distinctively high latent systemic significance."* (Weber et al., 2022) There are in total three different channels through which an industry has a high impact on overall price stability and can therefore be seen as systemically significant:

1. Proportion in the CPI
2. Sectoral average price volatility
3. Number of forward linkages

The direct inflation impact of an industry can be attributed solely to the proportion in the CPI and to the magnitude of the price shock, which we simulated through the sectoral average price volatility. Furthermore, the indirect inflation impact, the impact of the price increase of an industry on other related industries, can be attributed to the number of forward linkages as well. The greater the number of forward linkages, the more this industry is needed as an input by other industries.

Figure 2: Channels for Impact on prices



The above graph illustrates the different channels for how an industry can have an impact on the overall price level. The x-axis shows the number of forward linkages, the y-axis illustrates the sectoral price volatility from 2000-2019 and therefore the simulated magnitude of the price increase for the specific sector. The change of the darkness of the colour illustrates the proportion in the CPI. The darker the colour, the higher is the proportion of consumption by households for this specific industry. Finally, the siz

e of the dot represents the impact of the specific industry on the overall price level. Hence, the bigger the dot the bigger is the total inflationary impact of the industry. The ten industries with the biggest impact on price stability are highlighted with the industries short name.

Similarly, to the findings of Weber et al. (2022) for the US, 9 out of 10 industries with the highest impact on inflation can broadly be grouped into three groups for Austria as well, which are, *“energy, basic necessities and basic production inputs other than energy and commercial and financial infrastructure.”* (Weber et al., 2022)

The industry having the biggest impact on overall price stability in the category “energy”, is “Electricity & Gas”. This industry is also the one with the biggest overall impact on price stability throughout all industries. It includes the subindustries “Electric power generation, transmission and distribution” and “Manufacture of gas; distribution of gaseous fuels through mains” (NACE, 2023) and serves as a universal input for a wide range of industries (high number of forward linkages) and has therefore a high indirect CPI impact of 0,42 %. Furthermore, the industry has an above average proportion in the CPI of about 3,1 % in comparison to a mean proportion for all industries of 1,8%. Also, “Electricity & Gas” has a high sectoral price volatility of about 23,3 % and has therefore a high direct inflationary impact of 0,7 % as well. Similarly, the other two industries which are related to energy, namely “Mining” and “Coke”, become significant for overall price increases with an above average number of forward linkages of 4 for “Mining” and 2,7 for “Coke”. Furthermore, both industries have a high sectoral price volatility. Differently to the industry “Electricity & Gas”, both industries have a below average proportion in the CPI of 0,1% for “Mining” and 1,3% for “Coke”.

The group for “basic necessities” contains the industries “Retail trade”, “Real estate” and “Food”. In comparison, the industry “Retail trade” has a below average sectoral price volatility and forward linkages, hence, a small indirect inflationary impact, but has a large share in the CPI of 14,3 % and therefore, a high direct inflationary impact. This differs to some extent for the industry “Real estate”, which has a below average sectoral price volatility but a comparably high number of forward linkages. The industry inhibits renting and selling of commercial buildings like *“… non-residential buildings, including exhibition halls, self-storage facilities …”* (NACE, 2023) and thus serves as an important input for other industries. Furthermore, the industry inhibits renting and selling of private apartment buildings and dwellings and therefore has an above average proportion in the CPI of 21,9% which results in a higher direct inflationary impact of 0,18%. The industry food includes “Manufacture of food products, beverages and tobacco products” and has a slightly above average sectoral price volatility and forward linkages. Furthermore, the sector has also an above average proportion in the CPI of 3,4 %.

Finally, basic production inputs other than energy are “Metals”, “Land transport” and “Wholesale trade”. These industries have all a high inflationary impact due their large number of forward linkages. Hence, they have a ubiquitous usage and serve as an important input in other industries. Furthermore, the industry “Metals” has an above average price volatility of 11,6% but a below average proportion in the CPI. Therefore, the total inflation impact of the industry can primarily be attributed to an indirect inflationary impact. Differently, for the industries “Land transport” and “Wholesale trade”, both have below average sectoral price volatilities but a comparably high proportion in the CPI of 2,7 % for “Land transport” and 4,4 % for “Wholesale trade”. Hence, both industries have a high direct as well as indirect inflationary impact.

The last industry that cannot broadly be grouped into the three categories is “Accommodation”. This industry includes *“… the provision of short-stay accommodation … and the provision of complete meals and drinks fit for immediate consumption”* (NACE, 2023). The sector exhibits a below average sectoral price volatility of 0,9 % and a below average number of forward linkages of 1,7. The high inflationary impact can solely be attributed to the high proportion in the CPI of 15,2 %. Therefore, “Accommodation” can be seen as a downstream industry with a high degree of final usage.

3.3 Channels of inflation impact after 2019

The period after 2019 has been an exceptional time with very different inflationary episodes in comparison to the preceding decades. Thus, the question arises whether the industries with a high impact on overall prices have changed for the time span starting in 2021. The inflationary episodes since 2021 can broadly be grouped into an episode with sectoral price shocks resulting from the post-shutdown COVID-19 pandemic and an episode with price shocks as a consequence from the war in Ukraine.

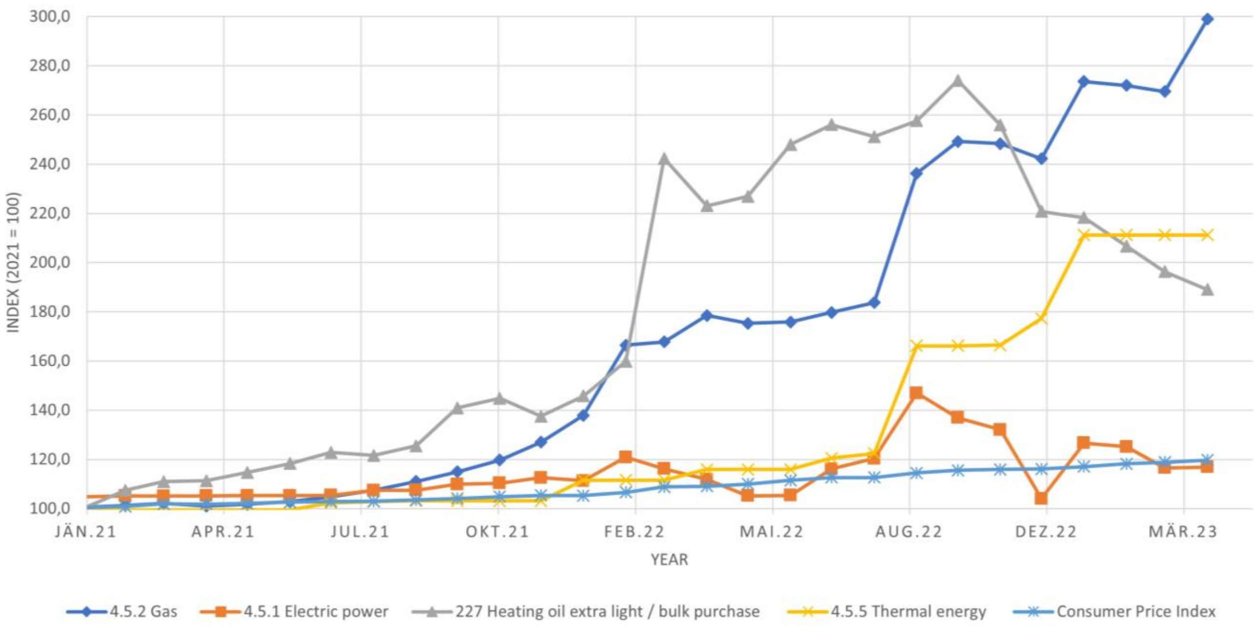
The inflation impact coming from the post-shutdown period are calculated by using the yearly relative price change from Q4-2020 to Q4-2021 of the respective industry as an exogenous price shock. The results of the top 10 industries with the highest impact are in figure 2 scenario b). For this scenario the inflation impact has about tripled in size in comparison to scenario a) (Sectoral price volatility from 2000-2019) due to the strong price changes in the industries. However, by comparing scenario a) and scenario b) the industries that have the biggest impact on the overall price level stayed largely the same. The only industry that is included in scenario b) but not in scenario a) is “Construction”, which experienced a high sectoral price increase of about 7,7%. Furthermore, the industry with the by far biggest influence on overall price changes is again “Electricity & Gas”, with an inflation impact of about 3,6% due to a large sectoral price increase of about 74%. In principle, the ordering of industries which have the highest influence on inflation stayed largely the same when comparing scenario a) with scenario b). Most notably are the changes for the industry “Construction”, which experienced a large sectoral price increase in the post shutdown period and for the industry “Land transport”, which had a large sectoral price increase of 11,7 % as well.

The inflation impacts covering the period during the Ukraine war are very similar to the results covering the post shutdown period. The again, by far most important industry is “Electricity & Gas” with an inflation impact of 3,1 %, due to a large sectoral price increase of 62,4 % from 2021/ Q4 to 2022/ Q4. Furthermore, the industries which have the biggest influence on overall price changes are largely the same. The only industry that is included in scenario c) but not in scenario b) is the industry “Agriculture” which experienced a larger sectoral price shock of about 24 %. While the industries, which have the biggest influence on overall price changes stayed largely the same, the ordering of the industries has changed by comparing scenario c) with scenario b). Especially downstream industries such as “Retail trade” and “Food” experienced a higher sectoral price increase of 10,8 % for “Retail trade” and 20,6 % for “Food”, from Q4 2021 to Q4 2022, and have therefore a higher inflationary impact of 1,6 % for the earlier and 1,2 % for the later. This shift in the ordering can most likely be attributed to the delayed transmission of price increases coming from more upstream industries such as “Electricity & Gas” towards the more downstream industries. Apart from these changes, the ordering stayed roughly the same.

4.Empirical Validation - Simulated Gas Price Shocks from 01-2021 to 02-2023

The past two years prices where especially driven by large changes in energy prices. Due to the war in Ukraine, especially prices for gas have increased dramatically. In Figure 3 are several energy related sub-groups of the CPI for Austria such as "Gas", "Electric power", "Heating oil" and "Thermal energy" plotted and compared to the total CPI for Austria.

Figure 3: Comparison Energy prices & CPI for Austria



Source: (STATISIK AUSTRIA, 2023)

Clearly, all energy related sub-groups have had a growth in prices which was above the CPI. Most remarkable, gas prices in Austria have increased from January 2021 to March 2023 by more than 197 % while the CPI has grown by 19 % in the same period. As pointed out in the previous chapter, energy related sectors are on one hand important as a ubiquitous input for other industries production (high indirect inflation impact) but are, on the other hand, also important as a consumption good for consumers and businesses alike (high direct inflation impact).

One issue that arises when obtaining economic analysis from considering the Basket of Goods, which constitutes the CPI, is that it can only measure the direct effect a price increase in energy related sectors has on the overall price level. It cannot explicitly measure the indirect effect that a price increase in energy related sectors has on other industries which in turn influences the CPI. For example, a price increase in gas leads to a price increase in the food sector, which in turn leads to a general price increase. One possibility is to do an input-output simulation with energy related sectors used as the price shocking industries. In this manner, the issue of how price shocks in petroleum and natural gas affect overall prices can be addressed. Furthermore, due to the global scale of the change in gas prices, the question arises, to what extent these price increases are imported.

To answer these questions, the WIOD can be used to simulate a global shock in gas prices.

The procedure is as follows:

1. Set industries that trade with petroleum and natural gas exogenous:
    a. "Mining and quarrying" (NACE B)
    b. "Electricity, gas, steam and air conditioning supply" (NACE D35)
2. Use monthly relative price increases of Industry B and D35 as exogenous shock scenarios.
3. Calculate shocks with different model specifications:
    a. Worldwide model without adjustment of profits
    b. Worldwide model with adjustment of profits
    c. Model without adjustment of profits only for Austria (Counterfactual scenario)
    d. Model with adjustment of profits only for Austria (Counterfactual scenario)
4. Aggregate results with weights for synthetic Consumer Price Index (CPI), Producer Price Index (PPI) and Import Price Index (IPI) for Austria.
5. Empirical validation of results by comparing with empirical/real CPI, PPI and IPI.

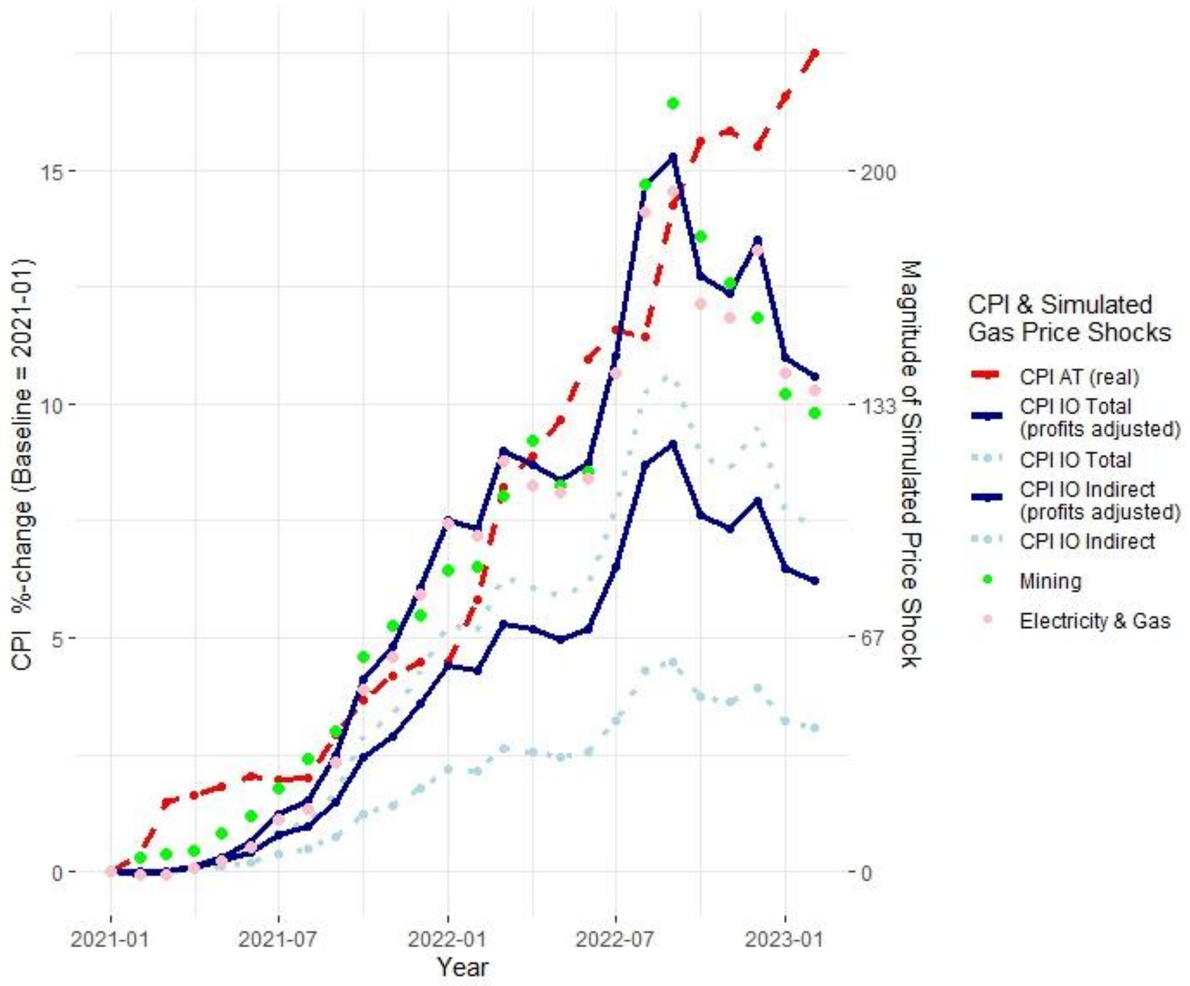
In the following sub-chapters, we compare the, through an Input-Output framework simulated gas price shocks, derived CPI, PPI and IPI with their respective real counterparts. Furthermore, we compare the simulated global gas price shocks with a counterfactual scenario, where we assume that Austria is completely self-sufficient, to assess the magnitude of the price increases due to imports.

4.1 Comparison to Consumer Price Index (CPI) – Profit adjustments

Figure 4 below plots the real CPI (in red), against the calculated inflation impact (dark blue and light blue), coming from simulated global exogenous shocks of industries which are trading with gas. The magnitude of the shocks is scaled on the right-hand axis and are calculated as monthly price changes relative to the baseline period in January 2021, for the NACE industries "Mining and quarrying" (NACE = B) and "Electricity, gas, steam and air conditioning supply" (NACE = D35). The shocks are indicated by the green dot ("Mining and quarrying") and the pink dot ("Electricity, gas, steam and air conditioning supply").

The simulated inflation impact and the real CPI also indicate the percentage change relative to the baseline month January 2021. The dark blue line indicates the total and indirect inflation impact coming from the gas price shocks where we assume that firms can adjust their profits accordingly to their price increase. The light blue dotted line shows the total and indirect inflation impact coming from the same shock scenarios where we assume that firms do not adjust their profits. Hence, in the first scenario we assume that firms can adapt their profits and pass on their increased profits by higher prices, while in the second scenario we assume that firms have a real profit loss due to the price increase.

Figure 4: CPI real and calculated after Gas Price Shocks -Profit adjustments



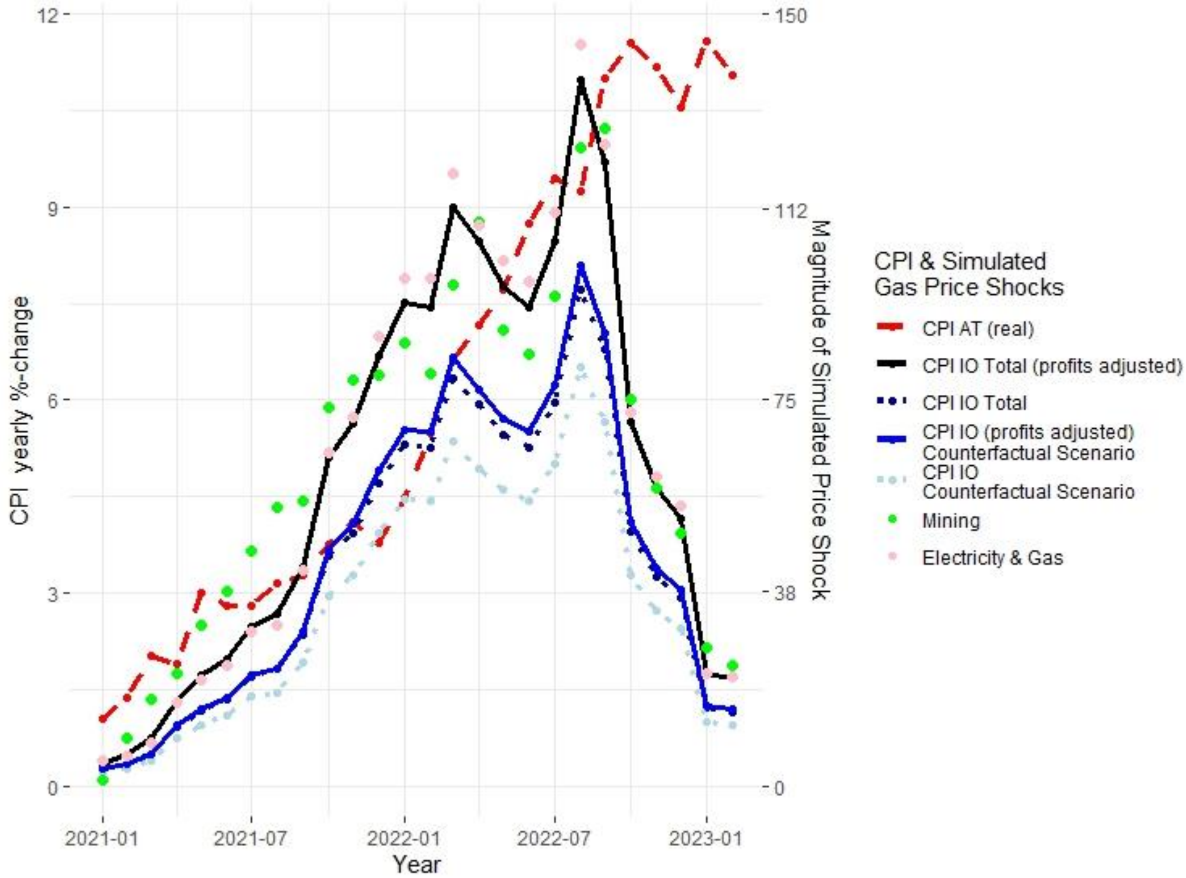
The graph indicates that price changes in the CPI especially for the period starting from January 2021 till September 2022 can very well be explained by gas price shocks. The average monthly price increase for the real CPI is at 5,3 % as well as the average monthly price increase for the price model with profit adjustment. The average price increase for the model without profit adjustment is at 3,7 % (all relative to baseline period 2021-01). After September 2022 the model seems to fail in explaining the price changes for the real CPI. While our calculated inflation impact reaches its peak with a relative price increase of 15,3 % in September 2022 and drops for the period from 2022-10 to 2023-02 to an average inflation impact of 12 %, the real CPI constantly increases for the same period to an average relative price increase of 16,2 %. Hence the model with profit adjustment underestimates the real CPI change by about 4 percentage points for this period. The results are indicating that the inflationary changes from January 2021 till September 2022 are very much driven by changes in energy prices, while the period after can potentially be better explained by other factors influencing price increases. One possibility could be, that after the period ending with September 2022, the shocks, which started in upstream industries that are trading with petroleum and natural gas transmitted through to more downstream industries such as "Wholesale trade" and "Food and beverage and tobacco products", which in turn pass on their industry specific price increases to the aggregated price level.

4.2 Comparison to Consumer Price Index (CPI) – Counterfactual Scenarios

Figure 5 below indicates again the real CPI (in red) against the calculated inflation impact (in black and different shades of blue), coming from simulated global exogenous shocks of industries which are trading with gas.

The magnitude of the shocks is again scaled on the right-hand axis and are calculated as yearly price changes, for the same NACE industries as before. The magnitude of the shocks are indicated by a green and a pink dot as well. The simulated inflation impact and the real CPI are also indicated by the yearly percentage change. The two solid lines are showing the two scenarios where firms can adjust their profits due to the increase in gas prices. The first scenario, coloured in black, indicates the global price shock scenario, where gas prices are transmitted through the whole world. The second scenario, coloured in blue, shows the counterfactual scenario, where we assume that Austria has no dependencies to industries in other countries and is therefore completely self-sufficient. The two dotted lines are showing the scenarios where firms cannot adjust their profits due to a gas price increase. The dark blue line indicates the global price shock scenario, the light blue line specifies the counterfactual scenario.

Figure 5: CPI real and calculated after Gas Price Shocks – Counterfactual Scenarios without Imports



The results show that price changes in the real CPI for Austria can be explained by simulated gas price shocks in an Input-Output framework for the inflationary period starting in January 2021 till September 2022. For this period, the average yearly percentage change is at 4,9% in the real CPI, at 5,2% for the scenario with profit adjustments and at 3,7% for the scenario without profit adjustments. After the period, the model fails in explaining the real CPI due to the relative drop in the yearly percentage change in gas prices.

The two counterfactual scenarios show an average yearly percentage change of 3,8% for the scenario with profit adjustment and 3% for the scenario without profit adjustment covering the period January 2021 to September 2022.

4.3 Summary Statistics for Consumer Price Index (CPI)

Table 3 shows the average price increase for various time periods indicating different parameters and model specifications. The upper half of the table shows the percentage change relative to the baseline period January 2021. The lower half of the table shows the yearly percentage change for the different parameters and model specifications. The parameters are the real CPI, the total inflation impact for the different model specifications with and without profit adjustments and the relative price increases for the sectors "B" and "D35" which were used for simulating the different exogenous gas price shock scenarios.

Table 3: Summary Statistics for CPI

CPI scenarios %-change (Basline 2021-01)								
							Shock Scenarios	
Statistic	Time Period	Inflation impact (no profit adjustment)	Inflation impact (profit adjustment)	Inflation impact - Counterfactual scenario (no profit adjustment)	Inflation impact - Counterfactual scenario (profit adjustment)	CPI Austria (real)	B	D35
Average price increase	total	4,6	6,6	3,9	4,8	7,4	88,5	84,9
	2021	1,2	1,8	1	1,3	2,2	28,5	22,1
	2022	7,5	10,8	6,3	7,8	11	140,9	138,6
	2023-01 to 2023-02	7,6	10,8	6,3	7,9	17	133,5	139,5
	2021-01 to 2022-09	3,7	5,3	3,1	3,9	5,3	72,7	68,1
	2022-10 to 2023-02	8,4	12	7	8,8	16,2	154,8	155,2
CPI scenario %-change (yearly)								
							Shock Scenarios	
Average price increase	total	3,4	4,9	2,9	3,6	6,1	62,8	63,2
	2021	1,9	2,7	1,6	1,9	2,8	42,2	33,9
	2022	5,3	7,6	4,5	5,6	8,6	89,6	99,4
	2023-01 to 2023-02	1,2	1,7	1	1,2	11,3	25,3	21,6
	2021-01 to 2022-09	3,7	5,2	3	3,8	4,9	66,6	67,2
	2022-10 to 2023-02	2,5	3,6	2,1	2,6	11,2	46,5	46

Based on the information presented in the table above, it becomes evident that the inflationary period in Austria, spanning the time 2021-01 to 2022-09, can very well be approximated by simulated gas price shocks in an Input-Output model. We find a slight overestimation in the model of 0,3 percentage points by comparing the yearly average price change for the model with profit adjustment with the yearly average price change of the real CPI in Austria. By using the month 2021-01 as a baseline, we find identical average percentage changes of 5,3 % comparing the model with profit adjustment to the real CPI in Austria, when focusing on the period 2021-01 to 2022-09.

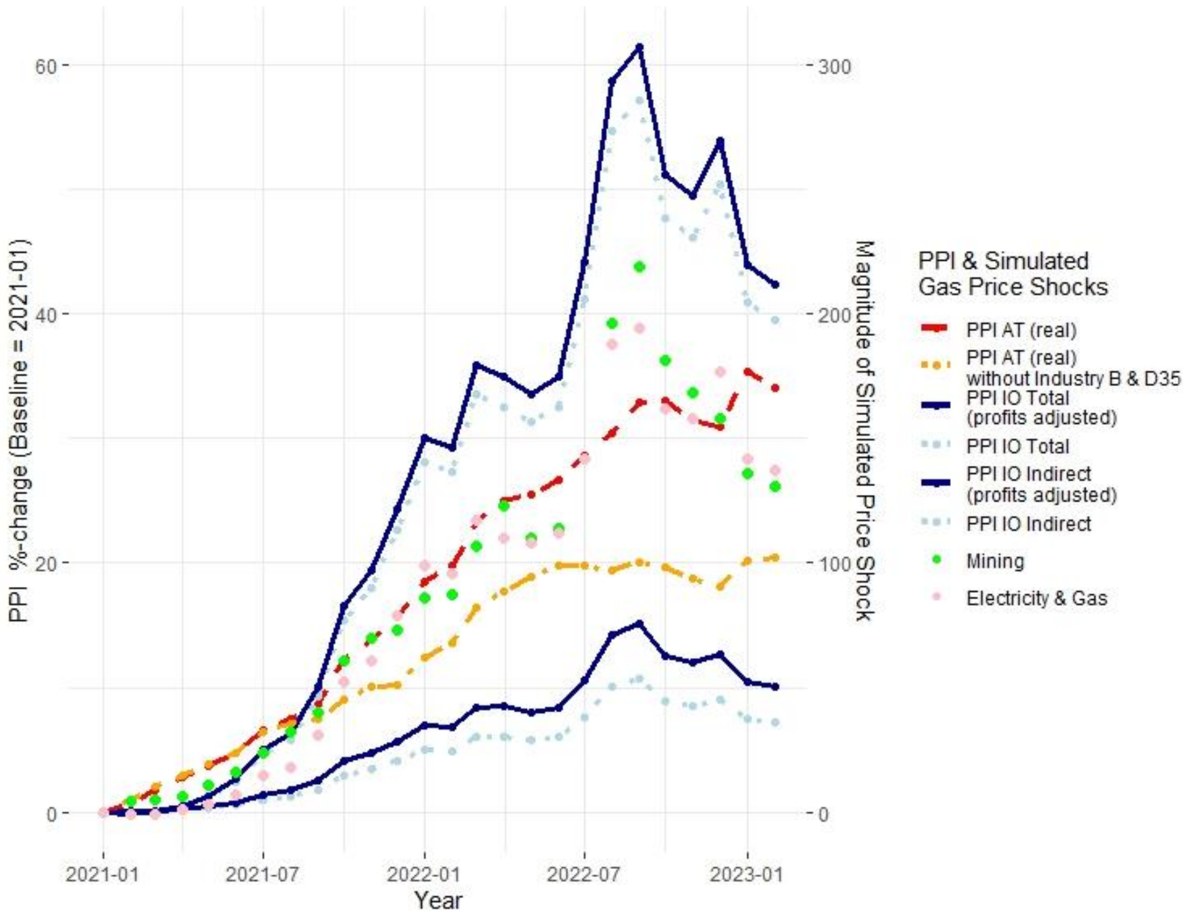
After the period, the model specification fails to explain price changes in the real CPI in Austria due to the drop in relative price increases for the exogenous sectors. Comparing the yearly average price change covering the period 2022-10 to 2023-02 of the model with profit adjustment with the real CPI, we find a calculated average inflation impact of 3,6 % for the model specification with profit adjustments and an average price increase of 11,2 % in the real CPI, resulting in an underestimation of 7,6 percentage points. Comparing the same period using 2021-01 as a baseline, we find a less dramatic misspecification due to a cumulative effect. By comparing the same model specification as before the calculated average inflation impact is at 12 % while the relative price increase for the real CPI is 16,2 %, resulting in a misspecification of 4,2 percentage points.

The results for the global and counterfactual model specifications, where a yearly percentage change was used for the different shock scenarios, are indicating that the average inflation impact for the period 2021-01 to 2022-09 is at 5,2% for the global price shock scenario with adaptation of profits and at 3,8% for the counterfactual scenario with profit adjustment. Hence, by taking the difference of the two model specifications the resulting average inflation impact due to imports is at 1,4%. Furthermore, by comparing the two specifications without profit adjustments, the average inflation impact is 3,7% for the global model specification and at 3% for the respective counterfactual scenario without profit adjustment, which results in an average inflation impact of 0,7% due to imports.

4.4 Comparison to Producer Price Index (PPI) – Profit adjustments

Figure 6 below shows the real PPI (in red) and the real PPI without the shocked industries "Mining and quarrying" (NACE B) and "Electricity, gas, steam and air conditioning supply" (NACE D35) (in orange) against the calculated price impact (in dark blue and light blue), coming from simulated global exogenous shocks of industries which are trading with gas. The magnitude of the shocks is scaled on the right-hand axis and are calculated as monthly price changes relative to the baseline period in January 2021, for the NACE industries "B" and "D35". The shocks are indicated by the green dot (B) and the pink dot (D35).

Figure 6: PPI real and calculated after Gas Price Shocks -Profit adjustments



The simulated price impact on the PPI and the real PPI as well shows the percentage change relative to the baseline month January 2021. The dark blue line indicates the total and indirect price impact on the PPI coming from gas price shocks where we assume that firms can adjust their profits according to their price increase. The light blue dotted line shows the total and indirect price impact on the PPI coming from the same shock scenarios, where we assume that firms do not adjust their profits. Hence, in the second scenario we assume that firms have a real profit loss due to the price increases.

The figure above indicates that the relative price changes in the simulated and real PPI are very much directly driven by price changes in the energy related industries, “B” and “D35”. The direct price impact is given by the difference between the total price impact and the indirect price impact. In the graph above, it can be seen by the space between the upper dark blue line and the lower dark blue line for the scenario with profit adjustment, by the space between the upper light blue dotted line and the lower one for the scenario without profit adjustment, and by the space between the red and the orange line for the real PPI. This high influence of the two industries comes from the comparably high proportion of the shocked industries in the PPI, with 2,4 % for industry “Mining”[8] and 21,3 % for industry “Electricity & Gas”, (STATISTIK AUSTRIA, 2023) and from the strong relative monthly price changes shown by the pink and green dots.

Both scenarios indicate an overestimation of the real price increases in the PPI for Austria when using gas price changes as simulated shocks. In the scenario with profit adjustment the average monthly price change (using 2021-01 as baseline) is 26,5 % for the period 2021-01 to 2023-02, while the average price change in the real PPI for Austria was at 18,2 % covering the same period. On the contrary, when focusing on the simulated indirect price impact and comparing it to the real price changes in the PPI without the two shocked industries, the results indicate that the indirect price impact underestimates the real price changes in the PPI for the period 2021-01 to 2023-02. The average indirect price increase for the scenario with profit adjustment is at 6,4 % while for the PPI without industry “B” and “D35”, the price change was at 12,3 %, using for both the month 2021-01 as the baseline.

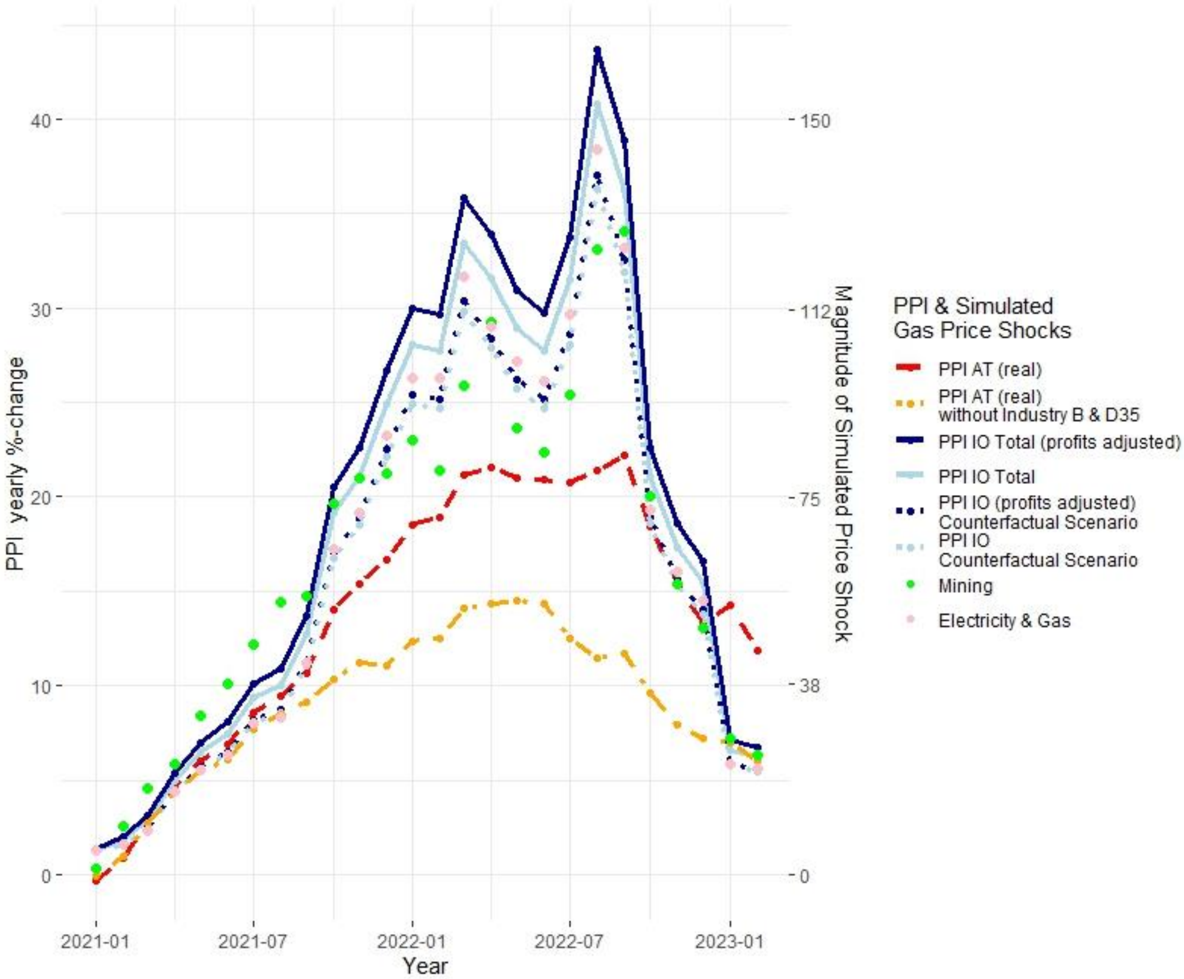
4.5 Comparison to Producer Price Index (PPI) – Counterfactual Scenarios

Figure 8 below plots again the real PPI (in red), the real PPI excluding industries “B” and “D35” (in orange) against the calculated price impact on the PPI (in dark and light blue) coming from simulated global exogenous shocks of industries which are trading with gas. The magnitude of the shocks is scaled on the right-hand axis and are calculated as yearly price changes, for the same NACE industries as before. The shocks are indicated by the green and the pink dot as well. The simulated inflation impact and the real PPI are also shown by the yearly percentage change and are scaled on the left y-axis. The two dark blue lines are indicating the two

[8] The proportion of the NACE industry „B- Mining and Quarrying” in the PPI had to be approximated since it is flagged as confidential by Statistik Austria. (STATISTIK AUSTRIA, 2023) See the table in Appendix for further information on the approximation.

scenarios where firms can adjust their profits due to an increase in gas prices. The first scenario, solid dark blue line, indicates the global price shock scenario, where gas prices are transmitted through the whole world. The second scenario, dotted dark blue line, shows the counterfactual scenario, where we assume that Austria has no dependencies to industries in other countries and is therefore completely self-sufficient. The two light blue lines show the scenarios where firms cannot adjust their profits due to a gas price increase. The solid light blue line indicates the global price shock scenario, the dotted light blue line indicates the counterfactual scenario.

Figure 7: PPI real and calculated after Gas Price Shocks - Counterfactual Scenarios without Imports



The results show again an overestimation of price changes in the calculated PPI when comparing it to the real PPI for Austria, by using yearly price changes of gas trading industries as simulated price shock scenarios. For the period of January 2021 until February 2023 the average yearly percentage change is at 13,7 % for the real PPI, at 19,6 % for the scenario with profit adjustments and at 18,3 % for the scenario without profit adjustments. Hence, the Input-Output model overestimates the average yearly price impact by 5,9 percentage points for the model with profit adjustments and by 4,6 percentage points for the model without profit adjustments.

The two counterfactual scenarios show an average yearly percentage change of 9 % for the scenario with profit adjustment and 8.9 % for the scenario without profit adjustment covering the period January 2021 to February 2023.

4.6 Summary Statistics for Producer Price Index (PPI)

Table 4 shows the average price increase for various time periods indicating different parameters and model specifications. The upper half of the table shows the percent change relative to the baseline period January 2021, the lower half of the table shows the yearly percent change, for different indices and model specifications. The indices and model specifications are the real PPI for Austria, the total price impact for the global price shock scenario (with profit adjustments and without profit adjustment), the counterfactual price shock scenario where we assume that Austria is completely self-sufficient (with profit adjustments and without profit adjustment) and the relative price increases for the sectors “B” and “D35” which were used for simulating the different exogenous gas price shock scenarios.

Table 4: Summary Statistics for PPI - Total price impact

PPI scenarios %-change (Basline 2021-01)								
							Shock Scenarios	
Statistic	**Time Period**	**Inflation impact (no profit adjustment)**	**Inflation impact (profit adjustment)**	**Inflation impact - Counterfactual scenario (no profit adjustment)**	**Inflation impact - Counterfactual scenario (profit adjustment)**	**PPI Austria (real)**	**B**	**D35**
Average price increase	total	24,7	26,5	21,8	22,2	18,2	88,5	84,9
	2021	6,6	7,2	5,8	5,9	6,5	28,5	22,1
	2022	40,2	43,1	35,5	36,1	27,2	140,9	138,6
	2023-01 to 2023-02	40,2	43,1	35,6	36,3	34,7	133,5	139,5
	2021-01 to 2022-09	19,9	21,4	17,5	17,8	14,7	72,7	68,1
	2022-10 to 2023-02	44,9	48,2	39,6	40,4	33,0	154,8	155,2
PPI scenario %-change (yearly)								
							Shock Scenarios	
Average price increase	total	18,3	19,6	16,1	16,4	13,7	62,8	63,2
	2021	10,2	11,0	8,9	9,0	8,0	42,2	33,9
	2022	28,3	30,4	25,1	25,6	19,5	89,6	99,4
	2023-01 to 2023-02	6,4	6,9	5,6	5,7	13,1	25,3	21,6
	2021-01 to 2022-09	19,4	20,9	17,2	17,5	13,4	66,6	67,2
	2022-10 to 2023-02	13,3	14,3	11,8	12,0	14,7	46,5	46,0

The upper table indicates an overestimation of price changes in the PPI for Austria for the time 2021-01 to 2023-03 for all four model scenarios. The overestimation of the average yearly price impact due to a shock in gas prices is ranging from 5,9 percentage points for the global shock scenario with profit adjustments to 2,4 percentage points for the counterfactual scenario without profit adjustments.

Comparing the four model scenarios, where a yearly percentage change was used for the different shock scenarios, the average calculated price change for the PPI for the period 2021-01 to 2023-02 is at 19,6% for the global price shock scenario with adaptation of profits and at 16,4% for the counterfactual scenario with profit adjustment. Resulting in an average price impact of 3,2% due to imports. Moreover, upon contrasting the two specifications without profit adjustments, the average price impact is at 18,3% for the global model specification and at 16,1% for the respective counterfactual scenario, which results in an average difference in prices of 2,2% attributable to imports.[9]

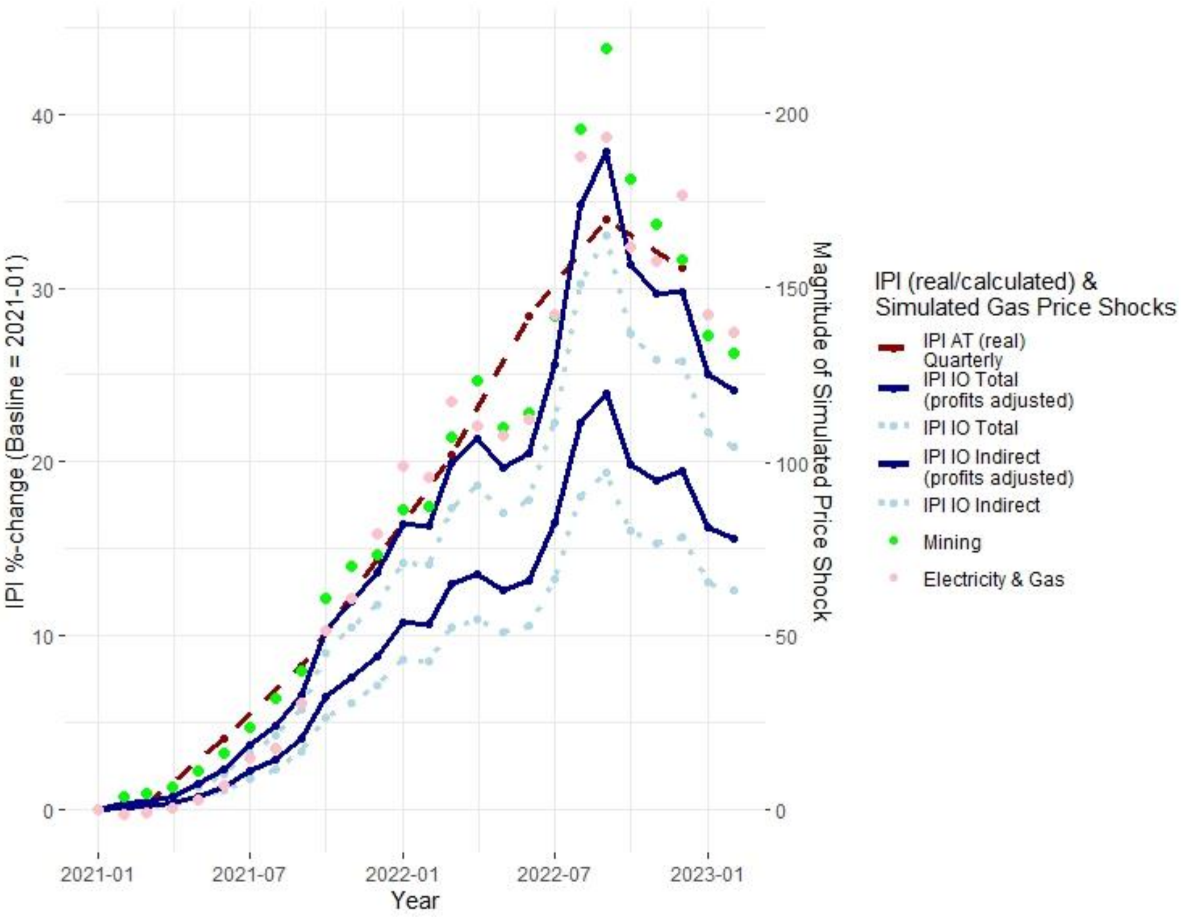
[9] Summary Statistics for the indirect price impact of the PPI can be found in the appendix.

4.7 Comparison to Import Price Index (IPI)

Figure 8 below shows the real IPI for Austria (in red) against the calculated price impact (in dark blue and light blue) coming from simulated global exogenous shocks of industries which are trading with gas. The magnitude of the shocks is scaled on the right-hand axis and are calculated as monthly price changes relative to the baseline period in January 2021, for the NACE industries “B” and “D35”. The shocks are indicated by the green dot (“B”) and the pink dot (“D35”). The simulated price impact on the IPI and the real IPI as well shows the percentage change relative to the baseline month January 2021.

The dark blue solid lines indicate the total and indirect price impact on the IPI coming from gas price shocks where we assume that firms can adjust their profits accordingly to their price increase. The light blue dotted lines show the total and indirect price impact on the IPI coming from the same shock scenarios where we assume that firms do not adjust their profits. Hence, in the second scenario, we assume that firms are having a real profit loss due to the price increase.

Figure 8: IPI real and calculated after Gas Price Shocks -Profit adjustments



The results indicate that price changes for the IPI in Austria have been largely driven by changes in energy related industries, for the period starting from January 2021 until February 2023. For this period the average price increase for the real IPI in Austria is at 17,6 %, for the simulated scenario with profit adjustments at 15,7 % and for the scenario without profit adjustments the IPI rises by 13,7 % (all relative to the baseline period 2021-01). Hence, the model specification with profit adjustment underestimates price increases in the IPI by 1,9 percentage points and by 3,9 percentage points for the model specification where we assume that firms do not adjust their profits accordingly.

4.8 Summary Statistics for Import Price Index (IPI)

Table 6 shows the average price increase for the IPI in Austria and the simulated total, direct and indirect price impact coming from different gas price shock scenarios for the case where firms adjust their profits and for the case where they are not able to adjust their profits. The table shows the percent change relative to the baseline period January 2021. The average magnitude of the different shock scenarios is indicated as well.

Table 5: Summary Statistics for IPI with different price impacts

IPI scenarios %-change (Baseline 2021-01)										
		No adjustments of Profits			With adjustments of Profits				Shock Scenarios	
Statistic	**Time Period**	**Total Price Impact**	**Direct Price Impact**	**Indirect Price Impact**	**Total Price Impact**	**Direct Price Impact**	**Indirect Price Impact**	**IPI Austria (real) - quarterly**	**B**	**D35**
Average price increase	total	13,7	5,6	8,1	15,7	5,7	10,1	17,6	88,5	84,8
	2021	4,1	1,8	2,4	4,7	1,8	2,9	6,8	28,5	22,0
	2022	22,0	8,9	13,1	25,3	9,0	16,2	28,5	140,9	138,5
	2023-01 to 2023-02	21,3	8,5	12,8	24,6	8,7	15,9	NA	133,9	139,8
	2021-01 to 2022-09	11,2	4,6	6,6	12,8	4,6	8,2	15,7	72,7	68,1
	2022-10 to 2023-02	24,3	9,8	14,5	28,0	10,0	18,0	31,2	155,1	155,1

The above results show that the real IPI in Austria can relatively well be approximated by an Input-Output model when using the price changes of the industries "B" and "D35" as exogenous shock scenarios. The average price impact for the model with adjustment of profits is at 15,7 %, for the model without adjustment of profits the price impact is at 13,7 %, focusing on the period 2021-01 till 2023-02 and using the month 2021-01 as baseline. When comparing it to the real IPI in Austria, where the average price change was at 17,6 %, the average underestimation of the real IPI is at 1,9 percentage points for the model with profit adjustments and at 3,9 percentage points for the model without profit adjustments. One possible explanation for the underestimation is that we exclude the adaptation of wages due to the price shocking scenarios. Hence, we assume a decrease in real wages. However, it is reasonable to assume, that workers would get at least some compensation for the real wage loss, which would set out another cascading price effect throughout the economy.

Concentrating on the model with profit adjustments, the average direct price impact is at 5,7 %. Hence, the two gas trading sectors are directly contributing on average 36% of the total price change in the IPI through there price increases. The remaining proportion of 64% or 10,1% can be attributed to indirect price changes caused by the two exogenous industries and transmitted through to the remaining industries in the IPI.

5.Potential Issues

There are several issues which arise when we try to simulate price shocks with Input-Output data. In principle some potential difficulties are firstly due to the theoretical foundations and mechanisms of Input-Output models in general and secondly due to some specific issues inherent when working with the WIOD.

5.1 General Issues

Assumption of no substitution - One potential issue, when using Input-Output tables in a static form, is that it must be assumed that industries do not substitute one good for another. The assumption is, that the matrix of technical coefficients is constant, therefore, the proportion each input industry takes up to produce one good of output in a certain industry stays the same no matter how high the prices of a certain input industry are rising.

Assumption of linearity in a Leontief production function – A further potential issue that arises from the assumption of constant technical coefficients is a linear dependence among industries. (Miller and Blair, 1982) Therefore, it must be assumed as well, that a linear dependence between the magnitude of a price shock from a certain industry and the respective total price impact of this price shock exists.

Figure 9: Relationship between magnitude of price shock and total price impact

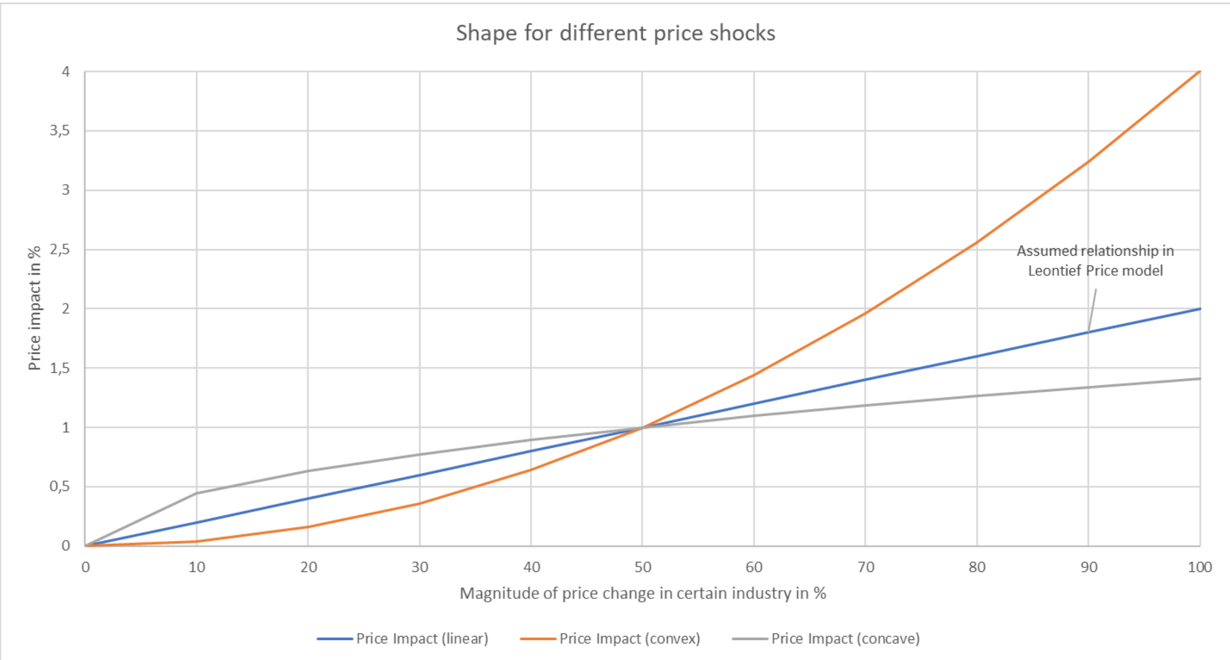


Figure 9 above shows different possible scenarios of the relationship between the magnitude of a price shock in a certain industry and the respective total impact on prices. The blue linear line indicates the assumed scenario imposed by a Leontief price model, where a change in the magnitude of a sectoral price shock leads to a proportionate change in overall prices. The other two lines indicate non-linear scenarios. The orange line shows a scenario with an increasing marginal overall price impact, due to an increase in sectoral prices. The grey line indicates a scenario with a decreasing marginal overall price impact. Further research would be needed to assess potential non-linearities in the relationship between sectoral price shocks and their impact on overall price stability.

Assumption of constant wages – Another issue is that we assume constant nominal wages. Therefore, we assume a real wage loss due to the price shocks. However, it is reasonable to assume that workers would get some compensation for their loss in real wages, which would lead to another cascading price effect through the economic system. We decided against constructing a scenario where we assume the adaptation of wages, due to potential issues in the usage of Input-Output tables covering the whole world in combination with the calculation of wage adapting scenarios, like in the works done by Rowthorn (1977) and Weber et al. (2022). However, incorporating changes in wages would lead to a more realistic scenario and could be a possible extension for future research.

5.2 Specific Issues for the WIOD

Assumption that economic structure of 2014 is transferable to economic structure of 2019 to 2023 – Due to the fact that the last release of the WIOD inhibits data which were collected for 2014, it must be assumed that the worldwide relationships among the industries and countries used in the data set did not change from 2014 to the years 2019 to 2023. This could have potential implications for the conclusions drawn in chapter 3, where we concluded that the industries which are having a significant impact on prices stayed largely the same for different inflationary periods. The issue could be, that the industries did stay largely the same because only the magnitude of the industry specific price shock changed but not the underlying relationships and dependencies among the industries, which are assumed to stay constant. However, in reality, certain input industries could have been substituted by other input industries, resulting in relationships and dependencies that have changed over time in a way leading to other industries having a significant impact on the overall price level. As a robustness check we calculated the different sectoral price shocking scenarios and their respective inflation impact using the WIOD's input-output tables from 2000 to 2014 as a basis. The results are indicating that the industries with the largest impact on inflation are mostly constant when using input-output tables of the other years as a foundation. For all scenarios the industry "Electricity & Gas" is the by far most important industry with regards to the total inflation impact.[10]

Assumption of Counterfactual Scenario for Austria-In the counterfactual scenario for Austria we assume that Austria works as a completely self-sufficient economy with no connection to industries in other countries, all else unchanged. With this adaptation it is assumed that the production streams within Austria are the same for the counterfactual scenario as well as for the global shock scenario. However, in a more realistic economic situation the production streams within industries would need to have a dynamic adaptation for the counterfactual scenario in the size of the previously imported inputs to be able to produce the same amount of output. One possibility would be to produce aggregated worldwide inputs for each input industry that is needed to produce the given amount of output for each industry in Austria and to assume that the total input needed of each output industry is assumed to be produced within Austria.

[10] See in Appendix Figure 10 for the average inflation impact using WIOD's Input-Output tables from 2000 to 2014 as a basis.

6.Conclusions

In this work we have simulated sector specific price shocks and identified industries which can have a significant impact on overall price stability. We find that these industries are largely the same by introducing shocks for different inflationary periods, covering the post-shutdown period and the period during the Ukraine war, and comparing them to the results found by introducing price shocks using average price volatilities between 2000-2019. However, it must be pointed out that for all three shock scenarios, the same economic structure had to be assumed, since the last release of the WIOD was for the year 2014[11]. These industries are "Electricity & Gas", "Manufacture of coke and refined petroleum products", "Manufacture of food products", "Real estate", "Wholesale Trade", "Retail trade", "Accommodation" and "Land transport". Hence, the industries with a significant impact on overall price stability can broadly be grouped into energy supply, necessities of life and essential production inputs. Similar results have been found for the US, where the sectors "… *Petroleum and coal products, Oil and gas extraction, Farms, Food and beverage and tobacco products, Chemical products, Housing, Utilities, and Wholesale trade …*" have been identified to be systemically significant for price stability. (Weber et al., 2022) Differences between the results for the US and for Austria can primarily be attributed to methodological differences in the data used.

In the second part of the paper, we used monthly global price changes of industries which are trading with gas as exogenous price shocks covering the period January 2021 to February 2023 using different model specifications. These model specifications can be summarized by three distinct scenarios. Firstly, a scenario where we assumed that firms cannot adjust their profits accordingly to the price increases. Secondly, a scenario where we assumed that firms can adjust their profits, which implies an increase in nominal profits. Thirdly, a counterfactual scenario where we assumed that Austria is completely self-sufficient and has no economic relations to other countries. Afterwards, we aggregated the results using the total household consumption of each industry as relative weight to construct a synthetic CPI as well as the weights of each industry for the producer price index (PPI) and the import price index (IPI) in Austria to construct a synthetic PPI and IPI. Subsequently, we compared the results to the relative price changes in the real CPI, PPI and IPI for Austria covering the same period to assess,

[11] Robustness checks have been done, finding that industries with a significant impact on prices stay relatively constant when using Input-Output tables from 2000 to 2014 as a basis.

to what extent shocks in gas prices can explain the price changes in early 2021 till the beginning of 2023.

For the CPI we find that the inflationary dynamics can very well be explained by gas price shocks using an Input-Output model for the period January 2021 to September 2022, where the average simulated inflation impact is at 5,3 % for the model specification with profit adjustment, 3,7 % for the model without profit adjustment and at 5,3 % for the real CPI in Austria (Baseline period is 2021-01). After the period, the model fails in explaining price increases in the real CPI in Austria. Comparing the results for the PPI, the average price impact, covering the period January 2021 to February 2023, is at 48,2 % for the model specification with profit adjustment, at 44,9 % for the model with no profit adjustment and at 33% for the real PPI in Austria. Hence, the model overestimates the impact of gas price shocks on the PPI by 15,2 or 11,9 percentage points depending on the model specification (Baseline period is 2021-01). For the IPI, we again find that price changes can relatively well be approximated by an Input-Output model, with a calculated average total price impact of 13,7 % for the model specification without profits, 15,7 % for the model specification with adjustment of profits and of 17,6 % for the real IPI in Austria. Leading to an average underestimation of 3,9 or 1,9 percentage points depending on the model specification (Baseline period is 2021-01).

Finally, we compared the counterfactual scenario, to the global shock scenario, for assessing, to what extent price changes in Austria are imported. We find for the CPI an average yearly price impact for the global scenario of 3,4 % without profit adjustment and of 4,9 % with profit adjustment. For the counterfactual scenarios we calculated an average price impact of 2,9 % for the scenario without profit adjustment and of 3,6 % for the scenario with profit adjustment. Hence, the average inflation impact due to imports is at 0,7 % or 1,4 % depending on the scenario. For the PPI we calculated an average yearly price impact of 18,3 % for the global shock scenario without profit adjustment and of 19,6 % for the global scenario with profit adjustment. Concentrating on the counterfactual scenarios, we find that the average yearly price impact on the PPI is at 16,1 % and at 16,4 % for the scenario without and with profit adjustments. Hence, the average price impact on the PPI due to imports is at 2,2 % or 3,2 % depending on the scenario.

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Table 6: Share of Producer Price Index (PPI) for AUT, EU-28 and for WIOD

Weighting 2022 (macro goods basket) for Producer Price Index - Producing Sector						
Industries AUT & EU-28				Industries WIOD		
Codes	**Description**	**Share AUT**	**Share EU-28**	**Codes**	**Description**	**Share**
B05	Mining of coal and lignite	0	0,3			
B06	Extraction of crude petroleum and natural gas	C	1,4			
B07	Mining of metal ores	C	0,2	B	Mining and quarrying	2,342
B08	Other mining and quarrying	0,399	0,6			
B09	Mining support service activities	C	0,4			
C10	Manufacture of food products	6,573	8,8			
C11	Manufacture of beverages	2,756	1,9	C10-C12	Manufacture of food products, beverages and tobacco products	9,6204
C12	Manufacture of tobacco products	C	0,3			
C13	Manufacture of textiles	0,577	1,1			
C14	Manufacture of wearing apparel	0,245	0,9	C13-C15	Manufacture of textiles, wearing apparel and leather products	1,127
C15	Manufacture of leather and related products	0,305	0,6			

C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	3,503	1,5	C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	3,503
C17	Manufacture of paper and paper products	2,851	2,1	C17	Manufacture of paper and paper products	2,851
C18	Printing and reproduction of recorded media	0,774	1,5	C18	Printing and reproduction of recorded media	0,774
C19	Manufacture of coke and refined petroleum products	C	1,2	C19	Manufacture of coke and refined petroleum products	1,166
C20	Manufacture of chemicals and chemical products	3,445	6,0	C20	Manufacture of chemicals and chemical products	3,445
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	1,081	4,3	C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	1,081
C22	Manufacture of rubber and plastic products	2,945	4,3	C22	Manufacture of rubber and plastic products	2,945
C23	Manufacture of other non-metallic mineral products	2,565	3,0	C23	Manufacture of other non-metallic mineral products	2,565
C24	Manufacture of basic metals	8,380	3,0	C24	Manufacture of basic metals	8,38

C25	Manufacture of fabricated metal products, except machinery and equipment	6,683	8,1	C25	Manufacture of fabricated metal products, except machinery and equipment	6,683
C26	Manufacture of computer, electronic and optical products	3,245	6,0	C26	Manufacture of computer, electronic and optical products	3,245
C27	Manufacture of electrical equipment	4,987	4,0	C27	Manufacture of electrical equipment	4,987
C28	Manufacture of machinery and equipment n.e.c.	10,207	9,4	C28	Manufacture of machinery and equipment n.e.c.	10,207
C29	Manufacture of motor vehicles, trailers and semi-trailers	7,447	9,1	C29	Manufacture of motor vehicles, trailers and semi-trailers	7,447
C30	Manufacture of other transport equipment	1,428	2,8	C30	Manufacture of other transport equipment	1,428
C31	Manufacture of furniture	1,307	1,5	C31_C32	Manufacture of furniture	2,501
C32	Other manufacturing	1,194	2,1			
C33	Repair and installation of machinery and equipment	2,162	3,5	C33	Repair and installation of machinery and equipment	2,162
D35	Electricity, gas, steam and air conditioning supply	21,295	10,3	D35	Electricity, gas, steam and air conditioning supply	21,295
E36	Water collection, treatment and supply	0,246	0,0	E36	Water collection, treatment and supply	0,246
	$\sum$	**96,6**	**100**		$\sum$	**100**

Table 7 shows the shares of each NACE industry for the PPI in Austria, EU-28 and for the WIOD. Since the industries "Extraction of crude petroleum and natural gas", "Mining of metal ores", "Mining support service activities", "Manufacture of tobacco products" and "Manufacture of coke and refined petroleum products" are flagged as confidential by STATISTIK AUSTRIA (c), these industries are approximated by using the total weight of the confidential industries of 3,4 % and approximate each industry by the relative weights of the PPI for the EU-28. Furthermore, several industries had to be aggregated due to the data structure in the WIOD. For example, the weights of the subindustries "Mining of coal and lignite" (B05), "Extraction of crude petroleum and natural gas" (B06), "Mining of metal ores" (B07), "Other mining and quarrying" (B08) and "Mining support service activities" (B09) had to be aggregated for the industry "Mining and quarrying" (B). Sources: (Eurostat, 2023); (STATISTIK AUSTRIA, 2023); (Dietzenbacher et al., 2014)

Table 7: Summary of data sources used for constructing simulated sector specific price shocks

Industry Code	IndustryDescription	RNr	Code	Comment
A01	Crop and animal production, hunting and related service activities	1	n	Price data approximated with aggregate of product 2000 provided by Eurostat Product 2000 = Input 1 + Input 2; Input 1 = "Goods and services currently consumed in agriculture", Input 2 = "Goods and services contributing to agricultural investment"
A02	Forestry and logging	2	n	Price data approximated with aggregate of product 2000 provided by Eurostat Product 2000 = Input 1 + Input 2; Input 1 = "Goods and services currently consumed in agriculture", Input 2 = "Goods and services contributing to agricultural investment"
A03	Fishing and aquaculture	3	n	Price data approximated with aggregate of product 2000 provided by Eurostat Product 2000 = Input 1 + Input 2; Input 1 = "Goods and services currently consumed in agriculture", Input 2 = "Goods and services contributing to agricultural investment"
B	Mining and quarrying	4	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C10-C12	Manufacture of food products, beverages and tobacco products	5	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C13-C15	Manufacture of textiles, wearing apparel and leather products	6	x	Use of aggregated price data for EU-28 as proxy for worldwide changes

C16	Manufacture of wood and of products of wood and cork, except furniture	7	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C17	Manufacture of paper and paper products	8	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C18	Printing and reproduction of recorded media	9	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C19	Manufacture of coke and refined petroleum products	10	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C20	Manufacture of chemicals and chemical products	11	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	12	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C22	Manufacture of rubber and plastic products	13	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C23	Manufacture of other non-metallic mineral products	14	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C24	Manufacture of basic metals	15	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C25	Manufacture of fabricated metal products, except machinery and equipment	16	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C26	Manufacture of computer, electronic and optical products	17	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C27	Manufacture of electrical equipment	18	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C28	Manufacture of machinery and equipment n.e.c.	19	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C29	Manufacture of motor vehicles, trailers and semi-trailers	20	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C30	Manufacture of other transport equipment	21	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C31_C32	Manufacture of furniture	22	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
C33	Repair and installation of machinery and equipment	23	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
D35	Electricity, gas, steam and air conditioning supply	24	x	Use of aggregated price data for EU-28 as proxy for worldwide changes

E36	Water collection, treatment and supply	25	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
E37-E39	Sewerage	26	N.A.	N.A.
F	Construction	27	a	Own aggregation of 7 countries for which data are provided by EUROSTAT; Countries used: ("AUT", "ESP", "FIN", "IRL", "ITA", "LTU", "NLD", "NOR", "POL", "PRT") aggregated by ratio of industry specific output to total output of the 7 countries
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	28	GER	Use industry specific price data for Germany
G46	Wholesale trade, except of motor vehicles and motorcycles	29	GER	Use industry specific price data for Germany
G47	Retail trade, except of motor vehicles and motorcycles	30	GER	Use industry specific price data for Germany
H49	Land transport and transport via pipelines	31	n	Use aggregated price data for industry H494-N812
H50	Water transport	32	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
H51	Air transport	33	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
H52	Warehousing and support activities for transportation	34	n	Use aggregated price data for industry H494-N812
H53	Postal and courier activities	35	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
I	Accommodation and food service activities	36	n	Use aggregated price data for industry H494-N812
J58	Publishing activities	37	n	Use aggregated price data for industry H494-N813
J59_J60	Motion picture, video and television programme production, sound recording and music publishing activities	38	n	Use aggregated price data for industry H494-N814
J61	Telecommunications	39	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
J62_J63	Computer programming, consultancy and related activities	40	n	Use aggregated price data for industry H494-N813

K64	Financial service activities, except insurance and pension funding	41	n	Use aggregated price data for industry H494-N814
K65	Insurance, reinsurance and pension funding, except compulsory social security	42	n	Use aggregated price data for industry H494-N815
K66	Activities auxiliary to financial services and insurance activities	43	n	Use aggregated price data for industry H494-N816
L68	Real estate activities	44	n	Use aggregated price data for industry H494-N817
M69_M70	Legal and accounting activities	45	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
M71	Architectural and engineering activities	46	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
M72	Scientific research and development	47	n	Use aggregated price data for industry H494-N815
M73	Advertising and market research	48	x	Use of aggregated price data for EU-28 as proxy for worldwide changes
M74_M75	Other professional, scientific and technical activities	49	n	Use aggregated price data for industry H494-N816
N	Administrative and support service activities	50	a	
O84	Public administration and defence	51	N.A.	N.A.
P85	Education	52	N.A.	N.A.
Q	Human health and social work activities	53	N.A.	N.A.
R_S	Other service activities	54	N.A.	N.A.
T	Activities of households as employers	55	N.A.	N.A.
U	Activities of extraterritorial organizations and bodies	56	N.A.	N.A.

Sources: (Eurostat, 2023); (Statistisches Bundesamt, 2023)

List of codes:

x = EUROSTAT data available

a = aggregation done by the author

GER = industry specific price data used from Germany

N.A.= industry specific data are not existing

Table 8: Summary Statistics for CPI - Inflation impact

CPI scenarios %-change (Basline 2021-01)							
Statistic	**Time Period**	**Inflation impact (no profit adjustment)**	**Inflation impact (profit adjustment)**	**Inflation impact - Counterfactual scenario (no profit adjustment)**	**Inflation impact - Counterfactual scenario (profit adjustment)**	**Price impact imported (no profit adjustment)**	**Price impact imported (profit adjustment)**
Average price increase	total	4,6	6,6	3,9	4,8	0,7	1,8
	2021	1,2	1,8	1	1,3	0,2	0,5
	2022	7,5	10,8	6,3	7,8	1,2	3
	2023-01 to 2023-02	7,6	10,8	6,3	7,9	1,3	2,9
	2021-01 to 2022-09	3,7	5,3	3,1	3,9	0,6	1,4
	2022-10 to 2023-02	8,4	12	7	8,8	1,4	3,2
CPI scenario %-change (yearly)							
Average price increase	total	3,4	4,9	2,9	3,6	0,5	1,3
	2021	1,9	2,7	1,6	1,9	0,3	0,8
	2022	5,3	7,6	4,5	5,6	0,8	2
	2023-01 to 2023-02	1,2	1,7	1	1,2	0,2	0,5
	2021-01 to 2022-09	3,7	5,2	3	3,8	0,7	1,4
	2022-10 to 2023-02	2,5	3,6	2,1	2,6	0,4	1

Table 9: Summary Statistics for PPI - Price impact

PPI scenarios %-change (Basline 2021-01)							
Statistic	**Time Period**	**Inflation impact (no profit adjustment)**	**Inflation impact (profit adjustment)**	**Inflation impact - Counterfactual scenario (no profit adjustment)**	**Inflation impact - Counterfactual scenario (profit adjustment)**	**Price impact imported (no profit adjustment)**	**Price impact imported (profit adjustment)**
Average price increase	total	24,7	26,5	21,8	22,2	2,9	4,3
	2021	6,6	7,2	5,8	5,9	0,9	1,3
	2022	40,2	43,1	35,5	36,1	4,7	7,0
	2023-01 to 2023-02	40,2	43,1	35,6	36,3	4,6	6,9
	2021-01 to 2022-09	19,9	21,4	17,5	17,8	2,4	3,5
	2022-10 to 2023-02	44,9	48,2	39,6	40,4	5,2	7,8
PPI scenario %-change (yearly)							
Average price increase	total	18,3	19,6	16,1	16,4	2,1	3,2
	2021	10,2	11,0	8,9	9,0	1,3	1,9
	2022	28,3	30,4	25,1	25,6	3,2	4,7
	2023-01 to 2023-02	6,4	6,9	5,6	5,7	0,8	1,2
	2021-01 to 2022-09	19,4	20,9	17,2	17,5	2,3	3,4
	2022-10 to 2023-02	13,3	14,3	11,8	12,0	1,6	2,3

Table 10: Summary Statistics for PPI - Indirect price impact

PPI Indirect scenarios %-change (Basline 2021-01)								
							Shock Scenarios	
Statistic	**Time Period**	**Indirect inflation impact (no profit adjustment)**	**Indirect inflation impact (profit adjustment)**	**Indirect inflation impact - Counterfactual scenario (no profit adjustment)**	**Indirect inflation impact - Counterfactual scenario (profit adjustment)**	**PPI Austria (real) - without B and D35**	**B**	**D35**
Average price increase	total	4,6	6,4	1,6	2,1	12,3	88,5	84,9
	2021	1,3	1,8	0,4	0,5	5,4	28,5	22,1
	2022	7,4	10,3	2,7	3,3	17,9	140,9	138,6
	2023-01 to 2023-02	7,3	10,2	2,7	3,4	20,3	133,5	139,5
	2021-01 to 2022-09	3,7	5,2	1,3	1,6	10,6	72,7	68,1
	2022-10 to 2023-02	8,2	11,5	3,0	3,7	19,4	154,8	155,2
PPI Indirect scenario %-change (yearly)								
							Shock Scenarios	
Average price increase	total	3,3	4,7	1,2	1,5	9,0	62,8	63,2
	2021	2,0	2,7	0,7	0,8	6,5	42,2	33,9
	2022	5,1	7,1	1,9	2,4	11,9	89,6	99,4
	2023-01 to 2023-02	1,2	1,7	0,4	0,5	6,5	25,3	21,6
	2021-01 to 2022-09	3,6	5,0	1,3	1,6	9,3	66,6	67,2
	2022-10 to 2023-02	2,4	3,4	0,9	1,1	7,5	46,5	46,0

Figure 10: Average Inflation Impact using 2000-2014 Tables

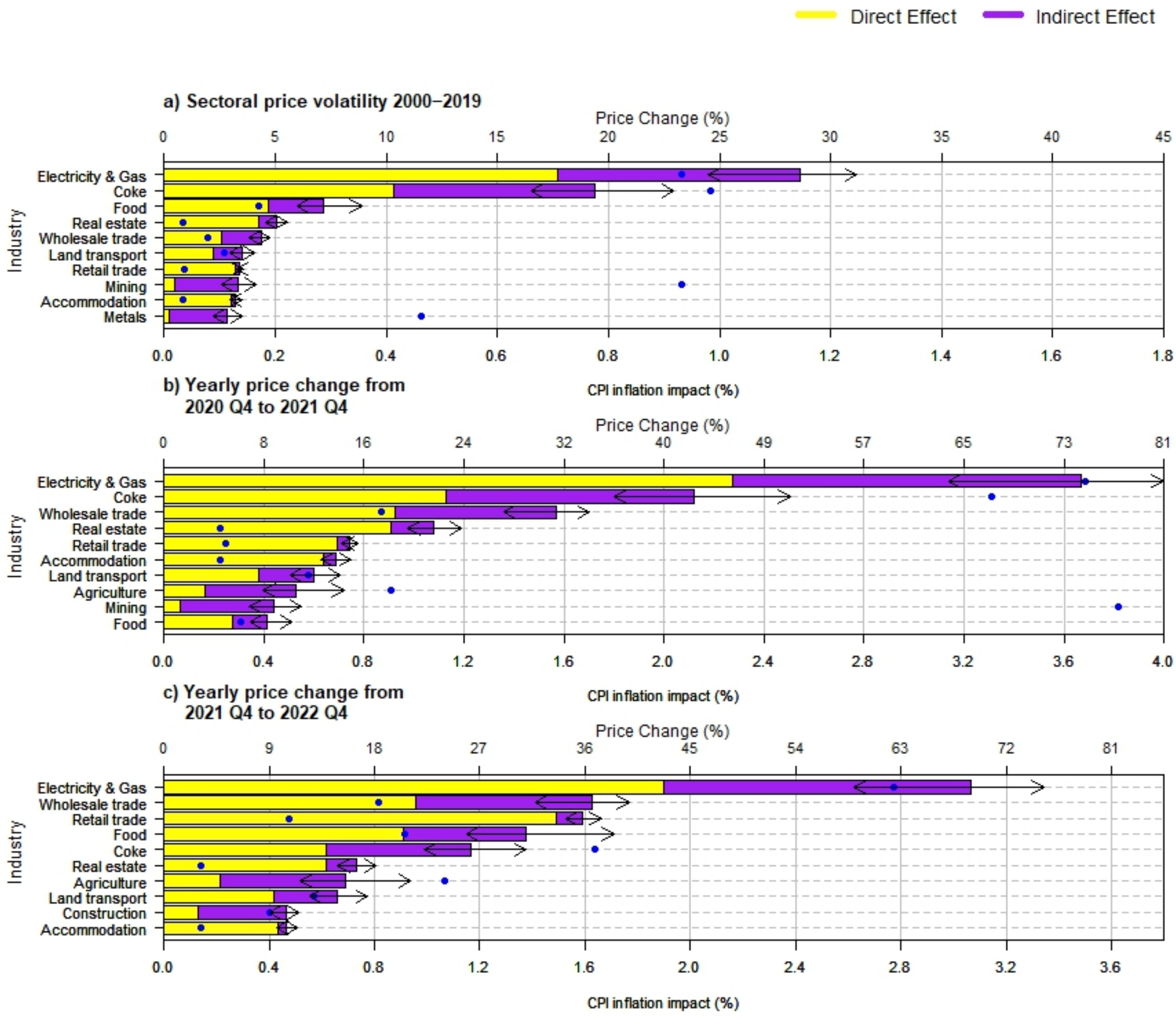

Figure 10 shows the average direct and indirect inflation impact using the WIOD's 2000 to 2014 Input-Output tables as a basis to construct the different sectoral price shocking scenarios. The arrows indicate the maximum and minimum total inflation impact of the industry from the years 2000 to 2014 and are scaled on the lower y-axis. The magnitude of the sectoral price shocks is the same as for the scenarios shown in Figure 1.