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# Contents

## Abstract

The aim of this paper is to assess the impact on the Polish economy of energy price shocks arising after the Russian invasion of Ukraine. We computed both the impact of the energy shocks (separately for gas, oil and coal prices) on the real side of the economy, and the pass-through of energy prices to the overall price level. The former part of the analysis was simulated using a computable general equilibrium (CGE) model of the Polish economy while the price effects of the shocks were simulated using a dual Leontief price model. Additionally, the price model was augmented with the mechanism of nominal wage adjustment suggested by the theory. This methodological novelty is our original contribution to empirical economics. Our simulations indicate that the price shock for all energy goods of the magnitude observed in 2022 resulted in a decrease in GDP of about 2.9% relative to the baseline solution. Moreover, we document a strong pro-inflationary effect of rising energy prices. After a combined shock to energy prices the consumption deflator increases by 10.3% (when we include the spreading the price increases across the industries), but the effect is simulated at 15.4%, when we account for an additional nominal wage adjustments (ensuring no real wage changes). We show that due to the differences in forward and backward propagation of shocks, the oil price shock had the strongest impact on real aggregates, whereas prices were hit the strongest by the gas price shock.



**JEL: C67, C68, D58, E16, E17, E31, Q43**

**Keywords: CGE, dual Leontief model, energy shocks, price pass-through**

# Introduction

The Russian invasion of Ukraine in February 2022 has triggered significant political, military and humanitarian consequences in Ukraine, but the ongoing war also exerts an impact on economic processes in Europe and even on the global scale. Although the overall importance of both Russia and Ukraine for the global economy is rather moderate, Russia has been a key supplier of energy carriers and some commodities to many European countries, including Poland. Before the war imports from Russia covered 35.0% for the total demand for energy products of the Polish economy, of which 45.5% for the natural gas, 76.3% for the oil and 13.4% for coal. All in all, Poland was more dependent on Russian energy products than the EU27 average, except for coal.[1]

Both the aggression and the accompanying period of growing political uncertainty raised legitimate concerns about the continuity of the supply of energy resources to EU countries, thus implying record high prices for energy carriers (see Figure 1). Increases in the prices of fossil fuels, as a result of the sudden reduction in their supply, were felt primarily on European stock exchanges. The prices of natural gas and hard coal spiked to levels exceeding long-term averages by several hundred percent. The oil prices also soared, but to a lesser extent. Thus, significant price increases were observed in electricity generation, fuels, transportation and gas used for heating or for production purposes. The increasing energy prices, coupled with rising food prices, and still present disruptions in supply of intermediates produced in global value chains, resulted in a rise of inflation and a slowdown of economic activity, triggering a stagflationary environment in European countries and in the whole global economy.

Due to its geographical location, the coal-dependent energy generation, and a significant reliance on Russian energy resources, the Polish economy was heavily affected by the rise of energy prices. The aim of this paper is to assess the impact that the energy price shock exerted on the Polish economy. We calculate the effects separately for gas, coal and oil prices (as they affect te economy in different ways), and jointly for all of them. We use the Computable General Equilibrium model of the Polish economy, which was developed in the NBP (for the documentation of the model, called $MOST_{PL}$, see Gradzewicz et al., 2021) to calculate the response of the

[1] Although Poland has domestic coal mining, it's used primarily by the energy sector, while the high quality coal imported from Russia was mainly used by the household sector for heating purposes.

real side of the economy (including the changes in relative prices) to the energy prices shocks. The results reveal the extent of substitution and complementarity adjustments between industries. Although the CGE-like models are the standard tools to model sectoral issues and shocks, they lack the nominal side of the economy. Thus, we use the dual Leontief model, calibrated consistently with the CGE model (except for the assumptions on the elasticities of substitution) to assess the pass-through of energy prices to the overall price level (measured as a consumption deflator). Moreover, we also calculate the additional price adjustment triggered by the so called second-round effect - a subsequent adjustment of nominal wages (leaving real wages unchanged). The latter is our original contribution to the empirical economics.

Our simulations indicate that the increases in the import prices of oil and gas have the strongest effects for the real economy, whereas the macroeconomic effects of the increases in the price of imported coal proved to be much weaker. The combined shock resulted in a GDP smaller by 2.8%. Moreover, the shock to gas prices have the strongest effect for the consumer prices, and the weakest reaction of consumer prices was observed for the shock to oil prices. A direct effect of the combined shock to prices of all three energy carriers, without any adjustment of the economy, was an increase in consumption deflator by 4.1%. Spreading of the combined shock into the economy increase the reaction of the consumer prices to 10.3%, and the further wage adjustment increase the price reaction to 15.4%.

The paper is structured as follows. After the literature review 1, Section 2 briefly describes both models used in the simulations. Next section present the definitions of the shocks. Then, Section 4 presents the outcomes of our calculations, and Section 5 concludes.

# 1. Literature review

The economic impact of the Russian invasion of Ukraine has been widely studied by researchers and economic policy analysts. Given a widespread consequences of the shock on individual economies, both at macro and sectoral level, various classes of models have been used to simulate the economic consequences of the war. Some authors have used Computable General Equilibrium (CGE) models to study the complexity of adjustment to the war shock. These models represent, in a detailed and consistent manner, the behavior of representative agents (households, firms, government) that guarantees the equilibrium of the economic system. When the equilibrium is disturbed by the shock (e.g. a shock to energy prices), agents re-optimize their behavior and the system moves to a new equilibrium (a new set of prices and quantities that maximize agents' welfare subject to their budget and resource constraints). Studies on the impact of the Russian aggression on Ukraine on the global and regional economies include: the World Bank analysis (see Ruta et al., 2022), applying the global computable general equilibrium model ENVISAGE; simulations using the Global Trade Model developed in World Trade Organization (see World Trade Organization, 2022, the model is a recursive dynamic extension of a static GTAP framework); simulations of the Bank of Italy (see Borin et al., 2022) applying a multi-sector, multi-country, general equilibrium trade model. Sokolowski et al. (2022) applied a DSGE modeling framework to assess economic consequences of the Russian invasion of Ukraine for the Polish economy.[2] The shock in this paper was defined as an embargo on fuels imported from Russia and the model simulations indicate it could reduce the GDP of Poland by 0.2–3.3% by the end of 2022 and by 2.1–5.7% by 2025, depending on the magnitude of the increase in prices of fuels.

Borin et al. (2022) provides a comprehensive analysis of the wide range of effects of the war on various regions of the global economy, and highlights some limitations of their model that may apply to CGE models in general. The authors point out that certain shocks, e.g. a sudden stop of energy supplies, as implied by the Russian invasion of Ukraine, generate frictions (e.g., contractual obligations and capacity constraints) that can be hardly handled within the modeling framework. For this reason, the results

[2] The model is dynamic and stochastic, in contrast to a static model used here, but it features a much less detailed disaggregation of the economy into industries, especially regarding energy sectors.

of the simulations may underestimate the impact of the shocks, especially in the short run, even for low elasticities of substitution. Therefore, the authors complement their analysis with a simplified model, focused on lower cross-sectoral input substitutability and a non-linear propagation of the shocks along the supply chain, relying on Baqaee and Farhi (2019a). The latter approach produces a much larger reaction of the war-related shock, resulting in a downward adjustment of the GDP of EU27 countries by 4% in the short-run, instead of 0.4% in case of CGE model. Bachmann et al. (2022) also stresses the role of substitution, showing that the effect of a stop of energy import from Russia for the German GDP ranges from 0.5% and 3% (the latter assuming the Leontief production technology).

One of the latest publications on the effects of the turbulences on the world energy markets stemming from the Russian invasion of Ukraine, with the use of a CGE model is the Chepeliev et al. (2022) paper. The authors applied a global CGE model ENVISAGE with a recursive dynamics and showed the results for both short and long term (year 2030). In reaction to a shock defined as 11% rise of energy prices households real income decline by 1.7% in the short term (closer to our comparative statics horizon) in the group of the EU countries. While the authors do not report specific results for Poland, they emphasize that the results may differ substantially across EU countries and that the poorer ones, with higher shares of energy and transport in household budgets (which is the case of Poland) are more vulnerable to energy price shocks.

Another limitation of the CGE modeling framework refers to its focus on the real economy and relative prices. In order to assess the impact of the shock to inflation, the macro-econometric models or the dual Leontief (input-output) models are often used in the literature, the latter especially in case when sectoral details matter. The examples of the applications of price input-output models to assess the impact of the shocks to energy markets include: Valadkhani et al. (2014); Llop (2020); Chang and Han (2020). The inflationary impact for different countries of the energy price increases after the Russian invasion of Ukraine were modeled by e.g. Yagi and Managi (2023), Zhang et al. (2023) or Martínez-García et al. (2023). All these papers use dual leontief models, but they differ from our approach, as they concentrate on a wider range of countries and they use standard IO matrices, with much less detailed information on energy sectors.

In our study we apply the dual Leontief model of prices in its form developed in Miller and Blair (2009), as it is well suited to our needs and can be calibrated consistently with our CGE framework. As the inflation rises after the energy price shock, triggering a decline in real wages, we additionally calculate the effect of energy price shock subject to no-change of real wages. The rationale for this step is that the price of one commodity should not permanently affect real wages of workers, as ultimately their productivity should not be altered by the relative price changes.

# 2. Description of models, definitions, and measurements

## 2.1. A short description of the CGE model $MOST_{PL}$

$MOST_{PL}$ is the model of the Polish economy that belongs to the class of the Computable General Equilibrium (CGE) of models.[3] The essential attribute of this class of models is the optimization by agents. Firms in each industry maximize profits producing its output using industry-specific CES technology modeled as a multi-factor production function with not only capital and labor (skilled and unskilled) but also materials (output of various industries, including energy carriers). The diagram of the production structure of the non-energy production sector (the energy sectors use slightly different structures, adjusted for the use of the primary energy carriers in the production processes) is presented in Figure 3 in the Appendix. Households maximize their utility from consuming different products, subject to budget constraints. Consumed products are nested into bundles, modelled as CES aggregates, as depicted in Figure 4 in the Appendix.

All agents operate within the markets for products and production factors. In each market there is a clearly defined equilibrium condition (price clearing the market). In each product market the supply of products is modelled as a CES aggregator of domestic production and imports, and the demand originates from both domestic agents (all production sectors buy products and use them as intermediates, households consume bought products, some of the products are also used for the purpose of investments) and foreign entities (exports). In each market for primary factors of production demand originates from all production sectors, and supply originates from all households. There are no industry-specific production factors.

This general structure of the model guarantees that all agents realize their optimal decisions, which are mutually consistent, i.e. demand equal supply in each market. The agents optimization problems allow for the substitution of production factors (in case of firms) or consumer goods (in case of households) in response to changes in relative

[3] The detailed documentation of the model (version as of April 2021), including its mathematical structure and exemplary simulations, can be found in Gradzewicz et al. (2021) and downloaded at https://nbp.pl/wp-content/uploads/2023/01/MOST_EN_dokumentacja.pdf. The $MOST_{PL}$ is built and solved using the gEcon package available in R environment, see https://gecon.r-forge.r-project.org/index.html.

prices. In CGE models all prices are expressed in relative terms (in $MOST_{PL}$ with respect to the fixed GDP deflator), since the model does not explain changes in the general price level.

$MOST_{PL}$ is a static model that represents a detailed characterization of the Polish economy. The model comprises 29 production sectors and the same number of goods and services produced and traded; three primary factors of production (capital and two types of labor: skilled and unskilled), three non-domestic trade areas (EU, Russia[4] and the rest of the world excluding Russia); and six household types distinguished by the dominant type of source of income and the place of residence. The model includes also a various taxes that are levied on different economic agents and at different stages of trade within the economy. Importantly, for the purpose of the appropriate transmission of energy shocks, $MOST_{PL}$ takes into account in detail both energy (including five distinct energy carriers) and environmental issues (emissions from domestic production and imports, environmental taxes, and EU ETS payments). Renewable energy sources (separated into electricity and heating) have been included into the model to represent increasing weight of these new technologies in the energy generation in Poland. The detailed treatment of the energy-related industries is a distinctive feature of the model, compared with the other models constructed for the Polish economy, which makes it well suited to address the question at hand.

In the simulations we adopted the mixture of the short-term and long-term elements of the model closure, i.e. 1) aggregate investments are a constant share of GDP, 2) wages are fixed (labor market clears via labor supply always meeting changes in labor demand at fixed wages[5]), 3) capital is mobile across production sectors, 4) balance of payments is fixed and variable exchange rates assures external equilibrium and 5) government budget constraint is met by deficit adjusting to changes in taxes (and to a lesser extent, part of the variable expenses). Since the $MOST_{PL}$ model is static, the simulations are interpreted as the comparative statics. Given no clear time dimension, the way we close the model indicates that the economy should adapt to simulated changes in relative prices after some period of time. The econometric results in Gu

[4]For the purpose of this study, Russia was separated from the rest of the world region in order to better quantify its dominating share in fossil fuels imports in modeling of the substitution effects.

[5]This way of closing the labor market in the model allows for the adjustment of the total employment in the economy.

et al. (2023) indicate that the time period for the economy to adjust to relative prices is between one and three years.

In the simulations on the $MOST_{PL}$ model we treat the energy shocks as increases of the foreign prices of energy carriers. They make the domestic production of the shocked energy carrier relatively cheaper (as it is not directly hit by the shock), which increases its domestic production. In most cases the domestic production is limited and the decline of imports is not compensated by the increase of domestic production, so the total supply of the energy carrier to the domestic market declines and its market price increases. Higher prices imply lower demand from both households and firms in the industries for an energy carrier being shocked and (to the extend limited by the substitution elasticities) an increase of demand for the other energy carriers, rising their production and prices.[6]. Higher energy prices propagate forward into the other prices in the economy, increasing the costs of production in other, especially energy-related industries, leading to a lower level of economic activity, lower demand for primary factors of production, including labor, and lower disposable income and consumption of households. The extent of the economic adjustment depends on the role of imports in the supply of the energy carrier being shocked, the size of the price shock and the dependance of the economy on this energy carrier.

## 2.2. A dual Leontief model of prices

We use a dual Leontief model (see Miller and Blair, 2009), based in a input-output matrix used in the $MOST_{PL}$ model, to derive the price effects of simulations. For the sake of exposition let us start with a brief description of the standard Leontief model. For each sector $i \in 1, \cdots, n$ the supply and demand for the products in that sector obeys:

$$X_i = \sum_{j \in 1, \cdots, n} v_{ij} + Y_i, \tag{1}$$

where $X_i$ is total supply (production of a sector plus imports) of a sector $i$, $v_{ij}$ is the output of sector $i$ used in the production processes of a sector $j$, and $Y_i$ is the final demand for products of a sector $i$ (including exports), all measured in current prices. As we do not use the world input-output data, we treat the open economy issues in

[6]In case of a simulation of a combined shock, with prices of all energy carriers increasing, the substitution possibilities are greatly limited.

the model in a simplified manner. Thus, we do not distinguish the rest of the world as a separate production sector, as we do not know its production structure. Instead, we include imports as an additional exogenous source of supply of products of a sector, and exports as an additional source of final demand. Defining a production structure matrix $A = [a_{ij}]_{nxn}$, where $a_{ij} = \frac{v_{ij}}{X_j}$ the model can be written in a convenient matrix form as: $X = AX + Y$, which has a solution of the following form: $X = (I - A)^{-1}Y = LY$. Matrix $L$ is known as a Leontief inverse.

Leontief dual price model (see Miller and Blair, 2009) introduces a separation of values into prices and volumes (i.e. $v_{ij} = x_{ij}p_i$), where $p_i$ is the price of goods in sector $i$ and $x_{ij}$ is the volume of production of sector $i$ used in sector $j$. The nominal cost of supplying products of sector $j$ can be expressed as:

$$X_j p_j = x_{1j}p_1 + x_{2j}p_2 + \cdots + x_{nj}p_n + v_j, \tag{2}$$

where $v_j$ is the vector with the values of the exogenous elements of total supply in the $j$-th sector - nominal value added (including the renumeration of primary factors of production) and imports. Dividing by $X_j$ and noting that $x_{ij}p_i = a_{ij}X_j$ we get the price within sector $j$:

$$p_j = a_{1j}p_1 + a_{2j}p_2 + \cdots + a_{nj}p_n + \frac{v_j}{X_j}. \tag{3}$$

Introducing $v_c = [\frac{v_j}{X_j}]_{nx1}$ and collecting the prices $p_j$ into a vector $p$, we get the equation $p = A^{'}p + v_c$, which has the solution given by:

$$p = (I - A^{'})^{-1}v_c. \tag{4}$$

The matrix $(I - A^{'})^{-1}$ is known as a Ghosh matrix. In contrast to the Leontief model, the dual model is not a general equilibrium model and describes only the production side of the economy (it does not include the market clearing condition, equation (1)). Thus, the changes in prices resulting from this model should be interpreted as changes in costs of production, holding the production cost structure fixed in real terms (due to the Leontief production function).

In the above system, prices are endogenous, and the shocks can enter the system through an exogenous $v_c$. In order to shock prices directly, Fullerton (1995) proposed to introduce an exogenous price wedge, treated as a surcharge (which can be interpreted as a tax $\tau$) on prices (for applications, see e.g. Hebbink et al., 2018; Bun, 2018). For instance, after imposing such a wedge on a sector $k$ only, the price equation in sector $j$ becomes:

$$p_j = a_{1j}p_1 + a_{2j}p_2 + ... + a_{kj}p_k(1+\tau_k) + \cdots + a_{nj}p_n + \frac{v_j}{X_j}. \tag{5}$$

Introducing the set of wedges $\tau_i$ existing on each market $i$ we can construct a diagonal matrix $1+\tau$ of the form:

$$1+\tau = \begin{bmatrix} 1+\tau_1 & 0 & \dots & 0 \\ 0 & 1+\tau_2 & 0 & \vdots \\ \vdots & 0 & \ddots & 0 \\ 0 & \dots & 0 & 1+\tau_n \end{bmatrix}_{n\times n} \tag{6}$$

Then the price model with the exogenous price components becomes $p = A^{'}(1+\tau)p+v_c$, which can be solved for prices:

$$p = (I - A^{'}(1+\tau))^{-1}v_c. \tag{7}$$

The model defined by equation (7) allows to introduce exogenous price variation and calculate how it translates into price of all other sectors taking into account the propagation of the cost shock throughout the input-output interconnections. The resulting price vector, inclusive of the shock, $(1+\tau)p$, can be then aggregated[7] with a use of arbitrary weights. We use the product structure of individual consumption in order to aggregate the results into a proxy of the consumption deflator.

In contrast to the CGE model, which 1) allows for substitution effects, existing in the demand, production and origins of supply to a domestic market and 2) takes into account the elements of macroeconomic adjustment, the Leontief price model is a "pure" price model. It does not take into account 1) the adjustments of the economic system to changing prices (assuming the fixed proportion Leontief production function), 2) the adjustment of prices or the usage of primary factors, 3) the adjustment of the demand to changes in relative prices. The prices from the dual Leontief model may be interpreted as changes in the costs of production, accounting for the input-output structure of the economic system.

[7] In the baseline solution to a dual Leontief model the vector of prices is unitary, so the solution to a shocked system can be directly interpreted as deviations from initial equilibrium.

The assumption of the Leontief technology (no substitution of inputs in production) used in the price model implies that one should interpret the results of the simulations as rather short-term and biased. The bias of the reaction of prices is positive, since accounting for the non-zero substitution would trigger the quantity adjustment and would limit the magnitude of the price effect.

We additionally complemented the results of the simulation with the wage adjustment mechanism of the simulated economic system. The dual Leontief model is a simple model of a price system of produced goods, which does not include the endogenous adjustment of prices of primary production factors, in particular wages (which are included in the exogenous component $v_c$). However, the shocks to energy prices result in a change of a consumption deflator, leading to a decline in purchasing power of nominal wages. One way to endogenize the wages in the simulation we perform is to assume that nominal wages need to adjust so as the real wages stay unaffected. Cost-push shocks that we consider are not direct shocks to productivity or effort and should not affect real wages.[8] Thus, nominal wages should increase in line with rising overall prices in the economy, pushing up prices further. We utilize this prediction and impose the no change in real wages restriction on the solution to equation (7). The solution is found in an iterative way. First, we solve the static price model given by equation (7) with just an exogenous shocks to $\tau$ and calculate the change in a consumption deflator $\Delta p_c = \sum_i \frac{c_i}{C} \Delta p_i$, where $c_i$ is consumption of good $i$ and $C = \sum_i c_i$. Then, we increase the $v_c$ with $\Delta p_c \frac{wL}{v_c}$ and solve the model with both an exogenous shocks to $\tau$ and an updated exogenous value added component. Then we recalculate the new vector of price changes, the change of the consumption deflator, update the $v_c$ and solve the model again. We repeat the steps until convergence, which occurs in 6-10 steps.

[8] A similar argument was used by Phelps (1967) and Friedman (1968) in the context of the long-run Phillips curve. Our choice of the wage adjustment mechanism is also consistent with the labor market assumptions made in $MOST_{PL}$ model. An alternative way to justify our choice is the assumption of a unitary elasticity of nominal wages to consumer price changes.

# 3. Definition of the shocks

In all simulations we apply a common definition of a price shock - an increase in the average monthly market[9] price of a energy carrier in 2022, relative to the average monthly price in the pre-pandemic period 2015-2019, as depicted on Figure 1. As the disruptions in gas supplies from Russia concerned Europe, the price increases in the natural gas were much higher in Europe than in the rest of the world. The price of natural gas on the European trade platform (TTF) increased by 590% (in 2022, relative to the average of 2015-2019), whereas on the US market (Henry Hub) gas prices rose by nearly 100%. In the simulations using CGE model we can impose different prices of imported goods from: 1) EU countries, 2) Russia, 3) the rest of the world. We assumed a gas price increase in 590% in case of gas imports to Poland from both Russia and the EU, and an increase of prices by 75% for imports from the rest of the world. A lower price increase for the rest of the world allows: 1) to mimic the lower price increases observed outside Europe, 2) to induce the substitution of imported gas away from Russia and into the other import directions, observed in practice[10], 3) to mimic the observed changes in the geographical structure of gas supplies to Poland, including an increase in the domestic production of natural gas by ca. 16%.

The increase in the coal prices was significant, but lower. On the ARA market[11] prices of coal in 2022 increased by 307% compared to the pre-pandemic average. Outside of Europe, the increase in prices was slightly lower - The Richard's Bay price of coal[12] rose by 265%. The CGE simulation assumed an increase in coal prices from Russia and the EU by 265%, and an increase by 30% for the price of coal from non-EU imports. Again, the lower increase in the rest of the world prices was intended to mimic the substitution between geographical regions taking place in practice and to replicate the fact that the coal imports to Poland increased from

[9]The simulation does not account for the tax and regulatory reactions introduced by the Polish government to dampen the reaction of prices of energy carriers, mainly for households.

[10]The only way to generate a substitution effect in the $MOST_{PL}$ model is to change relative prices, whereas in reality changes of the regional pattern of the energy imports were driven by the political and discretionary decisions. The macroeconomic results of the simulation were roughly unchanged with reasonable modifications of price changes in the rest of the world (it is not the main region of a supply of gas to Poland).

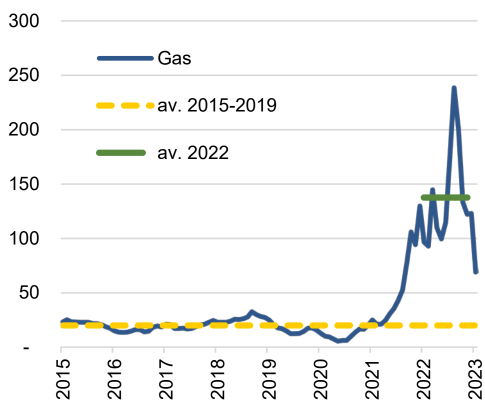
[11]ARA stands for Amsterdam, Rotterdam and Antwerp.

[12]The price of coal loaded at the Richard's Bay Coal Terminal in South Africa.

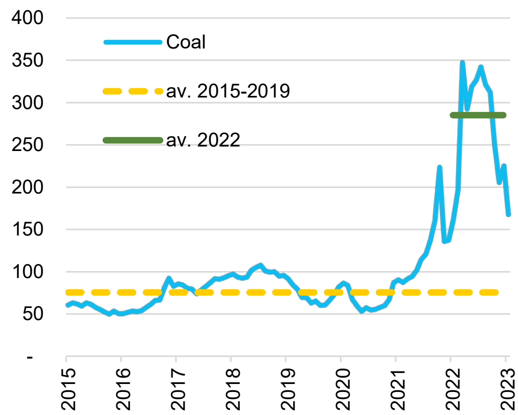
about 12.5 million tons in 2021 to more than 20 million tons in 2022.

**Figure 1:** Price developments for energy carriers: gas, coal and oil

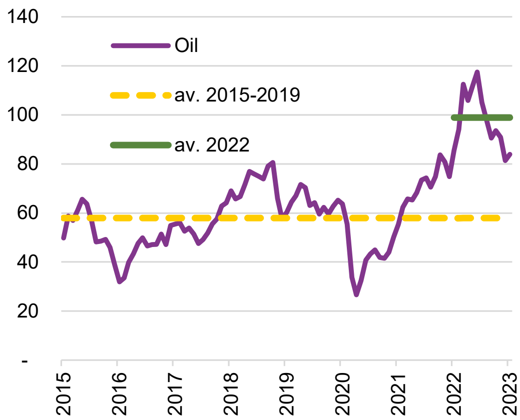
**(a)** Natural gas (TTF, USD/MWh)




**(b)** Coal (ARA, USD/t)




**(c)** Oil (Brent, USD/b)




Source: Own calculations

World prices of oil increased by about 71% in 2022 compared to the 2015-2019 average. In the CGE simulations we assumed a 100% increase in the price of oil imported from Russia and a 15% increase for EU and non-EU imports. The relatively stronger price increase for Russian oil introduces a price differential between import origins. It is also intended to mimic the effect of a strong decline in oil imports from Russia and a shift in the supply structure towards non-European and (to a limited extent) EU countries.

In the case of the price simulations, which use the dual Leontief model, the magnitudes of the shocks were calculated consistently with CGE analysis. The dual Leontief model is expressed in terms of total supply (the sum of domestic production and imports from all origins). Thus, the shocks, $\tau_i$ in the equations (6) and (7), were calculated as an increase in imports implied by the price increases in energy carriers just discussed, holding quantities imported fixed and expressed in terms of the value of the total supply of a given energy carrier on the domestic market. The simulation results were then aggregated using the product structure of consumption into the consumption deflator.

One should bear in mind, that the resulting effect for overall prices should be interpreted as a possible increase in consumer prices, originating solely from a change in the cost of production of the final consumer goods and services in the short term, with no adjustments in the structure of demand or production in response to changes in relative prices. The leontief model also assumes no change in corporate markups as a result of the energy shock. Moreover, the calculation assumes no changes in inflation expectations, which may cause secondary effects on consumer prices. Instead, we calculate the additional effects of nominal wage adjustment.

Moreover, it should be emphasized that due to the different structure of the basket of CPI and HICP indicators (which are based on COICOP classification of consumption categories) relative to the basket comprising the deflator of individual consumption based on basket in terms of NACE production categories (as in our case) and the different way in which they are constructed, the results obtained from the dual Leontief model and the $MOST_{PL}$ model should not be interpreted as changes in the CPI or HICP.

# 4. The results of simulations

The aim of the study is to determine the consequences of the price shocks and to contribute to the discussion on the magnitude of its impact on the key macroeconomic aggregates. We divide the description of the results of the energy shocks described in section 3 simulated using CGE model described in section 2.1 into the results for the main national accounts aggregates, and the impact on the selected, most crucial industries. Next, we present the result for prices using the dual Leontief model, described in section 2.2.

## 4.1. General equilibrium effects for aggregates

The magnitude of the reaction of the economy to the energy price shocks is a mixture of three features: 1) the size of the shock to foreign prices, 2) the share of imports in the total supply to domestic markets in a given industry, and 3) the exposure of the total economy to the shocked industry. First, as discussed in section 3, the largest price increases were observed for natural gas, lower increases were observed for coal, and the lowest price increases concern oil. Second, the exposure of industry to imports is the highest in case of coal (73%) used by households for heating[13] that is imported mostly from Russia (ca. 62%). In case of oil, almost 44% of the total supply relies on imports, of which ca. 33% from Russia. Imports of gas is also a significant part of the total supply (ca. 28%) and again Russia was the key supplier to Poland (ca. 45% of total imports). Third, the Polish economy is relatively highly exposed to oil industry - the share of value added of oil industry in the total value added is 2.1% and its Domar weight[14] is 6.6%. The exposure of the economy to gas is 0.9% and 2.1%, measured as value added share and Domar weight, respectively. Coal is the least important energy carrier from the macro perspective - its value added share is 0.75% and its Domar weight is 1.6%.

The increase in gas prices, as observed in 2022, results in a 1.1% reduction in GDP (denoted $Y$, see table 1), again mainly driven by a significant reduction in private

[13] In case of the coal used by the industry (mainly energy generation) the exposure to imports is much smaller - only ca. 16% of total supply is imported, of which ca. 43% from Russia.

[14] Domar weight is defined as a ratio of industry gross output to economy value added and is a sufficient statistics measuring the exposure of the economy to industry, inclusive of input-output linkages, see Domar (1961) or Baqaee and Farhi (2019b) for a more recent exposition.

(denoted $C$) and public (denoted by $G$) consumption (by 1.5% and 1.7%, respectively). Strong decline of the real consumption expenditures is mainly driven by the falling employment (by 1.2%), further strengthened by the increase of relative consumer prices by 0.3%. A reduced level of economic activity is accompanied by a decline in imports (denoted by $M$). Higher costs of domestic production translate into higher prices and reduce the exports ($X$).

**Table 1:** Changes in basic macroeconomic aggregates as a result of the shock (real changes, in % difference from baseline solution)

| NA aggregate / Shock type | Y | C | I | G | X | M | Labor |
|---|---|---|---|---|---|---|---|
| Gas | -1.1 | -1.5 | -1.1 | -1.7 | -0.7 | -1.3 | -1.2 |
| Coal | -0.3 | -0.6 | -0.3 | -0.2 | -0.3 | -0.6 | -0.3 |
| Oil | -1.3 | -2.2 | -1.3 | -1.3 | -1.0 | -2.1 | -1.7 |
| Combined | -2.8 | -4.6 | -2.8 | -3.4 | -1.9 | -4.2 | -3.3 |

Source: own calculations based on $MOST_{PL}v$.2.1.1. model

The rise in prices of imported coal translates into much weaker decline in economic activity than the rise in prices for other energy commodities. GDP drops by only 0.3%, and the shock operates mainly through consumption (which declines by 0.6%, twice as much as GDP). As with the gas shock, household consumption is pulled down by the mild drop of employment (by -0.3 %) and an increase of the relative consumer price index (by 0.4%). It is due to the fact, that the imported coal is mainly used by households (as the final consumption) and is less used by energy generation industry, which relies heavily on domestically produced coal, relatively untouched by the simulated changes of prices of foreign coal.

The increase in oil prices, as observed in 2022, impose the largest negative impact on GDP (i.e. a reduction of 1.3%, see Table 1). It is largely the result of a strong reduction in household consumption, by 2.2%, but also a decline in the other components of the domestic demand. Within the consumption bundle, there is a strong reduction in consumer demand for private transportation (by more than 10%) with an accompanying increase in demand for public transport (which is relatively less hit by the shock).

In reality, these three shocks hit the economy simultaneously, and it is interesting to simulate the effects of the combined shock. The results (presented in the last row of Table 1) are not just the sum of the individual simulations, as the underlying model is non-linear and the choice of substitution alternatives (with exception of more expensive energy carriers) is limited in the case of a combined shock. The response of GDP to a combined shock of simultaneous increases in prices of all three energy carriers is significant and amounts to -2.8%. The strongest impact of the combined price shock is observed for households, which reduce their consumer demand by 4.6%. The strong reaction of consumption is due to various forces. First, employment falls by 3.1%, translating into a decline in real disposable income of households of a similar magnitude. It is the main driver of the sharp drop of the household consumption. Second, with the contraction of the global output, the employment of capital falls slightly (by 0.2%) and its price declines substantially (by 3.5%), both negatively affecting the incomes of the households owning the capital assets (mainly small firms owners). Additionally, the combined shock induce a rise of a price of a consumption relative to GDP deflator by 1.5%, putting downward pressure on private consumption. The economy experiences also a reduction in investment (denoted $I$) and government consumption, by 2.8% and 3.4%, respectively. Increases in the price of imported energy commodities, together with the reduced domestic consumption, strongly limit the demand for imported goods, by 4.2%. Moreover, increases in the costs of domestic production lead to a decline in exports by 1.9%.

## 4.2. The effects for industries

Table 2 presents how the simulated shocks affect selected industries. Due to capacity limitation we show the results mainly for energy-related sectors. An increase in gas import prices induces a decrease in gas imports by over 50%, and the rise in relative prices on the domestic market by 46%, which stimulates an increase in the domestic production. As a result, gas supplies to the domestic market decrease by 13%. The necessary demand adjustment is achieved to a large extent by households, which decrease their gas consumption by over 26% and increase their demand for the other energy carriers (note that simulation does not account for tax and regulatory changes introduced in reality in order to dampen the reaction of prices for households). Rising gas prices have a significant pro-inflationary impact on prices and a negative impact on output in many manufacturing sectors, in particular in the sectors covered by the EU ETS system, where the relative market prices increase by 2.2%, and in the energy-intensive sectors (including heat and electricity production), where the relative prices increase by 1.9%. The increase in the gas prices induce a (limited) substitution effect within various energy carriers, from gas towards other energy sources, mainly coal and renewable energy sources.

The shock to prices of imported coal induce a strong decline in imports of coal used by households (by over 51%). The accompanying rise in the relative market price of coal (by 48%) affects positively domestic production (which rises by 31%), but its share in total supply is limited and the total supply of coal drops by almost 40%. A significant increase in the market price of coal triggers households to replace coal with gas, system heating and renewable energy sources, triggering production and total supply in these industries. The rise in import prices also applies to coal used by industry, but its impact on this market is limited - total supply declines by only 4.1% and relative market price rises by 10.7%. Contrary to the case of increases in gas prices, rising import prices of coal do not affect significantly other production sectors in the economy, with the important exception of coal-based energy (electricity generation) and heating, where a noticeable increase in prices is observed.

An increase in import prices of oil translates into an increase in relative market prices of fuel by 13%. Import volumes decline by 21%, which combined with a slight increase in domestic supply translates into a decline in total supply by 5.3%. Rising fuel prices on the domestic market have a particularly strong impact on consumer demand for fuels, which decreases by 12.2%. The increase in fuel prices and an accompanying decline in its supply affects negatively almost every industry. In particular, transportation sector is mostly affected, with relative prices rising by 2%. The production of transport services decreases by 1.5%, and the demand is limited mainly by enterprises, as consumers (moving their demand from individual transport to transport services) increase their demand for transportation by 4.1%. Moreover, the energy-intensive industries are relatively more affected by the shock.

**Table 2:** Sectoral results of the gas, coal, oil shocks for selected production sectors in Poland

| Shock type | | Sector | Production | Import prices | Market prices | Import | Total Supply | HH cons. |
|---|---|---|---|---|---|---|---|---|
| | **Gas** | Total | -0.7 | 1.3 | 0.6 | -1.5 | -1.0 | -1.5 |
| | | Gas | 18.8 | 172.7 | 45.9 | -53.3 | -12.8 | -26.2 |
| | | Coal HH | 5.7 | -3.0 | -2.1 | 14.1 | 11.1 | 10.0 |
| | | Coal indust. | 5.2 | -2.2 | 0.0 | 10.4 | 6.0 | 10.4 |
| | | Heat | 7.7 | -0.1 | 1.3 | 7.9 | 7.7 | 12.8 |
| | | Heat RE | 11.3 | -1.6 | -0.8 | 11.5 | 11.3 | 14.3 |
| | | Electricity | 4.2 | 0.0 | 0.9 | 5.8 | 4.2 | 0.8 |
| | | Electr. RE | 7.4 | 0.1 | -0.8 | 5.3 | 7.3 | 2.3 |
| | **Coal** | Total | -0.2 | 0.3 | 0.1 | -0.6 | -0.3 | -0.6 |
| | | Gas | 3.4 | -1.5 | -0.7 | 5.3 | 3.9 | 8.3 |
| | | Coal HH | 31.4 | 81.1 | 48.6 | -51.0 | -39.5 | -27.7 |
| | | Coal indust. | 12.6 | 117.8 | 10.7 | -57.9 | -4.1 | -3.8 |
| | | Heat | 0.6 | -0.1 | 1.4 | 0.8 | 0.6 | 4.3 |
| | | Heat RE | 2.9 | -1.1 | -0.2 | 3.1 | 2.9 | 5.7 |
| | | Electricity | 0.2 | -0.1 | 1.9 | 3.4 | 0.2 | 1.5 |
| | | Electr. RE | 2.4 | -0.1 | -0.2 | 1.9 | 2.4 | 3.5 |
| | **Oil** | Total | -0.9 | 1.2 | 0.3 | -2.6 | -1.3 | -2.2 |
| | | Industr. prod. | -0.7 | 1.4 | 0.6 | -2.9 | -1.6 | -3.4 |
| | | Transport | -1.5 | -0.2 | 2.1 | 1.8 | -0.6 | 4.1 |
| | | Oil | 4.7 | 24.3 | 13.2 | -21.3 | -5.3 | -12.2 |
| | | Coal HH. | -6.6 | -7.2 | -5.4 | 10.0 | 3.8 | 1.6 |
| | **Combined shock** | Total | -1.8 | 3.1 | 1.0 | -5.1 | -2.7 | -4.5 |
| | | Gas | 20.7 | 168.0 | 44.8 | -53.5 | -11.0 | -21.6 |
| | | Coal HH | 37.1 | 77.2 | 46.8 | -49.1 | -35.1 | -22.9 |
| | | Coal indust. | 17.6 | 109.6 | 10.6 | -55.5 | 0.8 | 4.2 |
| | | Oil | 1.7 | 20.8 | 11.6 | -19.6 | -6.6 | -13.1 |
| | | Heat | 6.7 | -0.6 | 2.4 | 7.1 | 6.7 | 15.7 |
| | | Heat RE | 13.9 | -7.3 | -2.3 | 15.4 | 13.9 | 19.7 |
| | | Electricity | 2.9 | -0.7 | 2.4 | 8.5 | 3.0 | 0.4 |
| | | Electr. RE | 9.3 | -0.2 | -2.3 | 4.5 | 9.2 | 4.7 |

Source: own calculations based on $MOST_{PL}$ model,

Remarks: HH cons. = Households consumption, Coal HH = Coal for households, Coal indust. = Coal used in industrial production, Electr. / Heat RE = electricity / heat from renewables, Industr. prod. = industrial production (NACE sections B-E), Import and market prices are price changes relative to GDP deflator

### 4.3. The effects of shocks for prices

As described earlier, we use a dual Leontief model to simulate the reaction of the levels of prices (in contrast to the results from the $MOST_{PL}$ model, which solves for relative prices) to the shocks to energy carriers. The columns 'p Leopntief' in Table 3 present the reaction of prices (both sectoral prices and aggregate consumer prices in the last row) to all the shocks considered. They indicate a strong, pro-inflationary effect of rising energy commodity prices, but the impact of the shocks on prices is different than in case of an impact on GDP (see Table 1). In case of real variables, the highest impact was observed for oil price shock, then gas price shock, and the lowest in case of coal price shock. In case of price reaction, gas price shock has the highest inflationary impact - the simulation shows that the increase in gas prices in 2022 (compared to the average of 2015-2019) resulted in an increase in a consumption deflator by 6.6%. The inflationary impact of coal and oil prices hikes was similar in magnitude and amounted to 2.4% and 2.3%, respectively. The differences in the exposure of prices and quantities to the shock is related to differences in forward and backward linkages of the energy sectors (see Table 5 in the Appendix).

As mentioned earlier, the price effects do not take into account the adjustments of demand or production technology in response to strong changes in relative prices, as well as changes in inflation expectations, and various rigidities in the wage and price-setting processes. In addition, the results of the underlying dual Leontief model can be interpreted as price changes originating only from changes in production costs, with unchanged markups (imposing zero price elasticity of demand). Despite these caveats, these simulations can be viewed as an important complement to the results of the CGE model, discussed in section 4.1.

Table 3 shows also the comparison, for each of the simulations considered, of percentage changes in absolute prices (from the dual Leontief model) and relative prices (from CGE model, together with percentage changes of quantities), for selected industries. The numbers are not directly comparable, but in the Leontief case subtracting a consumption price change from the total price change, makes the comparison more suited (CGE measures all prices relative to the GDP deflator, but the difference in consumption and GDP deflators is relatively small). The comparison of relative price changes show the extent of substitution, which is present in the CGE

**Table 3:** Changes in quantities and relative prices in simulations from CGE model and changes of prices in simulations from the dual Leontief model

| Shock type → | Coal | | | Gas | | | Oil | | |
|---|---|---|---|---|---|---|---|---|---|
| Sector ↓ | q MOST | p MOST | p Leontief | q MOST | p MOST | p Leontief | q MOST | p MOST | p Leontief |
| Agriculture | -0.6 | -0.1 | 0.3 | -1.5 | -0.2 | 2.3 | -1.2 | -0.2 | 0.8 |
| Biomass | 10.5 | -0.1 | 0.2 | 7.5 | -0.3 | 1.5 | -3.9 | -0.2 | 0.6 |
| Coal HH | -27.7 | 48.6 | 130.2 | 10.0 | -2.1 | 1.5 | 1.6 | -5.4 | 0.2 |
| Coal production | -3.8 | 19.7 | 28.0 | 10.4 | 0.0 | 4.9 | -2.8 | -1.0 | 0.6 |
| Food industry | -0.6 | -0.1 | 0.2 | -1.6 | 0.1 | 3.3 | -1.2 | -0.3 | 0.5 |
| Other industry | -0.6 | 0.0 | 0.2 | -1.5 | 0.1 | 2.2 | -2.1 | -0.1 | 0.4 |
| Oil processing | -0.5 | -0.2 | 0.8 | -0.4 | -1.2 | 1.3 | -12.2 | 13.2 | 15.3 |
| Electricity | 1.5 | 1.9 | 5.0 | 0.8 | 0.9 | 8.6 | -2.4 | -0.6 | 0.4 |
| Electricity RE | 3.5 | -0.2 | 0.0 | 2.3 | -0.8 | 0.0 | -1.9 | -1.2 | 0.0 |
| Gas | 8.3 | -0.7 | 0.1 | -26.2 | 45.9 | 271.0 | -1.3 | -2.4 | 0.4 |
| Heating | 4.3 | 1.4 | 4.1 | 12.8 | 1.4 | 12.2 | -3.2 | -0.5 | 0.5 |
| Heating RE | 5.7 | -0.2 | 0.0 | 14.3 | -0.8 | 0.0 | -2.6 | -1.2 | 0.0 |
| Construction | -0.5 | 0.0 | 0.3 | -1.7 | 0.0 | 3.0 | -2.1 | 0.1 | 0.9 |
| Transportation | -0.5 | -0.2 | 0.2 | -2.6 | 0.1 | 4.4 | 4.1 | 2.1 | 2.6 |
| Market services | -0.6 | 0.0 | 0.1 | -1.6 | 0.0 | 1.5 | -1.2 | -0.2 | 0.2 |
| Non-market services | -0.5 | -0.1 | 0.2 | -1.5 | -0.2 | 3.4 | -1.2 | -0.5 | 0.3 |
| Total price change | - | - | 1.8 | - | - | 6.6 | - | - | 1.8 |

Source: own calculations based on $MOST_{PL}v$.2.1.1. and the Leontief's model

Remarks: All numbers in the table are expressed in percentage changes from the baseline; prices in the MOST simulations are measured relative to GDP deflator

simulations, and is absent in the results from the dual Leontief model.[15] The substitution effects are especially visible in shocked industries (or industries directly related to a shocked industry, like transportation in case of oil price simulation). The relative price changes from CGE model are much more muted, due to a decline in demand (quantity), which drives the price adjustment down.

[15] One should bear in mind that substitution is not the only feature that differentiates the results.

## 4.4. Propagation of the price shocks

In this section, we concentrate on the magnitudes of different adjustment mechanisms of prices to simulated shocks. To this end we use the results of the model simulations for the aggregate consumption deflator, calculated under different assumptions:

- **Initial** - a response of consumption deflator only to price change in an industry directly hit by the shock, without the price adjustment of the rest of the economy; calculated as a industry shock times the share of industry products in a consumption basket.
- **IO** - baseline results; a response of consumption deflator to a shock, including the price adjustment in the other industries;
- **Wages initial** - a response of consumption deflator to a shock, including the price adjustment in the other industries and the initial effects of nominal wage adjustment with consumption deflator change calculated in previous step, **IO**;
- **Wages final** - a full adjustment of prices in all industries and nominal wages to a shock, holding real wages unchanged (an iterative solution of the model).

Both Table 4 and Figure 2 show the result of this exercise. The first row of table 4 presents that without any adjustment outside of the shocked industry, the change in the price of gas has the largest impact on consumption deflator, followed by a shock to coal prices and oil prices. However, accounting for the forward propagation of prices across the economy[16] enormously increases the consumer price response to the gas shock (by a factor of 4.3). In case of coal and oil shocks the forward propagation across the economy increases the consumer price responses, but on a much smaller scale (by a factor of 1.3 and 1.6 respectively).

Additional wage adjustment (see row **Wages initial** in Table 4) shows the effect of consumption price increases with an additional wage increase in the magnitude equal to price change from the previous step, without this additional wage impulse spreading into the other parts of the economy. There is a heterogeneity of labor shares across industries, but for the aggregate results only the overall size of the adjustment matters. Thus, the ordering of the magnitudes of reactions is unchanged. The initial

[16] See 5 in the Appendix.

**Table 4:** Changes in households' consumption deflator as a result of the energy commodity prices' shock (real changes, in % difference from baseline solution)

| Adjustment type | Shock propagation | Final effect (Consumption deflator, %) | | | |
|---|---|---|---|---|---|
| | | Gas | Coal | Oil | Combined shock |
| **Initial** | Shock in sector (without adjustment) | 1.5 | 1.4 | 1.1 | 4.1 |
| **IO** | Intermediate consumption adjustment | 6.6 | 1.8 | 1.8 | 10.3 |
| **Wages initial** | Intermediate consumption and initial wage adjustment | 8.7 | 2.4 | 2.3 | 13.7 |
| **Wages full** | Full shock propagation | 9.7 | 2.7 | 2.6 | 15.4 |

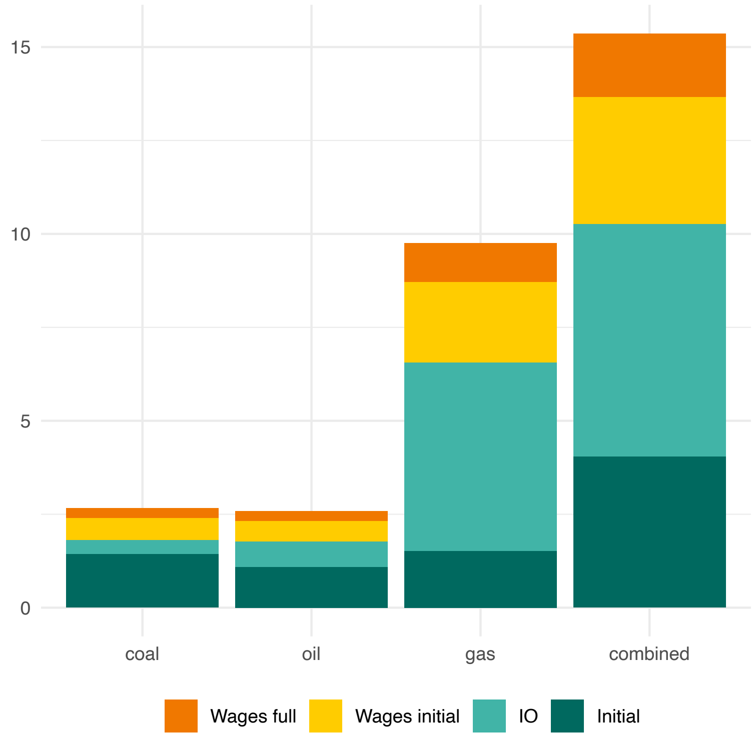
Source: own calculations based on dual Leontief model

adjustment of wages multiplies the reaction of consumption deflator by a factor of 1.3, quite homogeneous across shocks.

Feeding the shock to wages into the system, on top of the shock to energy prices, and allowing for endogenous adjustment of prices in all sectors increases the overall consumption price by an additional factor of 1.11-1.12, again homogeneous across the shocks. Thus, the final adjustment, with full shock propagation including wages, increases the reaction of consumption deflator (compared to the **IO** adjustment) by a factor of 1.46-1.49, i.e. by almost 50%.

The last column of Table 4 shows the percent change of a consumption deflator to a combined shock. The simulated impact excluding any additional adjustment is sizable and amounts to 4.1%. The reaction of all prices in the economy via the IO inter-linkages increases the reaction of consumption deflator by a factor of 2.5 and the consumption deflator due to changes in energy prices increases by 10.3%. A full propagation, inclusive of wage adjustment, makes the overall consumption deflator increase by 15.4%, i.e. by an additional factor of 1.5. Figure 2 shows the importance of

**Figure 2:** Propagation of energy price shocks into the economy [% change from the baseline]




Source: Own calculations based on dual Leontief model

various components of the full propagation mechanism for all shocks considered, and the combined shock.

One should bear in mind, that the results of the simulations are expressed in terms of comparative statics and should not be interpreted as consumer price changes within a year. Although it is hard to say exactly what is the time horizon of the simulated changes, the full propagation of shocks will last most probably a few years, till all wage negotiations and relative price changes settle down.

# 5. Conclusions

The Russian military aggression against Ukraine and the accompanying period of growing political uncertainty have raised legitimate concerns about the continuity of energy supplies to Europe, implying record high prices for energy carriers. In order to measure and evaluate the economic impact of rising prices of coal, gas and oil on the real economy, a simulation, using the a CGE model, of import price shocks for these energy commodities was carried out. In order to estimate the effects of energy price increases on the change in the level of consumer prices, a consistently calibrated dual Leontief model was applied.

In both the CGE and price Leontief model simulations, shocks to prices were defined as increases in average prices of a energy carrier in 2022 relative to the 2015-2019 average, which translated into strong price increases for natural gas, coal, and slightly lower for oil. Changes in the prices of individual energy commodities entailed macroeconomic effects, including consumption, of varying magnitude. The strongest were the real effects of increases in the import prices of oil and gas, whereas the macroeconomic effects of increases in the price of imported coal proved to be much weaker. The simulation results show that a combined shock, which actually took place, resulted in a GDP smaller by 2.8%.

Due to the differences in the forward and backward linkages of shocked sectors, the magnitudes of consumer price reactions was the strongest for shock to gas prices and the weakest for the shock to oil prices (and slightly higher in case of the shock to coal prices). As the increases in consumer prices could additionally translate into rising wages, feeding into the wage-price spiral, an additional set of simulations were calculated. They include the full propagation of price shocks, including nominal wage adjusting to the point with no change in real wages. Thus, the results of the price simulations increased by a factor of 1.5. The combined shock to prices of all three energy carriers, without any adjustment of the economy, translated into an increase in consumption deflator by 4.1%. Spreading of the combined shock into the economy increased the consumer price reaction to 10.3%, and further wage adjustment additionally increased the price reaction to 15.4%.

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# Appendix

## Forward and backward propagation of industry shocks

Table 5 presents measures of propagation of sectoral shocks in the Polish economy: forward (into prices) and backward (into quantities). The first column shows the backward propagation - the elasticity of value added to a sectoral shock, calculated as $\sum_j \left(\sum_i (I-A)\frac{X_i}{VA}\right)$. The next two columns present measures of forward propagation of two shocks to consumption prices. The second column shows the propagation of an increase of $\tau$ from zero to one (translating into doubling of the price level) in equation (7) to economy-wide consumer prices, measured as a consumption-weighted responses of industry prices (0.01 reads as an increase of consumer prices by 1%). The last column shows the propagation of a unit increase in $v_c$ (a ratio $\frac{v_j}{X_j}$ averages to 0.52 for the whole economy) in the basic Leontief model in equation (4) to economy-wide consumer prices, defined analogously.

**Table 5:** Forward and backward propagation

| Sector | VA effect | Price effect ($\tau$) | Price effect ($v_c$) |
|---|---|---|---|
| Agriculture | 0.048 | 0.096 | 0.101 |
| Biomass | 0.001 | 0.000 | 0.002 |
| Coal production | 0.011 | 0.014 | 0.013 |
| Coal HH | 0.003 | 0.000 | 0.011 |
| Food industry | 0.094 | 0.149 | 0.229 |
| Other industry | 0.662 | 0.368 | 0.517 |
| Oil processing | 0.086 | 0.064 | 0.139 |
| Electricity | 0.019 | 0.015 | 0.038 |
| Electricity RE | 0.003 | 0.002 | 0.004 |
| Gas | 0.015 | 0.033 | 0.034 |
| Heating | 0.003 | 0.005 | 0.008 |
| Heating RE | 0.002 | 0.001 | 0.002 |
| Construction | 0.056 | 0.121 | 0.083 |
| Transportation | 0.072 | 0.101 | 0.095 |
| Non-market services | 0.166 | 0.015 | 0.080 |
| Market services | 0.334 | 0.256 | 0.537 |

Source: own calculations based on the Leontief's model

## Additional figures

**Figure 3:** Diagram of cost structures of production industries

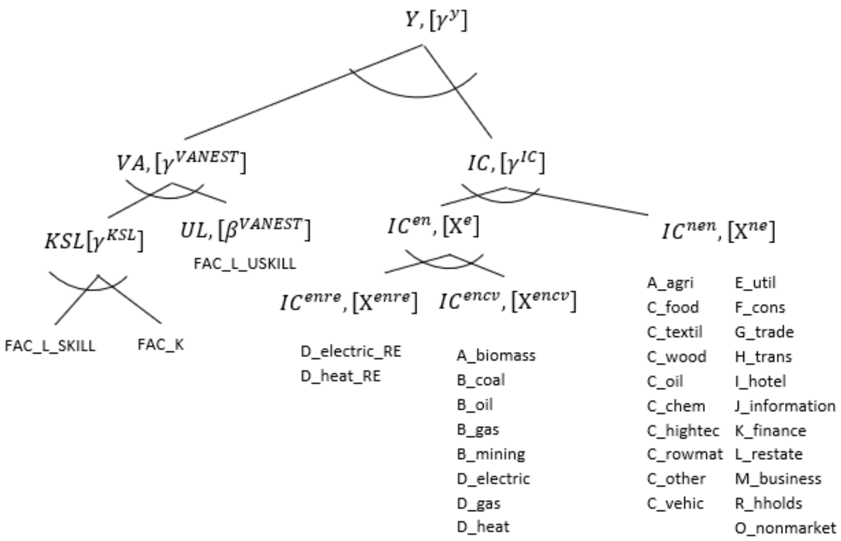
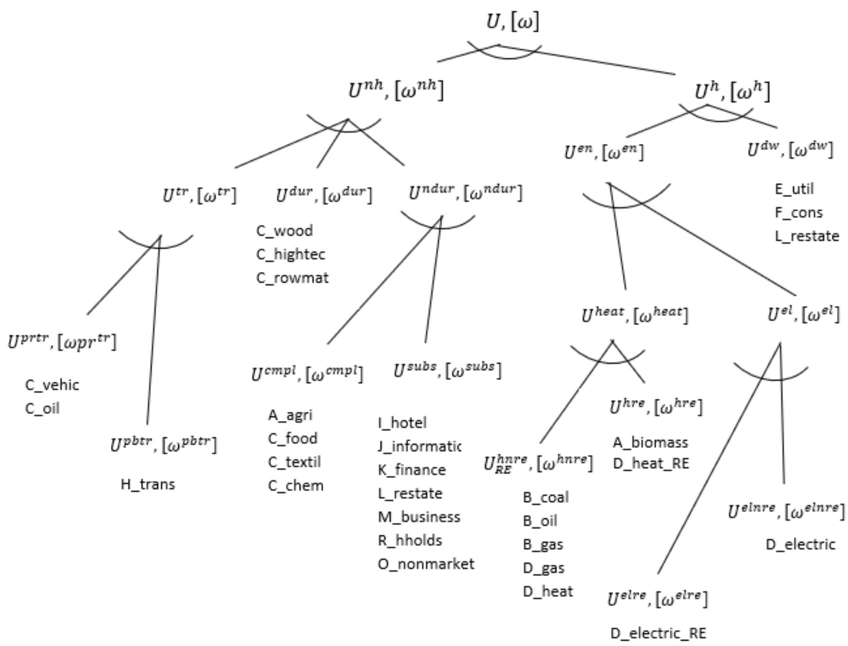



**Figure 4:** Diagram of households utility nests



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