# The effect of a ban on energy imports from Russia: The Case of Italy

Tommaso Castellani

Bocconi University, Milan
September 2022

*Before proceeding to the actual content of the Thesis, I wish to spend some words for those who helped throughout these years of personal and academic growth.*
*A heartfelt thanks to my thesis supervisor Prof. Basile Grassi for his exceptional guidance and patience during this last step of my undergraduate career.*
*I sincerely thank my family for always being there, especially in times of discomfort.*
*My special gratitude goes to my uncle Gianluca for the extraordinary support and advice that always helped me to find the right direction in my studies.*

*Thank you*

# Contents

# 1 Introduction

On Thursday, February 24th, 2022, the Russian Federation invaded Ukraine, bringing the ghost of war back to the European continent. The conflict has devastating military effects on the territory, causing thousands of casualties on both sides and, most, unfortunately, on civilians. Besides these regretful consequences, the war will also have a long-lasting impact on the world economy, mainly causing Russia's financial and economic isolation, which can disrupt supply and productive chains.

The countries sided against the war imposed economic sanctions on the aggressors; the European Union imposed an embargo on February 26th, 2022, on Russian products, leaving out energy namely Coal, Oil, and Natural Gas. It is imperative to highlight the strong economic links between European countries and Russia for all types of products but in particular for Energy products; the European Union as a whole is very dependent on Russian energy inputs, which account for nearly half of European energy generation [14]. Germany and Italy import 55% and 51% of their Natural Gas yearly consumption and more than 30% of their Oil consumption from Russia.

This economic dependence between these countries leaves space for two very plausible scenarios that lead to the same outcome. First, European countries may find it politically desirable to impose an embargo on Russian Energy products because it *"is the right economic decision and the fastest way to stop Putin's ability to finance his war in Europe"* from Guriev & Itskhoki (2022) [18]. It is possible to argue that the persistence of the war has a higher economic cost than imposing an embargo on Russia, as the war is an economic disaster for Europe; the Euro area is projected to be in a recession in the last quarter of 2022. Second, Russia could reduce or completely cut its gas and oil supplies to Europe during the winter as a counter-offensive to previous sanctions.

This paper aims to understand and quantify the economic consequences of these two scenarios focusing on Italy. The objective is to recognize the costs for Italy entailed by the political action of an embargo in the first scenario while uncovering the credibility of the Russian threat in the second scenario.

## 1.1 Related Literature

Since the beginning of the war, economic research on the possible outcomes and consequences has flourished. European reliance on Russian energy inputs has been a central area of study.

The paper from Bachman *et al.*(2022) [2] analyzes Germany's dependence on Russian energy inputs focusing mainly on Natural Gas where Russia accounts for 55% of German imports and nearly 27% of energy production. Landais *et al.* (2022) [4] perform the same type of analysis for France where Gas accounts for 15% of energy production and just 20% of it comes from Russia. Both papers quantify the effects of such a shock using two different models. On the one hand, they use a Baqaee & Farhi (2021)[3] multi-sector production network model reaching a similar result for both countries, a 0.3% GDP loss for Germany and a 0.2% GDP loss for France. On the other hand, they use a simpler model based on an aggregate production function with imperfect substitution across inputs. Following this approach, they estimate the economic damage at 2.2% GDP loss for Germany and 0.3% for France.

Our paper builds heavily on the literature on production networks. "Production networks and economic policy" by Grassi & Sauvagnat (2019) [13] to make a descriptive and quantitative analysis of Economic Networks. Works from Grassi *et al.* (2021) and Baqaee & Farhi (2021) [3] developed models to understand aggregate shocks into Production Networks.

## 1.2 Research Question

This paper investigates the economic effects for Italy of a potential ban on energy imports from Russia. We begin by developing a similar analysis to that of Bachman *et al.*(2022)[2] on Germany and Landais *et al.*(2022) [4] on France but focused on Italy. Similarly to their paper, we will first briefly describe the Italian dependence on Russian energy products (Section 4). Next, we will use these results to build a Simple Macroeconomic model with a CES production function to build the economic intuition for a reduction in energy inputs in general. This simulation will also allow us to pin down the upper and lower bounds of the shock's economic effect, highlighting the crucial role that policy should play. In the second part of the paper we will use a rigorous production network model to get additional estimates for the shock, but differently from other research, we will focus on Oil and Natural Gas decomposing the effect of the two (Section 5).

We will use these results to study the effects of possible policies within the frameworks of our models. Mainly we will go through some of the proposed policies by the IEA and the European Union (Section 6). To have a clear understanding of the Production Network theory underlying our models, we introduced a descriptive and quantitative analysis of the Italian Production Network accompanied by theoretical insights (Section 3) and by an accurate description of the data-set of Input-Output tables (Section 2).

# 2 Data

This section will briefly give a background theory for the structure of Input-Output tables and how it fits national accounting notions. Later, we will analyze our particular database in detail and describe the arrangements we took to use it.

World Input-Output tables summarize economic activity between countries and, more precisely, the inter-sectoral trade patterns between each country's different sectors. Input-output tables are a square matrix where the rows represent the sectors of production and the columns the sector of destination. Each table reports data for $m$ countries at a certain level of aggregation $n$ representing the number of economic sectors considered for each country. Hence, the square matrix M has dimension $(m * n) \times (m * n)$. Each element $M_{ij}$ represents the gross values of sales from industry $i$ to industry j.

The sum of each row $\sum_j M_{ij}$ is the total production of sector $i$ used as intermediate products for other goods. On the other hand, the sum of each column $\sum_i M_{ij}$ is the total intermediate consumption used by sector $j$ in other to make its products. On the rows, each industry $i$ produces goods used as intermediate products by sectors of all the different countries. It also sells products to either domestic or foreign final consumption made up of Household Consumption $(C_i)$, Government Spending $(G_i)$, and Investments $(I_i)$. Hence, for each sector i:

$$Y_i = C_i + G_i + I_i + \sum_j M_{ij}$$

Hence, the total production of each sector is either absorbed by final consumption or intermediate consumption, either foreign or domestic. Here we are looking at the total output of each industry, thinking of the world economy as a closed economy.

### 2.1 WIOT Groningen University Database

We use the 2014 World Input-Output database, the latest release of production network data from Groningen University [1]. It comprises sectoral data for 43 countries plus an aggregate "Rest of the World" residual sector that accounts for the missing data. It reports cross trade between the 54 economic sectors of each country, reported in column (1) of Table 1, filling a $2322 \times 2322$ squared matrix. Looking at each column of the table, after the cross-sectoral trades starting at column 2324, we have final consumption quantities for each sector of the world economy divided per country and in Private Consumption (C), Government spending (G), and Investments (I). After the 2322nd row of the table, we have some crucial quantities used in our analysis, namely "Taxes less subsidies on products", "Compensation of employees" and "Value added at basic prices".

The table is very large, and to run our economic model smoothly, sparing computational power, we modified the table to reach a simpler and more handily result. In our new table, we have just two countries, Italy, Russia and "Rest of the world" (ROW), that accounts for the missing countries. We differentiate the Italian economy in 54 sectors. At the same time, for Russia and ROW, we keep just two industries, namely (C19) "Manufacture of coke and refined petroleum products" and (D35) "Electricity, gas, steam and air conditioning supply" collapsing the rest of the sectors in an aggregate voice "Rest of the sectors" (ROS). D19 and C35 are the crucial sectors of our analysis representing respectively Oil and Natural Gas.

# 3 Analysis of the Italian production Network

In the previous sections, we have highlighted the crucial role played by the structure of the national economic network when studying the effect of shocks. In this part, we will first describe the Italian Production network as a closed economy studying the inter-sectoral trade patterns within the economy using a descriptive and quantitative approach.

To analyze the structure of the Italian Production network as an autarky, we ignore exports and imports, focusing on the domestic market. The structure of inter-sectoral trade can be seen as a network whose nodes are the economic sector that connects through edges when two sectors trade with each other. In our database, there are 54 nodes representing one sector of the economy indexed by {1,...,54}. It is functional to define and look at the adjacency matrix $\Gamma \subset \mathbb{R}^{54\times 54}$ where each element $(i, j)$ is the cost of input $j$ for the production of good $i$ divided total revenues of good i:

$$\Gamma = \begin{bmatrix} \frac{M_{11}}{Y_1} & ... & ... \\ ... & ... & ... \\ ... & ... & \frac{M_{nn}}{Y_n} \end{bmatrix}$$

The sum of each row $\sum_j \Gamma_{ij}$ is the total cost share of intermediate inputs for sector $i$, hence $VA = 1 - \sum_j \Gamma_{ij}$ is the value added by sector j, where some of it will be added by the employment component. Using the $\Gamma_{ij}$ values, we can make visual representations of the Italian production network for a first descriptive analysis.

[1] WIOD 2016 Release `https://www.rug.nl/ggdc/valuechain/wiod/wiod-2016-release`

### 3.1 Descriptive Analysis

Figure 1 represents the Italian Production Network in 2014 as a heat map where supply sectors are on the rows and use sectors on the columns. Each box is one element of the $\Gamma$ matrix hence the cost of industry $j$ as share of sector $i$ revenues; the darker the box, the higher the cost of that intermediate sector. From this figure, we can draw some conclusions about the structure of the Italian economy. First, it is easy to notice that the darker boxes are on the diagonal of the figure; hence firms use inputs mostly from other firms of the same productive sector, suggesting a mainly horizontal economic structure. Although, some sectors serve as suppliers for most of the others and are identifiable with darker rows, namely "Wholesale trade except of motor vehicles and motorcycles", "Land transport and transport via pipelines", "Financial Service Activities" and "Legal accounting activities". Additionally, we can notice some sparse and relatively darker boxes; for example, the "Manufacture of machinery and equipment" sector is unsurprisingly an important supplier for the "Manufacture of fabricated metal products". Summarizing, from this figure, we can conclude that the Italian economy is mostly horizontal because the self-links are the most important, but some critical interdependence across productive sectors exists.

Figure 2 represents the Italian Productive system a graph drawing technique based on Gansner *et al.* (1993)[11], Barth *et al.* (2002)[6] and Brandes and Köpf (2002)[8]. Each sector represents one productive sector, and its size is proportional to its total use (sum of domestic final and domestic intermediate production). The grey lines represent the edges between two nodes, and their thickness is proportional to their weight in the adjacency matrix $\Gamma$. In constructing the graph, we abstract edges of less than 2% and self-links to improve the chart's readability. From the graph, we can make multiple observations. First, Italian economic sectors are highly interconnected with each other differently than what the heat map suggested. There are many links between the different nodes, which are all above 2%. There is one sector only that is not connected "enough" (links are below 2%) to the rest of the economy, namely "Human Health" which we can observe to be on the right side of the graph. Second, we can watch a few sectors which are very large and are highly connected with other sectors; hence they have a significant total use value and are essential buyers/suppliers to the different sectors, i.e. "Wholesale Trade", "Real Estate", "Construction" and "Administrative Activities". Third, we can use this figure to uncover some productive vertical chains, from A01 "Crop and Animal Production" to C10-C12 "Manufacture of food products" to "Wholesale Trade" and "Food Services".

### 3.2 Network Statistics

The two figures below help us to get an initial idea of the structure of the Italian economy. However, they fail to give quantitative information about two critical features of production networks, namely *centrality* and *upstreamness*. Centrality measures the importance of a sector as a supplier to the economy, while upstreamness refers to the number of nodes between a given industry and the final demand.

We can measure centrality using two vital statistics, the weighted outdegree statistics and the Bonacich-Katz statistic. The weighted outdegree is computed by simply counting the number of customer sectors that use a given good or service as intermediate more or less intensively. Hence, the weighted outdegree is the sum of the $j$th row elements of the adjacency matrix $\Gamma$, $wo = \sum_i \Gamma_{ij}$. By construction, this measure varies from 0 (when the sector does not supply any sector of the economy) to the number of sectors (when it is the only supplier of all sectors of the economy). Looking at the Italian economy in 2014, we notice that the mean of the $wo$ is 0.6222 and the median is 0.4696 highlighting that the economy is mostly horizontal.

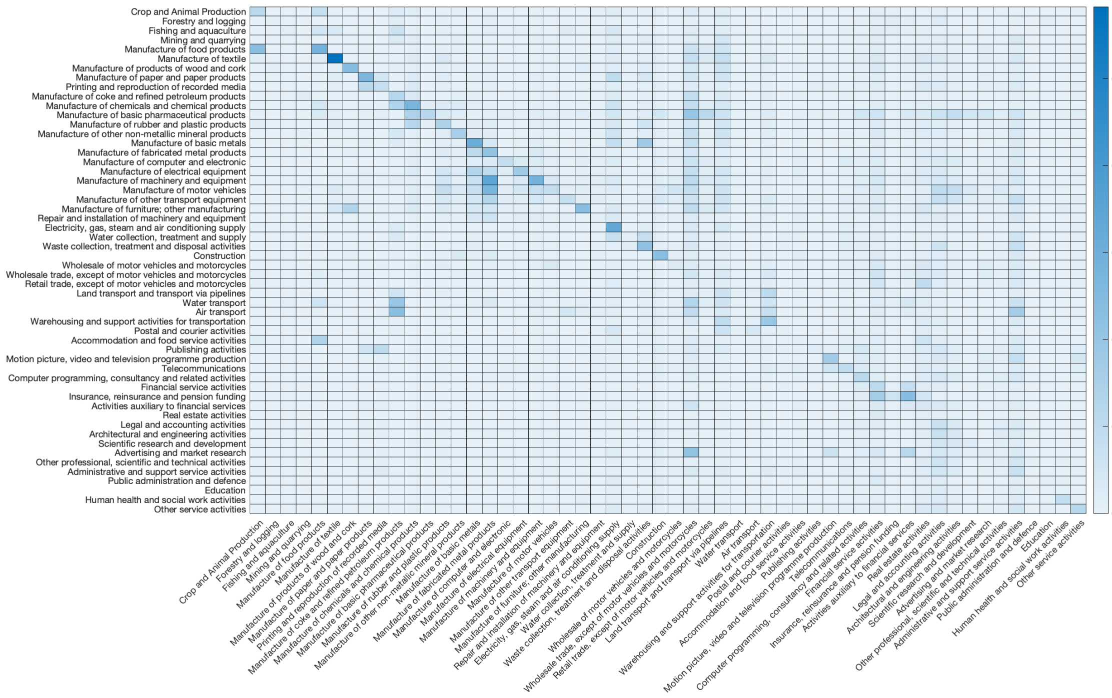


Figure 1: It represents the production network of the Italian economy in 2014. It plots the adjacency matrix Γ as a color map.

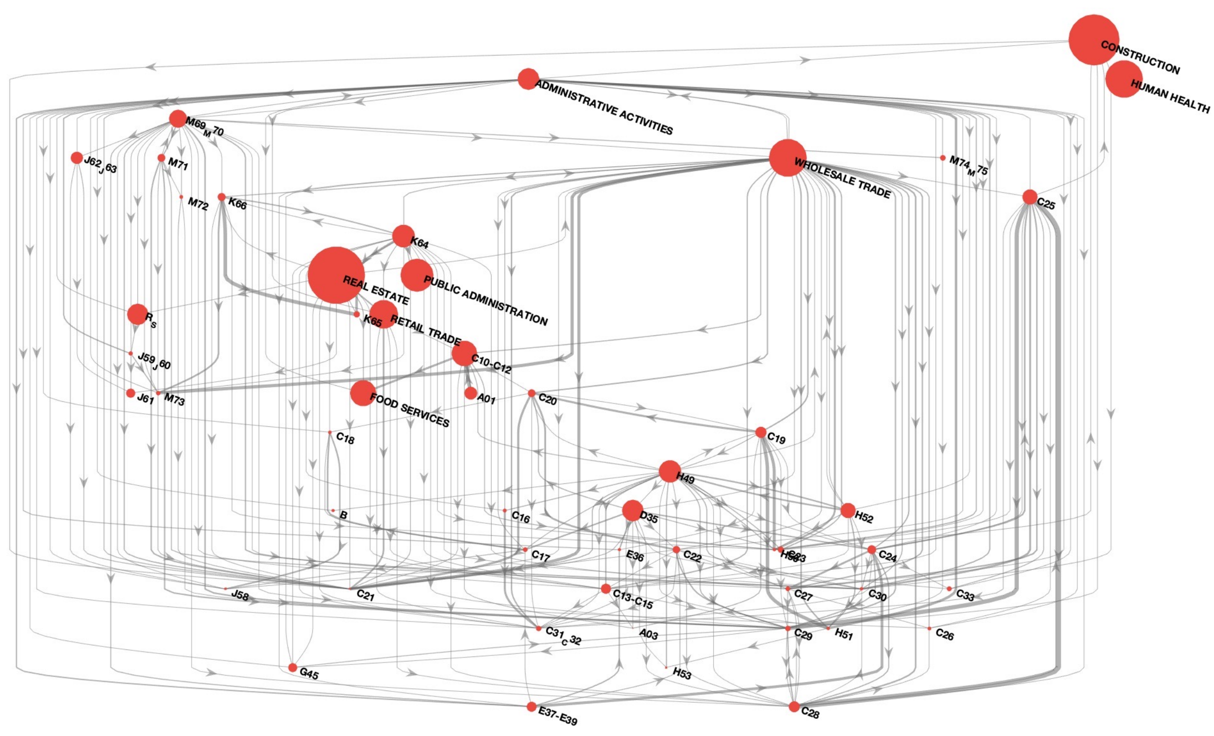


Figure 2: Node represents sectors. Node size is proportional to 'total use'. Edges thickness is proportional to the element of Figure 1 color map. Self-links and links below 2 percent are ignored.

Only a few sectors are important to a large number of counterparties. The maximum value of the weighted outdegree is 2.4723 for "Wholesale trade, except of motor vehicles and motorcycles" confirming what we noticed from Figure 1 and Figure 2. The minimum value of *wo* belongs to the "Forestry and logging" sector. Centrality can also be measured using the Bonacich-Katz statistic theorized by Bonacich (1987)[7], which is more accurate than the weighted outdegree because it considers both direct and higher-order linkages across industries. It is recursively designed as follows:

$$v_i = \beta_i + \sum_j v_j \Gamma_{ij}$$

Where $\beta_i = (C_i + G_i + I_i + X_i)/GDP$ hence the importance of sector $i$ as a supplier to final demand, and $\Gamma_{ij}$ is the adjacency matrix. The Bonacich-Katz statistic states that the centrality of a sector is equal to the importance of that industry as a supplier to final demand plus the weighted sum of the centrality of its customer industries. Table 1, column (3) reports the Bonacich-Katz centrality for the Italian economy in 2014. The mean is equal to 0.0371, and the median is 0.0218, suggesting similar results to the weighted outdegree, although with some differences. The maximum value is 0.1755 and corresponds to "Real estate activities" hence looking at the BK centrality, the "Wholesale trade, except of motor vehicles and motorcycles" is not the most central of the economy while it was for the *wo*. To conclude, the Bonacich-Katz centrality is a more reliable measure than the Weighted Out degree because it naturally arises from the construction of the production network, as shown by Bonacich (1987)[7].
When we analyze the upstreamness, we want to measure how close a sector is to final demand. There are some sectors that, in nature, produce goods not suited for final market, such as "Manufacture of basic metals" and "Manufacture of chemicals and chemical products" and need other transformations to be ready for the final consumers. This is the principle of a vertical economy with a production chain of multiple steps; we have identified some examples in the production network graph (Figure 2). The Upstreamness of a sector is defined recursively because a sector is more upstream in the production chain if it supplies upstream sectors. Hence, it is defined by Antras *et al.* (2012)[1] as follows:

$$U_i = 1 + \sum_j \frac{Y_j}{Y_i} \Gamma_{ij} U_j \tag{1}$$

The second term of Equation 1 embeds that a sector $j$'s upstreamness depends on the upstreamness of the $i$s customer sectors. In column (3) of Table 1, we have the upstreamness results for the 54 sectors of the Italian economy in 2014. We can notice that it ranges from 1.0609 to 4.0988 with a mean of 2.5242 and a median of 2.5647. The most upstream sectors are "Manufacture of basic metals" and "Printing and reproduction of recorded media" respectively, with upstreamness values of 4.0988 and 3.6054. On the other hand, the most downstream sectors are "Public administration and defence" with a value of 1.0609 and "Education" with 1.1287. On average, the goods produced by the median sector are transformed 2.5647 times before reaching the final consumers.

# 4 Italian Dependence from Russia

In this Section, we describe the Italian dependence on Russian Energy inputs. As we previously stated, it is crucial to understand that when we talk about energy inputs, we mean Natural Gas, Oil and Coal. These commodities are used in the production of energy as well as for secondary uses, i.e. Natural Gas

| Sector Code | Sector Name | (1) Outdegree | (2) Bonacich–Katz | (3) Upstreamness |
|---|---|---|---|---|
| A01 | Crop and Animal Production | 0.4710 | 0.0371 | 2.6890 |
| A02 | Forestry and logging | 0.0266 | 0.0011 | 2.0243 |
| A03 | Fishing and aquaculture | 0.0335 | 0.0011 | 1.9729 |
| B | Mining and quarrying | 0.0730 | 0.0070 | 1.8183 |
| C10-C12 | Manufacture of food products | 0.8149 | 0.0766 | 2.1549 |
| C13-C15 | Manufacture of textile | 0.8527 | 0.0289 | 3.5545 |
| C16 | Manufacture of products of wood and cork | 0.4724 | 0.0091 | 3.1688 |
| C17 | Manufacture of paper and paper products | 0.5974 | 0.0119 | 3.4474 |
| C18 | Printing and reproduction of recorded media | 0.4096 | 0.0082 | 3.6054 |
| C19 | Manufacture of coke and refined petroleum products | 1.0909 | 0.0320 | 2.9292 |
| C20 | Manufacture of chemicals and chemical products | 0.9404 | 0.0211 | 3.5314 |
| C21 | Manufacture of basic pharmaceutical products | 0.1874 | 0.0043 | 2.3068 |
| C22 | Manufacture of rubber and plastic products | 0.7541 | 0.0203 | 3.3546 |
| C23 | Manufacture of other non-metallic mineral products | 0.4682 | 0.0163 | 3.0384 |
| C24 | Manufacture of basic metals | 0.9984 | 0.0246 | 4.0988 |
| C25 | Manufacture of fabricated metal products | 1.4926 | 0.0446 | 3.3599 |
| C26 | Manufacture of computer and electronic | 0.2538 | 0.0089 | 2.2528 |
| C27 | Manufacture of electrical equipment | 0.4566 | 0.0122 | 2.8201 |
| C28 | Manufacture of machinery and equipment | 0.7960 | 0.0313 | 2.7530 |
| C29 | Manufacture of motor vehicles | 0.3286 | 0.0143 | 2.2387 |
| C30 | Manufacture of other transport equipment | 0.2486 | 0.0077 | 2.0116 |
| C31_C32 | Manufacture of furniture; other manufacturing | 0.4747 | 0.0141 | 2.6158 |
| C33 | Repair and installation of machinery and equipment | 0.2414 | 0.0127 | 2.2077 |
| D35 | Electricity, gas, steam and air conditioning supply | 1.4828 | 0.0640 | 3.1834 |
| E36 | Water collection, treatment and supply | 0.1021 | 0.0067 | 2.2329 |
| E37-E39 | Waste collection, treatment and disposal activities | 0.8651 | 0.0285 | 3.3560 |
| F | Construction | 0.8579 | 0.1555 | 1.6673 |
| G45 | Wholesale of motor vehicles and motorcycles | 0.3122 | 0.0253 | 1.7229 |
| G46 | Wholesale trade, except of motor vehicles and motorcycles | 2.4723 | 0.1143 | 2.4305 |
| G47 | Retail trade, except of motor vehicles and motorcycles | 0.5654 | 0.0864 | 1.3929 |
| H49 | Land transport and transport via pipelines | 1.5993 | 0.0667 | 2.8389 |
| H50 | Water transport | 0.1026 | 0.0075 | 2.0727 |
| H51 | Air transport | 0.1415 | 0.0073 | 2.4604 |
| H52 | Warehousing and support activities for transportation | 0.9286 | 0.0448 | 3.0764 |

| Sector Code | Sector Name | (1) Outdegree | (2) Bonacich–Katz | (3) Upstreamness |
|---|---|---|---|---|
| H53 | Postal and courier activities | 0.1219 | 0.0050 | 3.0368 |
| I | Accommodation and food service activities | 0.3744 | 0.0781 | 1.4193 |
| J58 | Publishing activities | 0.1126 | 0.0065 | 2.0578 |
| J59_J60 | Motion picture, video and television programme production | 0.3914 | 0.0105 | 2.6120 |
| J61 | Telecommunications | 0.4479 | 0.0258 | 2.2787 |
| J62_J63 | Computer programming, consultancy and related activities | 0.7404 | 0.0354 | 2.5174 |
| K64 | Financial service activities | 1.4438 | 0.0679 | 2.8498 |
| K65 | Insurance, reinsurance and pension funding | 0.1864 | 0.0165 | 1.6473 |
| K66 | Activities auxiliary to financial services | 0.8136 | 0.0221 | 3.3780 |
| L68 | Real estate activities | 1.1194 | 0.1755 | 1.5391 |
| M69_M70 | Legal and accounting activities | 1.5028 | 0.0530 | 3.1621 |
| M71 | Architectural and engineering activities | 0.7914 | 0.0215 | 3.3560 |
| M72 | Scientific research and development | 0.1790 | 0.0090 | 1.6219 |
| M73 | Advertising and market research | 0.3683 | 0.0111 | 3.3447 |
| M74_M75 | Other professional, scientific and technical activities | 0.4241 | 0.0149 | 3.0934 |
| N | Administrative and support service activities | 1.8012 | 0.0644 | 3.0249 |
| O84 | Public administration and defence | 0.0818 | 0.0993 | 1.0609 |
| P85 | Education | 0.1078 | 0.0564 | 1.1287 |
| Q | Human health and social work activities | 0.1597 | 0.1136 | 1.1379 |
| R_S | Other service activities | 0.5197 | 0.0631 | 1.6521 |
| | Mean | 0.6222 | 0.0371 | 2.5242 |
| | Median | 0.4696 | 0.0218 | 2.5647 |
| | Std. Dev. | 0.5233 | 0.0388 | 0.7461 |
| | Min | 0.0266 | 0.0011 | 1.0609 |
| | Max | 2.4723 | 0.1755 | 4.0988 |

Table 1: Italian Economic Sectors Statistics for 2014.

for heating and Oil for the production of gasoline. To have a clear overview of the effects of the shock, we have to look at the impact on the reduction in energy production and the ones on the secondary use of the commodity.
We will look at each input separately to understand the possible consequences of an embargo. It is essential to specify that the magnitude of such a shock depends on the ability of the national government to substitute Russia with other suppliers and on the capabilities of the production process to substitute between energy inputs. The different channels are likely to operate differently in the short-run and long-run. In the short-run, a stop of Russian exports has to be compensated through alternative energy sources from other countries and domestic sources to meet electricity, transport, heating and industrial demand or through substituting energy-intense production of certain products by direct imports. In the medium and long term, increased use of renewable energy and energy efficiency improvements can contribute significantly to lowering energy demand.
Italy relies primarily on natural gas for energy production (43.3%) while it gets around 20% from oil and around 5% from coal. Russia accounts for a large share of Italian production since Italy, together with Germany, is one of the most dependent countries on Russian energy imports. More than half of the Natural Gas used in energy production comes from Russia, as well as 18% of oil and 35% of Coal imports. First, coal accounts for a tiny part of energetic Italian production hence even if Russia exports a substantial share of it, the effects of an embargo are likely to be manageable because it is easy to substitute coal as an input in the production of energy. Moreover, most coal is used in thermoelectric power and does not play a significant role in any secondary use. The IEA estimates that there exists sufficient market capacity to substitute coal coming from Russia [14].
Second, oil accounts for around 30% of the Italian energy production, and almost 20% of it comes from Russia. An embargo on Oil products would cause a 5.98% drop in total energy production unless substituted. Although about 65% of oil is used in the production of gasoline used for transport by the industrial and household sector (Confindustria (2018) [9]). Hence, an embargo on Russian oil will cause more damage to the transport industry than to the energy one. Even in the case of oil, the IEA suggests that world production and global transport can substitute Russia as a supplier. The nature of oil allows for an increased speed of substitution between suppliers because of the means of transportation of the commodity that happens mainly via large oil tankers and does not require the construction of any infrastructure.
Third, Natural Gas is the commodity that will pose a significant threat to the Italian economy in case of an embargo and is, in fact, the most debated one. The paper from Bachman *et al.*(2022)[2] focuses just on Natural Gas because Germany, even more than Italy, is very dependent on it, and it is believed to be the most complex input to substitute in terms of world supplier. Natural Gas accounts for 43.3% of Italian energy production, and Russia made up 51% of it in 2020; post-Ukraine-war numbers should be lower. Moreover, just one-third of total gas consumption in Italy is used in thermoelectric power plants. In contrast, 42% is directly used by households and 28% by industry, trade, and commerce, mainly for heating purposes. Hence, an embargo on Russian Natural Gas is likely to threaten the energy sector and the consumption of households and industries.
Natural Gas extraction and transport make it very hard to substitute between suppliers, at least in the short run. In fact, according to Eni Extraction and Distribution document (2021) [10], gas is transported either in Gas form through pipelines or in Liquefied Natural Gas (LNG) form. Currently, 75% is transported via pipelines and 25% via LNG means such as LNG carriers. LNG is easy to move but requires a regasification process before final consumers can use it; hence, it involves constructing regasification

| | Italian Energy Market | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| | Coal | Oil | Gas | Renewables and Other |
| TJ | 198987 | 1842300 | 2448407 | 1171196 |
| % | 3.5 | 32.5 | 43.3 | 20.7 |
| From Russia | 34.5% | 18.4% | 51.0% | 0% |

Table 2: Italian Energy Market in 2020. Data come from IEA [14], CEPII [12], Eni [10] and the Worldbank databases. Note that all Russian imports overestimate actual and current data because the national government has already implemented measures to reduce in 2021 and 2022.

| | Italian Gas Consumption |
|---|---|
| Energy Generation | 30% |
| Households | 42% |
| Industry | 24% |
| Trade & Commerce | 4% |

Table 3: Italian Gas allocation the main four sectors. Data from National Energy Balance of the Italian Ministry of Ecological Transition 2020[17].

plants. Both pipelines and regasification plants are costly and need much time to be built, making it very hard to substitute between different suppliers, at least in the short run.

# 5 Model and Results

In this section, we will outline the two models we use to quantify and decompose the effects of the shock, giving an accurate description and interpretation of the results. First, we will use a simple macroeconomic model to get the intuition behind the effects of the shock and to estimate the upper and lower bound of the economic damages. Second, we will build a rigorous economic model that features a Production Network economy with linkages across countries and sectors. In both models, we will simulate different elasticities of substitution and isolate the shock focusing on Oil and Natural Gas.

## 5.1 Simple Macroeconomic Model

Let us now build a simple macroeconomic model following Bachman *et al.*(2022)[2] that we will use to get a sense of the magnitude of the effects of the shock.

In the previous Section (Section 4), we have stressed that energy inputs can be used for the generation of energy or final consumption, or intermediate consumption. For this simulation, we will focus on energy production, how the embargo will affect the latter and the consequences on the Italian economy.

If there was no substitution across countries and energy inputs, a complete embargo will cause a 1.19%[2] energy reduction from Coal, 5.98%[3] drop from Oil and a 22.08%[4] from Natural gas combining into a total 29.25% drop in total energy.

Assuming no substitution across countries and inputs is a very conservative scenario. There is consensus that all Russian energy inputs besides natural gas can be fully substituted by other suppliers also in the short run. Natural Gas is more complex because of the nature of the material and because it accounts for

[2] $34.5\% \times 3.5\%$
[3] $18.4\% \times 32.5\%$
[4] $51.0\% \times 43.3\%$

a large share of energy production. The IEA (2022)[14] estimates that Europe could substitute Natural Gas imports from Russia by 1/3 before the end of the year by applying a set of measures described in the report and summarized in Section 6.4. Hence, we will also consider a more realistic scenario that accounts just for a reduction in Natural Gas imports by 60% which, if entirely absorbed by the energy sector, transmits into around 0.15% reduction in gas allocated to energy production, which translates into a 15%[5] drop in energy production.

Summarizing, we will go over a worst-case scenario and a realistic one. The first one features no substitution across suppliers and across "brown" energy inputs, which translates into a 30% reduction in energy production. The second framework is more realistic, takes into account possible policy results, and is a better model for the current situation; it features a 15% reduction in energy production.

In this setup, we assume that Italy produces a good Y using either "brown energy" (gas, oil, and coal, i.e. the energy sources imports from Russia) denoted by $E$ and other inputs $X$:

$$Y = F(E, X)$$

Moreover, we assume a Constant Elasticity of Substitution (CES) production function:

$$Y = (\alpha^{\frac{1}{\sigma}} E^{\frac{\sigma-1}{\sigma}} + (1-\alpha)^{\frac{1}{\sigma}} X^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}} \tag{2}$$

Where $\alpha$ is the relative importance of brown energy in production with respect to the other inputs and $\sigma \in [0, 1)$ is the elasticity of substitution between "brown" energy and other inputs. As in Bachman *et al.* (2022)[2] we want $\alpha$ to be equal to the share of energy inputs (coal, oil and gas) in Italian Gross National Expenditure (GNE). The Italian GNE is \$1730bn [6] while the value of energy imports is \$35.332bn [7] meaning that a plausible value for $\alpha = 0.02$.

The values of $\sigma$ are also crucial in determining the magnitude of the shock. Two extreme cases are useful in our analysis because they identify the boundaries of the economic cost:

- Cobb-Douglass scenario ($\sigma = 1$): In this case the production function 2 becomes $Y = E^{\alpha} X^{(1-\alpha)}$, looking at the variation and taking the logarithm on both sides:

  $$\Delta \log Y = \alpha \times \Delta \log E$$

  In the worst case scenario of an embargo to Russian energy products, hence $\Delta \log E = 0.30$ we have $\Delta \log Y = 0.02 \times 0.30 = 0.006 = 0.6\%$ while in the realistic case, $\Delta \log E = 0.12$, we have $\Delta \log Y = 0.02 \times 0.15 = 0.003 = 0.3\%$. Hence, in the Cobb-Douglass case, there is a very manageable drop in GNE in the realistic and worst-case scenarios.

- Leontief Scenario ($\sigma = 0$): Now equation 2 becomes $Y = \min\{E/\alpha, X/(1-\alpha)\}$. A reduction in E implies that $Y = E/\alpha$ and hence:

  $$\Delta \log Y = \Delta E$$

  This means that the elasticity of substitution between energy and other inputs is zero, and production must decrease one-to-one with energy supplies. In the case of an embargo with no substitution across "brown" inputs and suppliers, a 30% reduction in energy inputs will mean a 30% drop in

[5] $0.60\% \times 51\% \times 43\% = 13\% \approx 15\%$
[6] World Bank 2020: `https://data.worldbank.org/indicator/NE.DAB.TOTL.CN?locations=IT`
[7] OEC 2020: `https://oec.world/en/profile/hs/crude-petroleum`

GNE. The same happens in the realistic case reducing production by 15%. This is a very extreme and implausible scenario as credible evidence exists to prove a short-run elasticity different than zero, at least to some extent.

Now that we have outlined the two extreme scenarios, let us find out what would be plausible values for the elasticity of substitution between energy and other inputs. The first aspect we can notice about elasticities of substitution is that they are very time-dependent; intuitively, elasticities tend to be larger in the long run than in the short run, or more rigorously, elasticity increases as the time horizon expands. In the very short run, production processes can be quite inflexible, i.e. the elasticity of substitution is low; however, over time, production processes can at least partially adapt to the different environment without Russian energy imports, i.e. the elasticity of substitution increases over time. We will focus on the short-run effects of the shock hence we need to estimate a plausible value for $\sigma$. As Bachman *et al.*(2022)[2] we will use $\sigma_1 = 0.04$ and $\sigma_2 = 0.1$ found trough past estimates of own-price elasticities from Labandeira *et al.* [15].
Now that we have two values for the elasticity of substitution, we can estimate the economic damage. However, outside of the two extreme cases laid out above, the relationship is more complex. We can use a second-order approximation of it:

$$\Delta \log Y \approx \alpha \log E + \frac{1}{2}\left(1 - \frac{1}{\sigma}\right)\alpha(1-\alpha) \times (\Delta \log E)^2 \tag{3}$$

The results of the model will be reported and discussed in Section 5.3.

## 5.2 Production Network Model

We use a production network model to evaluate the impact of an Italian Isolation from Russian energy, adapting the one used by Grassi *et al.*(2021)[5] to compute the sectoral effects of the COVID-19 social distancing in the US. To analyze the most plausible scenario, we will assume that the entire European Union (EU27) is isolated from Russia, and we will look at the effects on Italy alone.
In this framework, a representative household consumes a bundle of N goods and supplies labor ($l$) and capital ($k$). These N goods are supplied by one representative firm in each of the N sectors of the economy. The representative household consumption is a simplifying assumption, and we can consider it as the total final demand for each good $i$. For an equilibrium variable $X$ whose value at an initial equilibrium is $\overline{X}$ we denote $\hat{X} = \frac{X}{\overline{X}}$ the change from the initial equilibrium.
Household preferences are given by:

$$\hat{U} = \left(\sum_{i=1}^{N} \psi_i \hat{f}_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma-1}{\sigma}} \tag{4}$$

Where

$$\psi_i = \frac{\overline{p}_i \overline{f_i}}{\sum_i^N \overline{p_i}\overline{f_i}}$$

Is the share of total expenditure devoted to good $i$ hence the ratio between the price of good $i$ over the total expenditure. Moreover, $\hat{f}_i$ is the final demand of good $i$ composed of the sum of consumption, government spending, and investments. In equation 4 we find the elasticity of substitution across consumption goods $\sigma$, which is one of the critical parameters of the model. As outlined in Section 2, we have 54 Italian and

6 foreign sectors, of which 3 are from Russia and 3 from the aggregate ROW voice, hence $N = 60$. Each of the 60 sectors of the world economy produces based according to the following Constant Elasticity of Substitution (CES) production function:

$$\hat{y}_i = \hat{z}_i \left( \eta_i \hat{a}_i^{\frac{\theta-1}{\theta}} + (1-\eta_i)\hat{X}_i^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}} \tag{5}$$

Sector-specific output ($\hat{y}_i$) is given by the product between sector-specific productivity ($\hat{z}_i$) and the weighted sum of value added ($\hat{a}$) and intermediate bundle ($\hat{X}_i$) and influenced by the elasticity of substitution across value-added and intermediate inputs ($\theta$). The weights of the sum ($\eta_i$) is the share of value added in production.

Value added in production is then decomposed into:

$$\hat{a}_i = \left(\hat{l}_i\right)^{\gamma_i} \left(\hat{k}_i\right)^{1-\gamma_i}$$

Hence, it is a bundle of capital and labor weighted by the elasticity of substitution across primary factors ($\gamma_i$). Both inputs will be exogenous in our model, and we will focus on the short-run hence the change in capital will be 0 so that $\hat{k} = 1$.

The intermediate bundle is given by:

$$\hat{X}_i = \left( \sum_{j=1}^{N} \Omega_{ij} \hat{x}_{ij}^{\frac{\varepsilon-1}{\varepsilon}} \right)$$

It is the sum of the intermediate goods $j$ used in the production of $i$ weighted by the share of expenditure on good $j$ in total intermediate inputs used by sector $i$ $\Omega = \frac{\overline{p}_j \overline{x}_{ij}}{\sum_j \overline{p}_j \overline{x}_{ij}}$ and elevated to the elasticity of substitution across intermediate goods ($\varepsilon$).

Summing up, the model features 3 exogenous variable, namely $\hat{l}_i, \hat{k}_i, \hat{z}_i$ and $\beta_i$ representing respectively labor, capital, productivity and demand multiplier. It has three key parameters quantifying different elasticities of substitution:

- $\sigma$ which captures the elasticity of substitution across consumption
- $\theta$ which captures the elasticity of substitution across the capital-labor bundle and intermediate inputs
- $\epsilon$ which captures the elasticity of substitution across intermediate inputs

All the equations needed to solve the model are summarized in Table 4. From those, it is worth explaining the most important ones. The output of the model is found by solving the three key conditions of the model, namely, the Efficiency condition, Market Clearing condition and Price Index Condition.

The efficiency condition entails that prices equate marginal costs for each sector of the economy, hence this is a system of $N$ equations:

$$\begin{cases} \text{for } \theta \neq 1 & \hat{p}_i^{1-\theta} = \hat{z}_i^{\theta-1}\left(\eta_i \hat{v}_i^{1-\theta} + (1-\eta_i)\left(\hat{P}_i^M\right)^{1-\theta}\right) \\ \text{for } \theta = 1 & \hat{p}_i = \hat{z}^{-1} \hat{v}_i^{\eta_i} (\hat{P}_i^M)^{1-\eta_i} \end{cases} \tag{6}$$

The change in price of good $i$ depends on the change in productivity ($z_i$), in capital-labor bundle price ($v_i$), and intermediate bundle price ($P_i^M$).

Production Network Model Equations

| Description | Equation | Input-Output Parameter (s) |
|---|---|---|
| Intermediate good price | for $\varepsilon \neq 1,\ \hat{p}_i^M = (\sum_j \Omega_{ij}\hat{p}_j{}^{1-\varepsilon})$ | $\Omega_{ij} = \frac{\overline{p}_j \overline{x}_{ij}}{\sum_j \overline{p}_j \overline{x}_{ij}}$ |
| | for $\varepsilon = 1,\ \hat{p}_i^M = \prod_j \hat{p}_j^{\Omega_{ij}}$ | |
| Capital/Labor bundle | $\hat{a}_i = (\hat{l}_i)^{\gamma_i}(\hat{k}_i)^{1-\gamma_i}$ | $\gamma_i = \frac{\overline{w}_i \overline{l}_i}{\overline{v}_i \overline{a}_i}$ |
| Capital/Labor Bundle price | $\hat{v}_i = \hat{z}_i^{\frac{\theta-1}{\theta}} \left(\frac{\hat{y}_i}{\hat{a}_i}\right)^{\frac{1}{\theta}} \hat{p}_i$ | |
| Labor Income | $\hat{w}_i\hat{l}_i = \hat{v}_i\hat{a}_i$ | |
| Capital Income | $\hat{r}_i\hat{k}_i = \hat{v}_i\hat{a}_i$ | |
| Final Demand | $\hat{f}_i = \hat{\beta}_i\hat{p}_i^{-\sigma}\hat{P}^{\sigma}\hat{Y}$ | |
| Intermediate Demand | $\hat{x}_{ij} = \hat{z}_i^{\theta-1}\hat{p}_i^{\theta}\hat{p}_j^{-\epsilon}(\hat{P}_i^M)^{\epsilon-\theta}\hat{y}_i$ | |
| Prices = MC | for $\theta \neq 1,\ \hat{p}_i^{1-\theta} = \hat{z}_i^{\theta-1}\left(\eta_i\hat{v}_i^{1-\theta} + (1-\eta_i)\left(\hat{P}_i^M\right)^{1-\theta}\right)$ | $\eta_i = \frac{\overline{v}_i \overline{a}_i}{\overline{p}_i \overline{y}_i}$ and $1-\eta_i = 1 - \frac{\sum_j \overline{p}_j \overline{x}_{ij}}{\overline{p}_i \overline{y}_i}$ |
| | for $\theta = 1,\ \hat{p}_i = \hat{z}^{-1}\hat{v}_i^{\eta_i}(\hat{P}_i^M)^{1-\eta_i}$ | |
| Markets Clearing | $\hat{y}_i = \varphi_i\hat{f}_i + \sum_j \Delta_{ij}\hat{x}_{ji}$ | $\varphi_i = \frac{\overline{p}_i \overline{f}_i}{\overline{p}_i \overline{y}_i}$ and $\Delta_{ij} = \frac{\overline{p}_i \overline{x}_{ij}}{\overline{p}_j \overline{y}_j}$ |
| GDP Deflator | for $\sigma \neq 1,\ 1 = \hat{P}^{1-\sigma} = \sum_i \psi_i\hat{p}_i^{1-\sigma}$ | $\psi_i = \frac{\overline{p}_i \overline{f}_i}{\sum_i \overline{p}_i \overline{f}_i}$ |
| | for $\sigma = 1,\ 1 = \hat{P} = \prod_i \hat{p}_i^{\psi_i}$ | |

Table 4: For an equilibrium variable X whose value at an initial equilibrium is $\overline{X}$, we denote $\hat{X} = X/\overline{X}$, the change from the initial equilibrium. For sectors $i$ and $j$, $P_i^M$ is the intermediate input bundle price, $p_j$ is the price of good $j$, $a_i$ is the capital/labor input bundle, $l_i$ is the labor input, $k_i$ is the capital input, $v_i$ is the capital/labor bundle price, thus $v_i a_i$ is the value-added, $z_i$ is the productivity, $y_i$ is the quantity of good $i$ , $r_i$ is the rental rate of capital, $w_i$ is the wage, $f_i$ is the final demand for good $i$, $P$ is the price index of the aggregate good, $Y$ is the quantity of aggregate good, and, $x_{ij}$ is the intermediate input of good $j$ from sector $i$. Given exogenous variables, $z_i$,$k_i$,$l_i$, elasticities $\sigma$, $\theta$, $\varepsilon$, input-output parameters, the solution of this system of equations gives the endogenous variables, $P_i^M, p_i, y_i, a_i, v_i, r_i, w_i, f_i, Y, P = 1, x_{ij}$.

The Market clearing condition implies that total supply is equal to total demand for each sector $i$, again it is a system of $N$ equations:

$$\hat{y}_i = \varphi_i \hat{f}_i + \sum_j \Delta_{ij} \hat{x}_{ji} \tag{7}$$

In equilibrium sector specific total supply is equal to the sum of final demand and intermediate demand, where $\varphi_i$ is the share of final demand in total production before the shock, and $\Delta_{ij}$ is the share of intermediate demand in total production before the shock.
The Price Index condition is one equation:

$$\begin{cases} \text{for } \sigma \neq 1 \quad 1 = \hat{P}^{1-\sigma} = \sum_i \psi_i \hat{p}_i^{1-\sigma} \\ \text{for } \sigma = 1 \quad 1 = \hat{P} = \prod_i \hat{p}_i^{\psi_i} \end{cases} \tag{8}$$

The new equilibrium and change from steady state following a shock to the exogenous variables is found by solving a system of 2 × N +1 equations.
We solve the model under three fundamental assumptions:

- No nominal frictions: We assume that wages and prices adjust instantly or that the monetary authority does a "perfect job" in smoothing business cycle fluctuations.
- Markets are efficient: Prices are equal to marginal cost, there are no mark-ups or dead weight loss in the markets.
- All markets clear: There is no spared capacity or inventory for future periods. Supply is equal to demand in the final goods market, the intermediate market and the job market.

Let us now move to how we will model the shock, namely an embargo on Russian energy products for the European Union. We will use a counterfactual that fits our model to quantify a drop in energy imports from Russian energy sectors. We will assume a productivity shock affecting Russian Energy sectors, "Manufacture of coke and refined petroleum products" (RUS-C19) and "Electricity, gas, steam and air conditioning supply" (RUS-D35), representing respectively Oil and Natural Gas.
The drop in productivity is the shock that we need to study then the value of $\hat{z}_i$ is crucial for our analysis. In case of isolation of Russia from the European Union (EU27), exports from the affected Russian sectors to the EU will drop to zero, hence sales and production will decrease by the not exported amount. Thus, we want the drop in productivity to be equal to the share of exports to Europe over total production for sector $i$. Given that changes in capital and labor are exogenous and set to 1, production will decrease by the same value of the shock in productivity:

$$\hat{z}_i = 1 - \frac{\text{exports from sector } i \text{ to EU27}}{\text{total production of sector } i}$$

for the two shocked sectors, we find [8]:

$$\hat{z}_i = \begin{cases} \text{if } i = \text{C19}, \quad \hat{z} = 1 - \frac{4{,}912{,}754}{20{,}024{,}038} = 0.76 \\ \text{if } i = \text{D35}, \quad \hat{z} = 1 - \frac{10{,}765{,}221}{27{,}603{,}132} = 0.61 \end{cases}$$

[8]Numbers are in (TJ) from IEA 2021 Energy Database `https://www.iea.org/countries/russia`

| | Case 1: Energy Shock | | Case 2: Natural Gas Shock | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| | $\sigma_1 = 0.04$ | $\sigma_2 = 0.1$ | $\sigma_1 = 0.04$ | $\sigma_2 = 0.1$ |
| GNE, % | -2.71 | -1.39 | -0.82 | -0.50 |
| GDP, % | -2.22 | -1.14 | -0.67 | -0.41 |
| Cost per Capita | 790€ | 400€ | 240€ | 140€ |

Table 5: It reports the result of the Simple Macroeconomic model, where GDP loss is obtained from GNE and loss per citizen is obtained by dividing the GNE loss in absolute value for the Italian population in 2020. Note that all figures represent the annual economic cost for the entire duration of the shock.

We expect this shock on productivity to have multiple repercussions on the world economy and the Italian one. A sudden drop in $z_i$ will firstly affect sector $i$, reducing its production. This decrease in output will propagate in the world economy through multiple channels. The final consumption of consumers around the globe will be negatively affected, reducing the overall level of utility. Intermediate consumption from sector $i$ will decrease, threatening production in all those sectors that trade with sector $i$. A drop in production will also increase the price of good $i$, diminishing the buying power of final consumers and increasing the marginal cost of the upstream industries. These effects will interact with each other exacerbating the effects.

We will focus on three scenarios: the first in which we isolate the effects of the two sectors, and the last in which we look at the combined effects. We will assume two different frameworks for the key parameters:

- Cobb-Douglass Calibration (CD): $(\sigma, \theta, \varepsilon) = (1,1,1)$
- Standard Calibration (S): $(\sigma, \theta, \varepsilon) = (0.9,0.5,0.001)$ [9]

### 5.3 Results

We report in Table 5 the first model results. Knowing that Italian GDP is \$2100bn[10] and that GNE is \$1730bn, we get that GNE is 82% of GDP hence each loss in GNE can be converted into GDP loss and later on translated to an annualized loss in GDP per capita for the whole duration for the shock dividing the Italian population in 2020 [11]. Note that we need to know the embargo duration to get the GDP loss.

In case of a complete failure from the national government in substituting Russia as a supplier, the reduction in energy production would be 30% which is a considerable loss in a very conservative scenario. In this case, when the elasticity of substitution between "brown" energy and other inputs is low (Column (1)), the shock will cause an annualized GDP loss of -2.22% translated into a 750-800€ annualized loss per capita; with a higher and more natural elasticity of substitution (Column (2)) the loss is lower, -1.14% GDP loss and 450-500€ per capita.

When the national government can completely substitute Coal and Oil and at least 30% of Natural Gas using other suppliers, the shock entails a 15% reduction in energy production. The shock translates into a -0.67% GDP loss and a 200-250€ per capita loss with low elasticity of substitution (Column (3)) and into a -0.41% GDP loss and a 150-200€ per capita loss with higher elasticity (Column (4)).

Note that we are assuming that the economy is efficient, that it allocates resources maximizing welfare, hence that the loss in gas will be harder on the sectors that do not use gas as much; if the decrease in

[9] These values are the ones used by Baqaee and Farhi (2019)[3]

[10] World Bank 2020: `https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=IT`

[11] World Bank 2020: `https://data.worldbank.org/indicator/SP.POP.TOTL?locations=IT`

supply were not distributed efficiently, it would cause more considerable losses. This happens structurally in the presence of mark-ups and wage rigidities but must be adequately addressed through fiscal and monetary policy.
The first case is helpful to get an idea of the power that Russia had on the Italian economy before the start of the war with Ukraine; at least 1.14% of our GDP depended on their supplies and can be a reminder for future energy supply policies that should aim at diversify supply. In the second case, columns (3) and (4) can be used to more accurately assess the possible economic damage of an embargo on Russia, which is very manageable with the right approach. The difference between the two, as we will describe in Section 6.4, is a significant statistic because it represents the space of public policy intervention.
Table 5.3 reports the results of the Production Network Model. Let's look at the standard calibrations of each scenario, Columns (1), (3) and (5). The annualized GDP loss is equal to -0.23% in the case of an Oil Embargo, -0.31% in the case of a Natural Gas embargo, and -0.64% in the case of a combined embargo. The annualized cost per citizen is respectively 80€ ,100€ and 230€. We can notice that the impact of an embargo on Natural Gas has a stronger impact on the Italian economy than the Oil one for the same reasons reported in Section 4; Italian imports of Natural Gas are higher than the ones on oil, and Natural Gas is more difficult to substitute. Columns (2), (4), and (6) report the Cobb-Douglass results. Here, Hulten's theorem applies hence the difference between the standard calibration and the Cobb-Douglas case is a measure of the contribution of non-linearities (Baqaee & Fahri (2019) [3]). In the absence of inter-dependencies and linkages across the different sectors, the effect would have been less pronounced. In fact, in all three scenarios, non-linearities account for more than 50% of the effect of the shock. It is worth highlighting that non-linearities in production networks create an amplification effect that goes in the same direction as the shock; in this case, it is negative because we are looking at a negative disturbance.
Moreover, it allows for a distributive effect of the shock,i.e. an embargo on Natural Gas would reasonably hit more the sector that depends the most on it, but in the case of solid linkages, the effect of the shock is distributed across the other nodes of the network reducing the magnitude of the impact on the firstly hit sector but amplifying the overall impact on the economy. As we stated above, also in the Production Network model, we are assuming efficient markets hence in case of a misallocation of resources, the economic damage could be more significant. It is essential to spotlight the fact that the effect of the combined case is more powerful than the sum of the two separate cases by $\Delta = 0.10\%$[12] in the Standard Calibration while it is equal to the sum in the case of the Cobb-Douglas framework. This entails the fact that the multiplier effect of non-linearities is not additive when the shock hits contemporary more than one sector. The two models give similar results with some differences due to the different specifications and assumptions. All the results suggest manageable effects of isolation from Russian energy inputs, which are supposed to decrease in the long run due to a more elastic input market. The effects come up to be manageable for different reasons. As we stated above, the assumption of efficient allocation of resources definitely plays a role in keeping the numbers low. Still, it is possible to reach this outcome with the right policies. The share of "brown" energy over total GDP is slightly above 2% hence we cannot expect severe economic damage. By observing the results, you can note that the first model points to overall higher estimates than the production network model. The second model allows for trade across countries hence the effect of such a shock is "distributed" across the trade partners of the most hit sectors. Moreover, the way of modeling the shock used in the second model, a productivity shock in Russian energy sectors,

[12] $0.64\% - (0.31\% + 0.23\%) = 0.10\%$

| | Oil (19) | | Natural Gas (D35) | | Combined (C19+D35) | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | S | CD | S | CD | S | CD |
| GNE, % | -0.28 | -0.09 | -0.38 | -0.13 | -0.78 | -0.22 |
| GDP, % | -0.23 | -0.07 | -0.31 | -0.11 | -0.64 | -0.18 |
| Cost per Citizen | 90€ | 30€ | 100€ | 40€ | 230€ | 70€ |

Table 6: Reports the result of the Production Network Model, where S stand for Standard Calibration $(\sigma, \theta, \varepsilon) = (0.9{,}0.5{,}0.001)$ and CD for Cobb-Douglas $(\sigma, \theta, \varepsilon) = (1{,}1{,}1)$.

does not allow for a precise target of the shock, and some of it is absorbed by the other countries in the model.

## 5.4 Further research

The framework and the object of our analysis allow for numerous further research possibilities. Many of them come from relaxing strong assumptions we adopted throughout the paper.

As we have stressed in the previous Section, the assumption of efficient markets is crucial for an efficient allocation of resources across the sectors. In the presence of this assumption, the sectoral effects of the shock are the most efficient ones; public policy should aim at allocating resources in that way. Introducing realistic market imperfections such as mark-ups and taxes would allow us to reach a more realistic scenario and design policies to subsidize the sector with the most considerable impact on the national economy. To model the embargo on Russian energy products, one possibility would have been to add a tax on the right-hand side of the efficiency condition Equation 6 for the energy sectors, increasing the optimal equilibrium price for energy inputs having similar effects on the Italian economy. Even if the results on Italian GDP were quantitatively similar, this type of shock distorts the efficient allocation of resources; hence the sectoral effects are not optimal, and resources could be allocated differently to reach a better result. Although, it would be interesting to look at the difference between the sectoral effects in the two cases to design better aid policies. More specifically, it will allow us to develop a targeted industrial policy following the work of Liu (2019) [16] and used by Grassi & Sauvagnat (2019)[13] to study the network effects of competition policy.

The annualized cost for capita accompanies the GDP drop resulting from the two models; those numbers are significant because they represent the average cost per capita but do not consider the heterogeneity in the Italian population in terms of income. As I will continue in the next Section, this type of shock will have an asymmetric on the Italian population as studied by Bachman *et al.* [2] for Germany and Landais *et al.* for France; it would be attractive to do the same study for Italy.

In our Production Network model, we assume that capital is exogenous and fixed, hence we do not allow the shock to affect the labor component of the production function, eliminating any possible layoff effect. This is a strong assumption because, in case of a decrease in production due to the lack of intermediate inputs, firms in the various sectors would be forced to reduce the labor component. It is essential to understand such effects to design policies to address the issue.

Both models are focused on yearly data hence they do not consider seasonality in input demand which in the case of energy input can be a big deal. Oil and Natural gas are subject to large demand swings throughout the year. Oil and refined products such as gasoline are more required during the summer because of the increased car usage due to travel. On the other hand, natural gas, mainly used for heating purposes, is most needed during the winter when its demand more than doubles. It would be more accurate to use monthly or quarterly data to understand the distribution of the magnitude of the shock across the year.

# 6 Policy Actions

In this Section, we will revise proposals from different papers and reports, analyzing them in the framework of our models, indicatively quantifying the impact. These policies will aim at taming the economic damage caused by an isolation from Russian Energy inputs and are both ex-post and ex-ante measures.

## 6.1 Price Caps

The isolation of Russia from the Energy Inputs market will drastically reduce supply, as we have highlighted in the previous sections. Higher levels of spot prices will benefit supplying countries such as Russia at the expense of buying countries such as Italy.

In the framework of our Production Network model, higher input prices transmit through a higher average input bundle price into a higher marginal cost. A higher marginal cost is then converted into a higher final price faced by consumers that will find themselves with a lower purchasing power.

Price caps will cool down the energy market but risk creating political tensions between the counterparties of the deal; if imposed on Russia could lead to an actual embargo on energy inputs and all the consequences provided in previous sections.

The EU is currently discussing a price cap on Oil and Natural Gas and has not yet established if to target all the producers or just Russia.

## 6.2 Labor Market Policies

The drastic reduction in inputs coming from Russia will force some Italian sectors to reduce production to some extent, this drop in production and sales will be accompanied by a decreasing need for labor that will translate into increasing layoffs. As we have specified in Section 5.4, our models do not allow to model changes in labor demand as we assume exogenous or constant labor components. Although, it is intuitive to understand the causal relation that will bring a decrease in labor demand. We can think that this kind of shock will be persistent in the short-run only because of the increasing elasticity of substitution; hence targeted short-run-work policies should be enacted to support the most hit sectors of the economy.

## 6.3 Monetary Policy

As highlighted in the previous subsection, this situation will feature higher input prices that will fuel inflation. Moreover, the war with Ukraine severely threatens output growth, leaving the central bank with a hard choice on whether to prioritize output or prices. A credible pledge to a stable price level should ease the trade-off. Both our models work in the absence of nominal frictions and rigidities; prices and wages are supposed to adjust immediately to changes in other variables. Hence, they work under the assumption that monetary and fiscal policy can undo other effects from nominal rigidities in the economy and smooth business cycle amplification effects.

### 6.4 IEA 10-point plan

The International Energy Agency laid out a 10-point plan to reduce European Reliance on Russian Gas, IEA (2022)[14]. The IEA understands Russia's importance in European Gas consumption, which has been 155 billion cubic meters (bcm) and almost 40% of European Gas Consumption. As stated in Section 5.1, these measures could reach a 50 bcm per year reduction which accounts for almost 1/3 of yearly European imports from Russia, reducing the problem in the short-run. Moreover, if all European countries implemented all the suggested policies, it would eventually become possible to minimize Russian Gas imports by more than 80 bcm, more than halving energy imports from Russia. The IEA estimates that in the long run, Europe could eliminate Russia as an energy supplier as a side effect of reaching the European Green Deal objective of Net Zero Emissions in 2050. Hence, the problem exists in the short run and requires coordinated action between national governments.

The 10-point plan is divided into four macro categories based on the area they act upon: Gas supplies, Power Sector, End-use sector, and Cross-cutting.

For regard to Gas Supplies, we find:

1. "No new gas supply contracts with Russia"
2. "Replace Russian supplies with gas from alternative sources"
3. "Introduce minimum gas storage obligations to enhance market resilience"

Not renewing contracts with Russian suppliers is the first step to tackle the issue. A 15bcm yearly contract with Gazprom is set to expire at the end of 2021, allowing Europe to substitute the supplier and increasing supply diversity. Replacing Russian supplies with other countries could add about 30 additional bcm by the end of 2022. Europe could increase pipeline imports from Azerbaijan and Norway, on the other hand, it has a sizeable short-term potential in LNG imports from Asia. To exploit this potential, it is required a cooperated action increasing capacities at LNG regasification terminals. Gas consumption is subject to violent seasonal demand swings, which can translate into high price volatility and supply insecurity in this situation. To avoid this problem, it is essential to introduce minimum gas storage obligations.

Policies belonging to the Power Sector category are the following:

1. "Accelerate the deployment of new wind and solar projects"
2. "Maximise generation from existing dispatchable low-emissions sources: bio-energy and nuclear"
3. "Enact short-term measures to shelter vulnerable electricity consumers from high prices"

Favorable conditions for installing new solar PV and wind power facilities could produce an additional 35 TWh of electricity generation, reducing gas consumption by 6bcm. Possible national incentives could increase the speed of investment and revise the gains upwards. Europe can increase energy generation from existing dispatchable low-emissions sources, namely bio-energy and nuclear. Several nuclear reactors in Europe were taken offline in 2021 because of maintenance and safety checks; speeding up the control process could increase EU nuclear production by 20TWh. European Bio-energy facilities used only 50% of their capacity in 2021; reaching full capacity could generate an additional 50TWh. Bio-energy and nuclear together could generate an additional 70TWh saving up 13bcm of Natural Gas. These conditions will inevitably cause higher prices for Natural Gas that will transmit into higher electricity and heating prices for final consumers and higher profits for Energy companies. The IEA estimates excess profits of

€200 billion for these companies; temporarily increasing taxes for these companies can help to accumulate enough funds to help vulnerable groups reduce their energy bills.
Proposals belonging to the end-use sector category are the ones focused on the consumers and increasing efficiency in energy and gas consumption. The latter are:

1. "Accelerate energy efficiency improvements in buildings and industry"
2. "Encourage a temporary thermostat adjustment by consumers"

Improving energy and heating efficiency in private and business buildings makes it possible to decrease Gas consumption by an additional 2bcm within a year. Measures that could help to increase efficiency are installing intelligent heating controls and improving insulation. Moreover, it is already part of the European Agenda (Fit for 55[13]) to reduce yearly building gas consumption of 45bcm by 2030. Following the same reasoning, it is crucial to encourage a temporary thermostat adjustment by consumers, in particular, turning down building heating by 1°C would reduce gas demand by 10 bcm in 2022.
The last policy, part of the cross-cutting category, is to decarbonize and diversify the sources of the power system flexibility. Nowadays, in Europe, problems deriving from seasonal flexibility, demand shifting, and peak shaving are managed by Natural Gas electricity production. It is essential in the future to substitute natural gas in this role to drastically reduce European dependence on it.
In Section 5.1, we analyzed the effect of an embargo and a tariff using a simple macroeconomic model simulating a 60% shock in natural gas imports from Russia, assuming that around 30% could be substituted. We can use the result of equation 5.1 to quantify the impact of shock in case of a successful implementation of the IEA (2022) 10-point plan described above. In case of the positive performance of the measures, the economic damage to the Italian economy would be around 0.7% [14] while in the opposite case would be around 1.15% implying that the implicit gain of the 10-point plan for Italy is about 0.5% of GDP or 200-250€ per capita which is considerable.
Our paper does not cover distributional effects and asymmetric effects of isolation from energy inputs while it has been done by Bachman *et al.*(2022) [2] for Germany. Unsurprisingly, they found that this kind of shock will have an asymmetric impact on the population based on their income. The Low-Income group will be more affected than the High-income group that will be able to absorb the price increase creating a distributional force in favor of the wealthiest group. As proposed above, it is essential to counterbalance the distributional effect using lump-sum payments to low-income households. Such a scheme could be carried out by gas or power providers, who the state would compensate. This would allow for the lump-sum payments to be based on actual past energy consumption. This policy should be funded by taxing energy companies for the excess profit caused by high energy prices.

# 7 Conclusion

Our paper shows that the isolation of Italy from Russian energy inputs is costly, but its costs are manageable and likely to fall in the range from 0.2% to 2.70% of GDP or approximately 40-800€ per capita [15]. It points to the fact that Natural Gas (-0.2% GDP) is the main issue leading to a more considerable economic cost with respect to oil (-0.3% GDP). Moreover, it is highlighted the importance of the role

[13] European Plan Fit for 55: `https://www.consilium.europa.eu/it/policies`
[14] Assuming $\sigma_1 = 0.1$ as it is the most realistic scenario
[15] Both numbers are annualized losses for the entire duration of the shock.

played by elasticities of substitution in the propagation of the shock, suggesting that the shock is likely to pose a threat in the short-run only. We have shown that there is a vast space for policy intervention that can shape the magnitude of the shock's actual effect, some of which reduce the economic damage by at least 0.5% GDP. We can reconnect to the two possible scenarios highlighted in the Introduction (Section 1), a European enacted embargo and a Russian threat to reduce supply. If the European Union politically desires an active embargo, aligning such an action with the set of policies aimed at taming the economic damage is crucial. First, reducing the Italian reliance on Russian Natural gas following the IEA 10-point plan. Second, coordinating a sound monetary and fiscal policy to avoid asymmetric effects and inefficient allocation of resources ex-post. If all policies are appropriately conducted, the economic damage is likely to follow the lowest of our estimates. For the same reason, the Russian threat is not credible if national governments can take the proper precautions.

# References


[1] Pol Antràs, Davin Chor, Thibault Fally, and Russell Hillberry. Measuring the upstreamness of production and trade flows. *American Economic Review*, 102(3):412–16, May 2012.

[2] Ruediger Bachmann, David Baqaee, Christian Bayer, Moritz Kuhn, Andreas Löschel, Benjamin Moll, Andreas Peichl, Karen Pittel, and Moritz Schularick. What if? The Economic Effects for Germany of a Stop of Energy Imports from Russia. Technical report, 2022.

[3] David Baqaee and Emmanuel Farhi. Keynesian production networks and the covid-19 crisis: A simple benchmark. *AEA Papers and Proceedings*, 111:272–76, May 2021.

[4] David Baqaee, Benjamin Moll, Camille Landais, and Philippe Martin. The economic consequences of a stop of energy imports from russia. *conseil d'analyse économique*, Apr 2022.

[5] Jean-Noël Barrot, Basile Grassi, and Julien Sauvagnat. Sectoral effects of social distancing. *AEA Papers and Proceedings*, 111:277–81, May 2021.

[6] Wilhelm Barth, Michael Jünger, and Petra Mutzel. Simple and efficient bilayer cross counting. In *Graph drawing : 10th international symposium, GD 2002, Irvine, CA, USA, August 26 - 28, 2002 ; revised papers*, volume 2528 of *Lecture notes in computer science*, pages 331–360. Springer, 2002.

[7] Phillip Bonacich. Power and centrality: A family of measures. *American Journal of Sociology*, 92(5):1170–1182, 1987.

[8] Ulrik Brandes and Boris Köpf. Fast and simple horizontal coordinate assignment. In Petra Mutzel, Michael Jünger, and Sebastian Leipert, editors, *Graph Drawing*, pages 31–44, Berlin, Heidelberg, 2002. Springer Berlin Heidelberg.

[9] Confindustria. Petrolio. `https://www.confindustriaenergia.org/petrolio/`, 2018.

[10] ENI. Extraction and distribution of natural gas in italy. `https://www.eniscuola.net/wp-content/uploads/2011/02/pdf_natural_gas_21.pdf`, 2021.

[11] Emden Gansner, Eleftherios Koutsofios, Stephen North, and Khoi Vo. A technique for drawing directed graphs. *Software Engineering, IEEE Transactions on*, 19:214 – 230, 04 1993.

[12] Guillaume Gaulier and Soledad Zignago. Baci: International trade database at the product-level. the 1994-2007 version. Working Papers 2010-23, CEPII, 2010.

[13] Basile Grassi and Julien Sauvagnat. Production networks and economic policy. *Oxford Review of Economic Policy*, 35(4):638–677, 12 2019.

[14] IEA. Extraction and distribution of natural gas in italy. `https://www.iea.org/reports/a-10-point-plan-to-reduce-the-european-unions-reliance-on-russian-natural-gas`, 2022.

[15] Xavier Labandeira, José M. Labeaga, and Xiral López-Otero. A meta-analysis on the price elasticity of energy demand. *Energy Policy*, 102(C):549–568, 2017.

[16] Ernest Liu. Industrial policies in production networks*. *The Quarterly Journal of Economics*, 134:1883–1948, 11 2019.

[17] Italian Ministry of Ecological Transition. National energy balance. https://dgsaie.mise.gov.it/pub/ben/BEN_2020.pdf, 2021.

[18] Oleg Itskhoki Sergei Guriev. The economic rationale for an oil and gas embargo on putin's regime. https://intellinews.com/comment-the-economic-rationale-for-an-oil-and-gas-embargo-on-putin-s-regime-239019/, 2022.