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Cutting Russia's Fossil Fuel Exports: Short-Term Pain for Long-Term Gain

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Abstract

In response to the invasion of Ukraine, most OECD countries have announced punishing sanctions against Russia. In addition to targeting financial markets and service sectors, some countries have begun to impose restrictions on exports of Russia's fossil fuels. In this paper, we analyze a scenario whereby most OECD countries put major restrictions on Russia's energy exports. Results suggest that the short-term implications are likely to be non-trivial for EU – Russia's largest energy export destination. Households' real income could drop by 0.7-1.7 percent (relative to the reference case) with energy prices growing by as much as 11 percent. But after the initial adjustment period, the cost of such restrictions for the EU is expected to be more modest over the longer run (0.04 percent slowdown in the annual growth rate of real income over the 2022-2030 period), even as they lead to substantial environmental co-benefits through reductions in CO_2 (6.6 percent in 2030) and air pollutant emissions (2.8-5.9 percent in 2030). Such emission reductions would take the EU more than halfway to its Green Deal mitigation target, reducing the necessary carbon price by around 40 EUR per tCO_2. Adverse impacts on the Russian economy would be overwhelming and, in relative terms, 10 time larger than that for EU. By 2030 the cumulative reduction in Russian real income would exceed 1.1 trillion USD, while lost revenue from fossil fuel exports would be almost 1.4 trillion USD.

Key words: *Russia; Fossil fuel export restrictions; Economic impacts; European Union; Climate mitigation; Environmental co-benefits; Computable general equilibrium.*

JEL codes: *C68, O13, Q43, F17, F18*

1. Introduction

In response to the invasion of Ukraine, most of the countries of the Organisation for Economic Co-operation and Development (OECD), including the United States (US), Australia, Canada, South Korea, Japan, the United Kingdom (UK) and the European Union (EU), have announced punishing sanctions against Russia. These include restrictions on financial transactions, freezing assets of Russia's major banks and selected individuals, banning exports of high-tech equipment to Russia, as well as closing the airspace for Russian flights and waterways for the country's vessels (Funakoshi et al., 2022).

In addition to targeting financial markets and service sectors, countries have begun imposing restrictions on Russia's exports of fossil fuels – that country's primary source of foreign exchange. As of mid-March 2022, both the US and UK have announced a phasing out of energy imports from Russia (The White House, 2022a; HM Government, 2022). Other large energy consumers of Russian fossil fuels, in particular EU countries, have also outlined plans to reduce their energy dependence on Russia in a more rapid manner than considered earlier (EC, 2022a). In addition, international energy companies like Equinor, Exxon Mobil and Shell are restricting their operations in Russia (Funakoshi et al., 2022).

The EU, UK and US, together, have been the destination for more than half of Russia's fossil fuel exports. When combined with selected other countries that have imposed sanctions against Russia, such as South Korea, Japan, Norway, Singapore, Switzerland, Taiwan and Malaysia, the corresponding share increases to more than two-thirds of Russian fossil fuel exports, with a related export flow of 150 billion USD in 2019 (UN, 2022). If these revenue flows were to be cut off, this could have a dramatic impact on the Russian economy, which relies heavily on energy exports for financing its government budget, as well as supporting its military operations. At the same time, such an embargo is also likely to hurt the importers.

The EU, as the largest importer of Russian energy commodities, is expected to be impacted the most significantly under such a scenario. Unlike the US and UK, where Russia accounts for a relatively low share of total energy imports – 6.5 percent and 11.5 percent respectively in 2019 – the EU has much greater dependency on Russian fossil fuels, with the corresponding import share exceeding 30 percent (UN, 2022). In 2019, the EU imported over 111 billion USD worth of fossil fuels from Russia, with Germany, the Netherlands (largely re-exports), Italy, Poland and France among the top destinations.

The share of fossil fuel imports from Russia in total imports from all sources varies widely – from 22 percent in the case of natural gas, up to 36-37 percent for the cases of coal and petroleum products (Figure 1). However, when considering import dependency, it is important to account for domestic production. Using this metric, the EU's import dependency on Russian fuels is somewhat lower –ranging from 28 percent (crude oil) to 9 percent for petroleum products. In value terms, over 65 percent of all energy imports from Russia are associated with oil and petroleum products

(UN, 2022), which are easier and less costly to substitute compared to natural gas (Bachman et al., 2022).

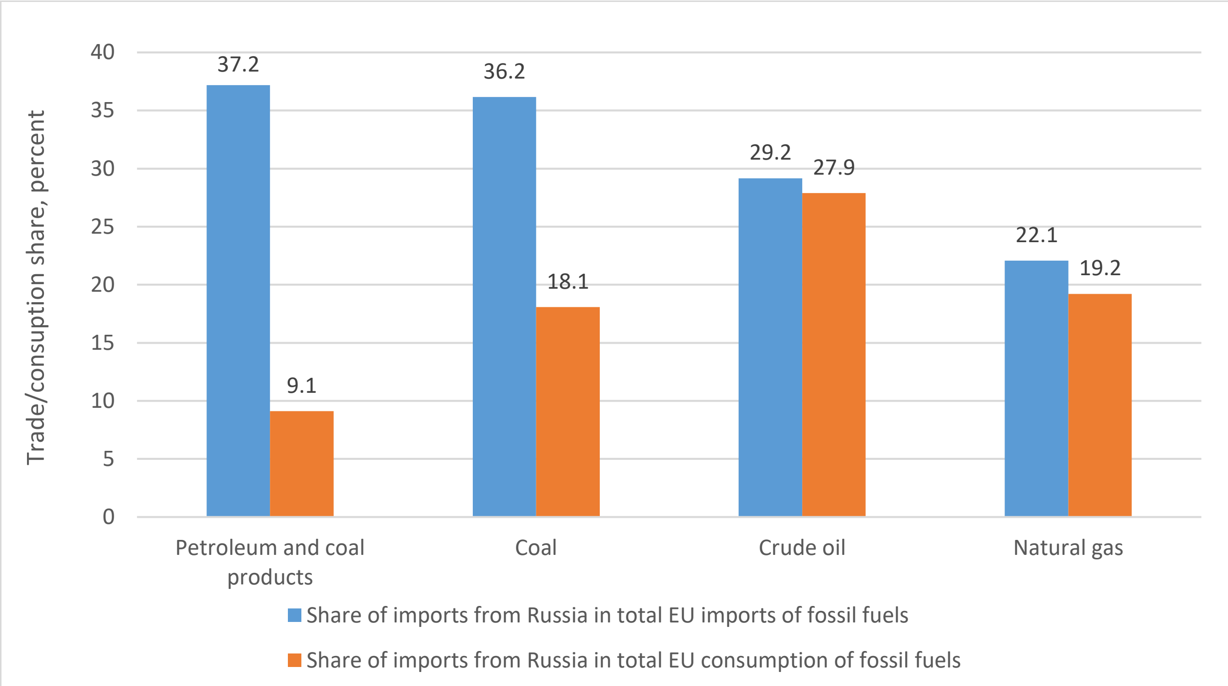

Figure 1. EU's reliance on imports of fossil fuels from Russia in 2017

Notes: Intra-EU trade is excluded from the estimates of EU total imports. Estimates represent value shares.
Source: Authors' estimates based on Global Trade Analysis Project (GTAP) 11p2 Data Base. [3]

The level of dependency on Russian fossil fuels varies considerably across EU member states. For instance, in Bulgaria, Finland, Slovakia, Lithuania, Poland and Czech Republic, the value share of imports in total energy consumption is at least 25 percent (Table A.1, Appendix A). For comparison, in Ireland, Belgium, Austria, Spain, France and Luxembourg the corresponding share does not exceed 7 percent. To put these numbers in context, in the case of the US – one of the first countries to announce a ban on energy imports from Russia – the share of Russian energy imports in total energy consumption is only 1 percent (Table A.2, Appendix A). For China, the second largest importer of Russian energy resources, this share is 3.1 percent. These numbers indicate that, from the point of view of energy dependency and security, the eastern countries in the EU are the most vulnerable to potential restrictions of the energy imports from Russia and the adverse implications of such a step could be substantial, especially in the short-run.

[3] For the simulation purposes, we use the GTAP 10A Data Base with 2014 reference year, which is the most up-to-date publicly available version of GTAP. The GTAP 10A also has all extensions and data features that are utilized in the paper, such as disaggregated electricity sector and air pollutant emissions. GTAP 11p2 Data Base has 2017 reference year and is a pre-release (interim) version of GTAP 11 Data Base (not yet publicly distributed). The former does not have all the satellites and extensions needed for the current set of simulations, but since it has a more recent reference year (2017) compared to GTAP 10A, we use the GTAP 11p2 version for descriptive statistics.

While discussion of restrictions on Russian energy imports has only recently appeared as a major topic in the policy agenda, several studies have already provided a preliminary assessment of the potential impacts of such bans, as well as discussed potential supply-side measures that could be implemented to mitigate adverse impacts of such moves.

Bachman et al. (2022) have analyzed a potential cut-off of the German economy from Russian energy imports using a state-of-the-art multi-sector open economy model. The authors show that the effects of such a restriction could be substantial, but manageable, with an associated GDP decline in range from 0.5 and 3 percent over the short-run. The magnitude of these adverse impacts largely depends on the assumed possibilities of substitution for Russian energy resources in the short-run. Bachman and colleagues also show that the likely distributional impacts of an increase in energy prices appear relatively moderate.

Aurora Energy Research (2022) looks into the additional supply measures and associated costs required in the event of an embargo on Russian gas supplies over the period October 2022 – March 2023. Their study finds that coping during the winter of 2022/2023 without Russian natural gas, would require storage refill at an additional cost of 60-100 billion EUR under prevailing prices. These costs are equivalent to around 0.4-0.6 percent of EU's GDP (IMF, 2021).

Evenett and Muendler (2022) analyze the macroeconomic impacts of an import ban on Russian oil and gas by the EU-27 and G7 countries. Those authors find that such a restriction would reduce Russian GDP by 0.58 percent in the medium- to long-term, while the combined GDP of sanctioning nations is expected to decline by a modest 0.04 percent. This study also finds that the Russian economy could lose more than 574,000 jobs (0.8 percent of the total labor force), while European Union would face more modest job losses (116,000 jobs or 0.05 percent of the total EU labor force) (WB, 2022).

While providing important early insights into the potential impacts of restricting Russian energy imports, existing studies have not addressed a number of important points. First, earlier studies have not focused on the assessment of impacts across countries and sectors, providing instead rather brief macro view of potential results. Second, an assessment of energy price implications and potential distributional impacts of restricting Russian fossil fuel imports has not yet been provided. While the study by Bachman et al. (2022) provides estimates of the energy expenditure shares across households in Germany, it does not discuss the associated changes in energy prices and hence the impacts on consumer purchasing power. Third, the existing studies have all applied a static modelling framework and have not explicitly distinguished between the timeframe of impacts. As shown by these previous studies, the consequences of the fossil fuel import ban could vary greatly across the short-, medium- and long-runs, leading also to changes in trade patterns and energy transition pathways. Finally, apart from the pure financial aspect of banning energy imports from Russia there is another dimension at stake – environmental quality. This aspect has also not been explored in the earlier studies.

The latter point is of particular importance, since the recently announced EU Green Deal, sets ambitious mitigation goals and establishes a target of reducing greenhouse gas (GHG) emissions by 55 percent in 2030 relative to the 1990 level (EC, 2019). To reach this goal a major reduction in fossil fuel consumption would need to take place in the coming years. This enhancement in mitigation ambition could be achieved through a mix of mechanisms and policy measures, including carbon pricing, energy taxes, energy efficiency improvements as well as changes in behavioral patterns. Restricting the imports of fossil fuels from Russia adds another option to this list, which could allow the EU to achieve additional reductions in greenhouse gas and air pollutant emissions, alongside the reduction in energy dependence and an enhancement of energy security.

In this paper we seek to cover the points discussed above and provide a comprehensive assessment of the potential implications of major restrictions on Russian fossil fuels imports by the EU and most other OECD countries. The rest of the paper is organized as follows. Section 2 provides an overview of the methodology and scenario framework. Section 3 introduces scenario framework. Section 4 discusses the key findings, focusing on short- vs long-term implications of potential import restrictions, distributional impacts of such a policy step, as well as covers potential environmental aspects of this policy. Finally, section 4 concludes.

2. Data and methods

For the quantitative assessment of potential impacts of restricting Russian energy imports, we rely on a global computable general equilibrium (CGE) model model—the Environmental Impact and Sustainability Applied General Equilibrium (ENVISAGE) (van der Mensbrugghe, 2019). The model follows a circular flow of an economy paradigm. Firms purchase input factors (for example energy, labor and capital) to produce goods and services. Households receive the factor income and in turn demand the goods and services produced by firms. Equality of supply and demand determines equilibrium prices for factors, goods and services. The model is solved as a sequence of comparative static equilibria where the factors of production are linked between time periods with accumulation expressions. Production is implemented as a series of nested constant-elasticity-of-substitution (CES) functions, the aim of which is to capture the substitutability across all inputs. Production is also identified by vintage—divided into *Old* and *New*—with the installation of *New* capital allowing for enhanced energy efficiency in the wake of higher fuel prices.

Income accrues from payments to factors of production and is allocated to households (after taxes). The government sector accrues all net tax payments and purchases goods and services. The model incorporates multiple utility functions for determining household demand—for this paper, the constant-differences-in-elasticities (CDE) utility function was chosen to allow for calibration of commodity specific own-price elasticities of demand. Trade is modeled using the so-called Armington specification that posits that demand for goods are differentiated by region of origin. The model allows for domestic/import sourcing at the aggregate level (after aggregating domestic absorption across all agents), or at the agent-level.

There are three key elements to the ENVISAGE model's dynamics. Labor supply (by skill level) grows at an exogenously determined rate. The aggregate capital supply evolves according to the standard stock/flow equation, i.e. the capital stock at the beginning of each period is equal to the previous period's capital stock, less depreciation, plus the previous period's level of investment. These capital stocks are sector-specific and evolve with new investments. The third element is technological change (labor augmenting)—calibrated to given assumptions about baseline GDP growth and inter-sectoral productivity differences. Detailed documentation of the ENVISAGE model is provided in van der Mensbrugghe (2019).

ENVISAGE incorporates the main greenhouse gases—carbon dioxide, methane, nitrous oxides and fluorinated gases (Aguiar et al., 2019; Chepeliev, 2020a). The model also tracks nine air pollutants, including particulate matter, sulfur dioxide and nitrogen oxides, based on data from Chepeliev (2020b).

The main strength of this CGE modelling approach is the consistent representation of the inter-dependencies between different sectors, households and markets in the economy. By capturing both the supply and demand sides, the model represents adjustments in quantities and prices following the implementation of the energy embargo.

The ENVISAGE model used in this study is calibrated to the Global Trade Analysis Project (GTAP) 10 Power Data Base with 2014 reference year, which distinguishes 141 regions and 65 sectors (Aguiar et al., 2019; Chepeliev, 2020c). The latter includes 11 electricity generation technologies, as well as an electricity transmission and distribution activity. For the purposes of this paper, we use an aggregation that includes 18 regions (Appendix B) and 36 sectors (Appendix C).

3. Scenario framework

When assessing the impacts of potential energy import restrictions, it is important to distinguish between short-term implications, within the first year following the implementation of the embargo, and the longer-term outcomes, occurring over a transition period (roughly 4 years in this case). In the short-run, countries have limited possibilities to adjust energy supply routes and secure additional import volumes from new sources. This applies to both energy importers and exporters. The latter, facing reduced energy demand from selected destinations are limited in their capacity to divert embargoed energy volumes to new markets. On the other hand, in the long-run, both energy importers and exporters have more opportunities to develop new energy supply routes and secure new contract agreements, thus allowing for a more substantial adjustment in trade patterns. To account for this difference, we adjust the trade substitution elasticities, lowering their value to represent the short-run implications, and allowing them to assume their long run values over time. The parameterization in this model is discussed in greater depth in Section 2.1.

Another important difference between short- and long-term implications is the possibility of changing the production structure of economy and reallocating capital across industries to adjust to the newly developed market conditions. For instance, considering that decisions to build new a solar power plant or liquified natural gas (LNG) terminal take time and require substantial investments, in the short-run opportunities of increasing corresponding energy production capacities are limited, while in the longer-run such shifts are possible. To account for this feature in our modelling framework, we use a vintage capital structure, as discussed above.

In what follows, we discuss the two sets of scenarios, focusing on the short-term and long-term implications respectively capturing the key differences between these two time periods as discussed above.

3.1. Short-term assessment

To explore the *short-term implications* of restricting imports of fossil fuel from Russia, we rely on a static version of the ENVISAGE model. We assume that restrictions on energy imports from Russia are imposed by the following countries and regions: EU, United Kingdom, United States, Canada, Japan, Australia, New Zealand, South Korea, Honk Kong, Taiwan, Singapore, Switzerland, Norway, Iceland and Liechtenstein. Import restrictions are imposed on coal, crude oil, natural gas, petroleum and coal products. Three short-term scenarios are explored by varying the intensity of import restrictions on Russian fossil fuel exports. Table 1 provides an overview of these scenarios.

Table 1. Short-term assessment scenarios

No.	Scenario name	Description
1.	SUBSTANTIAL	Reduction in fossil fuel imports from Russia by 80 percent and a low level of trade substitution (all trade elasticities are reduced by half relative to the standard values)
2.	HIGH	Reduction in fossil fuel imports from Russia by 90 percent and a low level of trade substitution (all trade elasticities are reduced by half relative to the standard values)
3.	SEVERE	Reduction in fossil fuel imports from Russia by 99 percent and a low level of trade substitution (all trade elasticities are reduced by half relative to the standard values)

Source: Developed by authors.

The first scenario dimension includes a level of potential import restrictions, which in our modelling framework is implemented via import tariff, so the associated revenue accrues to the EU and other importers. We distinguish substantial, high and severe levels of energy import reductions, which correspond to 80, 90 and 99 percent reductions in the importation of all fossil fuels from Russia by the abovementioned list of countries and regions.

A second dimension distinguishing the short-term scenario framework is the diminished level of import substitutability. As has been shown in the literature, the level of substitution between domestic and imported goods, as well across various import suppliers is a key driver of results in the CGE modelling framework (Felder and Rutherford, 1993; Hertel et al., 2007; Schürenberg-Frosch, 2015). With an imposition of major restrictions on energy imports from specific destinations, such as Russia, the potential for increasing imports from alternative sources is a major factor in determining the overall results. Trade elasticities used in most global CGE models correspond to the long-term estimates (e.g. Hertel et al., 2007; van der Mensbrugghe, 2019), while the focus of the short run simulations are short- to mid-term results. To take this into account we reduce trade elasticities by 50 percent. This assumption largely aligns with existing literature estimates suggesting that short- vs long-run trade elasticities tend to differ by a factor of two (Gallaway et al., 2003).

3.2. Long-term scenario framework

For the long-term assessment we rely on the dynamic version of ENVISAGE model. We first develop a *baseline scenario (BaU)* that relies on the GDP trends from the International Monetary Fund's (IMF) World Economic Outlook (WEO) (IMF, 2021). IMF's WEO projections pre-date the Russian invasion of Ukraine and cover period up to 2026. To represent the GDP trends post-2026, we rely on the Shared Socioeconomic Pathways (SSP) database, in particular, the OECD-developed SSP2 scenario (Riahi et al., 2018), which corresponds to the "middle of the road" pathway with intermediate socio-economic challenges for mitigation and adaptation. To capture the demographic trends we rely on projections from the World Bank's Global Income Distribution Dynamics (GIDD) microsimulation model (Maliszewska et al., 2020).

To capture the expected energy and emission trends within the baseline scenario, we incorporate a set of energy technology and preference assumptions. These include declining costs of renewable electricity generation, non-price related changes in preferences towards renewables, increases in electricity shares for final and intermediate consumers, improvements in energy efficiency, an increasing share of services and reduction in international transportation costs. Appendix D provides additional details on the baseline scenario calibration assumptions. These assumptions are designed for the 2050 timeframe, as discussed in appendixes, but within the current set of simulations the model is run till 2030.

In addition to the assumptions discussed above, we also implement carbon prices in selected countries and regions in the baseline scenario, including the EU, China and high-income countries. Appendix D reports corresponding price trajectories. Carbon prices are imposed on a selected set of energy-intensive sectors that correspond to EU emission trading scheme (ETS) activities. The latter include chemicals, metals, non-metallic minerals, petroleum products, wood products and electricity generation.

The baseline scenario discussed above represents a reference or business-as-usual situation, thus capturing an evolution of economy without additional (ambitious) climate mitigation measures and without the fossil fuel import restrictions. In the case of European Union, the developed baseline scenario results in a reduction in CO_2 emissions by 48.5 percent in 2030 relative to the 1990 level. This mitigation effort is more ambitious than EU's first NDC commitment (40 percent reduction in emissions), but less stringent than the EU's Green Deal abatement goal of 55 percent (EC, 2019).

4. Results

4.1. Short-term impacts

The Russian invasion of Ukraine has put significant pressure on global energy markets. Brent crude oil prices have been pushed above \$110 per barrel during the first weeks of conflict – levels that have not been seen since 2012 (CNBC, 2022). To address these market and supply disruptions, International Energy Agency member countries have committed to release 60 million barrels of crude oil from strategic reserves (IEA, 2022), but the pressure on gasoline prices continues to mount. Following the Russian invasion, the Dutch TTF natural gas prices have increased by over 35 percent in March 2022 relative to the November 2021 (Yahoo Finance, 2022), adversely impacting residential and industrial users in the EU.

Restrictions of Russian energy imports would put additional pressure on energy prices in the importing regions, adversely impacting net energy importers and benefitting net energy exporters, who would be able to step up and at least partially replace the market share that Russia is expected to lose. Our results suggest that energy exporters in Central Asia (ECA), such as Kazakhstan and Azerbaijan, as well as energy producers in Middle East and North Africa (MENA), including Saudi Arabia, Qatar and United Arab Emirates, are expected to benefit the most from restrictions of Russian energy imports (Figure 2). Both ECA and MENA are increasing the supply of oil and petroleum products to EU, while MENA is also increasing exports of natural gas. Another major energy supplier that is stepping up to compensate for the reduction in energy imports from Russia is Norway, which is part of Rest of high-income (XHY) region in our model.

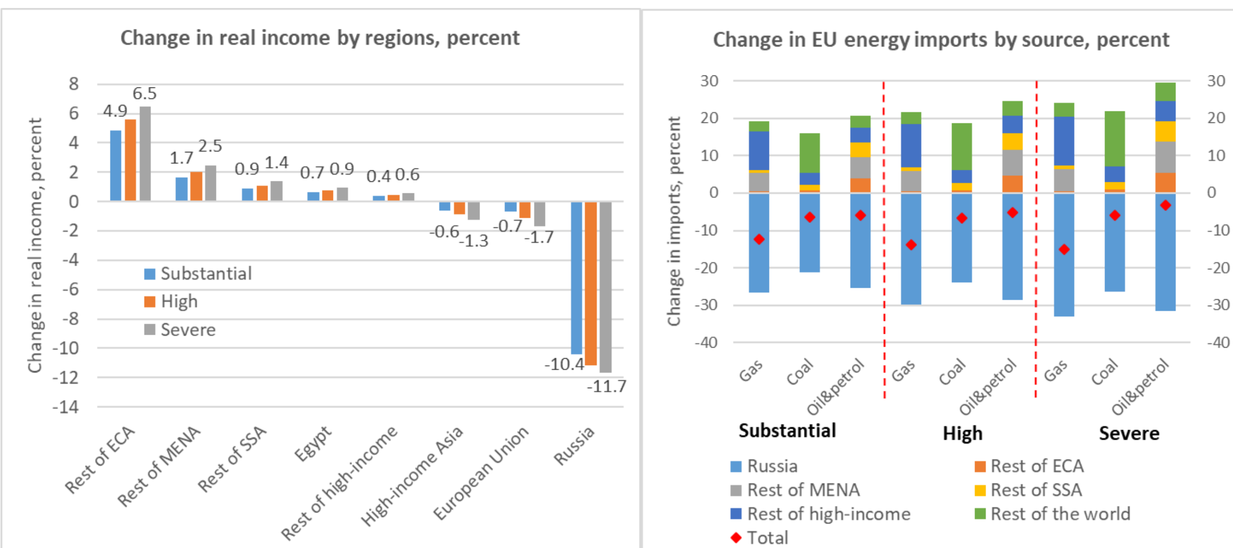

Figure 2. Change in real income by regions (left) and change in EU imports by source (right), percent, across scenarios: Substantial, High and Severe

Notes: For the case of changes in real income, only most impacted countries and regions are reported. Reported changes in energy imports exclude intra-EU trade.

Source: Estimated by authors using ENVISAGE model.

In terms of the most adversely impacted countries, estimates show that Russian economy would suffer the most from the import bans, losing between 10 and 12 percent of real income annually. Import restrictions coupled with limited opportunities to switch energy suppliers in the short-run would also put additional burden on consumers and producers in the countries that implement such bans (Figure 1). We find that the EU would be second most-impacted region after Russia, with potential short run income losses of around 0.7-1.7 percent, followed by High-income Asian countries, including Japan and Korea (0.6-1.3 percent income loss).

In the case of the EU, imports from Russia represent around 20 percent of total domestic energy consumption (Figure 1) and the region would need to substitute these flows using other sources. Considering that short-run substitution possibilities are limited, increasing energy demand for selected sources would increase energy prices, as well as prices of other commodities that rely heavily on energy as an input (e.g. electricity, transportation, metals, chemicals, etc.). Estimates suggest that a major reduction in energy imports from Russia would result in EU-wide energy price increases in the range of 8-11 percent, while transportation prices would grow by 5-6 percent (Figure E.1, Appendix E). While rising prices contribute to the reduction in households' real income, as the average cost of the composite basket of goods and services increases, there is a strong incentive to reduce energy imports. The latter is somewhat compensated by rising tariff revenues, ranging between 11 billion USD (Severe scenario) and 61 billion USD (Substantial scenario),[4] which in our simulations are redistributed to households in a form of lump-sum payments. While in the model we use a single representative household, potentially these revenues could be redistributed to the most vulnerable consumer groups. For instance, a redistribution of corresponding flows to the bottom quintile in the EU would be equivalent to per capita payment in a range of 120 USD (Severe scenario) and 680 USD (Substantial scenario).

There are three major channels through which market-mediated responses to higher energy prices would soften the transition away from Russian energy imports. First, rising prices lead to an overall reduction in energy demand. As a result, imports from new sources do not need to fully replace lost imports from Russia. Reductions in the EU-wide energy imports range from 3-6 percent for oil and petroleum products to 12-15 percent for natural gas (Figure 2). Second, increasing prices of imported energy commodities will serve to stimulate domestic fossil fuel production. In particular, we find that output of natural gas could increase over 20 percent, though from a relatively low base, while production of coal could rise by 9-13 percent, partly substituting for natural gas in the power generation (Figure E.3, Appendix E). Finally, the third channel includes a shift toward carbon-free energy sources, such as wind, solar, hydro and nuclear power, as well as other renewables (biomass and geothermal sources). Results suggest that both wind and solar power generation could increase by more than 12 percent stimulated by rising fossil fuel prices (Figure E.3, Appendix E). These three channels – consumer demand adjustment, fuel substitution

[4] Values are reported in constant 2021 USD at market exchange rate.

and structural transformations – could play a major role in reducing the adverse impacts from energy import restrictions.

While the EU-wide impacts of restricting Russian energy imports might be considered moderate in aggregate, it is important to understand what implications this policy could have for the most vulnerable consumers. In what follows, we discuss this point in detail.

4.2. Distributional consequences

Estimates suggest that Eastern European and Baltic member states are not only more dependent on energy imports from Russia (Table A.1, Appendix A), their households also spend a higher share of their budget on energy and transport (more than 10 percent in most cases) (Figure 3). Thus consumers in these countries are more vulnerable to energy import restrictions. Taking into account household expenditure shares, and focusing on the Severe imports restrictions scenario (with a 99 percent reduction in energy imports from Russia), we find that consumer prices could increase by up to 0.8 percent for EU on average, while Estonia, Hungary and Czech Republic, the consumer price index (CPI) could grow by more than 1 percent. In Bulgaria, which has the highest share of household expenditures on energy and transport, the estimated increase in the CPI is around 1.4 percent (Figure 3).

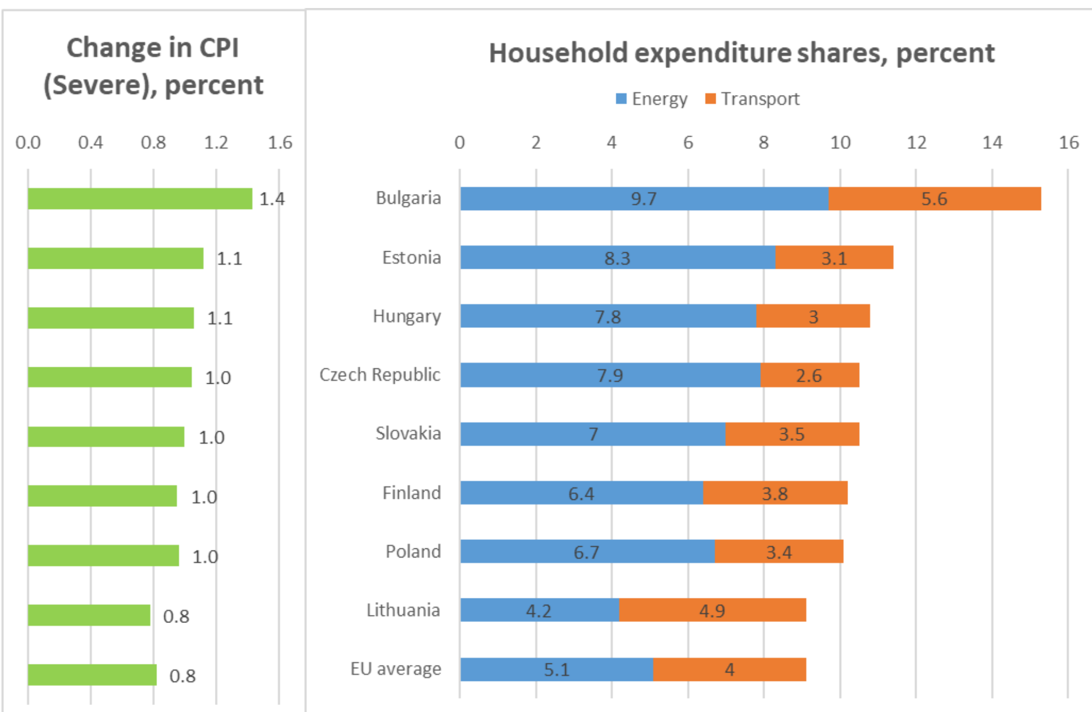

Figure 3. Expenditure shares and estimated changes in consumer price index for all goods and services (CPI) in selected EU countries, percent

Source: Authors' estimates based on Global Trade Analysis Project (GTAP) 11p2 Data Base with 2017 reference year.

Focusing on Bulgaria, as potentially the most impacted country, we further explore distributional implications of increasing energy prices across household types. As lower income households tend to spend a higher share of their income on energy, import restrictions could result in regressive distributional impacts putting relatively greater pressure on poor households. In the case of Bulgaria, households from the lower quintile spend on average 14.2 percent of their income on energy, while the corresponding expenditure share for the households from the top quintile is substantially lower – 7.8 percent (Figure 4). A different expenditure pattern is observed for transportation – households with higher income on average spend more on transportation services, as they travel more, as well as using more expensive forms of transport (e.g. air transport instead of railway). When the cost shares across household types are combined with short run changes in consumer prices for different fuel types, we observe moderately regressive price implications. While for the top quintile in Bulgaria consumer prices rise by 1.4 percent, for the bottom quintile a corresponding increase is higher – 1.9 percent (Figure 4). This suggests that in the case of most vulnerable energy consumers, a set of targeted compensatory measures might need to be implemented to protect them from adverse inflationary pressure.

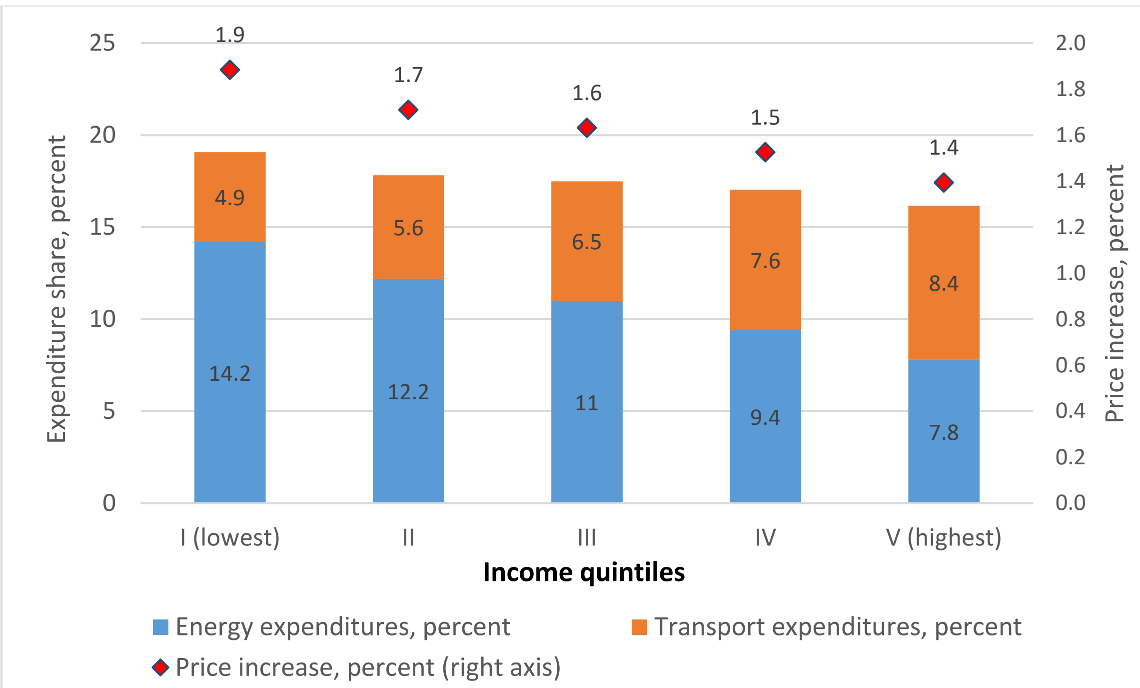

Figure 4. Household expenditure shares on energy and transport and estimated changes in consumer prices across quintiles in Bulgaria under the Severe scenario

Notes: Household expenditure shares correspond to 2015 reference year. These shares are different from the aggregate country shares reported on figure 3, as the latter correspond to the 2017 reference year.

Source: Estimated by authors based on NSI (2016) and Jiglau et al. (2022).

Our results suggest that even for the most vulnerable households in the Eastern EU member states overall price increases from major restrictions on energy imports from Russia will not exceed 2 percent. However, this outcome represents the impact of one specific policy measure. Of course, there are multiple other factors putting inflationary pressure on energy prices, including increasing energy demand following the recovery from the COVID-pandemic, supply chain disruptions and voluntary restrictions on energy supply by major producers, such as Organization of the Petroleum Exporting Countries (OPEC) (The White House, 2022b). All these factors are currently contributing to increasing prices of energy for industrial and residential consumers worldwide. However, these price increases likely represent short-term market fluctuations. This distinguishes them from the policy-induced, annual average price changes estimated in our analysis. Nonetheless, it is likely that higher energy prices would prevail on a more consistent basis leading to a much more substantial energy price pressure than that reported above.

To explore the potential impacts of substantially greater energy price increases across EU countries, we draw on the consumption expenditure shares for transportation and energy for final consumers and explore three hypothetical scenarios. These include 20, 30 and 40 percent increases in energy prices. Such price increases correspond to month-on-month changes in Dutch TTF Natural Gas prices. March average gas prices were 15 percent higher compared to October 2021, 27 percent higher than the January 2022 average price and 41 percent higher than the February 2022 price (Yahoo Finance, 2022). We further translate the corresponding energy price increases to changes in transportation prices. Based on the estimates provided on Figure E.1 (Appendix E), our modelling results suggests that 1 percent increase in consumer prices of energy under the short-term import restriction scenarios on average corresponds to 0.55 percent increase in transportation prices.[5]

When translating such higher energy and transportation price increases into CPI impacts, we find that they could result in a substantial inflationary pressure. In the case of 20 percent scenario, CPI increase by 1.1-2.6 percent across EU member states with an EU average rise of 1.5 percent (Table E.2, Appendix E). At the same time under a more dramatic 40 percent energy price increase scenario, EU average CPI rises by 2.9 percent, though in such countries like Estonia, Bulgaria and Greece an increase is over 4 percent (Table E.2, Appendix E). While in general our assessment of Russian energy import restrictions does not support such a high level of price increases, if considered in combination with other drivers and over a shorter-term horizon, these more dramatic energy price impacts are entirely possible. In such a case, there would be greater need for additional policy efforts to protect the most vulnerable from adverse distributional outcomes.

4.3. Long-term implications

So far our analysis has been focusing on the shorter-term implications of energy import restrictions – a timeframe with limited possibilities of adjusting trade, production and consumption patterns. In what follows, we discuss the potential long-term outcomes of restricting energy imports from Russia. For this assessment we rely on the dynamic modelling framework discussed in section 2.2. To represent the possibilities of adjusting the trade flows in the long-run we use long run values for the trade elasticities, as estimated using international cross section data on bilateral imports and trade costs (Hertel et al. 2007).

[5] This is an average estimate over three short-run scenarios reported in section 3.1.

With greater adjustment opportunities, we find that energy import restrictions could come at a very modest long-term cost for the EU economy. The cumulative reduction in real income is only 0.4 percent in 2030 (Figure 4). This translates to a slowdown in the income *growth rate* of only 0.04 percent per year. I.e., instead of growing at 2.18 percent per year in the baseline, the EU's real income would grow at 2.14 percent per year over the 2022-2030 period. Such modest impacts are explained in part by the fact that inflationary pressure diminishes over time – we observe energy and transportation price increases in EU in a range of 1-2 percent in 2030. In addition, the greater long run scope for structural adjustments in economy mitigates the cost to the EU economy. Output of fossil fuel power generation (oil and gas) decreases over time under this import restriction scenario, while renewable power generation grows (Figure F.1, Appendix F). Observed increases in non-fossil power generation are in a range of 5-6 percent in 2030 (relative to baseline levels), while reductions in oil and gas power generation are in the range of 17-21 percent. When translating these impacts into annual growth rates, we find that, even for the most impacted sectors, such as oil and gas power generation, the decline in annual average growth rate is in the range of -2.3-3.0 percent.

At the same time, we find substantial environmental co-benefits from restricting Russian fossil fuel imports – the reduction in CO_2 emissions reaches 6.6 percent in 2030 compared to the baseline. We also anticipate major health co-benefits that come from reductions in air pollutant emissions, such as fine particulate matter (PM2.5), sulfur dioxide (SO_2) and nitrous oxide (NO_x). The decline in emissions of these substances ranges from 2.8 to 5.9 percent in 2030. During 2019 alone, at least 178,000 premature deaths could have been avoided if all EU Member States had reached the World Health Organization's new air quality guideline (EEA, 2022): achieving such emission reductions would be a major contributor to reducing pre mature mortality in EU.

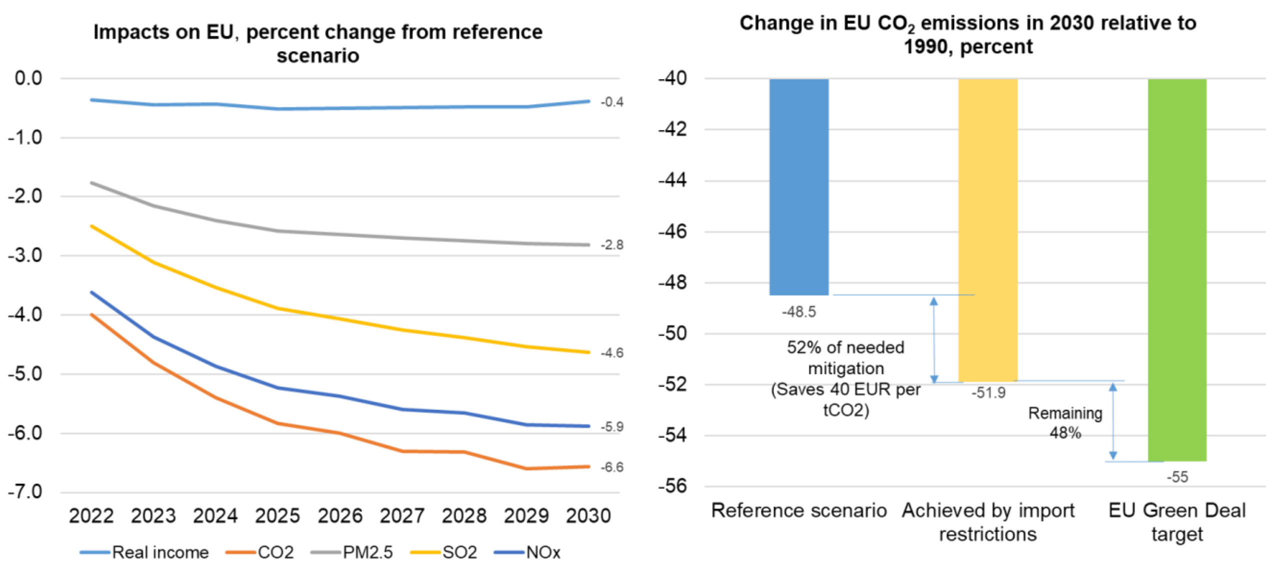

Figure 5. Long-term impacts of restricting energy import from Russia for EU
Source: Estimated by authors using ENVISAGE model.

We also find that restricting fossil fuel imports from Russia could play a major role in contributing to the EU Green Deal climate mitigation goals. In our reference scenario with current policies, CO_2 emissions drop by 48.5 percent in 2030 relative to 1990 level. The EU Green Deal pledges a 55 percent reduction in emissions or an additional 12.6 percent cut relative to our reference case. Bans on fossil fuel imports from Russia allow the EU to achieve half of this goal – with CO_2 emissions now falling by 52 percent in 2030 relative to 1990. Results suggest that the impact of such emission reductions is equivalent to the impact of a 40€ per tCO_2 carbon price, when taking into account current estimates of the marginal abatement costs for the EU region undertaken by Chepeliev et al. (2021).

By contrast, the restriction of EU fossil fuel imports would be a major burden on the Russian economy, slowing economic growth, reducing government budget revenues and substantially decreasing the country's ability to finance military operations. The reductions in real income could exceed 8 percent by 2030 (Figure 6). Our estimates also suggest that by 2030 the cumulative loss in income for Russia would exceed 1.1 trillion USD, while cumulative export revenue losses from reductions in fossil fuel exports would amount to almost 1.4 trillion USD.

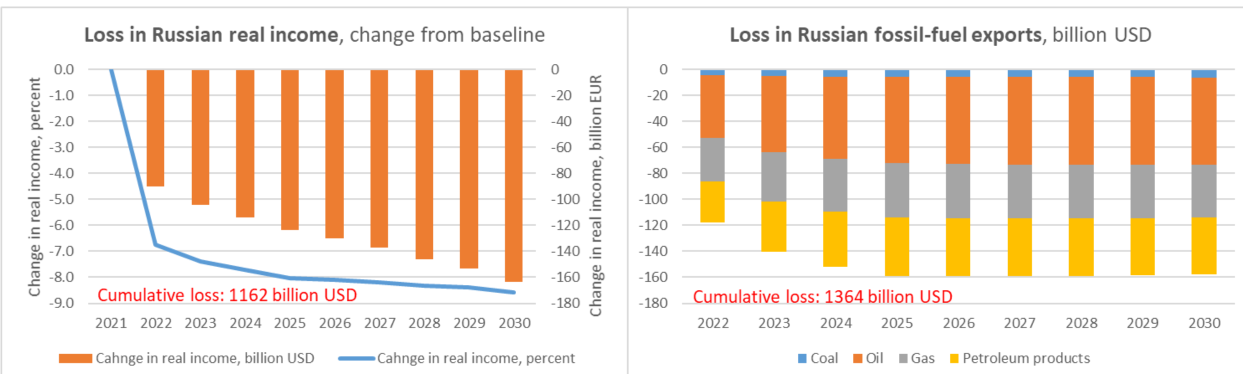

Figure 6. Impacts of restrictions of Russian fossil fuel exports on Russian economy
Notes: Estimated by authors using ENVISAGE model. All changes are reported relative to the baseline scenario. Values are reported in constant 2021 USD at market exchange rate.

This result is largely driven by the fact that, even in the long-run, Russia is not able to fully substitute the energy exports that have been lost to EU and other high-income countries (Figure 6). We find that on average in 2030 that Russia is able to substitute between 17-18 percent (gas and petroleum products) and 30 percent (coal) of the revenue lost from restrictions imposed on country's energy exports (Figure F.2, Appendix F). For instance, in the case of oil, countries that impose bans on energy imports from Russia reduce demand for Russian energy oil by 68 percent (as a share of total reference demand), while export demand from other destinations, mostly China, Turkey and Rest of ECA, increases by around 17 percent, recouping roughly one-quarter of the market share lost to sanctioning countries (Figure F.2, Appendix F). As a result overall demand for Russian oil falls by over 50 percent in 2030, relative to the reference case.

5. Conclusion

The short-term impacts of restrictions of Russia's fossil fuel exports are likely to be significant. In the case of the EU, Russia's largest energy export destination, households' real income could drop by 0.7-1.7 percent (relative to the reference case) with energy prices growing by 8-11 percent and transportation prices increasing by 5-6 percent. These impacts would vary greatly across EU member states and household types. We find that Eastern European and Baltic member states are not only more dependent on energy imports from Russia, but their households also spend a higher share of their budget on energy and transport (at least 10 percent). Thus consumers in these countries would be more vulnerable to energy import restrictions. In addition, lower income households tend to spend a higher share of their budget on energy, further heightening their vulnerability. At the same time, despite high level of dependence on energy imports from Russia, some Eastern European and Baltic member states, such as Lithuania, Latvia, Estonia and Poland, have already announced radical plans to stop buying Russian energy (Politico, 2022; Fortune, 2022).

Focusing on Bulgaria, the country with the highest share of household expenditures on energy and transport in EU, we find a moderately regressive incidence of the import ban, as the CPI for top quintile increases by 1.4 percent, while prices for the bottom quintile grow by 1.9 percent. Addressing the adverse impacts will require additional adaptation and diversification efforts from EU member states and implementation of policies that reduce the economic burden on the most vulnerable.

While we are focusing here on the markets for fossil fuels, the economic impacts of these policies are likely to be more extensive—notably on the market for cereals and fertilizers, that will have ripple effects on global food security, as well as spillovers from the significant and multiple sanctions placed on the Russian economy (Funakoshi et al., 2022).

There are multiple other factors that have been putting inflationary pressures on energy prices during 2021 and early 2022, including increasing energy demand following a recovery from COVID-pandemic, supply chains disruptions and voluntary restrictions on energy supply expansion by major producers, such as Organization of the Petroleum Exporting Countries (OPEC). In combination with Russian energy import bans, these factors could place much more substantial inflationary pressure on commodity prices than the estimates discussed above.

However, in the long-run, energy import restrictions would come at a far more modest cost for the EU economy, amounting to a decline in the annual growth rate of the EU of just 0.04 percent. Meanwhile this import restriction will be accompanied by substantial environmental co-benefits through reductions in CO_2 and air pollutant emissions. The achieved mitigation levels are equivalent to a 40 EUR per tCO_2 carbon price and thus could substantially reduce the necessary EU Emissions Trading Scheme (ETS) carbon price in the long-run.

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Appendix A. Additional trade statistics

Table A.1. Metrics of reliance on imports of fossil fuel from Russia in 2017 for individual EU countries

Country\indicator	Share of imports from Russia in total imports of fossil fuels (CIF prices), percent	Share of imports from Russia in total consumption of fossil fuels (market prices), percent	Share of imports from Russia in country's GDP, percent	Value of imports from Russia (CIF prices), billion USD
Bulgaria	64.9	36.6	4.9	2844.6
Finland	61.0	35.4	2.0	5072.0
Slovakia	59.9	33.8	2.9	2745.1
Lithuania	55.6	36.3	5.4	2575.4
Poland	51.2	25.0	1.9	10176.6
Czech Republic	50.2	28.3	1.6	3539.5
Estonia	48.5	18.2	2.1	558.1
Hungary	43.6	27.5	2.0	2750.7
Romania	35.5	12.5	0.8	1686.8
Italy	34.5	20.6	0.9	17871.2
Germany	34.1	18.7	0.8	27824.1
Greece	32.5	21.0	3.9	7800.5
Netherlands	28.0	19.2	1.5	11996.8
Denmark	27.6	13.1	0.5	1464.0
Croatia	25.7	15.0	1.2	645.0
Latvia	21.6	21.6	1.0	297.7
Sweden	17.4	11.5	0.3	1845.8
Malta	16.9	16.9	0.6	72.4
Portugal	15.5	9.8	0.7	1495.1
Slovenia	12.2	11.3	0.4	181.7
France	8.6	6.1	0.2	5102.0
Ireland	8.1	5.7	0.1	437.3
Cyprus	7.7	7.8	0.7	148.6
Belgium	7.1	5.3	0.4	1771.5
Austria	7.1	4.4	0.2	646.6
Spain	5.1	3.2	0.2	2566.4
Luxembourg	1.8	1.8	0.1	40.8
EU average	**25.6**	**15.7**	**0.8**	**114156.2**

Notes: Countries are sorted based on their share of imports from Russia in total imports of fossil fuels (CIF prices).
Source: Authors' estimates based on Global Trade Analysis Project (GTAP) 11p2 Data Base.

Table A.2. Metrics of reliance on imports of fossil fuel from Russia in 2017 for selected other countries

Country\indicator	Share of imports from Russia in total imports of fossil fuels (CIF prices), percent	Share of imports from Russia in total consumption of fossil fuels (market prices), percent	Share of imports from Russia in country's GDP, percent	Value of imports from Russia (CIF prices), billion USD
Turkey	29.4	18.8	1.3	11354.4
South Korea	11.4	6.6	0.8	11903.6
China	11.3	3.1	0.2	25639.2
Japan	10.8	5.6	0.3	15243.0
United Kingdom	8.3	3.9	0.1	3412.5
Taiwan	8.2	5.0	0.5	3115.9
Singapore	4.4	3.6	0.5	1609.8
United States	4.0	1.0	0.04	8006.1

Notes: Countries are sorted based on their share of imports from Russia in total imports of fossil fuels (CIF prices).
Source: Authors' estimates based on Global Trade Analysis Project (GTAP) 11p2 Data Base.

Appendix B. Regional aggregation

No.	Region	GTAP concordance
1	United States (USA)	United States of America (USA)
2	China (CHN)	China (CHN)
3	Russian Federation (RUS)	Russian Federation (RUS)
4	India (IND)	India (IND)
5	Turkey (TUR)	Turkey (TUR)
6	Brazil (BRA)	Brazil (BRA)
7	Indonesia (IDN)	Indonesia (IDN)
8	Philippines (PHL)	Philippines (PHL)
9	Egypt (EGY)	Egypt (EGY)
10	EU-27	Austria (AUT), Belgium (BEL), Cyprus (CYP), Denmark (DNK), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Ireland (IRL), Italy (ITA), Luxembourg (LUX), Malta (MLT), Netherlands (NLD), Portugal (PRT), Spain (ESP), Sweden (SWE), Czech Republic (CZE), Estonia (EST), Hungary (HUN), Latvia (LVA), Lithuania (LTU), Poland (POL), Slovakia (SVK), Slovenia (SVN), Bulgaria (BGR), Croatia (HRV), Romania (ROU)
11	Rest of East Asia and Pacific (XEA)	Mongolia (MNG), Rest of East Asia (XEA), Brunei Darussalam (BRN), Malaysia (MYS), Thailand (THA), Viet Nam (VNM), Rest of Oceania (XOC), Cambodia (KHM), Laos (LAO), Rest of Southeast Asia (XSE)
12	Rest of South Asia (XSA)	Bangladesh (BGD), Nepal (NPL), Rest of South Asia (XSA), Pakistan (PAK), Sri Lanka (LKA)
13	Rest of ECA (XEC)	Albania (ALB), Belarus (BLR), Ukraine (UKR), Rest of Eastern Europe (XEE), Rest of Europe (XER), Kazakhstan (KAZ), Kyrgyzstan (KGZ), Tajikistan (TJK), Rest of Former Soviet Union (XSU), Armenia (ARM), Azerbaijan (AZE), Georgia (GEO)
14	Rest of Middle East and North Africa (XMN)	Bahrain (BHR), Iran (IRN), Israel (ISR), Jordan (JOR), Kuwait (KWT), Oman (OMN), Qatar (QAT), Saudi Arabia (SAU), United Arab Emirates (ARE), Rest of Western Asia (XWS), Morocco (MAR), Tunisia (TUN), Rest of North Africa (XNF)
15	Rest of Sub-Saharan Africa (SSA)	Benin (BEN), Burkina Faso (BFA), Guinea (GIN), Senegal (SEN), Togo (TGO), Rest of Western Africa (XWF), Central Africa (XCF), South-Central Africa (XAC), Ethiopia (ETH), Madagascar (MDG), Malawi (MWI), Mauritius (MUS), Mozambique (MOZ), Rwanda (RWA), Tanzania (TZA), Uganda (UGA), Zambia (ZMB), Rest of Eastern Africa (XEC), Rest of South African Customs Union (XSC), Cameroon (CMR), Côte d'Ivoire (CIV), Ghana (GHA), Nigeria (NGA), Kenya (KEN), Zimbabwe (ZWE), Botswana (BWA), Namibia (NAM), South Africa (ZAF)
16	Rest of Latin America and Caribbean (XLC)	Mexico (MEX), Rest of North America (XNA), Argentina (ARG), Bolivia (BOL), Chile (CHL), Colombia (COL), Ecuador (ECU), Paraguay (PRY), Peru (PER), Uruguay (URY), Venezuela (VEN), Costa Rica (CRI), Guatemala (GTM), Honduras (HND), Nicaragua (NIC), Panama (PAN), El Salvador (SLV), Rest of Central America (XCA), Rest of South America (XSM), Dominican Republic (DOM), Jamaica (JAM), Puerto Rico (PRI), Trinidad and Tobago (TTO), Rest of Caribbean (XCB)
17	High income Asia (HYA)	Hong Kong (HKG), Japan (JPN), Korea (KOR), Taiwan (TWN), Singapore (SGP)
18	Rest of high-income (XHY)	United Kingdom (GBR), Switzerland (CHE), Norway (NOR), Rest of EFTA (XEF), Australia (AUS), New Zealand (NZL), Canada (CAN), Rest of the World (XTW)

Notes: Full list of the GTAP 10 Data Base regions is available at https://www.gtap.agecon.purdue.edu/databases/regions.aspx?version=10.211.
Source: Developed by authors.

Appendix C. Sectoral aggregation

No.	Sector code	Sector description	GTAP-Power 10 sectors
1.	ric	Paddy rice and processed rice	pdr, pcr,
2.	xgr	Other grains and oil seeds	wht, gro, osd
3.	xcr	Other crops	v_f, c_b, pfb, ocr, sgr
4.	ctl	Cattle and dairy	ctl, rmk, wol
5.	xlv	Other livestock	oap
6.	coa	Coal	coa
7.	oil	Oil	oil
8.	gas	Gas	gas, gdt
9.	frs	Forestry	frs
10.	nrs	Natural resource products	oxt
11.	pmt	Processed meat	cmt, omt
12.	dry	Dairy products	mil
13.	xfd	Other processed foods	fsh, vol, ofd, b_t
14.	wdp	Wood, paper and lumber products	lum, ppp
15.	twp	Textile, wearing apparel and leather products	tex, wap, lea
16.	p_c	Refined oil	p_c
17.	chm	Chemical products (incl. rubber and plastics)	bph, chm, rpp
18.	nmm	Non-metallic minerals	nmm
19.	met	Metals	i_s, nfm
20.	meq	Fabricated metal goods, vehicles and transport equipment	fmp, mvh, otn, omf
21.	elq	Electronics and electrical equipment	ele, eeq, ome
22.	etd	Electricity transmission and distribution	TnD
23.	nuc	Nuclear electricity	NuclearBL
24.	clp	Coal-fired electricity	CoalBL
25.	gsp	Gas-fired electricity	GasBL, GasP
26.	olp	Oil-fired electricity	OilBL, OilP
27.	hyd	Hydro-electricity	HydroBL, HydroP
28.	sol	Solar electricity	SolarP
29.	wnd	Wind electricity	WindBL
30.	xel	Other renewable electricity	OtherBL
31.	cns	Construction	cns
32.	trd	Trade including warehousing	trd, afs, whs
33.	wtp	Water transport	wtp
34.	atp	Air transport	atp
35.	otp	Other transport	otp
36.	xsv	Other Services	wtr, cmn, ofi, ins, rsa, obs, ros, osg, edu, hht, dwe

Notes: Full list of the GTAP 10 Data Base sectors is available at https://www.gtap.agecon.purdue.edu/databases/v10/v10_sectors.aspx#Sector65. GTAP-Power 10 Data Base sectors are listed in Chepeliev (2020).
Source: Developed by authors.

Appendix D. Additional information for the baseline scenario

Table D.1. Description of selected baseline assumptions

Assumption	Implementation	Specific assumptions
Costs of renewables are declining over time	The cost reduction is implemented using a hyperbolic specification with a cost asymptote. The curve is calibrated to three parameters—the asymptote (relative to current costs), a targeted reduction and the year the target is reached.	Wind and solar—the asymptote is 60% of today's price and the costs are dropping by 30% between 2014 and 2050. Other renewables—the asymptote is 70% and the costs are dropping by 20% between 2014 and 2050.
Non-price related changes in preferences towards renewables	Preference 'twist' parameters change the preference for one set of commodities in a demand system relative to other commodities, but without changing the aggregate cost (Dixon and Rimmer, 2002; van der Mensbrugghe, 2019).	We assume a target for renewable electricity as a share of total electricity demand and implement the twist assuming no change in prices (from the base year). The assumed shares are provided in Appendix D. The actual shares are likely to be higher given the decline in costs and the developments in the cost of other power activities. We do not introduce renewables, as a new technology, in case of countries with "0" renewables share in the benchmark 2014 year.
Target increase in electricity share for agents (trend towards electrification)		We assume that electricity consumption shares (in total energy consumption) increase two times by 2050 for all agents except transportation. For the case of air transport we assume a three times increase, for the case of road and water transport a four times increase. We also assume that the electrification rate in road transportation reaches at least 30 percent in 2050 and water transportation at least 10 percent. For households we assume a three times increase in electrification rates. An upper bound of 95% share of electricity in total energy use is set across all agents.
Energy efficiency improvements	Improvements in energy efficiency are captured by the autonomous energy efficiency improvement parameter (AEEI). We assume AEEI to be differentiated by countries, energy commodities and agents.	AEEIs vary between 1.5 and 3.0 percent across countries, with an exception of China with 3.5 percent. AEEIs are set to "0" in transformation activities and fossil fuel-based generation except gas power, where a 0.5 percent value is used. For energy intensive sectors (chemicals, metals and non-metallic minerals) a value of 1 percent is used, except China, where a 2 percent value is applied. AEEIs are assume to be higher in developing countries with a more rapid GDP growth and lower in the advanced economies. Overall, considering heterogeneous AEEI assumptions across countries, energy commodities and agents weighted average AEEIs range between around 1.0 and 2.0 percent.
Improvements in international transport costs		Costs decline by one percent per annum.
Increasing share of services		A trend toward increasing demand for services as intermediate inputs is incorporated within the baseline scenario – a 'servitization' assumption.

Table D. 2. Appendix E. Assumed shares of renewables in electricity generation under the baseline scenario (2050 target), percent[6]

Region	Targeted share
United States (USA)	40
European Union (E27)	45
Rest of Europe and Central Asia (XEC)	25
Turkey (TUR)	25
High income Asia (HYA)	25
Rest of high income countries (XHY)	30
China (CHN)	35
Russia (RUS)	30
Egypt (EGY)	20
Morocco (MAR)	30
Rest of Middle East and North Africa (XMN)	20
Rest of East Asia (XEA)	25
Indonesia (IDN)	25
Philippines (PHL)	25
India (IND)	25
Rest of South Asia (XSA)	25
Brazil (BRA)	25
Rest of Latin America and Caribbean (XLC)	25
Sub-Saharan Africa (SSA)	25

Table D. 3. Carbon price trajectories assumed under the baseline scenario, 2014 USD per tCO_2

Year\region	EU-27	China	Rest of high-income countries
2021	33.6	7.5	33.6
2022	37.3	8.6	37.3
2023	40.9	9.5	40.9
2024	44.6	10.5	44.6
2025	48.2	11.6	48.2
2026	51.9	12.9	51.9
2027	55.5	14.3	55.5
2028	59.2	15.8	59.2
2029	62.8	17.5	62.8
2030	66.4	19.3	66.4

[6] Renewables under targeting include, wind, solar and other renewable generation.

Appendix E. Additional short-term assessment results

Table E.1. Change in real income, percent

Region\scenario	SUBSTANTIAL	HIGH	SEVERE
Rest of ECA	4.9	5.6	6.5
Rest of MENA	1.7	2.0	2.5
Rest of SSA	0.9	1.1	1.4
Egypt	0.7	0.8	0.9
Rest of high-income	0.4	0.5	0.6
Turkey	0.4	0.4	0.4
Rest of EAP	0.3	0.3	0.4
Rest of LAC	0.3	0.3	0.4
Indonesia	0.2	0.2	0.3
Morocco	0.1	0.1	0.0
United States	0.0	0.0	0.0
Brazil	0.0	0.0	-0.1
Rest of South Asia	-0.1	-0.1	-0.1
China	-0.1	-0.1	-0.1
Philippines	-0.1	-0.1	-0.2
India	-0.2	-0.3	-0.3
High-income Asia	-0.6	-0.9	-1.3
European Union	-0.7	-1.1	-1.7
Russia	-10.4	-11.2	-11.7

Source: Estimated by authors using ENVISAGE model.

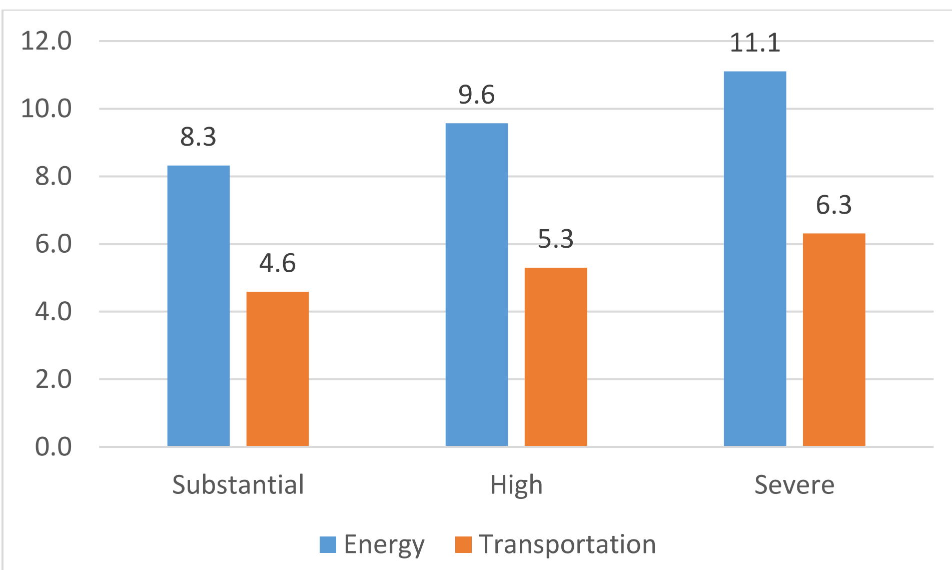

Figure E.1. Change in consumer prices of energy and transportation in EU, percent
Source: Estimated by authors using ENVISAGE model.

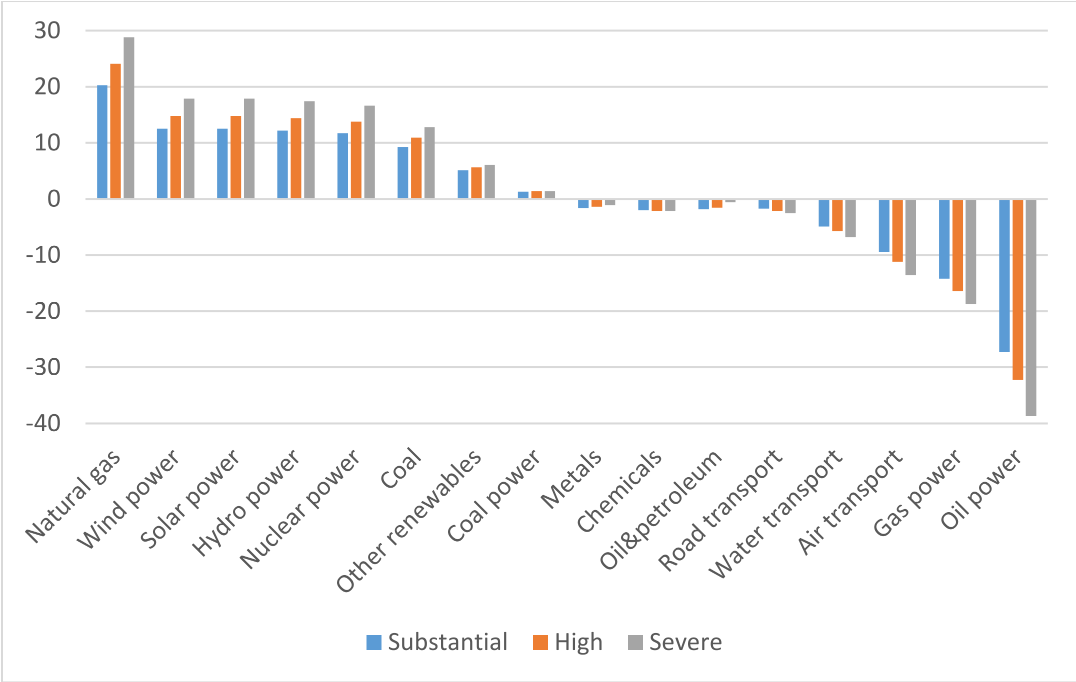

Figure E.2. Change in sectoral output for EU (selected sectors), percent
Source: Estimated by authors using ENVISAGE model.

Table E.2. Potential impacts of 20, 30 and 40 percent increases in energy price on CPI by EU member states, percent

Country\Scenario	20 percent	30 percent	40 percent
Bulgaria	2.6	3.8	5.1
Estonia	2.0	3.0	4.0
Greece	2.0	3.0	4.0
Hungary	1.9	2.8	3.8
Czech Republic	1.9	2.8	3.7
Denmark	1.9	2.8	3.7
Slovakia	1.8	2.7	3.6
Sweden	1.8	2.6	3.5
Cyprus	1.8	2.6	3.5
Poland	1.7	2.6	3.4
Ireland	1.7	2.6	3.4
Latvia	1.7	2.6	3.4
Finland	1.7	2.5	3.4
Croatia	1.7	2.5	3.3
Slovenia	1.5	2.3	3.1
Germany	1.5	2.3	3.1
Austria	1.4	2.1	2.9
Portugal	1.4	2.1	2.8
Lithuania	1.4	2.1	2.8
France	1.4	2.1	2.7
Romania	1.4	2.0	2.7
Netherlands	1.3	2.0	2.7
Italy	1.3	2.0	2.7
Spain	1.3	1.9	2.6
Luxembourg	1.3	1.9	2.6
Belgium	1.1	1.7	2.3
Malta	1.1	1.7	2.2
EU-27	1.5	2.2	2.9

Source: Estimated by authors.

Appendix F. Additional long-term assessment results

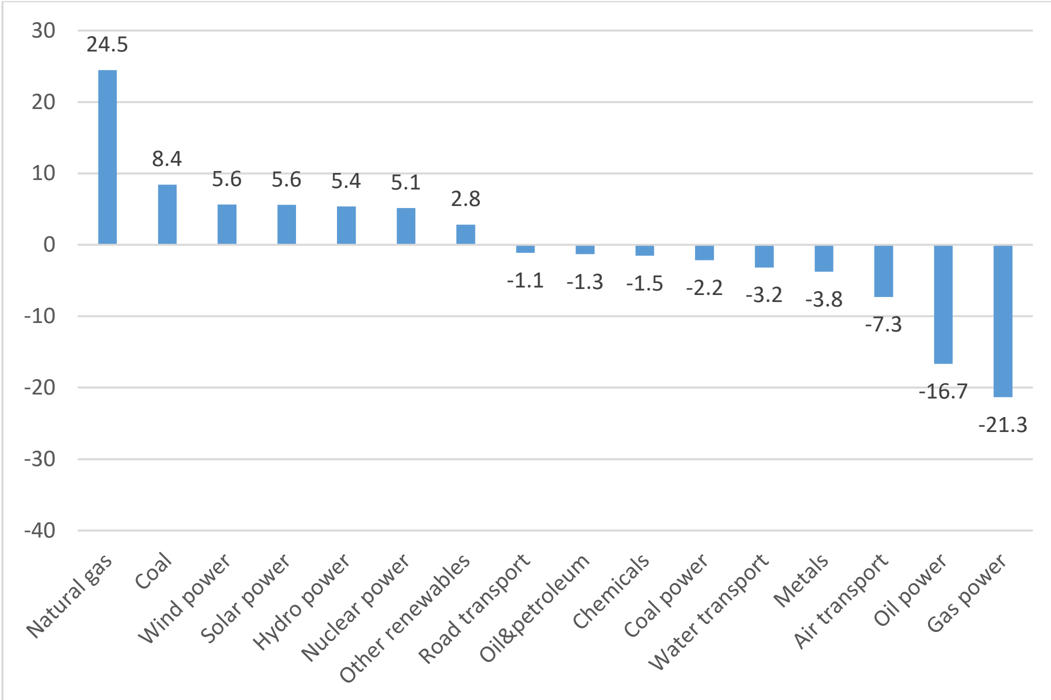

Figure F.1. Change in sectoral output for EU in 2030 (selected sectors), percent change relative to the baseline scenario

Source: Estimated by authors using ENVISAGE model.

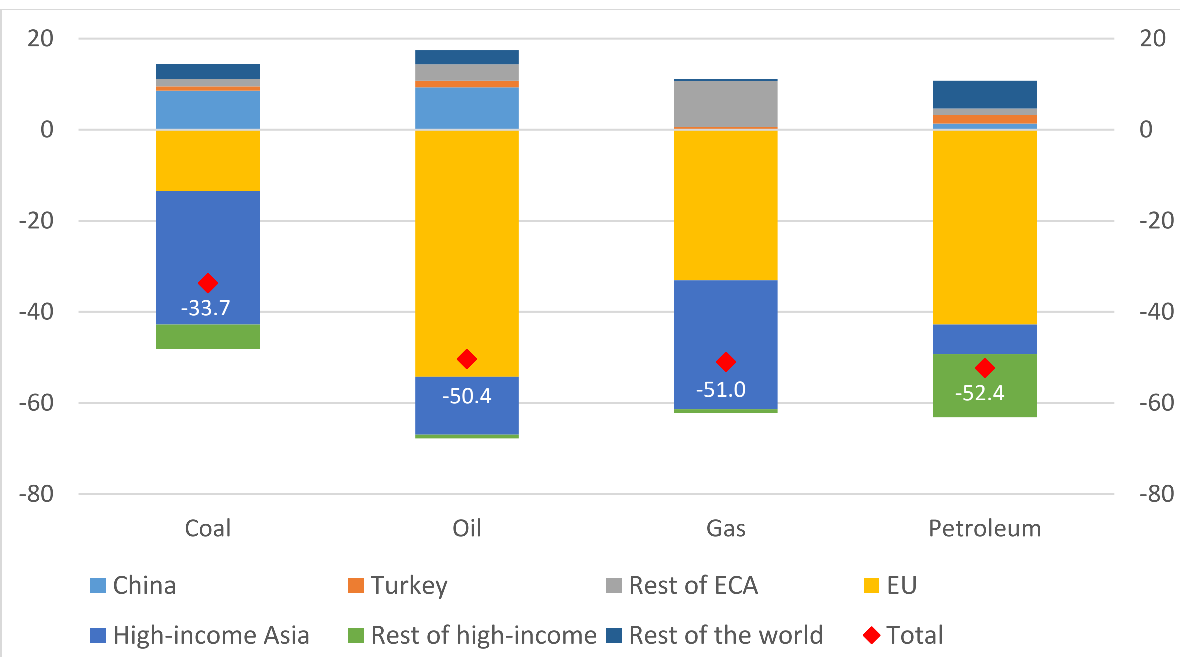

Figure F.2. Change in Russian energy exports by destinations in 2030, percent change relative to the baseline scenario

Source: Estimated by authors using ENVISAGE model.