Potential macroeconomic consequences of the war in Ukraine – simulations based on a severe risk scenario

Russia's war of aggression on Ukraine has worsened the economic outlook around the world, partly due to the direct effects of the hostilities and the uncertainty as to how the war will progress, and partly because the sanctions imposed against Russia by the European Union (EU) and its partners are likely to make themselves felt. These developments have sent prices for certain commodities, particularly fossil fuels, sharply higher, while foreign exchange and financial markets, too, have experienced major volatility.

As long as negotiations to end the war make no progress, there is a risk that hostilities will intensify further. An escalation of this kind would probably prompt a further tightening of the sanctions against Russia and possibly spark retaliatory action. Given these circumstances, discussion is turning to the possibility of dramatically reducing the EU's energy imports from Russia.

This article presents model calculations in an attempt to quantify the macroeconomic impact of such an escalation. Calculations are performed using the global macroeconomic model NiGEM, the Bundesbank's macroeconometric model (BbkM-DE), a linear sectoral input-output model, and various satellite models. NiGEM is used to model international economic relationships, the BbkM-DE model reflects the idiosyncracies of the German economy, and the input-output model is intended to capture rationing effects in the use of energy.

The simulations for Germany show that, in the severe crisis scenario with particularly high rationing effects, real gross domestic product (GDP) is likely to lag, in the short term, up to 5% behind the baseline scenario, as represented by the staff macroeconomic projections published by the European Central Bank (ECB) in March 2022. Since the ECB's projections were finalised in early March, they entailed only an initial assessment of the impact of the war. In the severe crisis scenario, real GDP would fall by just under 2% this year compared to 2021. Besides this, the inflation rate would be considerably higher for an extended period of time. The already very high rates of inflation projected in the baseline would be exceeded by around 1½ percentage points this year and by roughly 2 percentage points next year.

However, it should be noted that, even for a defined risk scenario, such calculations are subject to considerable uncertainty and may either overstate or understate future developments. One reason for this is that in some cases, the scale of the assumed shocks exceeds by far the magnitudes that prevailed when the model's elasticities were determined. Another is that the input-output tables used for this purpose are only a rough yardstick for the complex production linkages.

Introduction

Russia's war of aggression on Ukraine has darkened global economic outlook

Russia's war of aggression on Ukraine has dampened the economic outlook around the world. This is partly due to the direct effects of the hostilities and the uncertainty as to how the war will progress, and partly because the sanctions imposed against Russia and Belarus by the EU and its partners are likely to make themselves felt. Besides targeted measures against individuals and companies, these sanctions include bans on financing, investment and exports in certain business areas, capital market sanctions, and the exclusion of a number of Russian and Belarusian banks from SWIFT.[1] The EU Member States have also stepped up their efforts to reduce their dependence on Russian oil and gas supplies. Russian coal imports will be banned altogether in a few months' time.[2] The United Kingdom has taken similar action and, in addition, will stop purchasing Russian crude oil by the end of the year. The United States has gone one step further, banning imports of all energy sources originating in Russia.

Commodities significantly more expensive and financial market conditions poorer

The direct consequences of these developments were especially visible in commodity markets. The price of natural gas shot up initially in Europe. Prices for crude oil, coal, key industrial metals and food products, particularly grain and vegetable oils, rose significantly in global markets. Foreign exchange and financial markets likewise saw major volatility, especially during the first few weeks of the war. The Russian rouble initially plummeted in value, and global equity markets recorded sharp losses.

Widespread lowering of growth projections

The ECB responded as early as March 2022 to these developments, lowering its euro area growth projection for this year by 0.5 percentage point to 3.7%.[3] Other institutions also revised their forecasts downwards.[4] Initial economic data for the period after the outbreak of the war point in this direction, too. In March 2022, energy prices rose sharply at the consumer level as well. This was one of the reasons why annual inflation as measured by the Harmonised Index of Consumer Prices (HICP) climbed to 7.5% in the euro area and 7.6% in Germany. This backdrop and the prospect of continued price increases considerably eroded consumer confidence. On the business side, industrial enterprises, in particular, made downward revisions to their production expectations. According to the Ifo business climate index, German enterprises' business outlook even deteriorated more strongly than at the onset of the coronavirus pandemic in March 2020.

Downside risks to the economic outlook exceptionally high

Uncertainty about the further macroeconomic impact of the war in Ukraine remains extremely high. As long as negotiations to end the war make no progress, there is a risk that hostilities will intensify further. An escalation of this kind would probably prompt a further tightening of the sanctions against Russia and possibly spark retaliatory action. Given these circumstances, there is intense debate – especially in Europe – about the possibility of dramatically reducing all energy imports from Russia within a short space of time. This could be achieved by imposing tariffs on oil and gas imports, or through a complete embargo. One direct consequence of this would probably be a further significant rise in energy prices in Europe. Because it would be very difficult to completely replace Russian deliveries with higher imports from other commodity-producing countries in the

1 The Bundesbank, with its Service Centre for Financial Sanctions, is the competent authority in Germany for implementing EU financial sanctions regarding funds and provides the banking sector with the relevant information. The Peterson Institute for International Economics provides an overview of the sanctions imposed by many countries. See Deutsche Bundesbank (2022) and Peterson Institute for International Economics (2022).
2 The fifth sanctions package, adopted by the Council of the European Union on 8 April 2022, bans the import of coal and other solid fossil fuels with immediate effect. An exemption arrangement will apply until 10 August 2022 so that contractually agreed purchase obligations can be met. See Council of the European Union (2022).
3 See European Central Bank (2022a).
4 For instance, the German Council of Economic Experts lowered its forecast for economic growth in Germany this year by 2.8 percentage points to 1.8%. Germany's leading economic research institutions made a somewhat less pronounced downward revision to their growth projection in their latest Joint Economic Forecast. See German Council of Economic Experts (2022a) and Joint Economic Forecast Project Group (2022).

short term, bottlenecks in the supply of gas, especially, are likely to occur in this scenario.[5] The macroeconomic implications of such a scenario are currently the subject of lively debate amongst policymakers and academics.[6]

An adverse scenario from the perspective of macroeconomic models

Analysis of an escalation scenario using macroeconomic models

Macroeconomic business cycle models provide one possible framework in which the macroeconomic implications of a further escalation of the war in Ukraine and the sanctions against Russia can be analysed. Besides various dynamic stochastic general equilibrium models, the Bundesbank's analytical toolkit in this area contains semi-structural approaches, in particular.[7] These include the Bundesbank's macroeconometric model, known as BbkM-DE, which is the key instrument the Bank uses to coordinate its macroeconomic projections for the German economy.[8] The global macroeconometric model NiGEM has a similar basic structure.[9] However, it focuses less on capturing individual economies as accurately as possible. Instead, its strength lies in modelling the economic ties between countries, which are particularly important when it comes to analysing global events. Using simulation results for the international environment from NiGEM together with the macroeconometric model for the German economy is intended to combine the advantages of both approaches.[10]

Assumptions for the scenario calculations

Focus on consequences of higher commodity prices and uncertainty as well as trade restrictions

A hypothetical scenario in which the conflict escalates is analysed below.[11] This could be triggered, for example, by Russia stepping up its combat operations – assuming that the military conflict remains confined to Ukrainian soil. We assume that, in this case, the EU supports an embargo on Russian products, including fossil fuels. Through rising commodity prices, dwindling trade links and a prolonged period of heightened macroeconomic uncertainty, Germany and the other euro area countries would face greater economic strains than those outlined in the ECB's March projections.

Sentiment indicators for the euro area

Monthly data, seasonally adjusted

Sources: European Commission and S&P Global. **1** According to the European Commission's business and consumer surveys. **2** Expectations for the next 12 months; data for the total economy.

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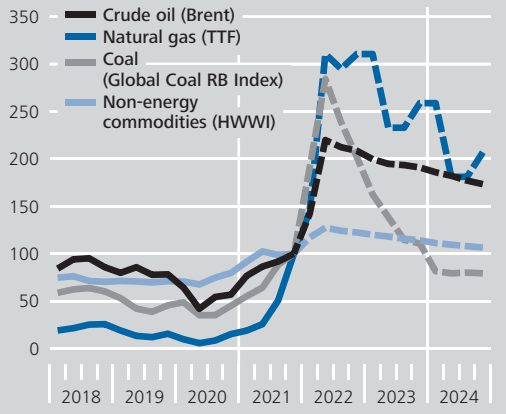
Assumptions for commodity prices …

Russia is a major supplier in the international markets for crude oil, natural gas and coal. Russia and Ukraine also account for a significant share of the global market when it comes

5 See, inter alia, McWilliams et al. (2022).
6 For an overview of selected studies on the consequences of an escalation of the conflict, see German Council of Economic Experts (2022b).
7 For an overview of the macroeconomic models used by the Bundesbank and their characteristics, see Deutsche Bundesbank (2020).
8 See Haertel et al. (2022).
9 For an overview of the model of the National Institute of Economic and Social Research, see Hantzsche et al. (2018).
10 For a similar approach for the economy in the Netherlands, see Berben et al. (2022).
11 The scenario was developed and calculated in mid-March 2022. The assumptions are therefore based on this data vintage. In the simulation calculations, the assumed intensification of the conflict thus already impacts in part on economic activity in the first quarter of 2022.

Commodity price assumptions*

Q4 2021 = 100



Sources: ECB and Bundesbank calculations. * Assuming a permanent boycott of Russian oil, gas and coal supplies.

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to a number of industrial metals and agricultural products. Owing to its geographical proximity and well-developed transport infrastructure, Europe is often the main buyer of these products (see the box on pp. 18 f.). If key buyer countries impose an embargo on Russian energy exports, it therefore stands to reason that commodity prices will rise well above their recent all-time highs. However, it is difficult to gauge exactly how prices will respond. Because the focus here is on a relatively adverse scenario, it is assumed that the price of a barrel of Brent crude oil rises to over US$170.[12] Coal prices could then climb sharply, too. Natural gas prices in Europe are expected to see the strongest rises since Russian deliveries will be very difficult to replace in the short term.[13] For non-energy commodities, the expected price mark-ups would be more moderate overall.[14] In all these cases, it is assumed that prices will peak in spring 2022 before declining slowly (sometimes with seasonal fluctuations). While it is assumed that the import bans on Russian products will remain in force over the entire simulation period, we also take into account the fact that supply and demand responses in all parts of the world increase over time.

… and export markets

The war and the sanctions imposed are already having a considerable negative impact on European companies' foreign business. Many firms have withdrawn voluntarily from the Russian market. These tendencies would probably be reinforced in the assumed scenario of an escalation of the conflict. The model calculations assume that there are no new exports at all from the euro area and the other G7 countries to Russia and Ukraine. In Germany, this would affect just over 2¼% of total goods exports (or less than 1% of GDP). The shares for the euro area as a whole are somewhat higher because Finland, Slovenia, Slovakia and the Baltic countries maintain close trade links with the conflicting parties. Russia and Ukraine even account for almost 15% of Lithuania's total goods exports, which means that the export value there comes to over 9% of GDP.

Uncertainty effects derived from SVAR models

Uncertainty in the euro area has increased significantly since the start of the military conflict in Ukraine.[15] An indicator of economic policy uncertainty based on a study of newspaper articles rose sharply in March 2022,[16] as did the distribution of future expectations in the surveys conducted by the European Commission among euro area businesses.[17] The first few weeks of the war even saw the implied volatility of the European stock index Euro STOXX 50 rise roughly as steeply as it had during the European sovereign debt crisis of 2012. Macroeconomic uncertainty has probably increased, too, given the uncertain outcome of the con-

12 Analysts from the Oxford Institute for Energy Studies believe that the price of a barrel of Brent crude oil could rise to more than US$160 in the event of an embargo, for example. See Fattouh and Economou (2022).
13 Specifically, a peak price of around €300 per megawatt hour (MWh) would have to be paid for natural gas at the TTF trading hub in the Netherlands in the scenario in question. That equates to around three times the current price. However, compared to the highest price recorded to date, at the beginning of March 2022, the difference only comes to just over €50 per MWh.
14 The model calculations make a distinction here between prices for metals, agricultural commodities, and food products.
15 For information about measuring uncertainty, see Deutsche Bundesbank (2018).
16 See Baker et al. (2016).
17 The dispersion of output expectations for the next three months in manufacturing is calculated on the basis of monthly business and consumer surveys conducted by the European Commission. For more information, see Bachmann et al. (2013) and Meinen and Röhe (2017).

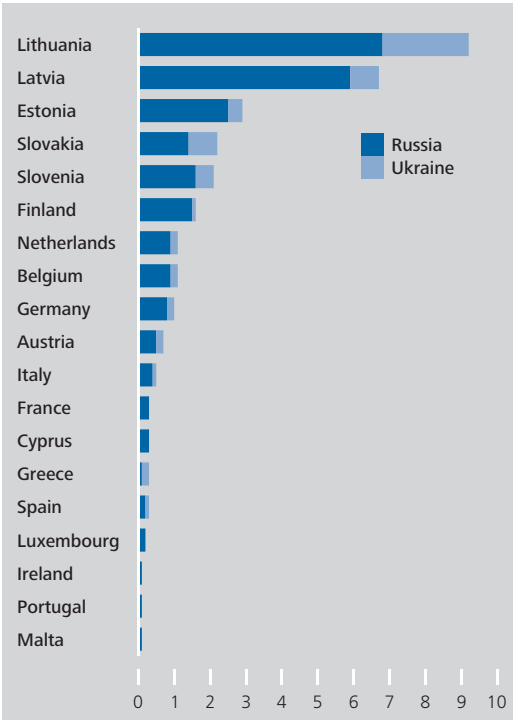
flict.[18] The scenario calculations assume that uncertainty will remain elevated for one quarter. The macroeconomic implications of this assumption are derived from a structural vector autoregression model (SVAR model) using a recursive identification scheme.[19] According to this approach, an uncertainty shock has a negative, statistically significant effect on private consumption, investment and real GDP, which gradually tails off over a period of around three years. An unexpected increase in uncertainty also tends to dampen inflationary pressure. In the macroeconometric models, the uncertainty effects are therefore implemented as demand shocks.

Additional public spending factored in for Germany

Fiscal policy priorities have recently shifted in the light of the violent conflict in Ukraine. The Federal Government paved the way for a significant rise in military spending. Other measures are aimed at easing the burden of the growing energy costs on households and enterprises. The simulation calculations take approximate account of these government measures to the extent foreseeable up to mid-March 2022.[20] For the rest of the world, meanwhile, no changes to the fiscal policy stance are assumed relative to the existing assumption made in March.[21] Monetary policy does not respond to the various shocks in the model calculations,

Significance of Russian and Ukrainian sales markets for euro area countries

Goods exports as a percentage share of GDP; data for 2021



Sources: Eurostat and Bundesbank calculations.
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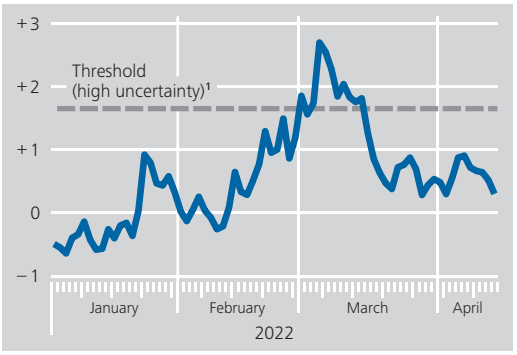
Implied stock market volatility in the euro area*

Daily data, standardised



Sources: Haver Analytics and Bundesbank calculations. * VSTOXX Volatility Index, calculated from options on the Euro STOXX 50. 1 Based on Bloom (2009): 1.65 standard deviations.
Deutsche Bundesbank

meaning that the simulation results may also provide an indication of the need for monetary policy action. The implications described below should be interpreted as a deviation from the

18 The preferred measure of uncertainty for the euro area in this case is derived from the volatility of forecast errors resulting from the forecasting of a broad selection of business cycle-relevant time series and financial market data. The fluctuation intensity of forecast errors determines the degree of uncertainty here. For a detailed explanation of the methodology, see Jurado et al. (2015) and Meinen and Röhe (2017).
19 In addition to a measure for macroeconomic uncertainty, inputs to the estimated Bayesian SVAR model include a stock market index, a shadow short rate as a measure of the monetary policy stance, the HICP, the unemployment rate, and real GDP on a quarterly basis.
20 Because this analysis was finalised early on, further relief measures agreed upon by the coalition committee at the end of March have not been included in the simulations. Nor do the calculations contain any additional spending for Ukrainian refugees.
21 The automatic stabilisers work freely, however. Nonetheless, the supporting effects of international fiscal policy are likely to be underestimated, if anything, since steps to cushion the impact of the surge in energy prices have also recently been taken in countries including France, Italy and Spain. The spillover effects of these measures on the German economy will probably be limited, however.

Russia's importance as a commodities exporter

Russia is one of the world's most important commodities producers. For each of the energy commodities – crude oil (and petroleum products), natural gas, and coal – Russia is among the three most important exporters.[1] It also holds a central position in the global markets for numerous industrial metals and minerals.[2] The country is, in fact, the global market leader for palladium, nickel and aluminium.[3] Russia is also, like Ukraine, an important exporter of agricultural products. Both countries hold a large share of the global market for wheat, in particular.[4]

European countries, including Germany and some eastern European nations, source a significant proportion of their raw materials from Russia. This is particularly true of energy imports.[5] More than one-fifth of European imports of crude oil and petroleum products originated in Russia in 2020.[6] Meanwhile, some 40% of natural gas imports to the European Union (EU) came from Russia.[7] Germany even sourced more than half of its gas imports from Russia.[8] Given these high import shares, it is difficult to imagine that they could be completely replaced at short notice. Russian natural gas imports, especially, could probably be substituted only partially in the short term, as other exporters do not have sufficient additional production capacity. In addition, there are capacity bottlenecks in Europe's gas infrastructure, especially in terms of liquefied natural gas terminals, regasification plants and natural gas pipelines.[9] Moreover, the fact that liquefied natural gas suppliers have long-term contracts with other customer countries limits their ability to supply Europe, at least in the short run.

Against this backdrop, the economic sanctions taken against Russia and those being mooted since Russia's invasion of Ukraine sparked concern that the commodities markets would experience a considerable shortfall in supply. In addition, the war caused disruptions to transportation, and the risk

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1 See bp (2021). Russian exports of crude oil represented just under one-eighth of global crude oil trade in 2020. The country's market share of petroleum products such as petrol, diesel or heating oil was somewhat lower, at just under 10%. In terms of natural gas, Russia even accounted for around one-fifth of the global market in 2020.

2 According to data provided by Trade Data Monitor (TDM), Russian exports of industrial metals and minerals represented around 5% of global exports of these commodities in 2020. This makes Russia the third most important exporter of this category of commodities worldwide.

3 TDM data show Russia to be the world's largest exporter of each of these three commodities, with the following shares in global exports: palladium (30%), nickel (13%) and aluminium (9%). Russia is also one of the world's most important producers of numerous other raw materials, some of them critical, including arsenic, cobalt, industrial diamonds, iron, gallium, germanium, lead, lime, magnesium, nitrogen, phosphate, platinum, silicon, silver, steel, sulphur, titanium, tungsten and vanadium, according to the U.S. Geological Service.

4 According to the Food and Agriculture Organization of the United Nations, Russia is the world's largest exporter of wheat, accounting for around 19% of global exports in 2020. Ukraine, in turn, was the world's fifth-largest exporter with a share of just over 9% of global trade.

5 However, even looking at industrial metals and minerals, the EU Member States as a whole source a particularly high percentage of their imports (around 12%) from Russia, according to TDM data.

6 Just under half of hard coal imports were supplied by Russia.

7 At the current end, the percentage of EU gas imports sourced from Russia lies at around 23% according to McWilliams et al. (2021).

8 In terms of crude oil and petroleum products, Germany acquired just under 30% of its imports from Russia in 2020.

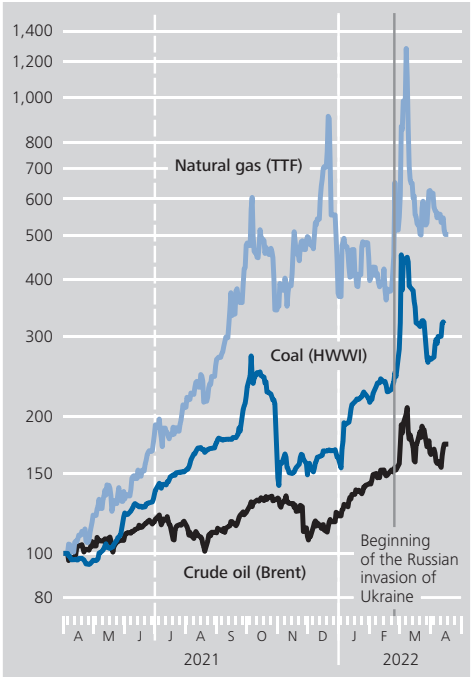
9 McWilliams et al. (2022) suggest that gas consumption in Europe would have to be curbed significantly if Russian gas supplies were to be halted altogether, as other exporters would probably not be able to fully replace the deliveries in the short term. Gas consumption, particularly for power production, could be reduced both by converting existing gas-fired power plants to oil burning and by making greater use of coal and nuclear power plants.

of potential retaliatory action as well as additional sanctions was seen. As a consequence, the prices of many commodities rose dramatically at the start of the war. Within a few days, the price of Brent crude oil, for instance, climbed by more than one-third to just under US$134 per barrel, its highest level in 14 years. European natural gas prices, which had already risen strongly in the preceding months, mainly as a result of a reduced supply from Russia, even doubled, at times. However, once it became clear that energy commodities would initially be largely exempt from western sanctions and with Russia's commodity exports falling only moderately to date, most prices came back down again significantly. This was also true of the prices of numerous industrial commodities and food products, whose prices had previously risen equally sharply. At the current end, prices of crude oil and European natural gas still exceeded pre-war levels by around 9% and 12% respectively. Prices for non-energy commodities were also above their pre-war levels, by around 4%, according to the Hamburg Institute of International Economics (HWWI).

Russia's large importance for numerous commodity markets and the fact that the supply situation in these markets was strained, in some cases, even before the war started means that commodity prices are subject to considerable upside risks. Prices could, in fact, exceed their recent highs in the event of greater restrictions of Russian commodities exports, for instance as a result of new sanctions or a suspension of Russian deliveries.

Prices for crude oil, natural gas and coal

Beginning of April 2021 = 100, daily data, log scale



Sources: Bloomberg Finance L.P., European Energy Exchange AG, HWWI and Bundesbank calculations.
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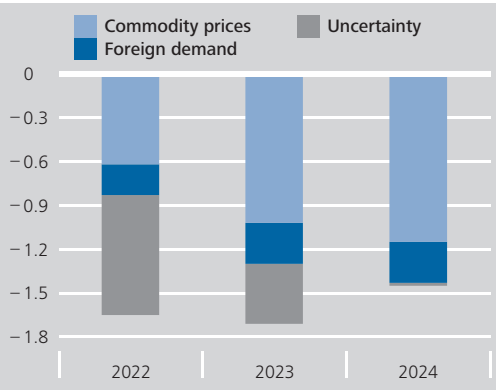
Potential GDP losses in the euro area as a result of the war in Ukraine

Percentage deviations from the baseline



Source: Bundesbank calculations using NiGEM and SVAR models.
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baseline, which reflects the ECB's March staff projections.[22]

Implications for the international environment

Considerable GDP losses in the euro area in the simulations

The simulations carried out using the global macroeconomic model NiGEM suggest that a further escalation of the war in Ukraine would substantially darken the economic outlook. They indicate that aggregate euro area GDP would be 1¾% lower this year than anticipated in the ECB's March projections. The level of economic activity would experience similar dips in 2023. The burdens would then probably ease slightly in 2024.[23]

Private consumption, investment and exports adversely affected

This timescale is largely attributable to the receding uncertainty shock. The adverse effects caused by persistently higher commodity prices increase successively, on the other hand. This is primarily due to significantly reduced private consumption stemming from losses in purchasing power. Private investment is another expenditure component that is likely to drop sharply compared to the baseline. The considerably gloomier export outlook in the model, meanwhile, reinforces the downward movement because the increase in commodity prices produces similarly adverse effects for many trading partners.[24] This is compounded by the fact that the loss of access to the Russian and Ukrainian sales markets directly limits European enterprises' export opportunities. Within the euro area, this has a particularly adverse effect on those economies with close trade links to both countries.

Significant deterioration in framework conditions for German economy, too

For Germany, the NiGEM simulations show a considerable reduction in foreign demand. German products do, however, become somewhat more competitive on balance in the global markets because the higher commodity prices make price pressures somewhat stronger still in the rest of the world and major exchange rate movements remain absent owing to the global nature of the shock and the assumed passivity of monetary policy.

Consequences for the German economy

Simulations with the macroeconometric model for Germany …

The potential macroeconomic consequences for Germany were estimated based on simulations with the Bundesbank's macroeconometric model (BbkM-DE). The model allows for a detailed analysis of the impact of the individual shocks, above all how they affect consumer prices. Government measures can also be incorporated relatively precisely. Similarly to the regularly published Eurosystem staff macroeconomic projections, the implications of the escalation scenario for the international environment described in the previous section are

22 These projections, which were finalised at the beginning of March 2022, only incorporate the initial assessment of the repercussions of the war for the euro area economy but not an escalation of the crisis as assumed in the scenario.
23 These figures are based on simulations in which Germany and the rest of the euro area were exposed to the same uncertainty shock. The results that were reused as input variables for the estimation of the effects on Germany in the macroeconometric model exclude this channel for Germany so as to avoid double-counting.
24 Over a longer period, the price increases simulated in the model also reduce the energy intensity of the economy. Via this channel, potential output also decreases with the lower factor input. Overall, the still relatively moderate increase in the price of crude oil has the greatest impact in NiGEM because it accounts for a large share of the energy mix.

fed into the simulations as exogenous developments.

… taking into account information from NiGEM and SVAR models

Alongside the information on the movements in commodity prices, foreign demand, foreign competitors' prices and exchange rates from NiGEM, the simulations also take into account the effects of heightened uncertainty on domestic demand in Germany. The latter effects were derived from satellite calculations using a SVAR model for Germany and implemented via shocks to private consumption and business investment.[25] In order to present a differentiated picture of the impact of higher energy and food commodity price quotes on consumer prices, disaggregated inflation forecasting models are used to gauge the effects on the energy and food components of the HICP. These are then integrated into the analysis with the BbkM-DE model. The government measures taken into account correspond to the relevant estimates made in mid-March 2022.[26]

Aside from elevated commodity prices …

The simulations indicate that the assumed steep rise in commodity prices exerts a strong immediate effect on economic activity. This effect is mainly transmitted via two channels. First, the aggregate production function in BbkM-DE takes energy into account as a third production factor alongside labour and capital. The increase in energy prices raises the cost of energy usage, which depresses factor demand and therefore also energy imports. Second, consumer prices rise as a knock-on effect of the HICP energy component. This dampens real income, thereby inducing households to reduce their consumer spending.

… and loss of foreign sales markets, …

German exports fall significantly below their baseline level. This is due to the major importance of the losses in foreign sales markets for German exports. This is not offset by the opposing effect of the German economy's increasing price competitiveness at the international level.

The negative implications of increased uncertainty for business investment and household spending amplify the decline in aggregate demand and therefore the contractionary effect of the other transmission channels.

… increased uncertainty also dampens aggregate demand

Significant decline in real GDP …

Overall, real GDP in the current year decreases by just under 2% relative to the baseline. In subsequent years, the simulation results – driven by the impact of commodity prices[27] – indicate that this decline will be stronger still. The positive fiscal stimulus is already included here, although this only absorbs a relatively small share. However, it can be assumed that in such a scenario, further fiscal support measures would probably be taken beyond the government measures that are already incorporated into these simulations and those which are now also in planning, as a way to further absorb the negative impact on GDP.[28]

… and substantial rise in inflation rate

In terms of prices, higher commodity prices for energy and food have a substantial impact on the HICP rate in Germany, putting it at around 1½ percentage points above the baseline in 2022. This effect is set to be even greater the year after. Even in 2024, the inflation rate is still elevated, albeit no longer as strongly. These dy-

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25 In the SVAR model used to estimate the effects for Germany, GDP was replaced by private consumption or business investment, respectively.

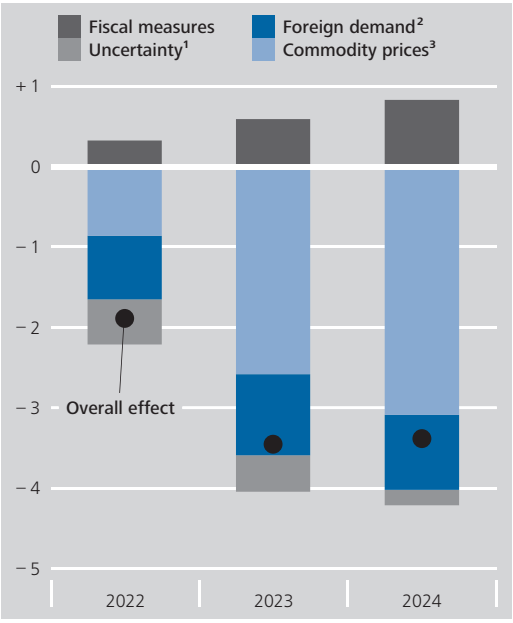
26 Higher government consumption and investment expenditure was assumed over the entire simulation period in order to capture the impact of increased military spending. In addition, it was assumed that higher monetary transfers and subsidies are granted in the second quarter of 2022 to provide households and enterprises with a degree of relief from the increased energy costs.

27 Note here that a significant share of this reflects indirect effects which are transmitted through subdued foreign demand and which, under a different definition, would be assigned to the sales market channel.

28 Comparing the results for the euro area (from NiGEM) with those for Germany (BbkM-DE), the GDP effects in the current year are of a similar magnitude. In the two years thereafter, however, real GDP in Germany (according to the BbkM-DE model) are significantly more subdued than the NiGEM results for the euro area would suggest. Two main factors can explain this: first, the income elasticity of imports is substantially higher in NiGEM, meaning that imports respond fairly strongly to changes in aggregate demand. This mitigates the negative GDP effects significantly. Second, the gas price shock cannot be implemented in a country-specific way in NiGEM. A greatly delayed but gradually increasing effect, such as would be expected for consumer prices in Germany (and is also specified thus in BbkM-DE) cannot be captured in NiGEM. Instead, the impact of the gas price shock there is immediate and is less persistent, similar to that of an oil price shock.

Possible GDP losses in Germany as a result of the war in Ukraine

Percentage deviations from the baseline



Source: Bundesbank calculations using BbkM-DE, including input from NiGEM and SVAR models. **1** Including the uncertainty effects with an indirect impact via German foreign demand. **2** Excluding the indirect effects of uncertainty and commodity prices on the sales markets. **3** Including the effects for trade partners stemming from the increases in commodity prices.

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namics reflect the lagged effects of gas price shocks, first and foremost. This is a particularity of the adjustment of German consumer gas prices to commodity price developments.

Financial market shocks only indirectly considered

When interpreting the simulation results, it should be noted that specific developments resulting from distortions in financial markets have not explicitly been taken into account. They can be relevant in particular in an adverse scenario like the one assumed here. Generally speaking, the effects of this type of financial market shock are limited in macroeconometric models of this kind. However, here they are likely to be partly covered by the uncertainty shocks.

Expenditure-side model approach used to illustrate production-side disruptions

The macroeconometric model framework used here is able to capture dynamic interactions resulting from the distinct shocks. At the same time, it is limited in that GDP is calculated using the expenditure-side approach, while the impact of the war also causes disruptions on the production side. This would be the case in the event of an energy embargo in particular, because production shortfalls could already materialise now in the short term as a result of rationing. Such rationing effects cannot be readily expressed in a model based on the expenditure-side approach, and can therefore only be captured indirectly through price effects. However, as the resulting quantitative adjustment in energy imports itself then only occurs gradually, this is unlikely to fully capture the effects of such an embargo.[29] In addition, the macroeconometric models used here disregard sectoral differences in production functions and linkages via value chains. For these reasons, it is worth observing the direct effects of a sudden energy embargo from another perspective.

Additional disruptions to the German economy in the event of an energy embargo

Rationing effects estimated on the basis of sectoral input-output tables

A complete stoppage of Russian energy supplies would probably not only produce effects that are confined to prices and the quantitative adjustments these trigger, but also lead to a rationing of energy use in the German business sector. The fact that Germany sources a large portion of its gas from Russia plays a particularly critical role here. Coal imports, meanwhile, are of lesser significance.[30] The resultant declines in enterprises' production are quantified using a linear sectoral input-output model.[31]

29 In addition, the estimated price elasticity of energy imports is relatively low.

30 In the case of coal, the availability of short-term substitutes for Russian imports is likely to be significantly greater than for natural gas. Russian coal could be fairly quickly substituted with bituminous coal imports from other coal-producing countries. See Federal Ministry for Economic Affairs and Climate Action (2022).

31 For similar analyses based on input-output tables, see also European Central Bank (2022b) and OECD (2022). Bachmann et al. (2022) uses a non-linear static international trade model based on input-output tables, as well as the partial model of the constant elasticity of substitution (CES) production function. What these approaches have in common is their focus on volume effects resulting from energy shortages, whilst other transmission channels (e.g. uncertainty effects) are not considered in either case.

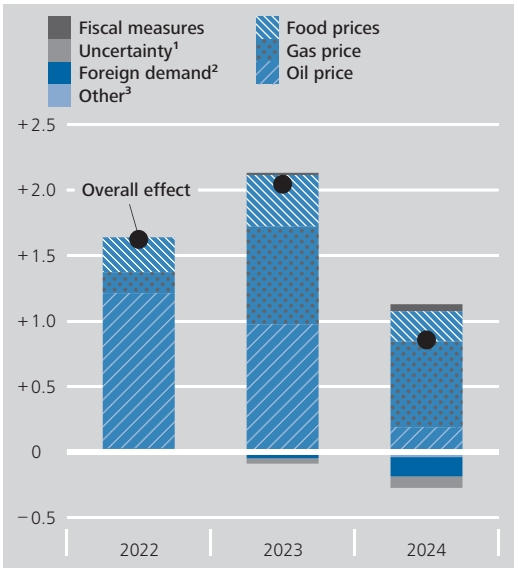
The advantage of such a model is that intermediate inputs between economic sectors can be examined as well as associated amplification effects. One disadvantage, however, is this model's static and partial perspective.

Scenario in which Russian supplies of natural gas, oil and bituminous coal cease

The supplementary simulation calculations are based on the assumption that the sudden stoppage of Russian energy supplies would reduce the use of natural gas, bituminous coal and refined petroleum in the sectors that rely on these sources of energy by 40% this year, as from the second quarter.[32] The assumed scale of the shock is based on the share of Germany's primary energy consumption made up by Russian supplies of these three energy sources in 2019.[33] It is assumed here that no possible substitutes are available in the short term.[34] In the linear input-output system of equations, shortfalls of energy intermediates reduce the output values of directly affected sectors by the same percentage, in arithmetical terms.

Possible effects on HICP inflation in Germany as a result of the war in Ukraine

Percentage point deviations from the baseline



Source: Bundesbank calculations using BbkM-DE, including input from NiGEM and SVAR models. **1** Including the uncertainty effects with an indirect impact via German foreign demand. **2** Excluding the indirect effects of uncertainty and commodity prices on the sales markets. **3** Including the effects for trade partners stemming from the increases in commodity prices and exchange rate effects.

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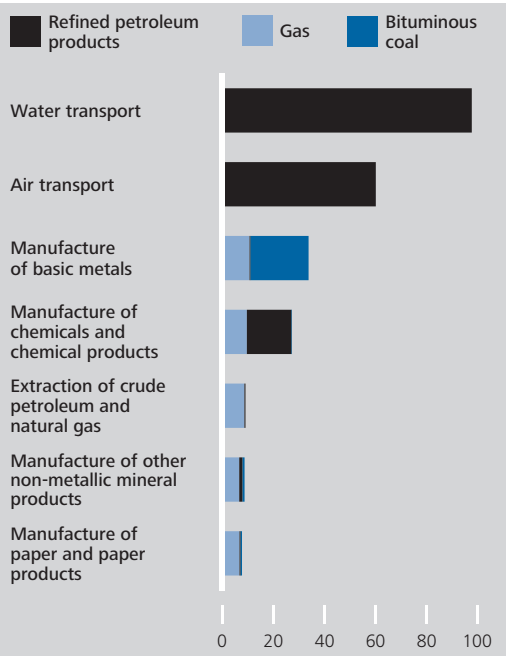
Energy-intensive sectors particularly hard-hit by energy rationing

A certain degree of discretionary scope is inherent in the modelling with regard to the extent to which economic sectors are directly exposed to shocks and those which are only indirectly affected via input-output relationships. For this reason, two model versions are calculated. In the first version, only the energy production and supply sectors are cut off directly from supplies of Russian energy.[35] In the model, the shocks directly impact downstream sectors in line with the degree to which they depend on the energy sectors to provide their intermediate inputs. The second version of the calculation assumes that in addition to energy suppliers, energy-intensive sectors are also directly af-

32 This procedure is based on the hypothetical extractions method. See Miller and Blair (2012), pp. 563 ff., and Dietzenbacher and Lahr (2013). The calculations are based on the German input-output table for 72 categories of goods as per the Federal Statistical Office for the year 2018. The shock duration of three quarters is based on a starting date in mid-March 2022, which is when the scenarios were determined. One assumption is that natural gas could also be rationed outside of the heating season this year if the topping-off of barely-filled gas storage tanks takes priority during this time. See also Holz et al. (2022).
33 According to AG Energiebilanzen (2020), bp (2020) and comments made by the German National Academy of Sciences Leopoldina (2022), Germany sourced just over 50% of its natural gas imports, 45% of its bituminous coal imports and over 30% of its crude oil imports from Russia in 2019. Germany's dependence on imports was very high for each of these energy sources. Its total primary consumption of energy from natural gas, refined petroleum and bituminous coal came to more than 8,800 petajoules (PJ) in that year, according to AG Energiebilanzen (2020). Were Russian energy imports to cease, then, this would reduce primary energy consumption by approximately 3,500 PJ, or around 40%.
34 Microeconomic studies on production stoppages resulting from supply chain disruptions (in the aftermath of natural disasters, for example) indicate that intermediate inputs cannot be easily substituted on account of search frictions and relationship-specific investments, at least not in the short term (see Barrot and Sauvagnat (2016), Boehm et al. (2019) and Carvalho et al. (2021)). Energy is, in principle, a fairly homogeneous product that is generally relatively easy to substitute. However, natural gas and refined petroleum products are primarily supplied by Russia to Germany via pipelines, which makes it difficult to substitute them in the short term. That being said, certain saving and substitution possibilities would exist in the current year, even for natural gas (see German Council of Economic Experts (2022a)).
35 These include the manufacture of coke and refined petroleum products as well as energy supply sectors (gas, steam and air conditioning and electricity). In 2018, these two sectors respectively accounted for a 0.1% and 1.5% share of the value added in all sectors, according to the input-output table.

Energy intensity in selected sectors in Germany*

Energy intensity[1]



Source: Federal Statistical Office. * Sectors other than energy production and processing, for which energy intensity for one of the energy sources listed exceeds the value 5 in 2018. **1** Ratio of energy use in terajoules to value added in € million.
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fected by the energy supply shortages.[36] These are primarily sectors which use fossil energy sources to power their production plants or which process fuels as raw materials. This reflects the expectation that the energy supply of some energy-intensive sectors would also be restricted in the event of an energy embargo – an assumption consistent with a scenario where supplying households and basic social services with energy would take priority in the event of rationing.[37]

Substantial GDP losses possible in the short term in the event of energy rationing, also on account of cascade effects via value chains

For the current year, the supplementary model calculations produce GDP losses of 1% in the first version of the calculation and 3¼% in the second version in the event of a stoppage of energy supplies.[38] Substantial amplification effects resulting from input-output linkages are evident in both versions. The aggregate impact of the shock is more than twice as large in each case when intermediate inputs are also taken into account. This is due to the fact that above all the sectors closer to the start of the value chain, such as producers of basic materials in the manufacturing sector, would be hit hard by the shock.

Calculations subject to great uncertainty

The scenario calculations are subject to a great deal of uncertainty for two reasons. First, the effects of an energy embargo strongly depend on the availability of substitutes in the short and medium term. The assumption that no substitution is possible could overstate the economic losses. Global shortages of the embargoed energy sources and the limited transport options – neither of which are captured by the model – also have a bearing on the availability of possible substitutes. The complex technical challenges of replacing pipeline-bound gas and oil supplies cannot be sufficiently captured by the model, either.[39] Furthermore, it is uncertain which sectors would be particularly hard-hit by rationing, as this would also be at the discretion of state authorities, at least in the case of natural gas supply. Second, the diversity and complexity of value chains as well as potential regional differences in terms of impacts within Germany cannot be fully captured in the eco-

36 These include the manufacture of paper and paper products (0.3% share of value added in all sectors in 2018, according to the input-output tables), the manufacture of chemicals and chemical products (1.2%), the manufacture of other non-metallic mineral products (0.5%), the manufacture of basic metals (0.7%), crude petroleum and natural gas extraction (less than 0.1%), water transport (0.2%) and air transport (0.2%).
37 See Federal Ministry for Economic Affairs and Energy (2019).
38 The assumed duration of the shock (three quarters) is captured in the statistical model framework by reducing the GDP losses calculated on an annual basis by one-quarter. Owing to the type of modelling used in the calculations and the natural gas-intense nature of the majority of the directly affected sectors in the two versions of the calculations, the rationing effects of natural gas account for the lion's share of the calculated GDP effects. Excluding shortages of bituminous coal and oil products, the rationing effects for the current year would be around one-third smaller in the second version of the calculation.
39 In the short term, the shortfall caused by the stoppage of Russian crude oil supplies could, in principle, be covered by additional imports from other countries and by Germany's existing oil reserves. Even so, replacing the supplies to refineries in eastern Germany might present logistical challenges (Bloomberg (2022)).

nomic model. This would tend to result in an underestimation of amplification effects.[40]

Interpreting the results

Energy embargo likely to weigh significantly on economic activity and drive up inflation

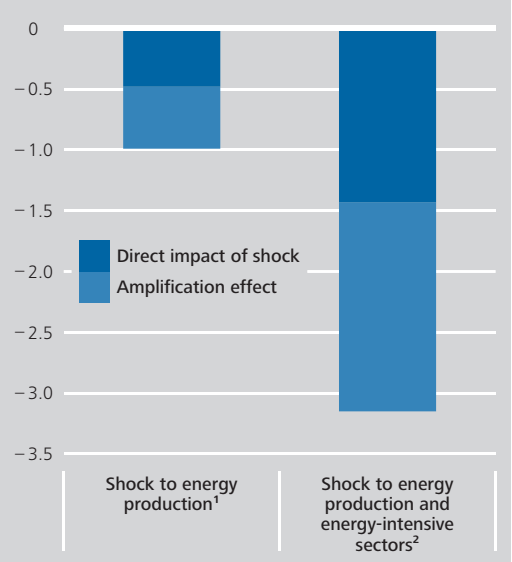
Viewed overall, the severe crisis scenario would produce considerable negative GDP effects for Germany. However, the actual size of these effects is hard to quantify, even for a defined scenario. If the losses quantified in the macroeconometric model and the input-output framework are taken together, the GDP loss in Germany for the current year could total up to 5%, according to the calculations presented here.[41] The following years would see the losses decline again somewhat, particularly if the Russian energy supplies can gradually be replaced in part and the associated rationing effects ease off. But even in 2024, economic activity would still be significantly below the baseline.[42] Another aspect fraught with great uncertainty is the impact on the inflation rate. According to the simulations, the inflation rate would be 1½ percentage points above the baseline on average this year and would reach a considerably higher level in the subsequent period on account of the delayed pass-through to final consumer gas prices.

Results of macroeconometric model and input-output analysis additive in the short term, for the most part

The analysis assumes that the GDP losses computed with the macroeconometric model and the input-output analysis can, for the most part, be added up in the short term. However, it is possible that they could overlap, at least to some extent. This is due in part to the differing perspectives of the two model approaches. The macroeconometric model framework can only capture supply-side effects indirectly, as the effects on GDP unfold via the expenditure components and their response to energy price hikes. However, the model-endogenous response of aggregate energy consumption does give some clues. In the short term, its price elasticity is relatively low in the model estimations, meaning that the calculated volume effects of supply stoppages are only covered by the direct responses to the energy price hikes

Possible GDP effects in Germany through quantitative restrictions on energy in 2022*

%



Source: Calculations based on the 2018 German input-output table produced by the Federal Statistical Office. * Assumed sectoral shock of 40% lasting for three quarters. **1** Comprises manufacture of coke and refined petroleum products as well as electricity, gas, steam and air conditioning supply. **2** Sectors with a high consumption of refined petroleum products, natural gas or bituminous coal relative to value added.
Deutsche Bundesbank

to a minor extent.[43] This speaks in favour of adding up the contributions from model simulations and input-output analysis. However, such an approach could lead to a certain over-

40 In the model framework, shocks are passed through to downstream production sectors in proportion to the share of the sectors' production value accounted for by intermediate inputs such as energy. This share is generally modest, dampening amplification effects. In fact, though, even the failure of components with little economic value can create significant production shortfalls. For example, the war in Ukraine has led to supply bottlenecks in cable harnesses, resulting in production stoppages in the automotive industry. Furthermore, the analysis is based on the German input-output table. Additional negative spillover effects resulting from production stoppages at trading partners as a consequence of an international energy embargo are not considered here.
41 The calculations depart from a baseline established at the beginning of March 2022, which – on the basis of a continuing recovery from the impact of the pandemic – had already assumed GDP shortfalls and increased inflation for the current year due to the outbreak of the war.
42 This is likely to be due to the delayed pass-through of gas price hikes to the consumer, with an accordingly dampening effect on household consumption. Furthermore, the sales prospects of German exporters would still be below their baseline level.
43 Simulations using NiGEM yield the same conclusion. For more on this, see also Behringer et al. (2022).

statement of the overall impact. This is particularly relevant beyond the short term, as substitution effects are then likely to come more into play. At a fundamental level, the time profile of the rationing effects is subject to uncertainties. If these effects materialise primarily during the winter months, the GDP losses are likely to roll over to the coming year to a greater extent.

Estimation of macroeconomic impact very uncertain

Estimations of GDP losses are subject to both high upside and downside risks owing to the variety of relevant transmission channels whose complexity means that they can only be captured partially in the models, if at all. It should be noted that the scale of the assumed shocks in some cases far exceeds the magnitude that applied during the estimation period used to calculate the model elasticities.

Adjustment pressure from pivoting away from fossil fuels increased by war

However, short-term substitution possibilities for fossil energy sources could, in fact, be greater than assumed, as substitution possibilities are unobservable, and, therefore, reliable estimates are not available. Additionally, the substitution elasticity in the current situation could be increased by means of prudent crisis management, for example. Furthermore, it can be assumed that the fiscal policy response considered in the simulations would be significantly stronger in the event that the crisis were to escalate. This would partially offset the decline in GDP. All things considered, the war in Ukraine is, in any case, intensifying adjustment pressure from pivoting away from fossil fuels – an issue that the German economy was already facing prior to the outbreak of the war.

Inflation effects could be stronger still

With regard to the impact on inflation, the upside risks are likely to predominate. Potential price increases resulting from energy rationing at downstream production stages have been disregarded, as have wage increases in an environment of massively increased energy costs (which have not been observed on this scale in recent decades), which may be stronger than assumed in the model. Equally, enterprises may demand higher mark-ups than usual on account of the supply bottlenecks that originated during the coronavirus pandemic in some cases.

Informative value of model calculations severely impaired at present

All of this demonstrates the high uncertainty underlying these and similar model calculations and the difficulties involved in capturing the complex technical conditions for supplying energy, as well as their significance for supply chains, in macroeconomic models. Nevertheless, they do suggest that a supply stoppage could lead to considerable GDP losses and a further, more protracted rise in the inflation rate in Germany and in the wider euro area.

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