

Republic of Poland: Selected Issues



REPUBLIC OF POLAND

SELECTED ISSUES

June 2023

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REPUBLIC OF POLAND

SELECTED ISSUES

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Approved By
European Department

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BALANCING DECARBONIZATION WITH ENERGY SECURITY IN POLAND¹

A. Introduction

1. Ensuring energy security is a top priority of Poland's energy strategy. The Energy Strategy of Poland (PEP2040) approved in February 2021 placed the highest priority on energy security. Poland's high dependency on a single supplier for natural gas and crude oil was identified as an obstacle for competitive pricing, as well as a vulnerability in the foreign policy domain. A long-term contract for natural gas deliveries from Russia, that expired in end-2022, maintained high dependency on imports from Russia.

2. The energy crisis of 2022 tested Poland's preparedness. The intermittent supply of natural gas from Russia to Europe in late 2021 and the consequences of Russia's war against Ukraine exposed Europe's dependency on imports of energy from Russia. Natural gas prices increased 15-fold between early 2021 and mid-2022, with spillover effects on electricity markets. Although Poland was heavily reliant on deliveries from Russia, infrastructure had been developed to increase import capacity from other directions, and immediate shortfalls were avoided. Nevertheless, the energy crisis had a significant impact on Poland's economy via high energy prices, which moved the government to introduce costly mitigation measures.

3. High and volatile natural gas prices have prompted a revision of the decarbonization path outlined in PEP2040. Electricity production in Poland relies mostly on domestically produced coal (72 percent, including lignite). PEP2040 envisaged the partial replacement of coal with natural gas to reduce carbon emissions, while maintaining an adequate level of baseload energy until nuclear power comes online in the 2030s. However, the disruption in natural gas supply and price volatility prompted a reconsideration of this strategy.² Leapfrogging gas as a transitional fuel may result in accelerated decarbonization but would need to be accompanied by policies to limit new energy security risks related to reliance on renewable energy sources.

4. Transitioning to a low-carbon economy does not necessarily lead to higher import dependency. Decarbonizing the economy involves the electrification of sectors that currently rely on imported fossil fuels. Therefore, the power sector plays a crucial role in achieving a successful energy transformation. The analysis in this paper of decarbonization scenarios confirms that a fundamental shift towards renewables in the power sector can significantly contribute to reaching decarbonization targets, without a sizable impact on import dependency thus reducing additional effort needed in other sectors.

¹ Prepared by Krzysztof Krogulski

² See Art. 3.16 of the Energy Law. The definition is more specific than other commonly used formulations, such as by the International Energy Agency ("reliable, affordable access to all fuels and energy sources"), or the European Commission ("stable and abundant supply of energy", EC, 2014).

5. A carbon tax could be an important part of a policy package to decarbonize the economy. Carbon pricing is an efficient tool for decarbonization, already covering the power sector and industry (EU ETS). A carbon tax can partially adjust prices for externalities such as an adverse impact on climate and air pollution. However, fossil fuel externalities may also include detrimental effects on energy security. Economic incentives to improve energy efficiency and to electrify household heating and transport would reduce energy import dependency, provided that the share of foreign inputs into electricity generation remains low. Raised revenues could be partly used to mitigate the impact on vulnerable consumers.

6. The remainder of the paper is organized as follows. Section 1 describes the evolution and challenges related to the energy security situation and greenhouse gas (GHG) emissions in Poland over the last decades in the context of EU climate agenda. Section 2 analyzes possible decarbonization paths and implications for energy import dependency. Finally, section 3 offers a discussion of policy measures to facilitate decarbonization while preserving energy security.

B. Energy Security and GHG Emissions in Poland

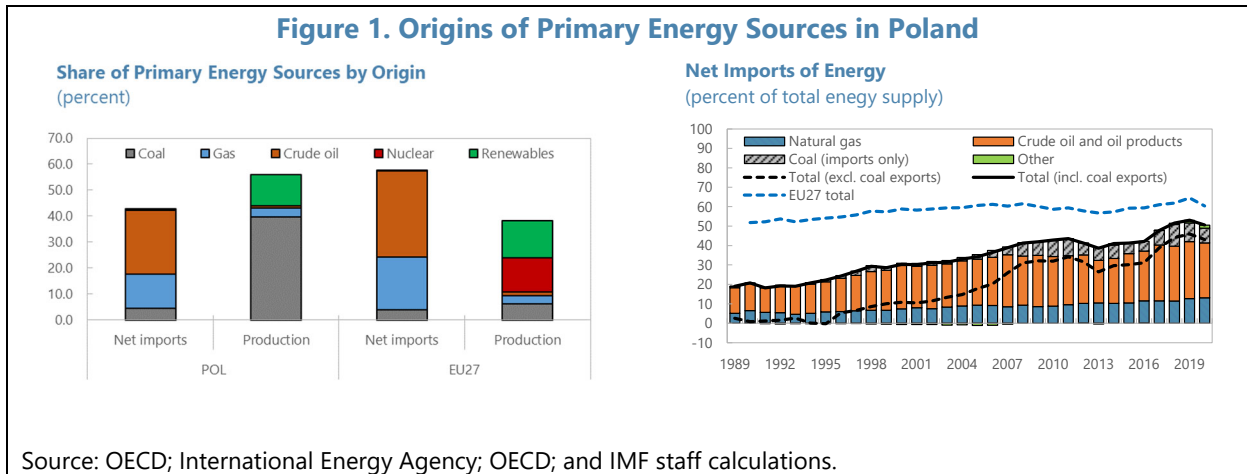
Energy Security

7. Containing energy imports is a key aspect of energy security. The Polish Energy Law defines energy security as *the state of economy enabling the coverage of current and prospective demand of consumers for fuels and energy in a technically and economically justified manner, while maintaining environmental protection requirements*.³ It is a multi-dimensional concept encompassing physical, economic, and environmental aspects, all of which gained significance recently due to the disruption in energy supply from Russia. Energy import dependency, which we will use as the primary measure of energy security, is an important indicator reflecting vulnerability to supply disruptions from abroad and international price shocks, which has become particularly relevant in times of heightened geopolitical tensions.

8. Growing imports of crude oil weigh on Poland's energy import dependency. With natural gas being a main energy security vulnerability, Poland has not followed other European countries in switching from domestic coal to less carbon-intensive but imported natural gas for power generation. However, a growing economy and rising living standards resulted in higher demand for road fuels making crude oil by far the largest contributor to import dependency. At the same time, the demand for natural gas has increased in industrial and household sectors. Overall, the structure of energy consumption has tilted towards imported energy sources over the last decades (Figure 1).⁴

³ See Art. 3.16 of the Energy Law. The definition is more specific than other commonly used formulations, such as by the International Energy Agency ("reliable, affordable access to all fuels and energy sources"), or the European Commission ("stable and abundant supply of energy", EC, 2014).

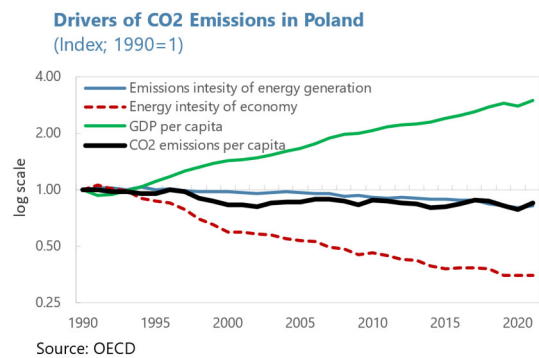
⁴ Net imports of energy were also significantly reduced by a decline in coal exports, which have affected the trade balance but not energy security.



9. Diversifying import channels has been a policy objective in Poland to enhance its energy security. Until 2022, Poland imported most of its hydrocarbons from Russia, using an oil pipeline built in the 1960s and a natural gas pipeline in the 1990s, and taking advantage of relatively low prices. However, since the late 1990s, increasingly aware of the high dependency on Russian supplies,⁵ Poland started developing infrastructure to increase the capacity of alternative import routes. The construction of the Baltic Pipe, completed in September 2022, connecting Norwegian gas fields to Denmark and Poland, is the latest project to diversify the supplier base. Investment in energy security proved critically important when Russia cut off natural gas supply in April 2022 (see Box 2).

GHG Emissions

10. Despite increasing consumption of imported fossil fuels, Poland has managed to decouple economic growth from carbon emissions. Since the beginning of the economic transition in 1989 through 2022, GHG emissions in Poland declined by 31 percent, while the size of the economy tripled. The biggest progress was achieved in electricity and heat production, where the carbon footprint was reduced by a third, while output increased by 10 percent.⁶ The only sector where emissions have been increasing consistently is transport, as increasing traffic was not offset



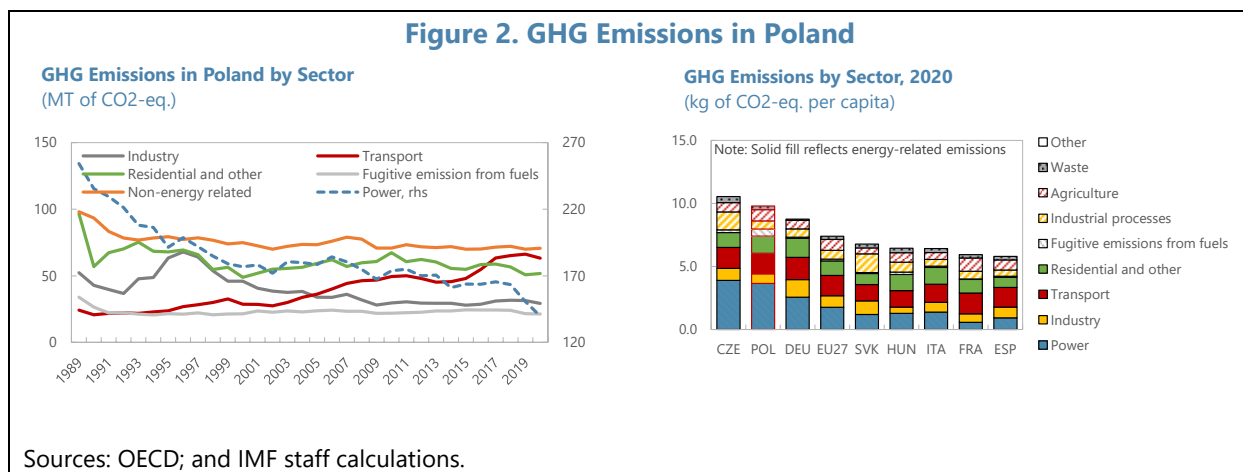
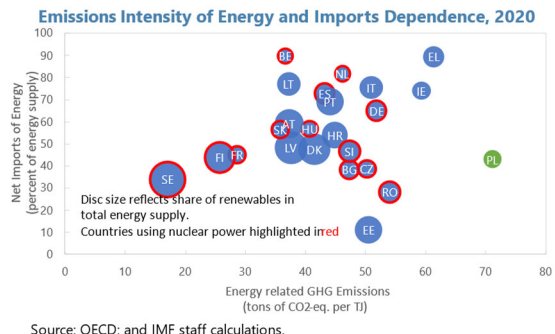
⁵ Disruptions in the supply of Russian energy commodities affected supplies to Lithuania (2003, 2008) and Ukraine (2006, 2009, 2014). Disputes between Russia and Belarus resulted in temporarily reduced transit to Europe in 2019 and 2021.

⁶ The improvement can be attributed to the efficiency-enhancing modernization of coal power plants and the increasing share of renewable energy.

by improvements in the emissions performance of vehicles. Consequently, imported fossil fuels account for an increasing share of GHG emissions.⁷

11. There is scope for a further reduction in GHG emissions without compromising energy security.

The energy dependency of Poland is well below the EU average, due to a high reliance on domestic coal which accounts for 72 percent of coal-fired power generation. In contrast to all its neighbors, Poland has never used nuclear power,⁸ and it underperforms in terms of renewable energy.⁹ Poland ranks high in terms of energy security, but its carbon intensity of energy is the highest in the EU (Figure 2). From a cross-country perspective, there is no correlation between low carbon emissions and energy import dependency. Clean energy technologies, such as renewables and nuclear power, help in both decarbonization and higher energy security.¹⁰

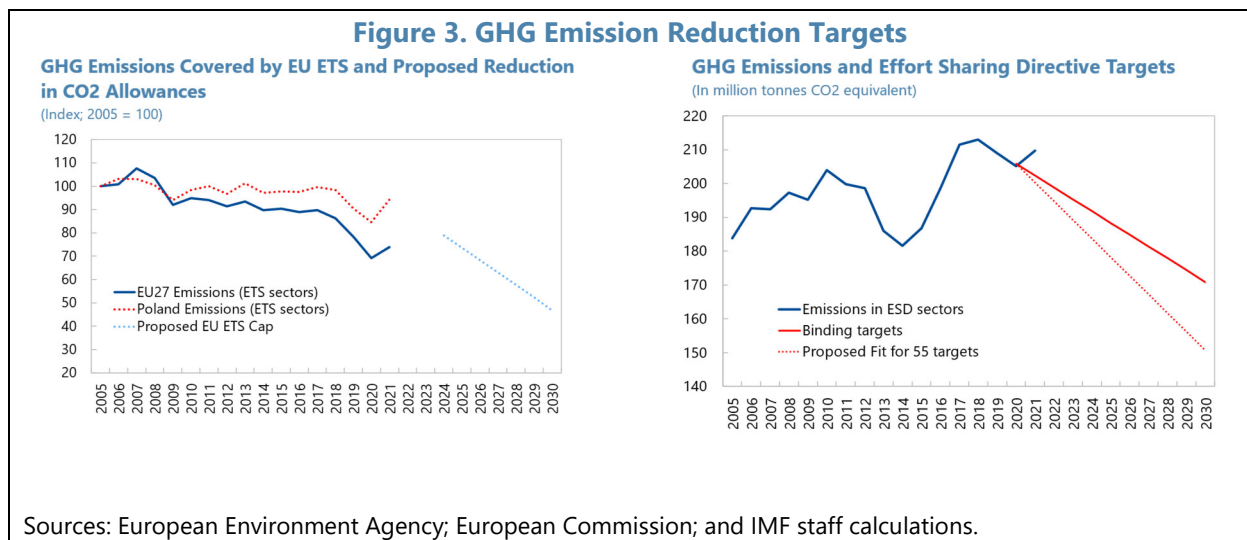


12. Poland has committed to GHG emission reduction. As an EU member, Poland is expected to support the realization of the EU-level NDC (Nationally Determined Contribution), a commitment to reduce GHG emissions. Poland participates in the EU Emissions Trading System (ETS) covering the

⁷ See Krogulski (2022) for a discussion of main decarbonization challenges in Poland.
⁸ The first large-scale nuclear power construction in the 1980s was discontinued after the Chernobyl disaster. According to the timeline of the current nuclear power project, the first reactor will be connected to the grid in 2033.
⁹ Renewable energy in Poland accounted for 12 percent of energy supply in 2021, well below 18 percent, on average, in the EU. Biomass is by far the main source of renewable energy (74 percent), mostly used for space heating. Renewables in power generation accounted for just 4 percent of total energy supply in 2020, of which wind and solar power produced only half.
¹⁰ Cevik (2022) finds a positive relationship between a higher share of low carbon-intensive energy and energy security. While fuels for nuclear power plants will need to be imported, its high energy density allows to establish strategic inventories; fuel supply for up to two years is typically stored at power plants (World Nuclear Association, 2022).

power sector and industry and is subject to country-specific targets for emission reductions in other sectors.¹¹ With declining ETS allowances for carbon emissions and an increasing emission reduction target in other sectors, Poland will need to step up its decarbonization efforts.

13. The Fit for 55 legislative initiative will further tighten decarbonization targets. In 2020, the European Commission published draft regulations to achieve the climate change mitigation targets set in the 2030 Climate Target Plan. The draft regulations, which are on track to be approved by end-2023, will require Poland to steepen the decarbonization path (Figure 3). Part of the effort will be achieved via faster reduction of ETS allowances, which will affect the cost of carbon emissions in the power sector and industry. Targets for renewable energy and energy efficiency will also be increased, while GHG emission pricing will be extended to transport and buildings in 2027.



¹¹ The emission reduction target for Poland in the Effort Sharing Decision is 7 percent compared to the 2005 level.

Box 1. Energy Strategy Update

The authorities' energy strategy document approved in early 2021 (PEP2040) prioritized energy security and outlined a relatively unambitious path of GHG emissions reduction. The authorities planned the development of natural gas and oil infrastructure for imports and storage to mitigate the risks of over-reliance on a single supplier, while the transition to renewable energy sources and improvements in energy efficiency were expected to limit the increase in imports of fuels. At the same time, the strategy implied a sharp increase in gas consumption, which would result in much greater overall energy import dependency. The plan envisaged a more than doubling of the share of gas-fired electricity production from 4.2 percent to 9.3 percent by 2030, while incentives for switching from coal to less carbon-intensive sources, including gas, were planned for the household sector. The projected GHG emission reduction was 30 percent by 2030, compared to 1990 level, well below the 55 percent reduction target for the EU as a whole.

Measures to achieve decarbonization targets were not well defined. The document envisaged a 25 percent reduction in GHG emissions in the SOE-dominated power sector (in the high EU ETS prices scenario), where changes can be introduced using administrative measures. It follows that the progress in the remaining sectors would have to exceed 25 percent, but the policy agenda to achieve this was not well specified.

Assumptions of the PEP2040 review. The published assumptions of the energy strategy update, which is expected in Q2 2023, strengthened the energy security agenda. Besides accelerated adoption of renewable energy and a further reduction in energy demand, the document postulated extending the lifespan of coal units to limit the increase in natural gas consumption.

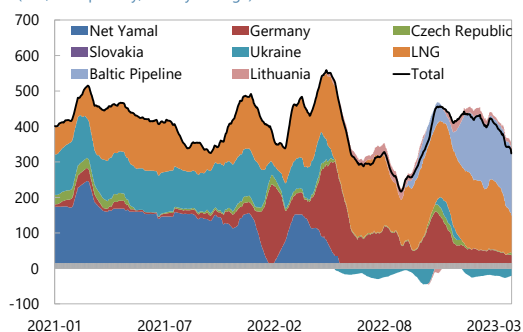
Box 2. 2022 Energy Crisis

Poland was well prepared for disruptions in energy supply. The Russian invasion of Ukraine in February 2022 and the energy crisis that ensued tested Poland's resilience to energy supply shocks. Gas import capacity, including an LNG terminal, combined with a relatively high level of storage levels reduced the risk of gas shortages. However, Poland was not immune to the price shock. Natural gas consumption dropped by 17 percent in 2022, mostly in power generation and industry (-31 percent). Crude oil supply from Russia continued via the Druzhba pipeline, as long-term contracts remained binding pending EU sanctions, but Russia's share in oil supply fell from 60 percent in 2021 to 26 percent in Q4'2022. However, coal for household heating experienced a serious import disruption. Poland introduced a ban on Russian coal already in April 2022, before the EU embargo in August. Russia was the main supplier of higher-grade hard coal suitable for small furnaces, and the import ban resulted in local coal shortages. The authorities commanded energy SOEs to step up imports from Colombia, South Africa, and Australia to ensure sufficient supply ahead of the 2022-23 heating season. A local government-assisted program for subsidized coal distribution, and mild weather in the fall, helped alleviate shortages by early-2023.

Box 2. 2022 Energy Crisis (concluded)

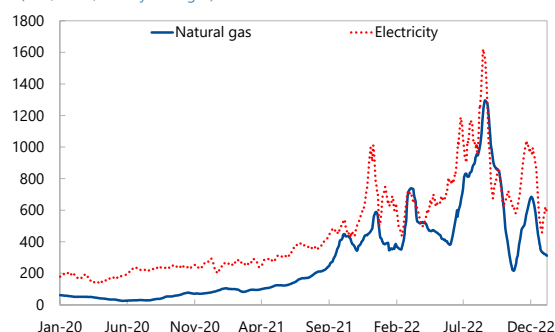
Natural Gas Net Inflows to Poland

(Net, TWh per day, 30-day average)



Wholesale Prices of Electricity and Natural Gas

(PLN/MWh, 14-day averages)



Sources: European Network of Transmission System Operators for Gas, Towarowa Gielda Energii; and IMF staff calculations.

Note: Chart shows providers of LNG to Poland on a net basis. Net Yamal is difference between inflows to Poland and outflows to Germany via Yamal pipeline. Negative values indicate net outflows from Poland.

C. Scenario Analysis¹²

14. We compare alternative decarbonization scenarios to analyze the impact on energy security and macroeconomic variables. Within a CGE model framework (IMF-ENV model, see Annex 1), we endogenize the policy effort, measured by an implied carbon tax, needed to comply with defined decarbonization targets. We then present the impact of the decarbonization policies on the main economic outcomes, including imports as a share of energy consumption by 2030. Table 1 describes two reference scenarios (1-2) and four policy scenarios (3-6). The reference scenarios assume no decarbonization effort in the projection years, but scenario 2 incorporates the impact of the Russian invasion of Ukraine, by imposing constraints on trade with Russia in the model. Scenario 3 assumes that G20 countries, including all EU countries, comply with their NDCs, implying a 55 percent reduction in GHG emissions.¹³ However, this scenario does not assume any directive policies to engineer a change in the electricity mix (see below). Hence, the reduction in GHG emissions, including in the electricity sector, would be driven entirely by the carbon tax. The electricity mix for EU countries is calibrated to the values from the PRIMES model (see Annex 1 for the model description).

15. The Poland-specific policy scenarios assume significant changes in the electricity mix and varying degrees of decarbonization ambition.

¹² This section benefited from a contribution by Hugo Rojas-Romagosa (RES).

¹³ According to its NDC submitted in 2020, the EU targets economy-wide net domestic reduction of at least 55 percent in greenhouse gas emissions by 2030 compared to 1990. While there are country-specific targets for non-ETS sectors (Figure 3), the model assumes that each EU member state will reduce emissions by 55 percent, due to limitations in capturing differentiated impact of EU ETS.

- Scenarios 4-6 use different assumptions for the power companies' switch from coal to gas and renewables. The energy sector in Poland is largely state owned and while economic incentives, such as the EU ETS, play a role, investment decisions are ultimately a matter of policy. Due to model limitations, the impact of the EU ETS, and its increased stringency over time, on the electricity sector is not modelled directly. Instead, the electricity mix in scenarios 4-6 is calibrated to pre-defined values to reflect the authorities' plans expressed in the 2021 energy strategy (scenario 4 "PEP") and in the more ambitious power generation decarbonization paths (scenarios 5 "Energy Security" and 6 "Coal to Gas").¹⁴ The "Energy Security" scenario assumes only a small increase in the role of natural gas, while scenario 6 reduces the share of coal further, replacing it with imported natural gas.
- As in scenario 3, scenarios 5-6 assume that GHG emissions will decline by 55 percent from the 1990 level in EU countries, in line with the EU's NDC; however, this ambition is restricted to just 30 percent in scenario 4 ("PEP") – reflecting the stated targets of the 2021 energy strategy.
- The implied carbon tax in these scenarios offers a measure of the policy effort needed to reach the GHG emissions targets (by changing actions in all sectors except for the electricity sector) in addition to the measures implemented in the electricity sector.

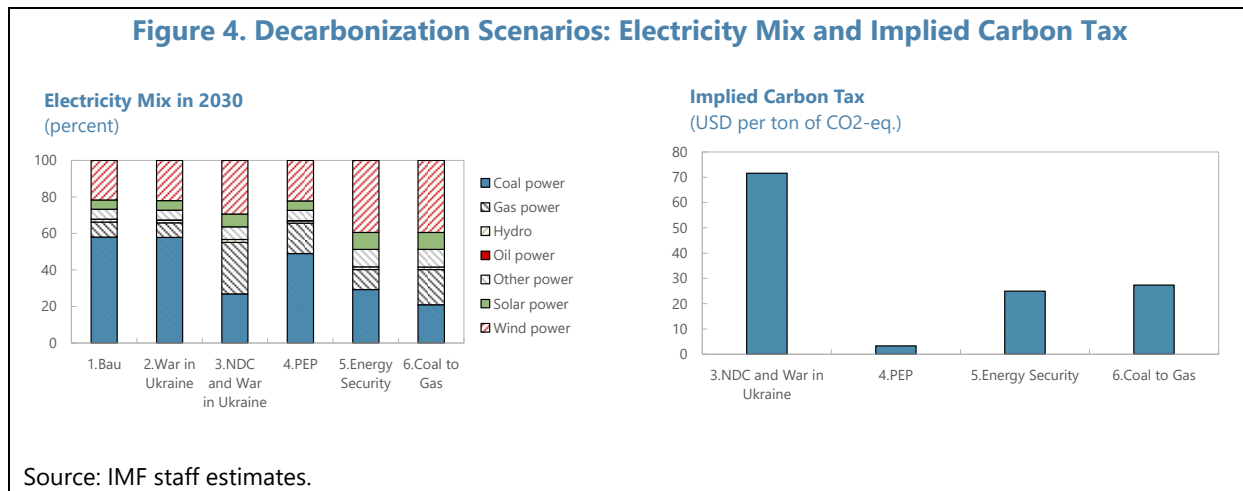
Table 1. Poland: Description of Scenarios

No.	Scenario	Description	Electricity mix	GHG emissions target (relative to 1990)
1.	BaU	Business as usual	34 percent renewables 58 percent coal 8 percent natural gas	n/a
2.	War in Ukraine	Business as usual with constraints on imports from Russia	34 percent renewables 58 percent coal 8 percent natural gas	n/a
3.	NDC and War in Ukraine	As in Scenario 2. but G20 countries (incl. the EU) reduce emissions in line with their NDCs	45 percent renewables 27 percent coal 28 percent natural gas	-55 percent
4.	PEP	As in Scenario 3. but Poland achieve targets envisaged in the energy strategy (PEP2040)	34 percent renewables 49 percent coal 17 percent natural gas	-30 percent
5.	Energy Security	As in Scenario 3. but more renewable energy in power generation and no significant deterioration in energy imports dependency	60 percent renewables 30 percent coal 10 percent natural gas	-55 percent
6.	Coal to Gas	As in Scenario 3. but more renewable energy and less coal in power generation.	60 percent renewables 20 percent coal 20 percent natural gas	-55 percent

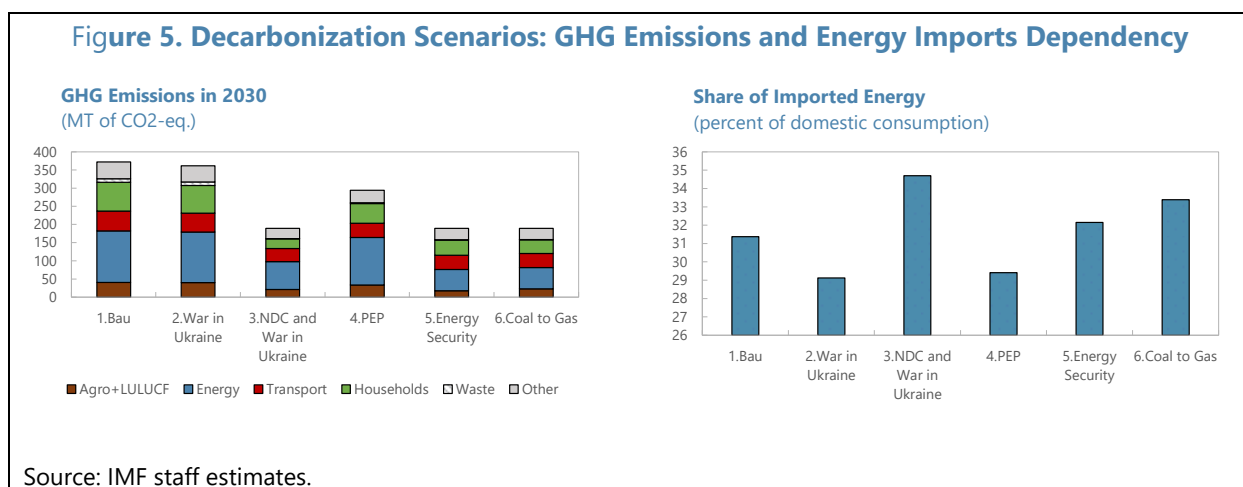
Source: IMF staff.

¹⁴ A report by PSE (2022), the Polish Grid Operator, indicates that the share of renewables in electricity production will exceed 50 percent by 2030. Analyses by Tatarewicz et al. (2023), Bloomberg NEF (2023) and Kubiczek et al. (2023) indicate that increasing the share of renewable energy well above 50 percent is possible by 2030.

16. Changes in the electricity mix towards renewables reduce needed policy effort in other sectors. The importance of changes in the power sector is highlighted by the high implied carbon tax in scenario 3, where changes in the power sector are slow and the burden of decarbonization falls on other sectors. Changes in the power sector in scenarios 5 and 6 imply much lower policy effort, even at the same level of decarbonization ambition. The implied carbon tax in “PEP” scenario is very small, reflecting both the smaller share of coal-fired power and much lower GHG emissions reduction target (Figure 4).

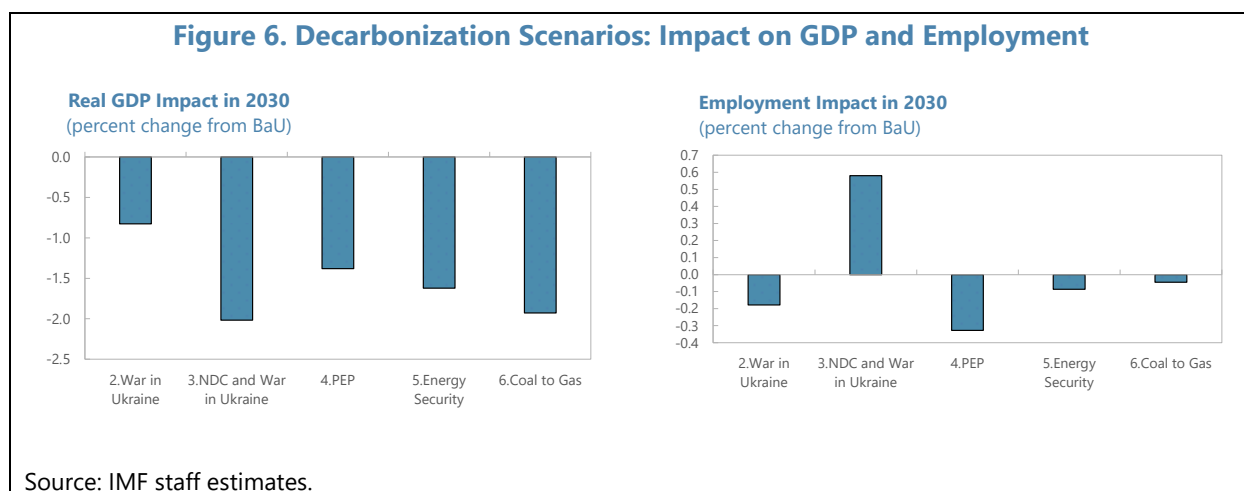


17. In the model, decarbonization has only a marginal impact on energy import dependency. The share of imported energy varies slightly depending on the scenario in a narrow range between 29 and 35 percent in 2030. Results are strongly correlated with the role of natural gas in the electricity mix. Reaching a 55 percent reduction in GHG emissions would increase energy imports dependency by 3-4pp. Comparing scenario 3 with the scenarios 5 and 6 illustrates that this effect is smaller with a stronger push towards renewables. The import share is the lowest in scenario 4, due to still-high reliance on domestic coal and a relatively smaller increase in electricity imports (Figure 5).



18. Both the war in Ukraine and the more ambitious decarbonization objectives have costs in terms of GDP. Higher imported energy prices resulting from the war reduce GDP by 0.8 percent in 2030 compared to the baseline scenario. While the cost of EU ETS allowances, which are outside the model, will likely have an impact on the economy in all scenarios, the additional economic cost of carbon taxation (which leads to production and consumption patterns that deviate from the lowest-cost options—if one ignores climate costs) in the Poland-specific scenarios is the smallest in the unambitious “PEP” scenario (0.6 percent), and only slightly higher in scenarios 5 and 6 (0.8 and 1.1 percent, respectively).

19. Economic outcomes, in particular for employment, depend on how carbon tax receipts are spent. We assume that the implied carbon tax is fiscally neutral, and receipts are used to reduce the personal income tax (PIT) to improve labor market participation of less productive workers. This assumption more than offsets the adverse impact of carbon taxation on employment (comparing the scenarios 2 and 3). In scenario 4, the employment level declines the most, despite low climate ambition. This is because the low implied carbon tax allows for only small reduction in PIT (Figure 6). Alternatively, part of carbon tax revenues could be directed to the most vulnerable households, as discussed in Section 3 below.



20. The model does not capture all factors affecting economic outcomes, nor all policy options. Carbon emissions and air pollution have costs that are not captured in the model, such as the effects of climate change and health effects of air pollution. These costs would be partly mitigated in the policy scenarios. Moreover, Poland’s attractiveness for FDI could be adversely affected if decarbonization was delayed compared to EU peers. Also, the policy effort measured by the implied carbon tax is not restricted to carbon pricing. While policy effort is operationalized by the carbon tax in the model, the actual policy package can be more nuanced and include a range of instruments.

D. Policy Considerations

21. The objectives of energy security and decarbonization can be aligned. Fossil fuel imports are the main source of risk for energy security, while also being responsible for almost half of energy-related CO₂ emissions. Policies to shift away from these fuels will benefit both climate mitigation and energy security. While decarbonizing the power sector will not directly contribute to energy security, it can be achieved without endangering it. Switching to renewable energy, and possibly developing nuclear power over a longer time frame, combined with further electrification across sectors, can offer a solution that addresses both concerns.

Power Sector

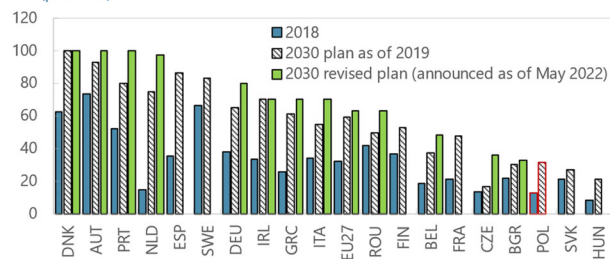
22. A transition of electricity generation away from coal seems unavoidable. With the EU aiming for net-zero emissions by 2050, coal power will need to be phased out. The phase out is supported by the relatively high price of coal-fired power, partly an effect of the price of emission allowances in the EU ETS, but also due to wear and tear of coal assets and associated large investment needs (URE, 2023). While natural gas has been considered as a transitional fuel due to its lower carbon intensity, its role will be limited by increased energy security concerns and an unfavorable price outlook.

23. However, leapfrogging to renewable sources may generate new risks to energy security. Renewable sources such as wind and solar are weather-dependent, generating challenges for balancing the electricity system. Compared to other EU countries, the share of renewable energy in Poland is still low, and with an appropriate market structure and the development of

energy storage, these risks can be managed (Czyzak et al., 2021). High concentration of supply chains for renewable energy technologies poses another risk. Rare earth metals used in wind turbines and solar panels are predominantly sourced from a single country—China—creating a potential vulnerability (IEA, 2023). The European Commission has proposed a set of actions to ensure access to a secure, diversified, and sustainable supply of critical raw materials.¹⁵

24. The authorities should remove obstacles to the deployment of renewables. The regulatory framework, including landscape protection regulations introduced in 2016, adversely affected development of onshore wind farms. While recent revisions go in the right direction, regulations remain overly constraining (Kubiczek et al., 2023). Moreover, administrative procedures

Planned Share of Renewables in Electricity Production
(percent)



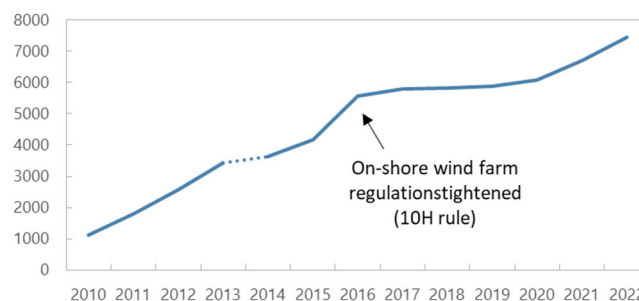
Source: CREA and Ember

¹⁵ Proposal for a regulation of the European Parliament and of the Council establishing a framework for ensuring a secure and sustainable supply of critical raw materials, COM(2023) 160

should be streamlined, in line with recent EU proposal to accelerate renewable energy deployment.¹⁶ Modernization of the power grid and a planned increase in energy storage capacity are needed to increase the sustainable level of weather-dependent renewable power in the electricity mix.

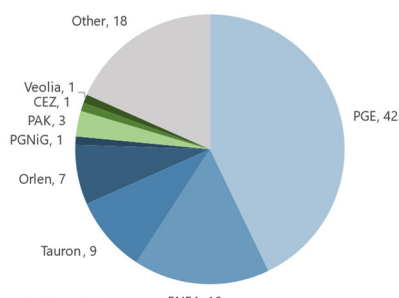
25. Market design needs to support energy investments. Currently, SOEs account for three-quarters of wholesale electricity market turnover in Poland, making the state both the main market participant and its regulator. Moreover, the largest energy companies are vertically integrated, which further increases risks of anti-competitive practices. The energy transformation would be helped by a more dispersed and competitive energy market. It is important to prevent vested interests from obstructing or distorting necessary changes in the regulatory framework.¹⁷

On-Shore Wind Energy
(Installed Capacity, MW)



Source: OECD; and IMF staff calculations.

Wholesale Electricity Market Shares, 2021
(percent)



Note: SOEs in shades of blue
Source: Energy Regulatory Office

26. Coal mining is the main recipient of fossil fuel subsidies. Apart from an excise exemption for fuels used in agriculture, the consumption of fossil fuels is not significantly subsidized in Poland.¹⁸ There is, however, sizable state support for coal mining. Between 2017 and 2021, transfers and tax credits reached PLN27 billion (1.2 percent of annual GDP),¹⁹ and further support until end-2031 (PLN29 billion) was approved in 2022. Continued reliance on coal in the power sector will require a stable supply of coal in the coming years, and state support may be needed in the phaseout stage. A well-defined timeline, including a coal phase-out date, would reduce uncertainty around the process and allow better planning by local governments. The EU's Just Transition Fund is available to provide support for re-skilling of coal-mining employees and for the diversification of local economies in coal-dependent regions.

Beyond the Power Sector

¹⁶ Part of REPowerEU initiative: Amendments to Renewable Energy, Energy Performance of Buildings and Energy Efficiency Directives.

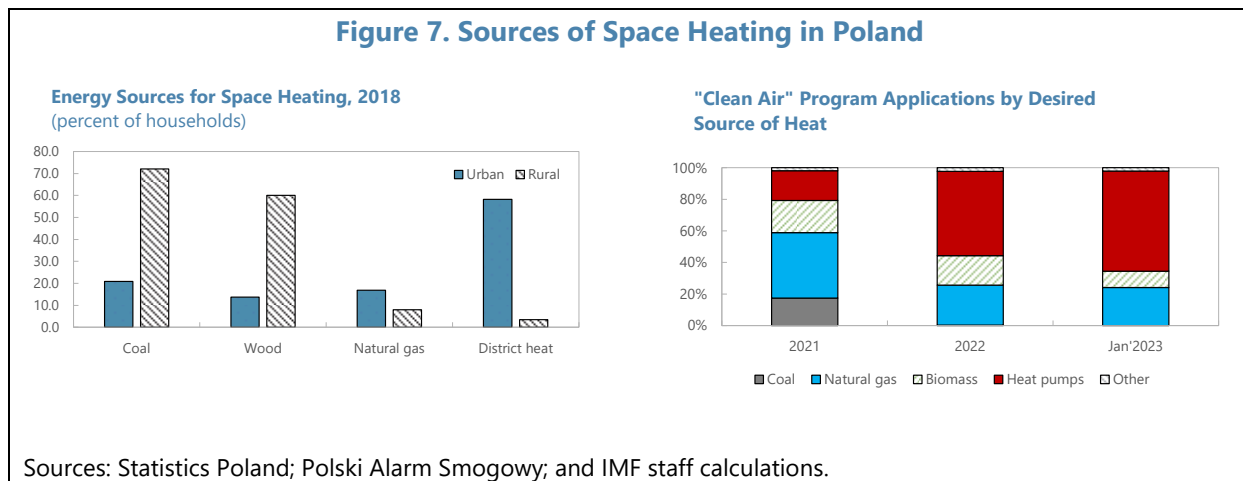
¹⁷ World Bank (2022) provides detailed description of regulatory challenges and policy recommendations.

¹⁸ The explicit subsidies to fossil fuels in Poland amounted to 0.2 percent of GDP (see Parry et al., 2021 and IMF Fossil Fuel Subsidies Database)

¹⁹ State aid awarded to cover costs related to mine closures was PLN9 billion in 2017-21.

27. Poland needs to address its coal heating problem. According to the Ministry of Climate and Energy, 3.8 million households use coal as the main heating fuel. Coal heating in the residential sector generates 20 Mt of CO₂, which accounts for two-thirds of the reduction needed to meet ESD targets by 2030 and half of the reduction envisaged in the Fit for 55 draft regulations (Figure 7). Eliminating coal from residential heating would thus significantly contribute to decarbonization and improve air quality. It will also enhance energy security, as the supply of larger-grade coal for residential heating heavily relies on imports. The Cohesion Funds and RRF Funds have earmarked over EUR5 billion for clean air and residential energy efficiency, making a significant contribution to heating modernization efforts.²⁰ The revenues from the EU ETS could further strengthen the financial resources to support phasing out of coal from the residential sector.

28. A carbon tax is an efficient—but not the only – tool to support decarbonization. The transition to a low-carbon economy is a complex task, and policymakers need to consider a wide range of measures to design an efficient policy package (IMF, 2019). Besides the EU ETS, decarbonization in Poland has mostly been supported by subsidies for investment in energy efficiency and green energy technologies, including the popular “Clean Air” program. While such support is needed, the pace of transition will also depend on relative prices of energy sources. Unlike fossil fuel used in individual heating, GHG emissions from electricity production are subject to carbon pricing (ETS). Most green technologies, such as heat pumps or EVs, rely on electricity and, therefore, the pace of their adoption would be enhanced if carbon pricing also covered the use of fossil energy beyond the ETS.



29. A carbon tax corrects market failure and raises fiscal revenues. A tax on GHG emissions has two key functions: increasing the relative price of carbon-intensive technologies and generating fiscal revenues. Fossil fuels are heavily subsidized if both explicit and implicit costs of emissions are considered (Parry et al., 2021). Unaccounted costs include the impact on climate change but also air pollution’s impact on health. A carbon tax can reduce such implicit subsidy, improving the

²⁰ EU funds earmarked for “clean air” and residential energy efficiency program amount to some PLN6,500 per household using coal as primary heating source.

effectiveness of pricing mechanisms for resource allocation and making it an efficient tool for decarbonization (Stern and Stiglitz, 2017). Resulting revenues from a carbon tax can be used to directly finance the energy transition and support consumers most affected by higher energy prices.

30. The proposed Fit for 55 package envisages the introduction of carbon pricing for GHG emissions from buildings and transport. The European Commission has acknowledged the difficulty in decarbonizing these sectors and has proposed a new EU-wide carbon pricing mechanism to be implemented in 2027. Countries with an equivalent carbon tax will be exempted from the new ETS until end-2030. In Poland, implementing a carbon tax on buildings and transport would not only supplement existing policies aimed at achieving the 2030 emissions reduction targets, but it would also help smooth the introduction of the new EU ETS.

31. The energy crisis of 2022 highlighted the need to protect consumers from high energy prices. In response, countries across Europe introduced measures to ensure affordability of energy for households and to protect industry from the energy price shock. However, many of these policies were introduced quickly and lacked targeting, resulting in significant cost for public finances.²¹

32. A consumer support scheme could help overcome political obstacles to carbon pricing. IMF (2020) provides recommendations to consider in the design of a support scheme. In principle, spending should adequately support vulnerable groups and be sustainable (IMF, 2020). In the climate mitigation context, the support should also be conducive to decarbonization and energy efficiency. Therefore, the modality of the support matters: means-tested transfers that do not affect the marginal price of energy consumption would be preferable to direct subsidies that distort price signals and do not allow the recipient to allocate the support according to personal preferences. A well-designed support scheme could help build political support and overcome skepticism towards decarbonization efforts.

Conclusions

33. Energy transformation can strengthen Poland's resilience. A well-developed and diversified energy import infrastructure and high reliance on domestic energy sources helped Poland weather 2022 energy crisis. With technological advancements and falling prices of renewable energy sources, phasing out carbon-intensive coal does not require sacrificing energy security. Even in an ambitious decarbonization scenario, energy import dependency remains low by European standards. Investing in clean electricity generation will also contribute to decarbonization of other sectors reducing reliance on imported fossil fuels.

34. Introducing a carbon tax could support the phase-out of imported fossil fuels while generating revenues to protect vulnerable groups. Decarbonization efforts in the residential sector will require continued financial support for necessary investments but should be

²¹ Arregui et al. (2022) discuss principles of helping households during 2022 energy crisis, emphasizing the role of price signals and proper targeting of measures.

complemented with carbon pricing measures to discourage the use of fossil fuels. The gradual phase out of coal in a socially responsible manner will also require further financial support. A carbon tax would not only address misallocation resulting from negative externalities but would also generate revenues that could shield most vulnerable groups from the impact of the energy transition.

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Annex I. IMF-ENV Model and Data Description

Model

1. IMF-ENV is a global recursive dynamic computable general equilibrium (CGE) model developed by the IMF Research Department.¹ Dynamic CGE models are well suited for the

analysis of structural change and sectoral impacts that result from energy and climate shocks and policies. The model allows simulating impacts on energy demand and supply, greenhouse gas (GHG), macroeconomic variables, sectoral outcomes, and trade. The model is based on a neo-classical framework, which optimizes consumption and production decisions by households and firms but deals mainly with real values and with almost perfect markets for commodities and production factors (labor, capital, land).

2. The model is based on the activities of the key actors: firms, households, and markets. Firms purchase inputs and primary factors to produce goods and services.

Households receive the factor incomes and in turn demand the goods and services produced by firms. Markets determine equilibrium prices for factors, goods, and services. Finally, countries exchange goods on international markets. Factors of production are almost perfectly mobile across sectors (real rigidities make adjustments sluggish in short run) but not across countries. However, an important feature of IMF-ENV is that capital stocks have vintages such that firms' production and behavior are different in the short and long run.

3. The model is recursive dynamic: it is solved as a sequence of comparative static equilibria. The factors of production are taken exogenously at each point in time and linked between time periods with accumulation expressions, like the dynamics of a Solow growth model. Production follows a series of nested constant-elasticity-of-substitution (CES) functions to capture the different substitutability across all inputs. International trade is modeled using the so-called Armington specification that posits that demand for goods is differentiated by region of origin. This specification uses a full set of bilateral flows and prices by traded commodity. The model also links economic activity to environmental outcomes, specifically to the emission of greenhouses gases and other pollutants.

Data and Baseline Values

4. The model is built primarily on a database of input-output tables, combined with national accounts and bilateral trade flows. The central input of the model is the GTAP 10 Power database (Aguar et al., 2019; Chepeliev, 2020b). The database contains country-specific input-

¹ The model documentation is still being drafted. Meanwhile readers interested in the model can consult the documentations of the twin-models on which IMF-ENV is built on: the ENVISAGE model (van der Mensbrugge, 2019) and the OECD's ENV-Linkages Model (Château et al., 2014).

output tables for 141 countries and 65 commodities and real macro flows.² The database also represents world trade flows comprehensively for a given starting year. To allow a detailed modeling of energy supply, the database includes eight electricity generation technologies, as well as an electricity transmission and distribution activity. Finally, the database also includes all main greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases – hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6).³

5. The model describes how economic activities and agents are inter-linked across economic sectors and world countries or regions. The model can be used for scenario analysis and quantitative policy assessments. For scenario analysis, the model projects up to 2050 and contains an internally consistent set of trends of all economic, sectoral, trade-related, and environmental variables. In this context, the model can be used to analyze economic impacts of various drivers of structural changes like technical progress, increases in living standards, changes in preferences and in production. A second use for the model is quantitative economic and environmental policy assessment for the coming decades, including scenarios of a transition to a low carbon economy. In this case the model assesses the costs and benefits of different sets of policy instruments for reaching given targets like GHGs emission reduction. However, the model’s projections for the very long-run are especially uncertain since disruptive technology innovations could materialize at longer horizons.

6. For this study, we include two adjustments to the GTAP database. First, we employ the most recent data on Russian natural gas exports using UN-COMTRADE data for 2021. This allows us to update the main export markets for Russian natural gas. The second data adjustment is to update the natural gas imports into the EU and the United Kingdom (UK). For this adjustment we employ a combination of the IEA Natural Gas Information Statistics and Eurostat natural gas consumption statistics.

7. A major adjustment to the model is that Poland was separated from the regional aggregate. For this we employ the data for Poland in the GTAP database, combined with the most recent macroeconomic projections taken from the WEO 2022. These include real GDP growth, investment share in GDP, current account balance, government budget balance, labor supply statistics (working age population, unemployment and participation rates). GHG emission projections are taken from CPAT (FAD). Electricity generation and the electricity mix by power source were taken from the European Commission, Joint Research Centre (JRC-Seville).⁴

² This version of the model employs 36 activities, 28 commodities sectors and 26 country/regions.

³ Cf. Chepeliev (2020a).

⁴ Wojtowicz, Krzysztof; Rey, Luis; Garaffa, Rafael; Tamba, Marie; Vandyck, Toon; Weitzel, Matthias (2021): Baseline GECO 2021. European Commission, Joint Research Centre (JRC). <http://data.europa.eu/89h/3ffc59a1-edff-491f-8894-3147d2202e42>.

Scenario Assumptions

- **Business as Usual (BaU):** baseline scenario used to assess the impact of war-related trade shocks for Poland.
- **War in Ukraine:** used as a benchmark to assess the economic impact of policy scenarios. It adds the following trade shocks to the reference scenario:
 - Russian sanctions from the EU, Australia, Canada, Japan, Korea and the US. We assume a total embargo on all Russian imports, excluding sectors with no import bans into the EU (i.e. agriculture, food and electricity).
 - We include the ban on crude and refined oil products imported to the EU (there is likely a redirection of trade flows: Russian exporting to non-EU markets and EU importing from other non-Russian sources).
 - The EU also imposes export bans on iron, steel, wood, cement and seafood.
 - We also cease the flows of Russian exports of natural gas to the EU, as Russia unilaterally stopped most of these flows. In addition, we assume that Russia cannot divert its pipeline natural gas exports that currently go to the EU to other regions, while the EU is limited to increase its natural gas imports from other non-EU regions (mainly USA and Qatar).

All subsequent scenarios incorporate the impact of the war.

- **NDC and War in Ukraine:** All G20 countries and Poland achieve their NDC emission targets through an increase in a single carbon tax rate for the entire economy. For the EU this means that there is no differential treatment of ETS and non-ETS sectors. The electricity mix for EU countries is calibrated to the values from the PRIMES model (JRC-Seville) based on this carbon tax. The NDC target for the EU is to reduce total GHG emissions by 55 percent with respect to 1990 values. This target is applied to all EU countries separately.
- **PEP:** Reflects the current government energy strategy (PEP2040). The emission reduction target is 30 percent with respect to 1990 values. The same carbon tax is applied to both ETS and non-ETS sectors. The electricity mix is calibrated to the values projected in the strategy (high ETS prices scenario). In this and subsequent scenarios, G20 countries achieve their NDC.
- **Energy Security:** The energy imports as a share of total domestic consumption are kept close to 2021 levels. The emission reduction target is 55 percent. The same carbon tax is applied to both ETS and non-ETS sectors. The share of renewable generation in the electricity mix is increased to 60 percent. Coal represents 30 percent and gas 10 percent of total generation.
- **Coal to Gas:** A more ambitious power sector decarbonization scenario with the same overall emission reduction target (55 percent). The share of renewables in electricity generation is set at

60 percent, but 10 percentage points of coal-fired power is replaced with generation from natural gas.

MONETARY POLICY ANALYSIS USING THE QUARTERLY PROJECTIONS MODEL¹

With inflation in Poland significantly above the target, the need for a tight monetary policy stance has been clear. However, the degree of tightening needed and the monetary policy path to achieve the target over the policy horizon remains subject to debate. Monetary policy models such as the IMF's Quarterly Projections Model (QPM) are an important input into the monetary policymaking process. In this paper, we adapt the QPM to Poland to analyze possible paths for monetary policy. We use the QPM to construct a model baseline scenario for monetary policy and decompose projections to analyze the factors that may drive policies and the disinflation process. We also examine alternative scenarios to explore how economic developments may prompt adjustments to the path of monetary policy. While recognizing the limits of the QPM, the scenarios outlined point to the possibility that the policy rate may need to be increased further or held at its peak for longer to reduce core inflation to the target. It will thus be critical for the NBP continue to respond to changing data and conditions, monitor the realism of its projections, and adjust the policy rate path as necessary to guide inflation back to the target.

A. Introduction

1. Monetary policymakers face a historically difficult task in the wake of the pandemic.

Economic output, commodity prices, and inflation have been subject to unusually large swings, while unprecedented non-economic forces have disrupted labor markets, saving behavior, and supply chains. The fiscal policy response was also extraordinary, with uncertain effects on output and inflation. These uncertainties compound the already-difficult task of monetary policy setting. Not only is it difficult to project the impact of monetary policy on the economy and inflation as such relationships are not precisely known, given the lags of economic data (which often contain contrasting signals) and the difficulties of estimating concepts such as the output gap, it can also be difficult to simply diagnose the state of the economy at the current moment. It is thus a challenge to set and communicate a path for monetary policy.

2. Model-based monetary policy analysis can help guide policymakers at this difficult time.

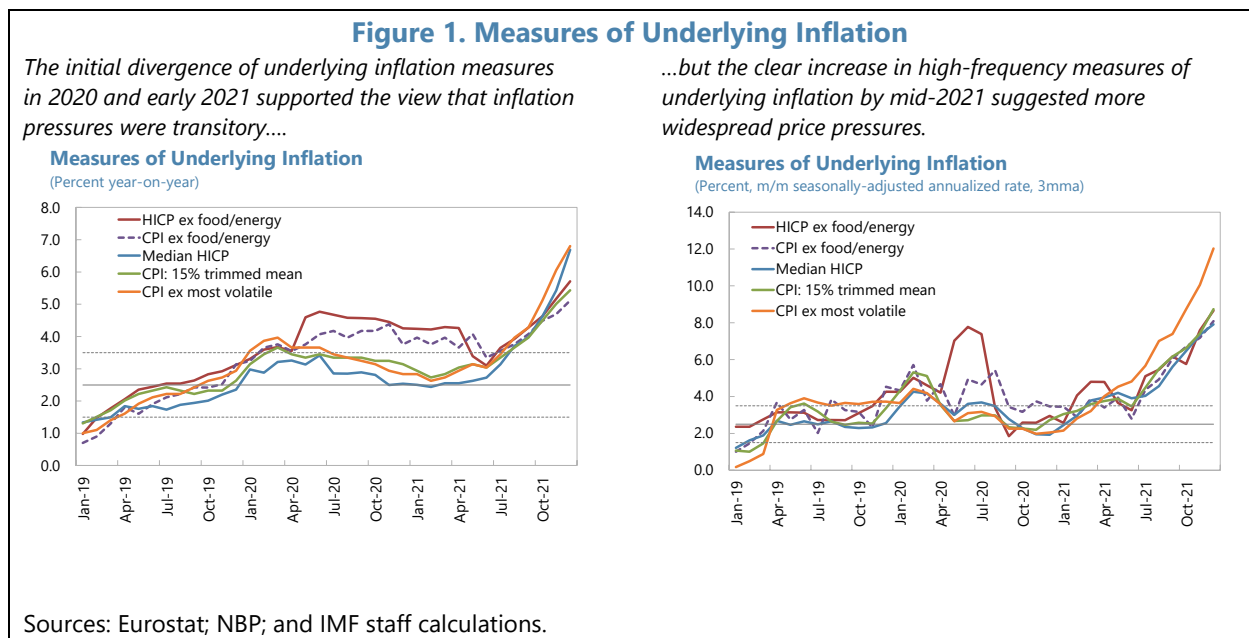
With inflation well above targets in many countries, monetary policy tightening has clearly been needed. Without models to help understand the position of the economy and the possible impact of tightening on output and inflation, however, it would be near impossible to take a view on *how much* monetary policy should be tightened. Thus, the risk of over- or under-tightening would be greatly increased. While subject to significant uncertainties, models can help provide guidance on monetary policy paths that might achieve policymakers' goals. They also can help break down the mechanics of how monetary policy influences the real economy and analyze a range of scenarios beyond the baseline. Still, models are but one input into the monetary policymaking process and

¹ Prepared by William Lindquist. The author thanks Jörg Decressin and Alfredo Cuevas for inspiration and encouragement. Staff of the IMF's European Department and the National Bank of Poland provided valuable feedback during presentations of this work.

should always be supplemented with expert judgement and consideration of factors that models, by their nature, do not incorporate.

B. Analysis of Recent Inflation Developments

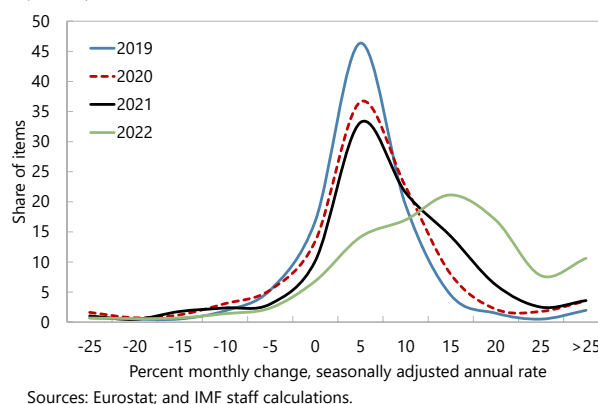
3. The initial increase in underlying inflation in Poland during the pandemic – as in much of the world – was initially diagnosed as transitory. Traditional measures of core inflation, which exclude volatile food and energy prices, averaged 4 percent in 2020-21, above Poland’s inflation target and tolerance range of 2.5 ± 1 percent. At the same time, however, other measures of underlying inflation that are more median based and exclude the most volatile prices (regardless of their category), such as median HICP inflation and trimmed-mean CPI inflation, were close to the target until mid-2021 on a year-on-year basis (Figure 1). This divergence was attributed to large price increases in certain goods whose supplies were constrained by the pandemic, leading to a diagnosis that underlying price pressures remained stable and that traditional measures of core inflation would decline as production normalized.



4. By mid-2021, however, the convergence of different measures of underlying inflation above the target suggested widespread underlying price pressures. The turning point in measures such as median HICP inflation is visible in mid-2021 in a three-month moving average of month-on-month annualized data (Figure 1). Around this time, the estimated output gap had closed, and labor markets had tightened, suggesting a more prominent role of demand in increasing underlying inflation.

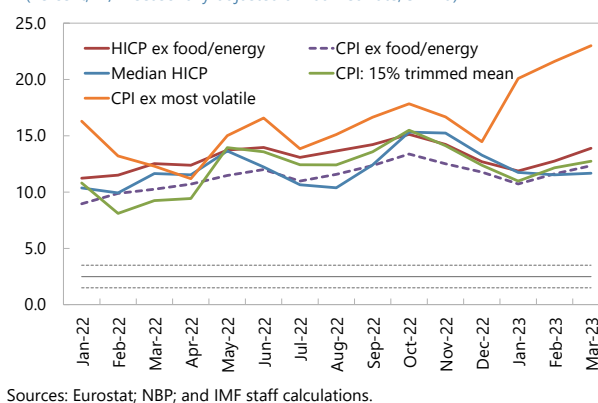
5. While energy and food price shocks brought headline inflation to multi-decade highs in 2022, underlying inflation also further accelerated. Month-on-month annualized median HICP inflation already exceeded 11 percent in Q1 2022, when Russia’s invasion of Ukraine exacerbated the food and energy price shock. Around this time, Poland’s economy was estimated to have been operating well above potential. Second-round effects from energy and food prices also likely contributed to the high level of underlying inflation in 2022. The change in the distribution of price increases in the HICP basket in 2022 is striking, exhibiting a significant upward shift in the median.

Distribution of Core HICP Inflation by Item
(Percent)



6. Headline inflation is projected to decline significantly in 2023 on commodity price base effects, but clear signs of a loss of momentum in underlying inflation are not yet visible. More moderate projected increases in food prices and stable fuel prices – along with government measures to cap natural gas and electricity prices – will contribute to a projected decline in headline inflation from 16.6 percent at end-2022 to 7.7 percent by end-2023. At the same time, as of early 2023, high frequency measures of underlying inflation appear to have stabilized but not yet declined.

Poland: Measures of Underlying Inflation
(Percent, m/m seasonally-adjusted annualized rate, 3mma)



C. Overview of the Quarterly Projections Model

7. The Quarterly Projections Model (QPM) is one of the IMF’s workhorse models for monetary policy analysis. The QPM was developed to provide the core analytical support for a “forecasting and policy analysis system” (FPAS) designed to support forward-looking monetary policy formulation based on economic data and analysis. The FPAS built on the pioneering work of the early inflation targeting central banks in the 1990s to develop tools to provide analytics to guide interest rate settings (Maehle and others 2021).

8. The QPM is a reduced form, structural, neo-Keynesian model. An advantage of the QPM’s reduced form is that its economic interpretation and key relationships are straightforward, avoiding the problem of complicated econometric models that can become “black boxes.” The model is structural in the sense that the equations have economic interpretations with parameters that are estimated or set outside the model. The QPM is also neo-Keynesian in that it incorporates real and nominal rigidities (Berg, Karam, and Laxton 2006). The model also assumes that monetary

policy is neutral over the medium term. In other words, monetary policy can affect the path of output around its equilibrium but cannot affect the level of output over the medium term, when output returns to its potential level.

9. The QPM is a “gap” model that relies on estimates of key gaps in the economy to inform monetary policy settings with the goal of guiding the economy back to equilibrium.

The QPM estimates gaps in output, inflation, the real interest rate, and the real exchange rate from targets (inflation), trends (real exchange rate), or equilibrium positions (output gap). The model itself does not attempt to explain movements in potential output or other trends but takes them as given (Berg, Karam, and Laxton 2006). The model includes an endogenous monetary policy reaction function that suggests a path for interest rates, based on the estimated gaps.

10. The core model consists of four key behavioral equations.

- *Aggregate demand (IS curve)* in which the output gap (\hat{y}_t) is a function of output persistence (\hat{y}_{t-1}), a monetary conditions index (mci_t), the foreign output gap (\hat{y}_t^*), and aggregate demand shocks (ε_t^y). The monetary conditions index is a weighted average of the deviation of the real interest rate from its neutral rate (\hat{r}_t) and the deviation of the real effective exchange rate from its trend level (\hat{z}_t).

$$\hat{y}_t = b_1 \hat{y}_{t-1} - b_2 mci_t + b_3 \hat{y}_t^* + \varepsilon_t^y$$

$$mci_t = b_4 \hat{r}_t + (1 - b_4)(-\hat{z}_t)$$

- *Phillips Curve* in which inflation (π_t) is a function of persistence (π_{t-1}), expectations (π_{t+1}), real marginal costs, which is a weighted average of the output gap (to capture the real marginal costs of domestic producers) and the real exchange rate gap (\hat{z}_t) (to capture the real marginal costs of importers), and cost-push shocks (ε_t^π).

$$\pi_t = a_1 \pi_{t-1} + (1 - a_1) E_t \pi_{t+1} + a_2 rmc_t + \varepsilon_t^\pi$$

$$rmc_t = a_3 \hat{y}_t + (1 - a_3)(\hat{z}_t)$$

- *Uncovered interest parity (UIP)* relates the nominal exchange rate (s_t) to its expected future value ($E_t s_{t+1}$), the differential between domestic (i_t) and foreign (i_t^*) nominal interest rates, and a risk premium ($prem_t$).² The nominal exchange rate is defined as units of domestic currency per unit of foreign currency. (In this case, the euro is the foreign currency.)

$$s_t = (1 - e_1) E_t s_{t+1} + e_1 (s_{t-1} + \frac{2(\bar{\pi}_t - \bar{\pi}_t^* + \Delta \bar{z}_t)}{4}) + (i_t^* - i_t + prem_t)/4 + \varepsilon_t^s$$

² Note that the second term in the UIP equation is the backward-looking component of the exchange rate, which projects the exchange rate as an extrapolation of the past exchange rates adjusted for the trend growth rate of the real exchange rate and the average inflation differential. This reliance on purchasing-power parity tends not to explain exchange rate movements well in the short run but does tend to hold at longer horizons.

- *Taylor Rule* describes a monetary policy reaction function in which the nominal policy interest rate (i_t) is set as a function of rate persistence (i_{t-1}), the deviation of expected inflation (π_{t+4}^e) from the target ($\bar{\pi}_{t+4}$), and the output gap. The neutral interest rate (i_t^n) is the nominal interest rate that would prevail if inflation were equal to the target and the output gap equal to zero. It is the sum of the trend real interest rate (\bar{r}_t) and model-consistent inflation expectations (π_{t+4}^e).

$$i_t = g_1 i_{t-1} + (1 - g_1)(i_t^n + g_2(\pi_{t+4}^e - \bar{\pi}_{t+4}) + g_3 \hat{y}_t) + \varepsilon_t^i$$

$$i_t^n = \bar{r}_t + \pi_{t+4}^e$$

D. Calibrating the QPM for Poland

11. To provide relevant results, the QPM must be calibrated to fit the characteristics of the Polish economy. Calibration involves two main processes. First, trend values must be calibrated, which involves setting the steady-state levels of the model. Second, the parameters of the individual equations must be set to describe the business-cycle properties of the model, including, for example, how monetary policy (in other words, changes in the nominal policy interest rate) affects the real variables in the model.

12. The QPM for Poland is centered around core – rather than headline – inflation. While core inflation has been elevated recently, non-core factors (food and energy price shocks) have been the primary drivers of headline inflation. As food and energy price inflation has largely been driven by factors unrelated to monetary conditions and the domestic output gap, the QPM would perform poorly in explaining the past increase in headline inflation and projecting its future. For these reasons, the Poland QPM projections focus on core inflation (inflation excluding food and energy prices), which is much more endogenous to the model.

13. The steady-state values of key parameters are set exogenously. The QPM converges to the long-term values of potential output growth, equilibrium real exchange rate appreciation, and domestic and foreign trend real interest rates. The targets for domestic and foreign inflation are also set as parameters. Key long-term parameters are set as follows:

- *Potential output growth:* Potential output growth over the medium term is set at 3.1 percent, drawing on recent IMF work on potential output in Poland (IMF 2022).
- *Domestic inflation target:* The NBP's inflation target is 2.5 percent.
- *Foreign inflation target:* The foreign sector in the model is set as the Euro Area. As such, the foreign inflation target is set at the ECB's target of 2 percent.
- *Equilibrium real exchange rate appreciation:* Trend real exchange rate appreciation is set at 1 percent per year. Although zero is calculated as the average annual change in the REER since 2010, it is reasonable to assume at least a small degree of trend real exchange rate appreciation for Poland as an emerging market economy, in line with the Balassa-Samuelson effect.

Table 1. Poland: Calibrated Parameter Values

Parameter	Significance	Value	Explanation
IS Curve			
b_1	Output persistence	0.8	Estimated via regression of log of output on its lagged value and trend. Tends to vary between 0.5 and 0.9.
b_2	Impact of monetary conditions on output gap	0.3	Tends to vary between 0.1 and 0.5. Calibrated such that resulting impulse response function of policy rate on output gap is similar to that estimated in NBP (2020).
b_3	Impact of external demand on output gap	0.5	Tends to vary between 0.1 and 0.7. Set at a level consistent with Poland's structure as a somewhat sizeable open economy.
b_4	Weight of real interest rate and REER gaps in monetary conditions index	0.7	Effective coefficient on response of output gap to real interest rate becomes $0.3 * 0.7 = 0.2$; and on REER becomes $0.3 * (1-0.7) = 0.1$. These effective coefficients tend to vary between 0.05 and 0.30. Calibrated such that resulting impulse response function of policy rate on output gap is similar to that estimated in NBP (2020).
Phillips Curve			
a_1	Core inflation persistence	0.8	Estimated via regression of quarter-on-quarter rate of core inflation on its lagged value. Tends to be above 0.5 for most countries.
a_2	Passthrough of marginal costs to inflation	0.3	Estimated via regression of the rate of core inflation on the output gap. Tends to vary between 0.1 and 0.5, with 0.25 to 0.35 a reasonable range for most countries. Implies a sacrifice ratio of 0.2.
a_3	Ratio of domestic costs in firms' aggregate costs	0.7	Tends to vary between 0.5 and 0.9. Can be related to 1 minus the share of imported goods in CPI basket. 27 percent of the CPI basket is imported goods and intermediate goods that are inputs to consumer goods production. Implied exchange rate passthrough is 0.1.
Taylor Rule			
g_1	Policy rate persistence	0.7	Policy persistence term tends to vary between 0 and 0.8; setting of 0.7 reflects empirical evidence that policy rate persistence is high in Poland. Consistent with Chmielewski and others (2020).
g_2	Policy reactivity to core inflation	1.1	Coefficient on core inflation should be higher than output gap, as NBP is an inflation targeter. Consistent with Chmielewski and others (2020).
g_3	Policy reactivity to output gap	0.4	While NBP is an inflation targeter, in practice it should still take into account the output gap in rate setting, even if only due to its indirect impact on inflation. Consistent with Chmielewski and others (2020).
UIP			
e_1	Nominal exchange rate persistence	0.4	Tends to vary between zero (purely forward-looking FX markets) and 0.9 (backward-looking agents). Calibrated at level that produces the most reasonable impulse response functions for monetary policy and other shocks.
Sources: IMF staff calculations and estimates; and Laxton, Rose, and Scott (2009).			

- *Domestic real neutral interest rate:* The real neutral interest rate is set at 2 percent, which implies a nominal neutral interest rate of 4.5 percent. This setting is taken from various estimates of the natural rate of interest in Arena and others (2020).
- *Foreign real neutral interest rate:* The foreign (Euro Area) real neutral interest rate is set at -1 percent, which implies a nominal neutral interest rate of 1 percent. This setting is taken from various estimates of the natural rate of interest in Arena and others (2020).

14. The calibration of the business-cycle properties of the model relies on a mix of economic theory, empirical estimation, and intuition. While some parameters can be empirically estimated using econometrics, other model parameters are difficult to estimate due to ongoing economic and structural changes, especially in an emerging market economy, that make older data less relevant (Maehle and others 2021). The specific calibration choices made for the Poland QPM are detailed in Table 1.

15. The calibration of the QPM suggests a moderate “sacrifice ratio” in Poland. The sacrifice ratio refers to the output cost of lowering inflation. In the QPM, the sacrifice ratio is defined as the product of a_2 and a_3 in the Phillips Curve, or the product of the sensitivity of inflation to real marginal costs and the share of the output gap in real marginal costs. A lower number indicates a high sacrifice ratio and a flat Phillips Curve. For example, a large decline in the output gap would be needed to lower inflation. Conversely, a higher number indicates a lower sacrifice ratio and a steep Phillips Curve. As the coefficient a_2 on the passthrough of real marginal costs to inflation is in the middle (0.3) of suggested typical ranges of 0.1 to 0.5, the resulting calibrated sacrifice ratio (0.2) for Poland is moderate. The sacrifice ratio of 0.2 is consistent with the estimate in the NBP’s Small Structural Model of Monetary Policy (Chmielewski and others 2020).

16. The calibration is also consistent with a comparatively low pass-through of exchange rate movements to inflation. In the Phillips Curve, exchange rate pass-through is the product of a_2 and $(1-a_3)$, or the product of the sensitivity of inflation to real marginal costs and the share of the real exchange rate gap in real marginal costs. The resulting exchange rate pass-through is $0.3 * (1 - 0.7)$ or 0.09. This calibration is consistent with estimates in Greszta and others (2012), which suggested a pass-through coefficient of 0.13.³ More recently, Ortega and Osbat (2020) estimated exchange rate pass-through to overall consumer prices in Poland to be in the range of 0.05 to 0.07, noting that estimates of pass-through for non-euro area EU member states to import prices were somewhat higher than for euro area countries. Chmielewski and others (2020) also estimate exchange rate pass-through to be approximately 0.06 to 0.08, noting that this impact is higher than in euro area countries due to Poland’s higher production import intensity and the high share of imported goods in private consumption. Still, these estimates of short-run exchange rate pass-through are fairly low for an emerging market economy (Caselli and Roitman 2016). Chmielewski and others (2020) also note that estimated pass-through before 2004 was over 0.2 and that Poland’s

³ In Greszta and others (2012), the coefficient on impact of the real exchange rate on core import prices is estimated at 0.44, and the coefficient on core inflation of core import prices is $(1-0.69)$, the product of which is 0.13.

EU accession, increased participation in global value chains, and the increased credibility of monetary policy had all contributed to the decline in pass-through over time.

17. The Taylor Rule is calibrated for greater sensitivity to deviations of inflation than the output gap. The calibrated coefficients of 1.1 on deviations of inflation and 0.4 on deviations of the output gap have been chosen as a modification from the original Taylor Rule estimation of 0.5 on both, recognizing that the NBP is an inflation targeting central bank and thus should show greater sensitivity to deviations of inflation. These coefficients are also consistent with Chmielewski and others (2020), in which the NBP details a Small Structural Model of Monetary Policy (MMPP), including an estimated equation for the three-month WIBOR (interbank rate), which moves closely with the policy rate. In their estimation, the coefficients on inflation and the output gap were 1.1 and 0.4, respectively.

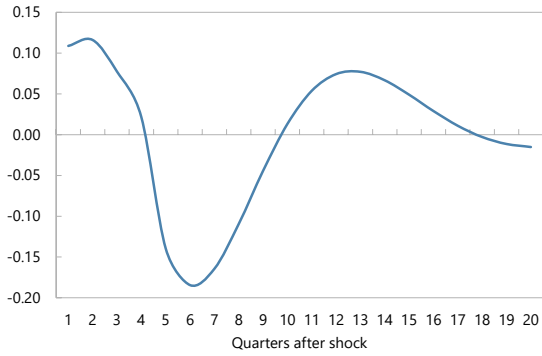
18. Impulse response functions (IRFs) allow us to explore the properties of the model. The transmission mechanisms in the QPM can be illustrated with IRFs, which depict the response of endogenous variables in the model – in terms of deviation from their equilibrium values – in response to a one-off shock, defined as a 1 percentage point deviation from equilibrium.

- *Exchange rate shock:* In response to a 1 percent exchange rate depreciation, the output gap increases by about 10 bps, peaking after two quarters, as monetary conditions loosen (Figure 2). Core inflation (year-on-year) increases by about 25 bps at a peak four quarters later, reflecting exchange rate pass-through and the increase in the output gap. The endogenous response of the policy interest rate to higher inflation and a larger output gap is to increase about 25 bps, with a peak impact four quarters after the shock. These responses are broadly consistent with those specified by the NBP in the 2012 re-estimation of its NECMOD model (Greszta and others 2012). The estimates of the impact of a NEER shock in Chmielewski and others (2020) using a Small Structural Model of Monetary Policy suggest a somewhat smaller impact of an exchange rate shock on interest rates, the output gap, and inflation.
- *Aggregate demand shock:* In response to a 1 p.p. increase in the output gap, core inflation (year-on-year) increases by about 20 bps with a peak after four quarters (Figure 3). In response to higher inflation and a larger output gap, the policy rate increases about 35 bps after three quarters. The nominal exchange rate appreciates by about 80 bps after three quarters, reflecting the interest rate differential with the foreign interest rate and the larger output gap.
- *Cost-push shock:* An exogenous shock to core inflation of 1 p.p. immediately feeds through to annualized quarter-on-quarter core inflation, with the peak impact on year-on-year inflation taking four quarters (Figure 4). In response to higher inflation, the policy rate increases, peaking at about 55 bps after four quarters. The nominal exchange rate appreciates by about 75 bps after two quarters, reflecting the increased interest rate differential. The output gap decreases by about 30 bps after six quarters in response to the tightening of monetary conditions, from both the policy rate and a more appreciated exchange rate.

Figure 2. Impulse Response Functions to Exchange Rate Depreciation Shock

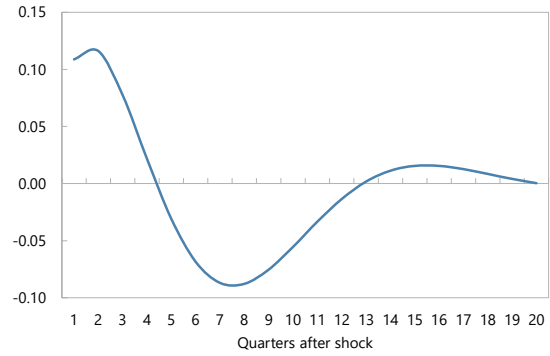
Real GDP Growth

(Percent, year-on-year)



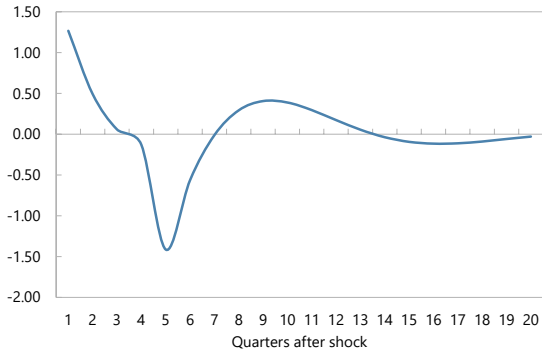
Output Gap

(Percent of potential GDP)



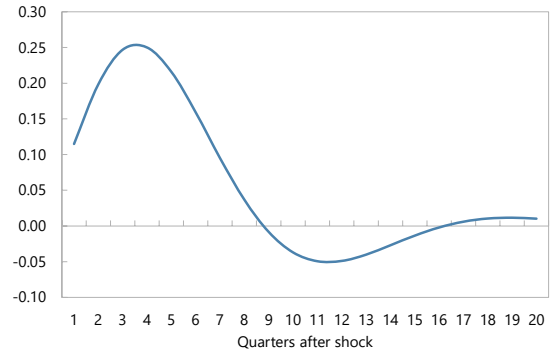
Nominal Exchange Rate

(Percent, year-on-year)



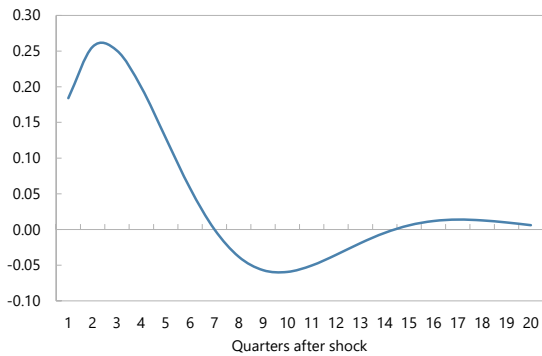
Nominal Policy Interest Rate

(Percent)



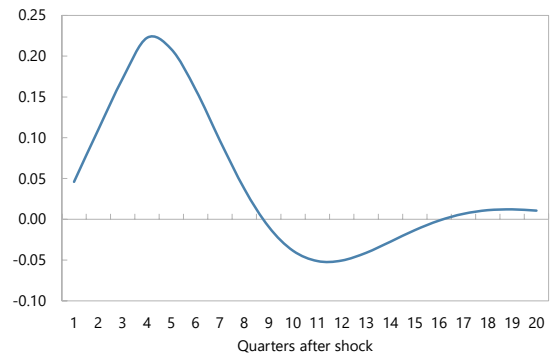
Core Inflation

(Percent, quarter-on-quarter annual rate)



Core Inflation

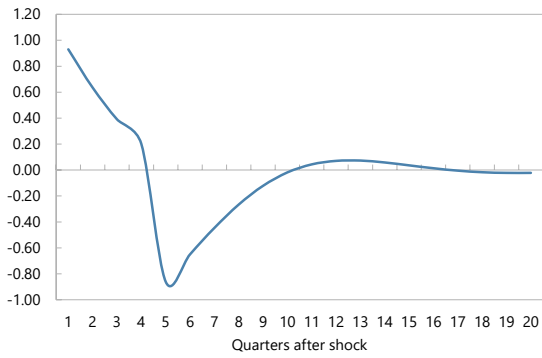
(Percent, year-on-year)



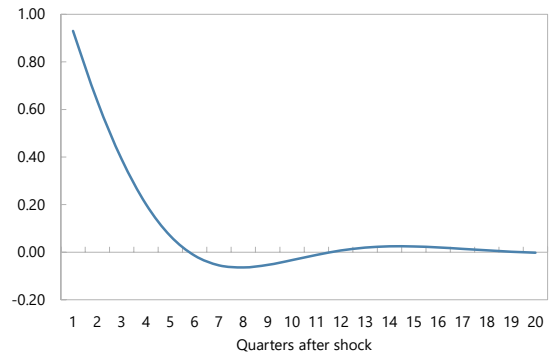
Source: IMF staff calculations.

Figure 3. Impulse Response Functions to Aggregate Demand Shock

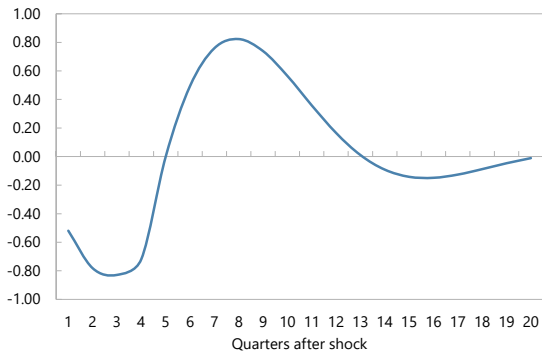
Real GDP Growth
(Percent, year-on-year)



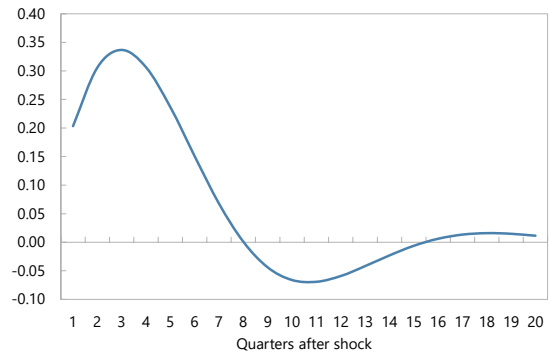
Output Gap
(Percent of potential GDP)



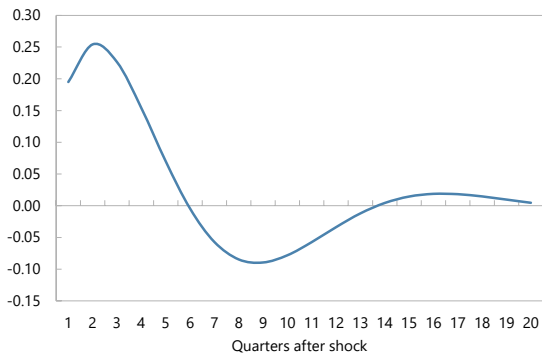
Nominal Exchange Rate
(Percent, year-on-year)



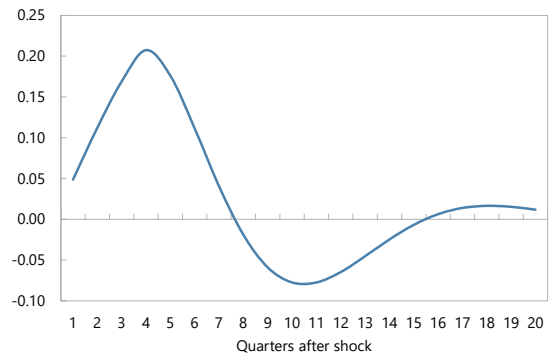
Nominal Policy Interest Rate
(Percent)



Core Inflation
(Percent, quarter-on-quarter annual rate)



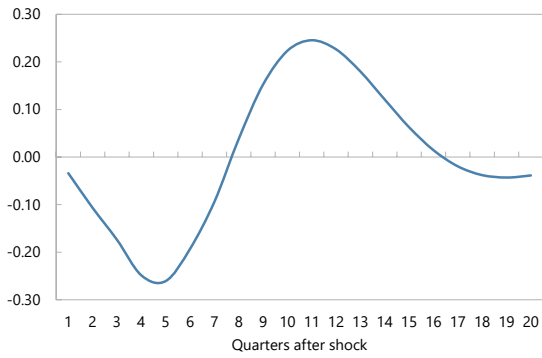
Core Inflation
(Percent, year-on-year)



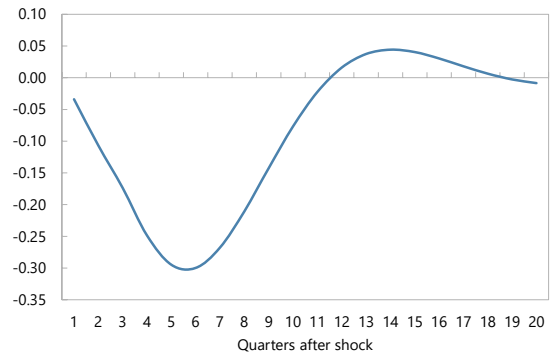
Source: IMF staff calculations.

Figure 4. Impulse Response Functions to Cost Push (Inflation) Shock

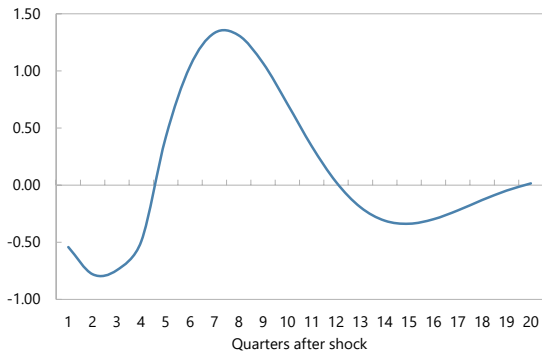
Real GDP Growth
(Percent, year-on-year)



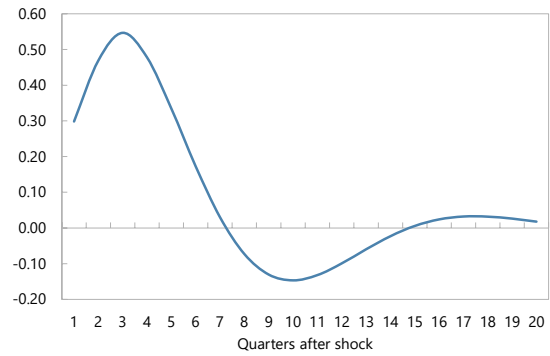
Output Gap
(Percent of potential GDP)



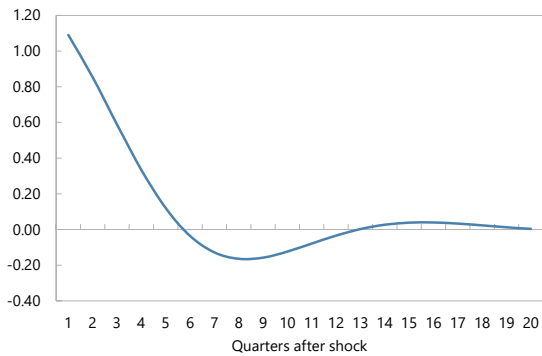
Nominal Exchange Rate
(Percent, year-on-year)



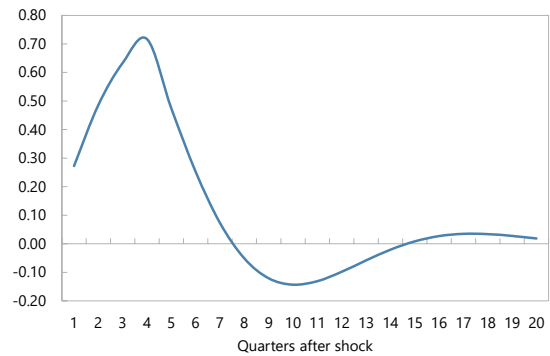
Nominal Policy Interest Rate
(Percent)



Core Inflation
(Percent, quarter-on-quarter annual rate)



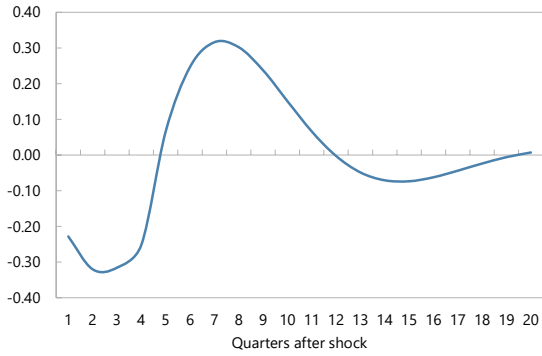
Core Inflation
(Percent, year-on-year)



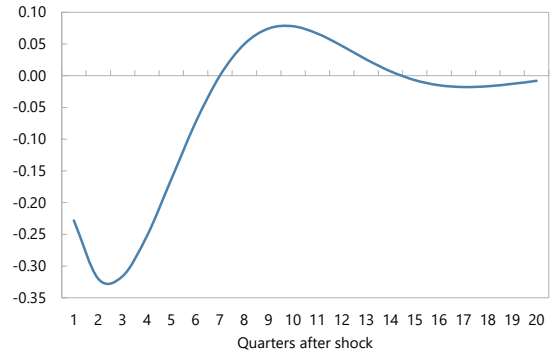
Source: IMF staff calculations.

Figure 5. Impulse Response Functions to Monetary Policy (Interest Rate) Shock

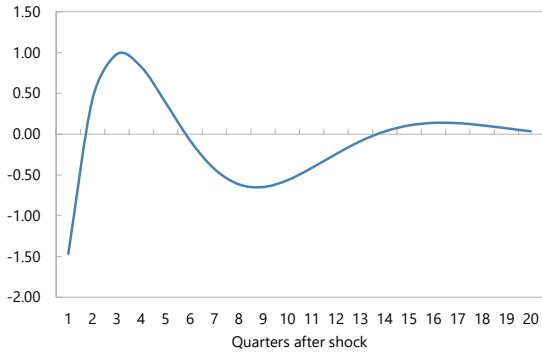
Real GDP Growth
(Percent, year-on-year)



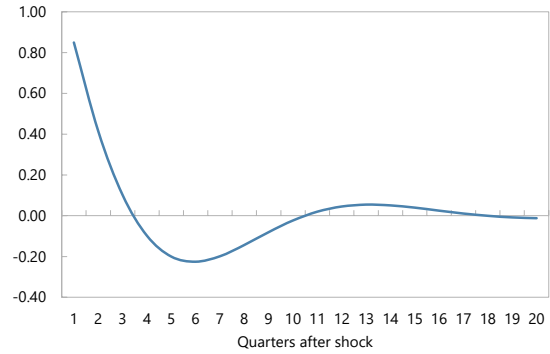
Output Gap
(Percent of potential GDP)



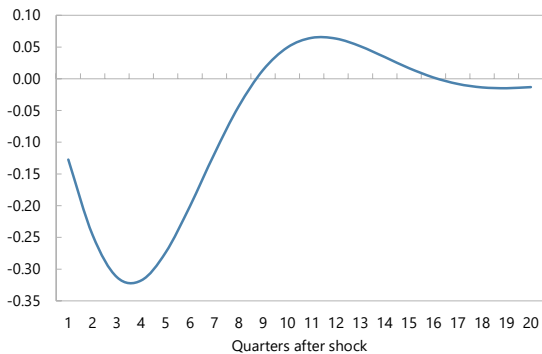
Nominal Exchange Rate
(Percent, quarter-on-quarter annual rate)



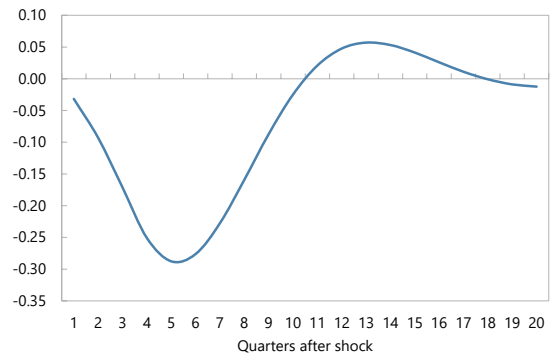
Nominal Policy Interest Rate
(Percent)



Core Inflation
(Percent, quarter-on-quarter annual rate)



Core Inflation
(Percent, year-on-year)



Source: IMF staff calculations.

- *Monetary policy shock:* In response to a 1 p.p. increase in policy interest rates, the nominal exchange rate appreciates about 145 bps quarter-on-quarter immediately following the rate increase (Figure 5). As monetary conditions tighten, the output gap declines about 35 bps after three quarters. Core inflation (year-on-year) also declines 30 bps, with a peak impact after five quarters.

19. The QPM response to a monetary policy shock is broadly consistent with NBP research on monetary policy transmission. Chmielewski and others (2020) analyze the monetary policy transmission mechanism in Poland, using two monetary policy models with similar foundations as the QPM, being neo-Keynesian and built around the same four main macroeconomic relationships. Table 2 summarizes the estimated impact of a 1 p.p. monetary policy shock from the QPM against the range of results from the two NBP models. The impact on most of the endogenous variables is similar in scale and lag, with the exception of the nominal exchange rate, where the response of the nominal exchange rate is stronger in the NBP's models.

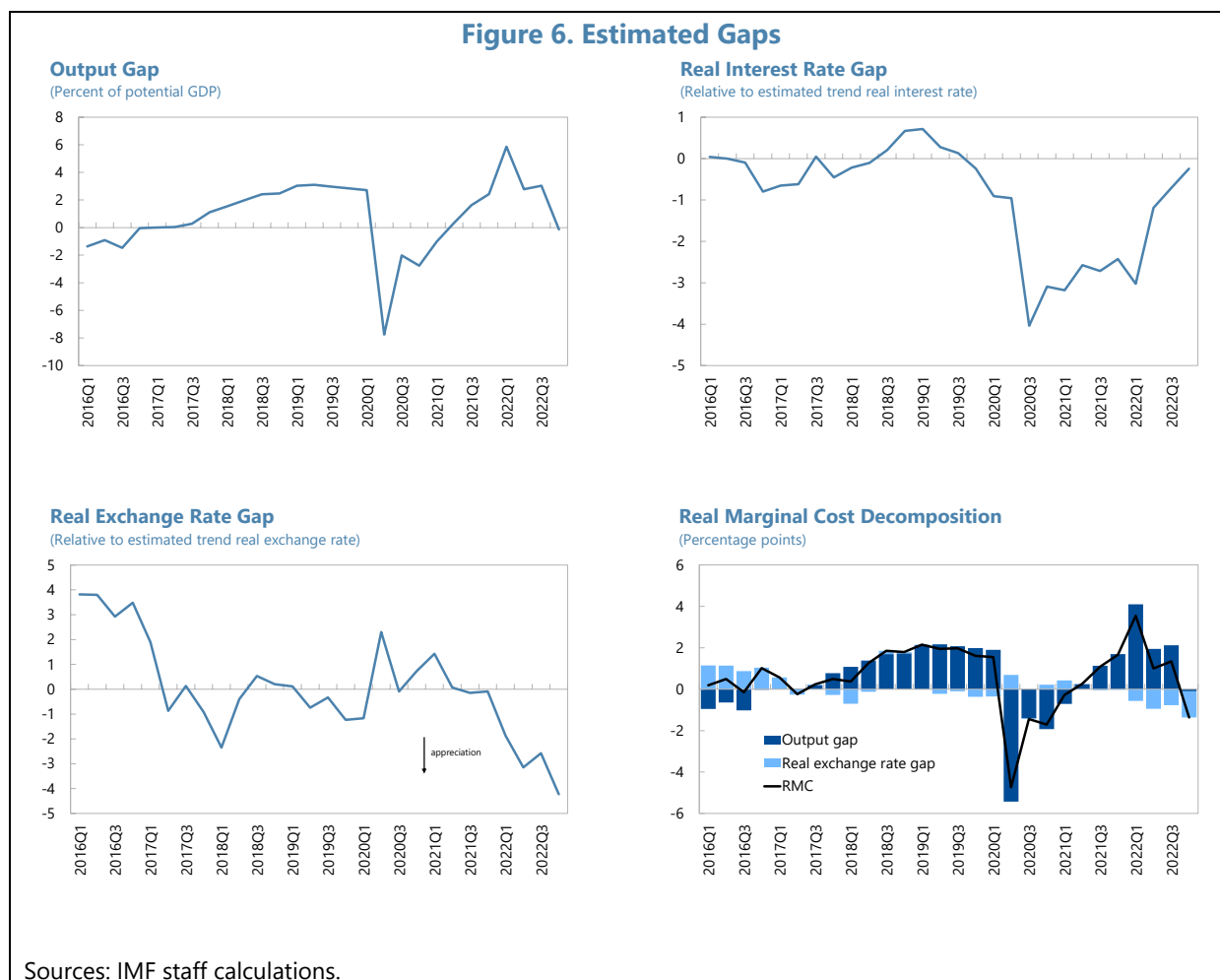
Table 2. Poland: Impact of Monetary Policy Shock (Increase in policy rate by 1 p.p.)		
Variable	Peak impact (p.p.)	Lag of peak impact (quarter)
Core inflation (y/y)		
QPM	-0.3	5
NBP	-0.2 to -0.3	3 to 7
Nominal exchange rate appreciation (y/y)		
QPM	0.4	1
NBP	0.9 to 1.1	2-4
Real GDP growth (y/y)		
QPM	-0.35	2
NBP	-0.2 to -0.4	2-3
Output gap (percent)		
QPM	-0.35	3
NBP	-0.2 to -0.4	4
Real exchange rate gap (percent)		
QPM	0.6	4
NBP	0.7 to 1.0	2-3
Sources: IMF staff calculations; and Chmielewski and others (2020).		

E. Using the QPM: Model Baseline Scenario

20. The first step in constructing projections with the QPM involves an assessment of initial conditions, including key gaps. The QPM uses a Kalman filter to estimate unobserved variables, including trends and the output, inflation, and real exchange rate gaps (Figure 6).

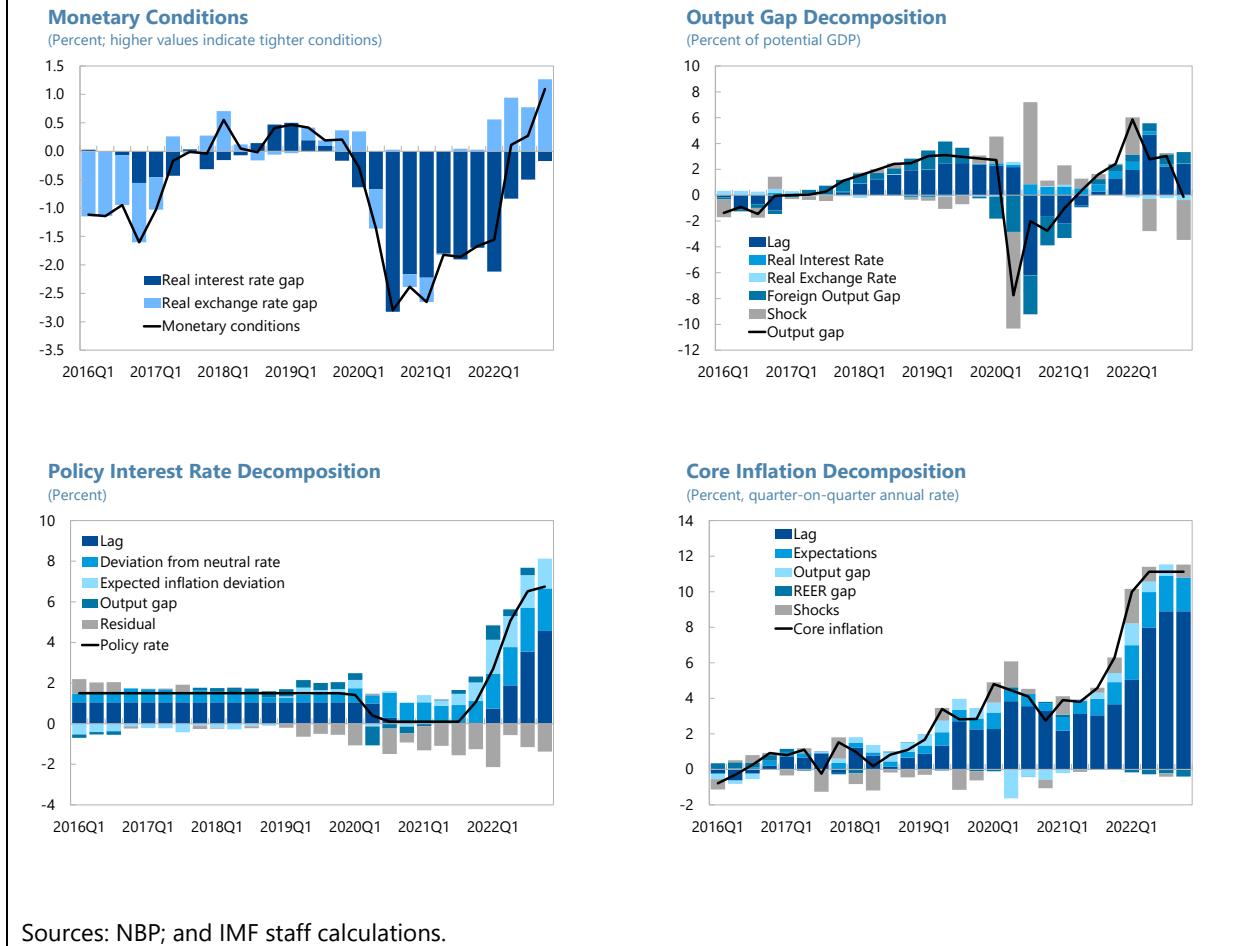
- *Output gap:* The Kalman filter suggests that the large negative output gap that developed at the beginning of the pandemic was quickly closed, subsequently turning into a sizeable positive output gap by the beginning of 2022. As the economy slowed during 2022, the output gap narrowed significantly, estimated to be about zero in Q4 2022. The output gap estimated by the Kalman filter is broadly consistent with the estimates from the methodology described in IMF (2022), which uses a production function approach.
- *Real interest rate gap:* The estimated real interest rate gap suggests that real interest rates were extremely accommodative in the aftermath of the pandemic. As rates began to increase in 2021-22, the gap began to narrow, though the real interest rate gap had yet to turn positive as of Q4 2022.
- *Real exchange rate gap:* The estimated real exchange rate gap before and during the pandemic was fairly small, but large inflation differentials with trading partners contributed to real exchange rate appreciation in 2022.
- *Real marginal costs:* Overall, real marginal costs (the combination of the output gap and real exchange rate gap) were positive in 2022, contributing positively to inflationary pressures. However, over the course of 2022, real exchange rate appreciation partially offset the large positive output gap, which also began to close by the end of 2022.

Figure 6. Estimated Gaps



21. The QPM framework also allows us to decompose key variables to examine the factors behind their recent movements. Prior to the pandemic, monetary conditions are assessed to have been fairly neutral, though they loosened significantly during the pandemic, driven by a large (negative) real interest rate gap (Figure 7). Monetary conditions tightened in 2022 due to interest rate increases and real exchange rate appreciation. During the pandemic, the large swing in the output gap was, unsurprisingly, not well explained by changes in monetary conditions or the foreign output gap and attributed to a shock (the pandemic). Negative real interest rates did contribute modestly to the closure of the output gap in 2021-22. The decomposition attributes the large increases in policy rates in 2021-22 in part to the deviation from the estimated neutral rate and expectations for future inflation to exceed the target. The increase in core inflation in 2022 is not well explained by the model, attributed partially to shocks.

Figure 7. Decomposition of Initial Conditions



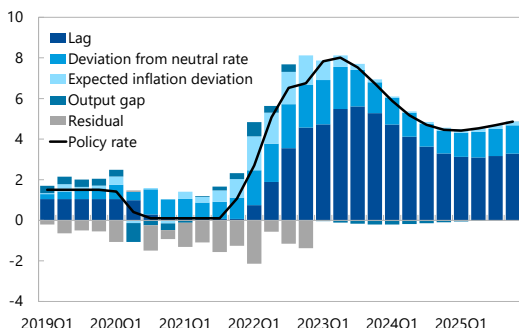
22. The QPM baseline scenario is constructed as an unconditional forecast. The QPM provides flexibility to allow the model to make endogenous projections or impose conditions on the model. For example, specific scenarios for the policy rate or exchange rate can be specified, which can be useful for scenario analysis. In the QPM baseline scenario, no conditions are imposed. External sector assumptions (for the Euro Area) are generated within the QPM through autoregressive processes. Projections begin in Q1 2023.

Figure 8. QPM Baseline Projections

Some additional tightening of the policy rate...

Policy Interest Rate Decomposition

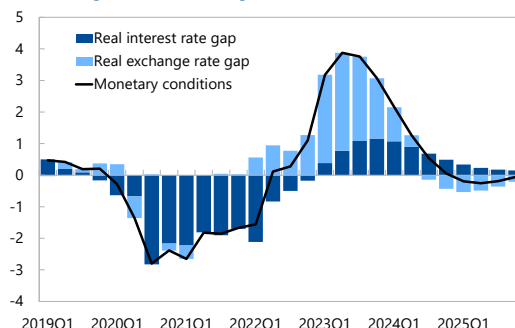
(Percent)



...and projected real exchange rate appreciation would tighten monetary conditions...

Monetary Conditions

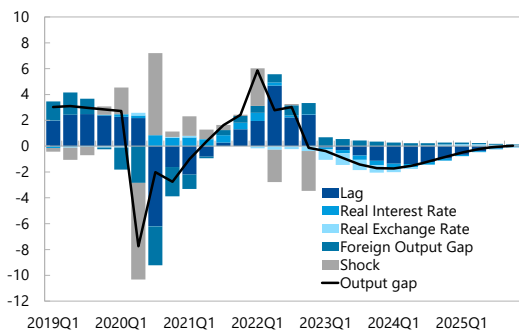
(Percent; higher values indicate tighter conditions)



...leading to a negative output gap...

Output Gap Decomposition

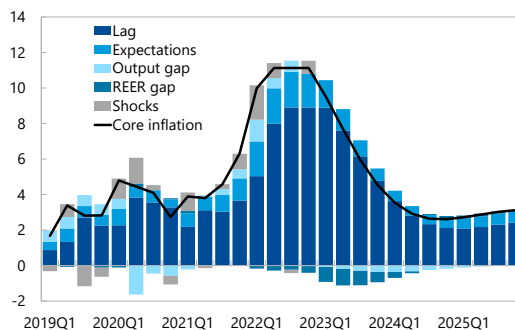
(Percent of potential GDP)



...and a decline in core inflation.

Core Inflation Decomposition

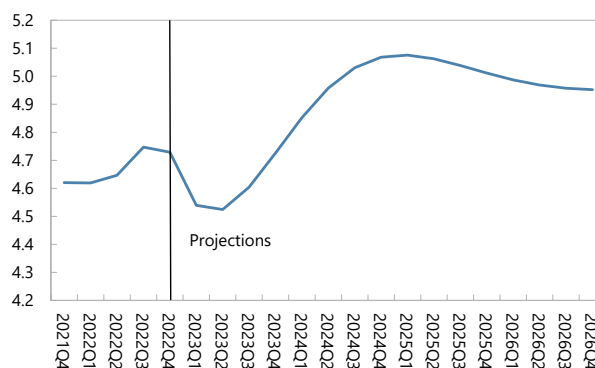
(Percent, quarter-on-quarter annual rate)



Sources: NBP; and IMF staff calculations.

23. The QPM baseline suggests that some additional monetary policy tightening would put core inflation on a downward path. Based on the initial level of core inflation and the estimate of the output gap, the Taylor rule suggests that the policy interest rate (held at 6.75 percent as of end-2022) should be raised another 125 bps to 8 percent before easing in late 2023 (Figure 8). The model also projects further real exchange rate appreciation, based on nominal appreciation linked to interest rate differentials and a continued positive inflation differential, which in combination with policy rate hikes would further tighten monetary conditions. The tightening in monetary conditions contributes to the development of a negative output gap, which in combination with real exchange rate appreciation helps place

QPM Baseline: Nominal Exchange Rate Projection
(PLN/EUR)



Source: NBP; and IMF staff calculations.

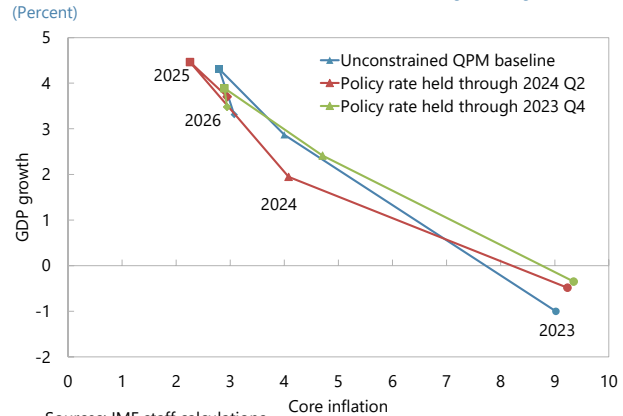
core inflation on a downward path. Core inflation returns near the 2.5 percent target at the end of 2024, though at the cost of a negative output gap peaking around 1.5 percent of GDP in early 2024.

F. Alternative Scenarios and Sensitivity Analysis

Alternative Scenarios

24. The tradeoffs between inflation and output under alternative monetary policy scenarios can also be illustrated. Earlier, more aggressive tightening comes at the cost of a larger negative output gap and lower growth in the near term, but with a faster disinflation and more rapid recovery. (As the QPM assumes monetary policy neutrality over the medium term, the level of output converges by 2026 in the various scenarios.)

Growth and Core Inflation Under Monetary Policy Scenarios



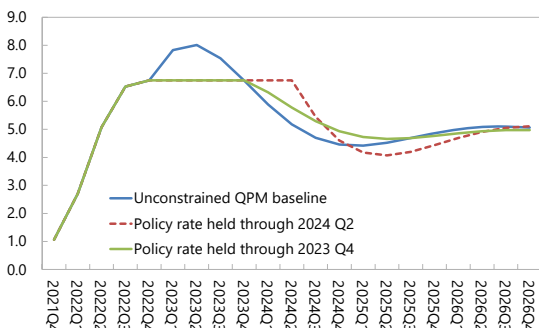
- Policy rate held through 2023 Q4:* Holding the policy rate through 2023 would tighten monetary conditions, though not as strongly as in the unconstrained model baseline. Once allowed to operate endogenously starting in Q1 2024, the Taylor rule suggests that the policy rate could be slowly reduced in 2024 back towards the neutral rate. Compared to the unconstrained model baseline, the contraction in the economy would be less severe in 2023 (growth of -0.3 percent versus -1 percent), but the recovery would be slower (GDP growth of 2.4 percent versus 2.9 percent in 2024), and core inflation would only approach the target in 2025 rather than 2024 (Figure 9).
- Policy rate held through 2024 Q2:* The QPM suggests that a faster disinflation could be achieved by holding the policy rate at its current level through Q2 2024. Monetary conditions would remain tighter for longer, after which the Taylor rule suggests that the policy rate could be lowered more quickly in 2024. Core inflation would reach the target by the end of 2024, though GDP growth in 2024 would be the slowest of the three scenarios at 1.9 percent.

Figure 9. Monetary Policy Scenarios

Tighter monetary policy in the near term....

Policy Interest Rate

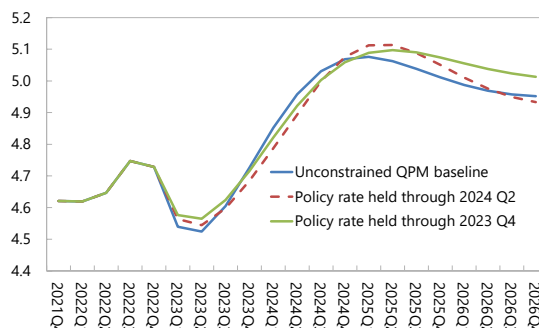
(Percent)



...is associated with a stronger nominal exchange rate appreciation response...

Nominal Exchange Rate

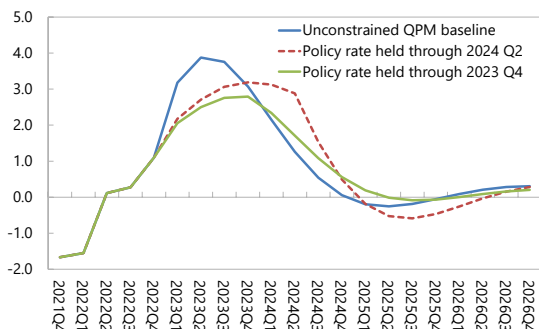
(PLN/EUR)



...and a faster tightening of monetary conditions...

Monetary Conditions Index

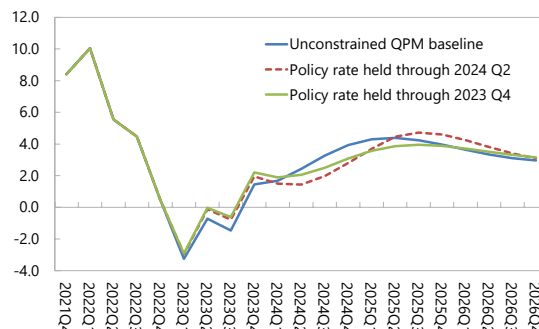
(Higher number = tighter conditions)



...which slows growth more rapidly...

Real GDP Growth

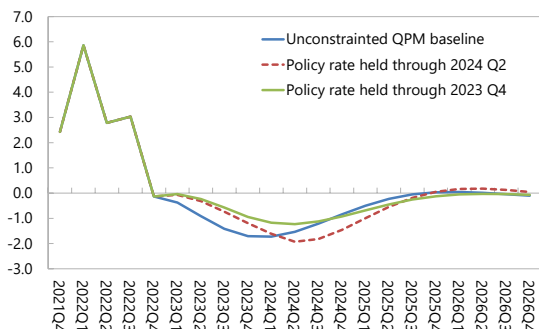
(Percent y/y, based on 2015 constant prices)



...leading to a larger negative output gap more quickly...

Output Gap

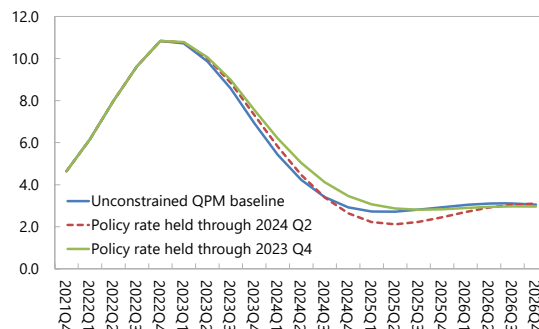
(Percent of potential output)



...and a faster pace of core disinflation.

Core Inflation

(Percent y/y)



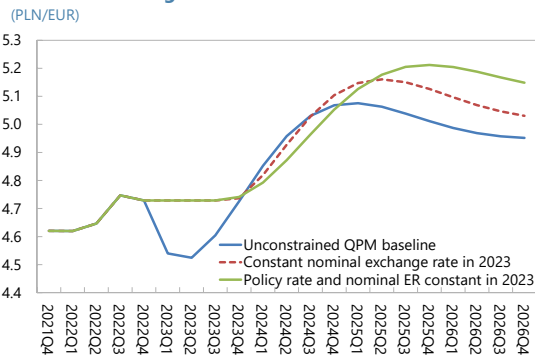
Sources: NBP; Statistics Poland; and IMF staff calculations.

25. The behavior of the exchange rate is also important to the setting of the policy rate and the speed of disinflation. In each scenario, the positive interest rate differential contributes to nominal appreciation against the euro. This appreciation makes a greater contribution to the tightening of monetary conditions in the near term than the policy rate (see Figure 8). Despite the significant monetary policy tightening in Poland since 2021 relative to the Euro Area, the nominal exchange rate did not appreciate against the euro as of end-2022, perhaps due to an increase in the risk premium related to regional geopolitical risks. A continued lack of exchange rate appreciation in coming quarters would mean a smaller contribution of the real exchange rate gap to the tightening of monetary conditions. In such a scenario, either: (1) the policy rate would need to be tightened further to achieve a similar pace of disinflation; or (2) absent additional tightening, the pace of disinflation would be slower than in the model baseline (Figure 10). The model also suggests that without a nominal exchange rate appreciation, if the policy rate were held at its current level for 2023, monetary conditions may need to tighten at the beginning of 2024, implying further interest rate increases.

Figure 10. Constant Exchange Rate Scenarios

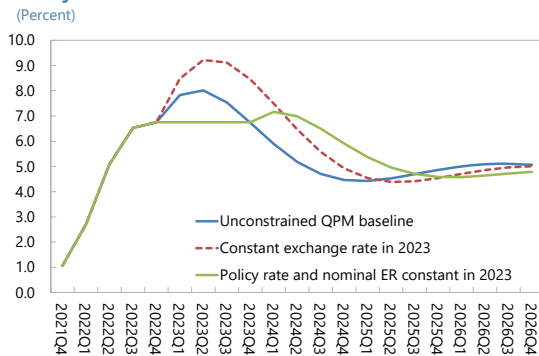
If the nominal exchange rate were to remain constant in 2023...

Nominal Exchange Rate



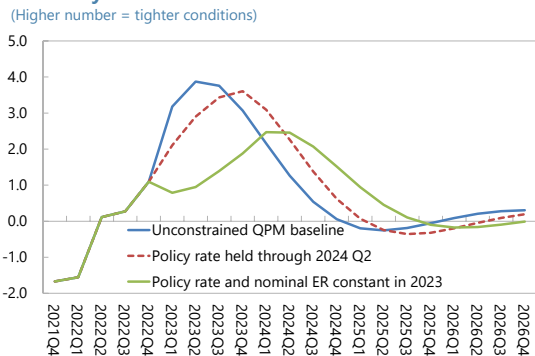
...the policy rate would need to increase further...

Policy Interest Rate



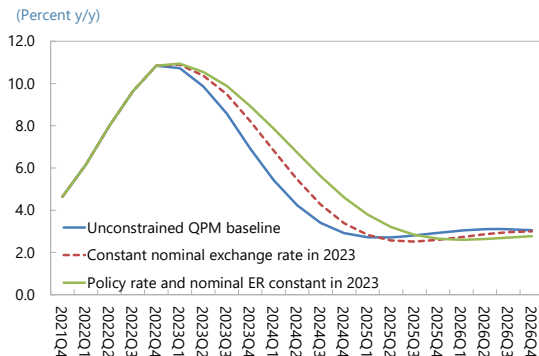
...to achieve a similar tightening of monetary conditions...

Monetary Conditions Index



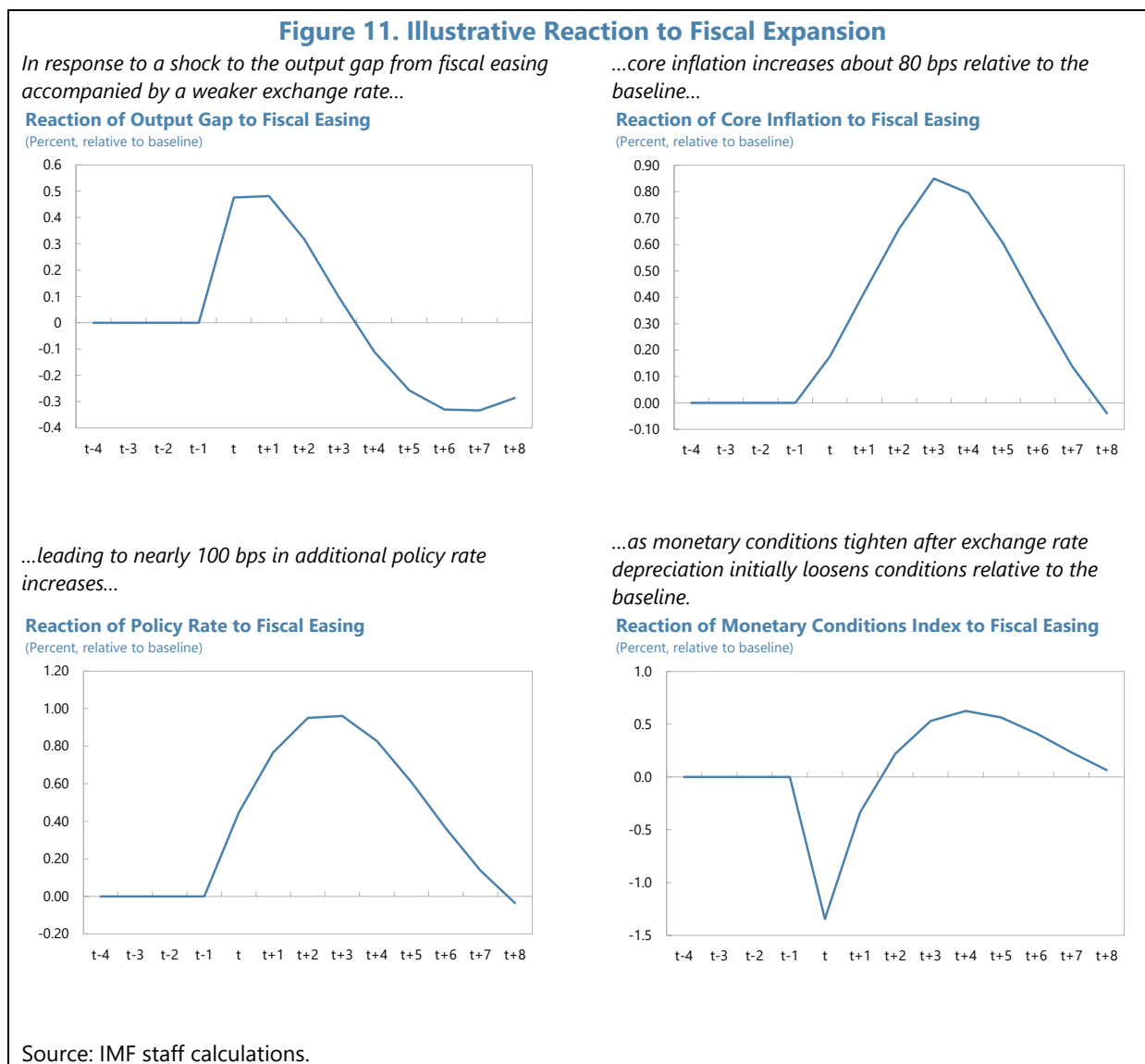
...to place core inflation on a similar downward path.

Core Inflation

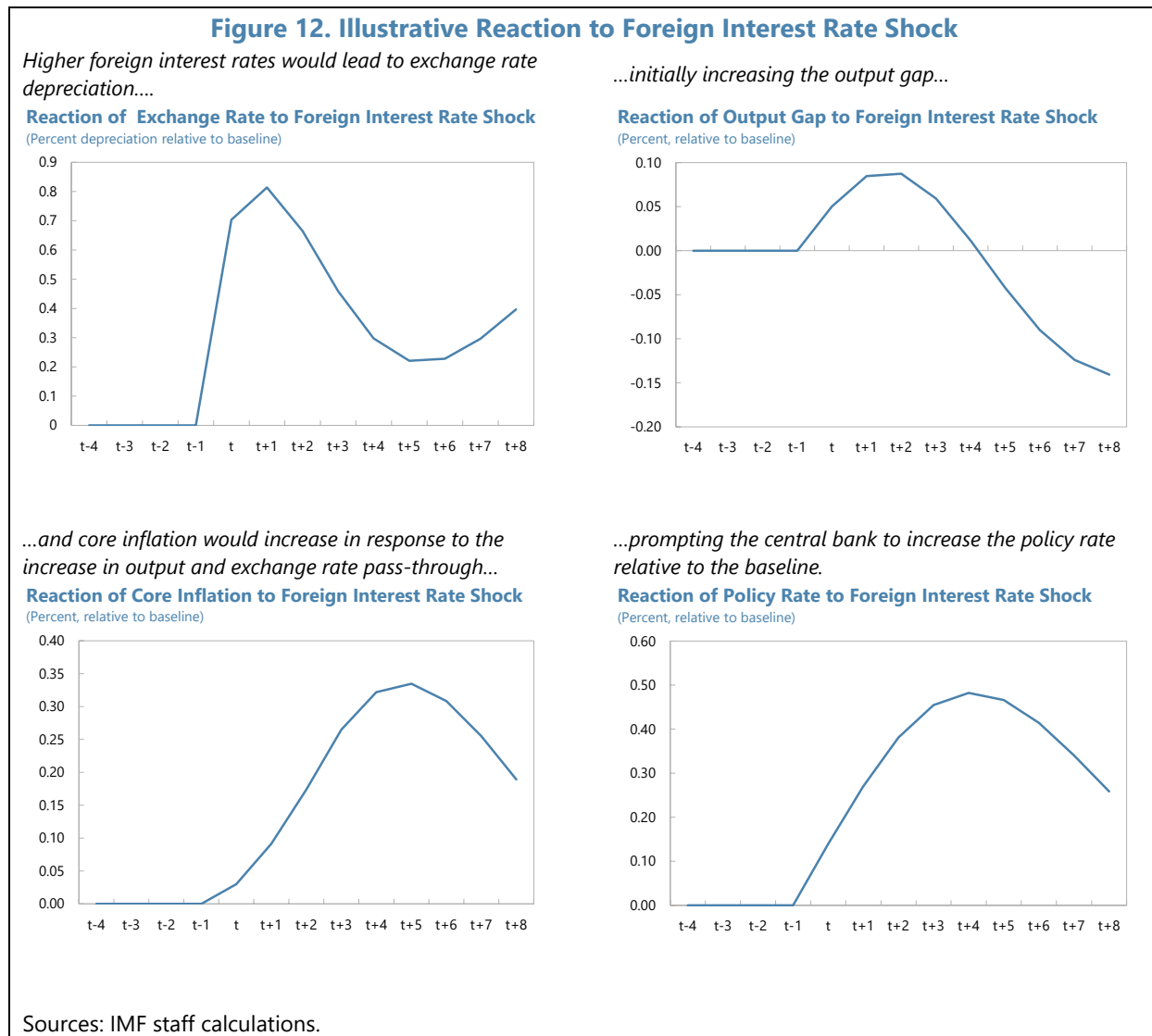


Sources: NBP; and IMF staff calculations.

26. A fiscal expansion that increases output could increase inflation and spur additional monetary policy tightening. In the QPM, a fiscal expansion could be modeled through its impact on the output gap. Assuming a conventional fiscal multiplier of 0.5, a 1 p.p. reduction in the structural fiscal balance would cause a 0.5 p.p. positive shock to the output gap. We also assume that markets would react negatively to fiscal easing, leading to a 5 percent weakening of the nominal exchange rate relative to the model baseline scenario. The weakening of the exchange rate initially loosens monetary conditions, which combined with the positive shock to the output gap lead core inflation to increase about 80 bps after three quarters relative to the model baseline scenario. In response to higher core inflation, Taylor rule suggests that the policy rate would increase an additional nearly 100 bps relative to the model baseline scenario (Figure 11).



27. Greater monetary policy tightening by the ECB could also present an upside risk to policy rates in Poland. If the ECB were to tighten policy rates by an additional 100 bps relative to the model baseline scenario, the UIP condition in the QPM would suggest a depreciation of the nominal exchange rate. While this depreciation would increase the output gap marginally due to a loosening of monetary conditions, core inflation would increase relative to the baseline mainly due to exchange rate pass-through. In reaction to higher core inflation, the policy rate would increase by nearly 50 bps after four quarters (Figure 12).

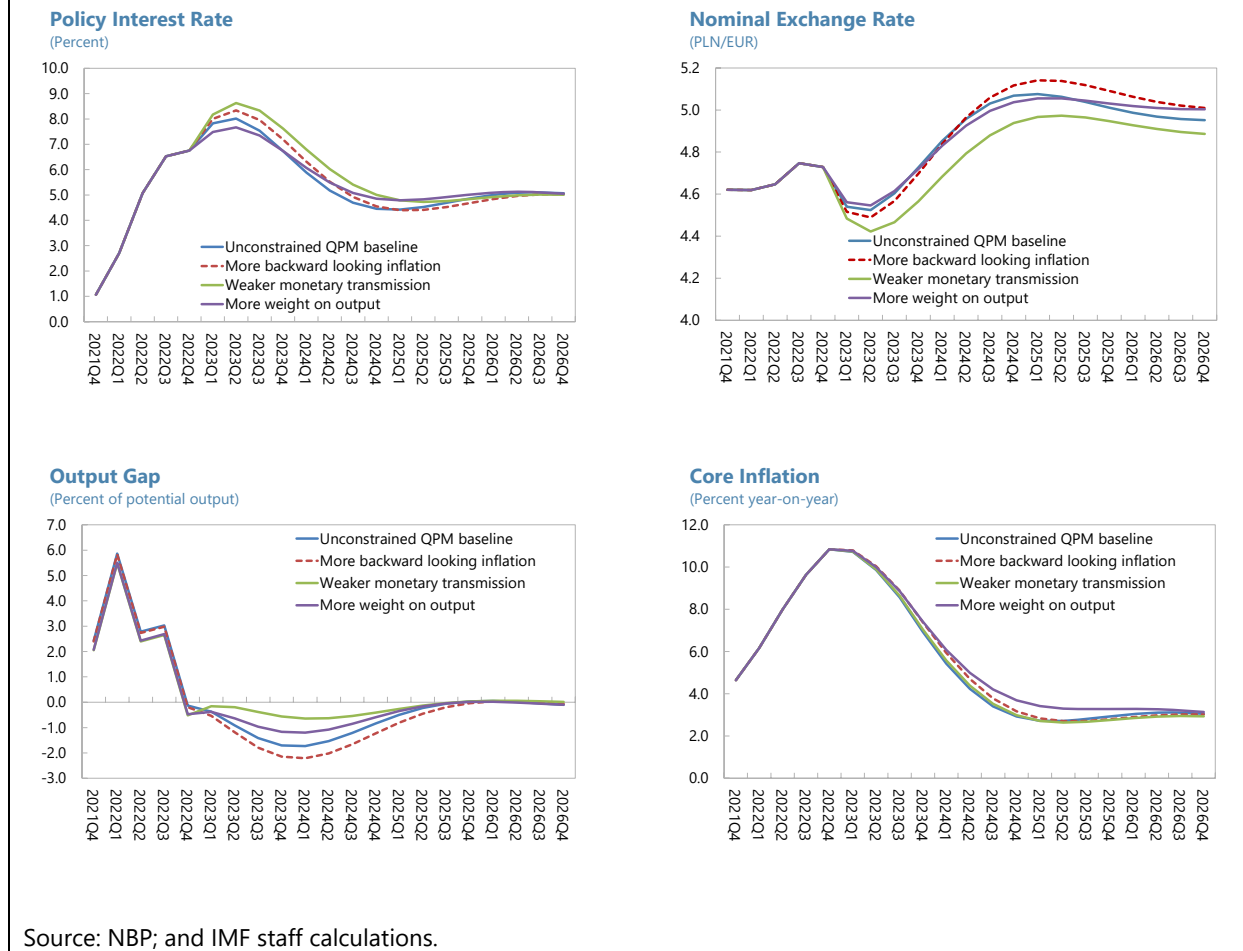


Sensitivity Analysis

28. Deviations in the calibration of the QPM can also have a significant impact on the projections. Calibration of the QPM ultimately requires making judgements on coefficients, the values of which are subject to significant uncertainty in estimation. Current characteristics of the economy may also affect the transmission of monetary policy, including, for example, mortgage payment holidays. Thus, it is worth exploring how model uncertainty in a few specific scenarios could affect the projections (Figure 13):

- *More backward-looking price formation:* One of the risks of a prolonged period of high inflation is that price formation could become more backward looking, with the inflation target becoming a less credible anchor for price setting. In the model, this could be captured by increasing the coefficient in the Phillips curve on lagged inflation, for example from 0.8 to 0.9. In this scenario, the policy rate would need to be increased by an additional 30 bps compared to the baseline, with disinflation requiring a higher cost to output compared to the baseline.
- *Weaker monetary policy transmission:* The impact of tighter monetary conditions on the output gap is uncertain and could change over time and in response to other policies. For example, the mortgage payment holiday implemented in Poland in 2022 weakens the transmission of interest rate increases by dampening the effect of rising floating mortgage rates on household disposable incomes. In the model, weaker transmission could be reflected by lowering the coefficient of monetary conditions on the output gap from 0.3 to 0.15. In this scenario, the policy rate would need to increase about 60 bps further than in the baseline and remain at a higher level to achieve a similar path of disinflation. Reflecting the higher interest rate differential, more of the disinflation in this scenario owes to exchange rate appreciation, rather than rate increases.
- *More output-weighted Taylor rule:* If a central bank were temporarily to prioritize the stabilization of output over the achievement of the inflation target, such a scenario would be illustrated by decreasing the Taylor rule coefficient on inflation (from 1.1 to 0.5) and increasing the weight on the output gap (from 0.4 to 1.0). Under this modified reaction function, the policy rate would be lower in the near term compared to the baseline, and the negative output gap would be smaller. However, the disinflation process would be slower over the medium term.

Figure 13. Sensitivity of Projections to Model Calibration



G. Policy Implications and Conclusions

29. A few caveats about QPM-based monetary policy analysis are warranted. It is important to recognize the limitations of a reduced form model and treat its projections as illustrative rather than precise, helping to inform but not dictate projections and policy recommendations. Key estimates in the model, including the output gap and real interest rate gap, are themselves subject to significant uncertainty. The QPM also cannot capture certain global inflationary factors in core inflation that are independent of the output, real interest rate, or real exchange rate gaps. Looking back at the decomposition of initial conditions in Figure 7, recent movements in the output gap and core inflation are explained partially through “shocks.” In other words, there are factors for which the QPM cannot account. For example, supply chain pressures independent of the output gap contributed to the increase in core inflation; thus, the easing of such pressures could contribute to core disinflation.

30. Nevertheless, the range of scenarios analyzed in this paper point to the possibility that the policy rate may need to be increased further or held at its peak for longer to reduce core inflation to the target by the end of 2025. While the analysis suggests that a scenario that many

market participants expect – constant rates through 2023 followed by rate cuts – could be consistent with such a reduction in inflation within the monetary policy horizon, this path appears to be narrow. Under a range of possible developments – including the absence of exchange rate appreciation, a fiscal expansion, or greater-than-anticipated monetary policy tightening abroad – the policy rate may need to be increased further or held at its current level for longer. The QPM also illustrates the tradeoffs between output and inflation under various scenarios for the policy rate path. While a slower pace of tightening may improve growth in the near term, if more tightening is needed later in the monetary policy horizon, the cost to growth will simply be delayed.

31. The NBP should carefully monitor the realism of its projections under the current monetary policy path. The Monetary Policy Council believes that tightening already delivered remains sufficient to return inflation near the target by the end of 2025. Should the NBP’s current economic projections, in particular the path of core inflation, appear to overestimate the pace of core disinflation, the MPC should be prepared to raise the policy rate further to a level consistent with the desired projections.

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