INTERNATIONAL MONETARY FUND

SELECTED ISSUES PAPER

Impact of High Energy Prices on Germany's Potential Output

Yushu Chen, Ting Lan, Aiko Mineshima, and Jing Zhou

SIP/2023/059

***IMF Selected Issues Papers* are prepared by IMF staff as background documentation for periodic consultations with member countries.** It is based on the information available at the time it was completed on July 17, 2023. This paper is also published separately as IMF Country Report No 23/259.

2023
JUL

 SIP/2023/059

IMF Selected Issues Paper

European Department

Impact of High Energy Prices on Germany's Potential Output

Prepared by Yushu Chen, Ting Lan, Aiko Mineshima, and Jing Zhou[1]

Authorized for distribution by Kevin Fletcher

July 2023

ABSTRACT: The surge in energy prices since Russia's invasion of Ukraine has reduced the energy-intensive sector's production in Germany, although the non-energy intensive sector's production has held up thanks in part to firms' efforts to improve energy efficiency. Energy prices are expected to remain elevated in the foreseeable future, compared to pre-war levels, adversely affecting firms' productivity and thus lowering Germany's potential output. Economic modeling suggests that this effect could be around 1¼ percent of GDP in staff's baseline, with some uncertainty around this estimate, depending on the ultimate magnitude of the energy price shock and the degree to which increased energy efficiency can mitigate it. Policies can promote effective adjustment to the shock by increasing productivity and maintaining strong price incentives to conserve energy and invest in renewable energy production.

RECOMMENDED CITATION: Chen, Y., Lan, T., Mineshima, A., and Zhou, J. (2023). Impact of High Energy Prices on Germany's Potential Output. IMF Selected Issues Paper (SIP/2023/059). Washington, D.C.

JEL Classification Numbers:	D24, E22, E23, O44, Q43, Q55, Q58
Keywords:	Germany, energy prices, energy efficiency, productivity, potential output, potential growth, directed technical change.
Author's E-Mail Address:	AMineshima@imf.org, JZhou@imf.org, TLan@imf.org, ychen30@worldbank.org

[1] The authors would like to thank Oya Celasun, Kevin Fletcher, the German Ministry of Finance, the German Ministry for Economic Affairs and Climate Action, the Bundesbank for useful comments. All remaining errors are our own.

SELECTED ISSUES PAPERS

Impact of High Energy Prices on Germany's Potential Output

GERMANY

INTERNATIONAL MONETARY FUND

GERMANY

SELECTED ISSUES

June 28, 2023

Approved By
European Department

Prepared By Yushu Chen, Ting Lan, Aiko Mineshima, and Jing Zhou

CONTENTS

FIGURES

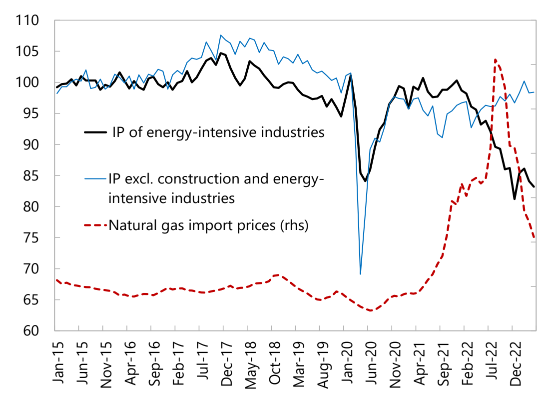
IMPACT OF HIGH ENERGY PRICES ON GERMANY'S POTENTIAL OUPUT[1]

The surge in energy prices since Russia's invasion of Ukraine has reduced the energy-intensive sector's production in Germany, although the non-energy intensive sector's production has held up thanks in part to firms' efforts to improve energy efficiency. Energy prices are expected to remain elevated in the foreseeable future, compared to pre-war levels, adversely affecting firms' productivity and thus lowering Germany's potential output. Economic modeling suggests that this effect could be around 1¼ percent of GDP in staff's baseline, with some uncertainty around this estimate, given uncertainties about the ultimate magnitude of the energy price shock and the degree to which increased energy efficiency can mitigate it. Policies can promote effective adjustment to the shock by increasing productivity and maintaining strong price incentives to conserve energy and invest in renewable energy production.

A. Introduction

1. The surge in energy prices since Russia's invasion of Ukraine has led to a contraction in the energy-intensive sector's production, while the non-energy intensive sector's industrial production has remained resilient. At their peak in 2022, Germany's natural gas import prices reached nearly tenfold their 2021 average, before falling to below threefold the 2021 average as of April 2023. In response to the surge in gas prices, production of energy-intensive industries[2] declined almost 20 percent from pre-war levels between late 2021 and late 2022 (Figure 1). Meanwhile, production of other industries saw limited declines during 2022, followed by a gradual increase in 2023 as pandemic-induced supply disruptions started easing and external demand recovered.

Figure 1. Gas Price and Industrial Production
(2015=100, seasonally adjusted)



Sources: Destatis and Haver Analytics.

2. Amid the surge in gas prices, German industries have considerably reduced gas consumption by substituting gas with other types of energy or improving their energy efficiency. During the second half of 2022, German industries' gas consumption was on average

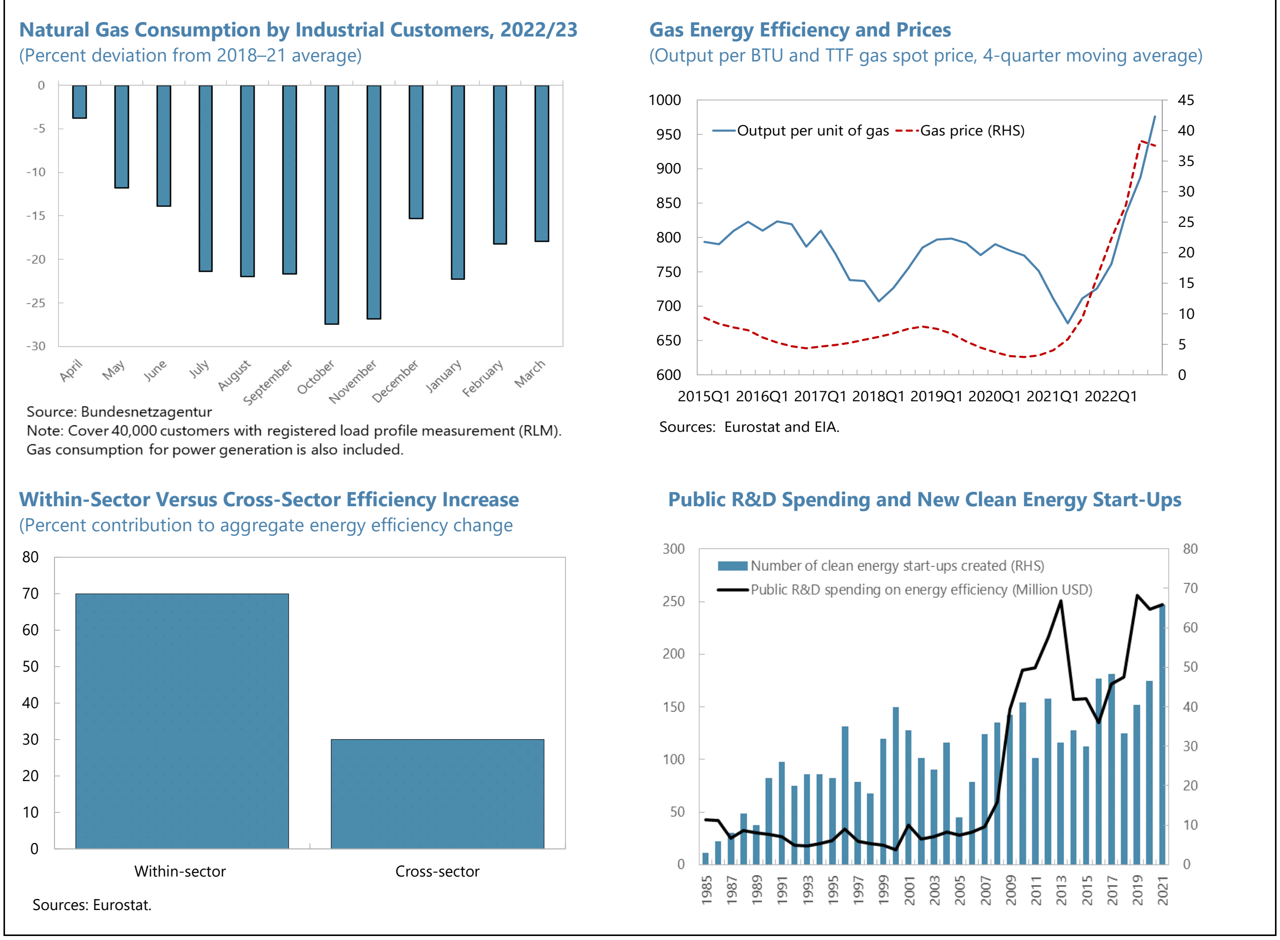
---

[1] Prepared by Yushu Chen, Ting Lan, Aiko Mineshima, and Jing Zhou (all EUR).

[2] Energy-intensive industries include: (i) manufacture of chemical products; (ii) metal production and processing; (iii) manufacture of glassware, ceramics, stone, and earth processing, (iv) manufacture of paper, cardboard, and goods made from them; and (v) coking plant and petroleum processing. These industries constituted 13.2 percent of industrial production in 2015 (the base year for the current IP data), and 3.1 percent of GDP in 2020 (the latest available data point).

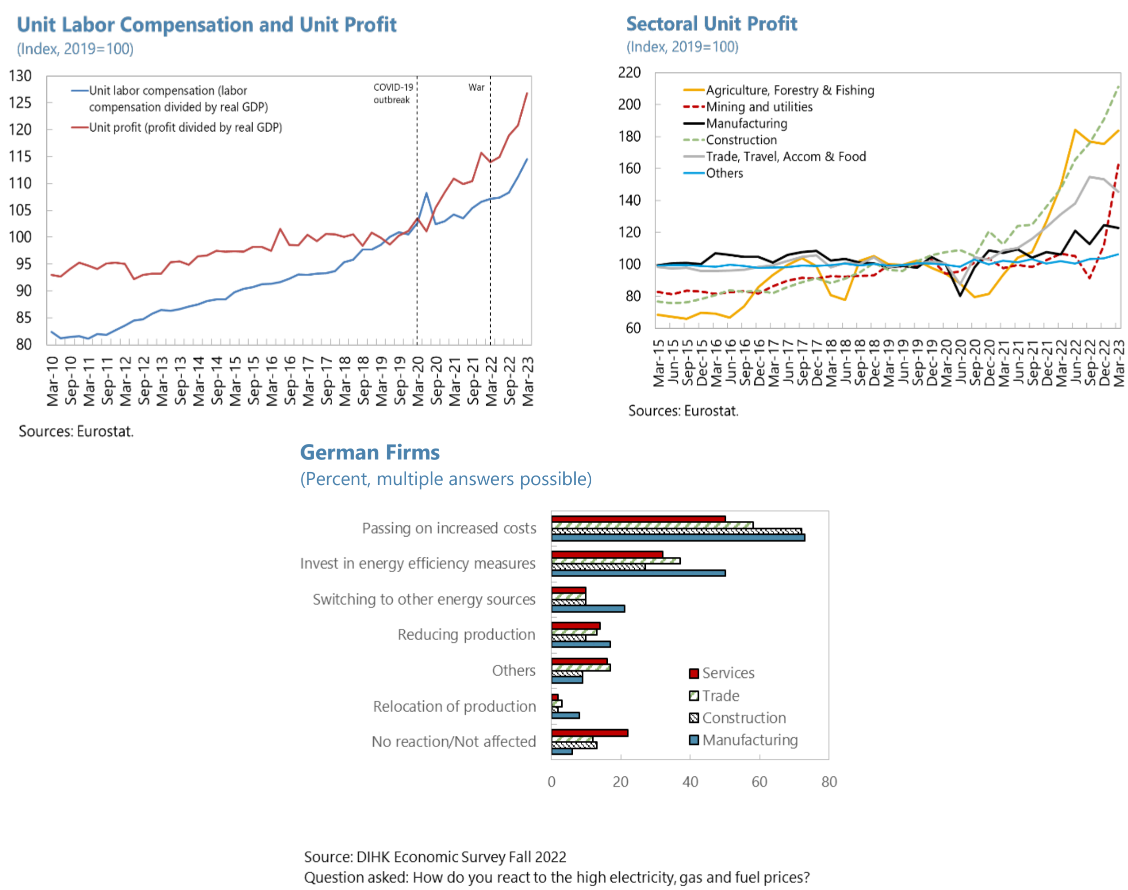
22 percent below their 2018–22 levels (Figure 2, top left). Their gas intensity—measured by output per unit of gas—improved by around 25 percent since 2021 (Figure 2, top right), of which about two-thirds was driven by efficiency gains within sectors and one-third from shifts in production from energy-intensive sectors to other sectors (Figure 2, bottom left). This is consistent with survey results that show more than half of manufacturing firms planned to invest in energy efficiency measures (Figure 3, bottom), plans supported by rises in public spending on clean energy R&D and in the number of new clean energy start-ups (Figure 2, bottom right). Survey evidence by the Ifo Institute for Economic Research shows that 75 percent of German firms were able to save natural gas without reducing production.

Figure 2. German Industries' Gas Consumption and Gas Efficiency



3. Despite high energy prices, corporate profits have remained resilient. Unit profit per real output has exceeded the historical trend and increased by almost 20 percent in the last two years (Figure 3, left), and the average profit share between 2022Q1 and 2023Q1 was 2 percentage points higher than the 2019 average. On the contrary, after a temporary spike during the 2020Q2 lockdown during the COVID-19 pandemic, unit labor cost has not surpassed its trend despite high inflation, although with an uptick in late-2022. The increase in unit profit was concentrated in agriculture, construction, manufacturing, utilities, and contact-intensive service sectors (Figure 3, right). A survey conducted by DIHK suggests that facing higher energy costs, three-quarters of manufacturing firms in Germany planned to pass high production costs onto end-users (Figure 3, bottom). And some companies have taken advantage of their pricing power to increase their sales prices more than was indicated by the development of purchase prices.[3] For the utility sector its unique market structure allowed for windfall profit gains; due to the inframarginal pricing in the electricity market, where electricity prices are determined by the marginal cost of production (which was driven by fossil-fuel-based electricity producers in 2022), electricity producers that use renewable sources experienced virtually no increases in their marginal costs but much higher revenues. For contact-intensive sectors such as food and travel, the post-pandemic pent-up demand provided them with pricing power and led to increases in profit margin. Similarly, the construction sector enjoyed larger pricing powers, aided by buoyant demand for housing. Agriculture and manufacturing, which produce a larger share of tradable goods than the other sectors, have benefited from rising global prices (e.g., the food shortage caused by Ukraine grain exports disruptions).

Figure 3. Corporate Labor Compensation and Profit



[3] See, for instance, German Companies in Trade, Construction, and Agriculture Used Inflation to Increase Profits.

4. Against this background, we analyze the possible effects of the energy price shock on Germany's potential output over the medium term. We do this using a closed-economy, directed technical change model. The rest of this chapter discusses this model's set-up and results. It then concludes with a discussion of possible policy responses.

B. Analytical Approach

5. We analyze the impact of energy price shocks on potential *growth* and *output* with a closed-economy, directed technical change model.[4] The directed technical change model, initially proposed by Acemoglu (2002), considers that technological progress is shaped by deliberate choices made by firms, rather than considering it as exogenously given. In this model, firms allocate resources towards technologies that complement specific factors, and the relative profitability of different types of technologies determines the direction of technical changes. There are two competing factors that shape the relative profitability of different types of innovation. The first factor is the price effect, which incentivizes the development of technologies used in the production of more expensive goods or those that rely on more expensive inputs for production. The second factor is the market size effect, which encourages the development of technologies that have a larger market share, particularly those utilizing the more abundant factor. These two effects are in competition with each other, as the price effect favors technological advancements benefiting scarce factors, while the market size effect drives innovations complementing the abundant factor. The relative strengths of these effects are determined by the elasticity of substitution between the factors. When the elasticity of substitution is low, scarce factors command higher prices, leading to a relatively more dominant price effect. Our analysis reveals that there is a relatively low elasticity of substitution between energy and labor-capital inputs. This suggests that when energy prices increase, the price effect becomes dominant in influencing firms' production decisions. In response, firms tend to prioritize and direct their technical changes towards enhancing energy efficiency.

Firms' Optimization Problem for Technology and Inputs

6. Assuming that energy is a key input for production with its own productivity parameter (energy efficiency), the firm's production function can be written as follows:

$$y_t \equiv F(A_t k_t^{\alpha} l_t^{1-\alpha}, A_{et} e_t) = \left[(1-\gamma)(A_t k_t^{\alpha} l_t^{1-\alpha})^{\frac{\epsilon-1}{\epsilon}} + \gamma(A_{et} e_t)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}},$$

where ϵ is the elasticity of substitution between capital (k_t) / labor (l_t) and energy (e_t), A_t is capital-labor productivity, A_{et} is energy productivity, and γ is the share parameter in the CES production

[4] The model draws inspiration from the work of Acemoglu (2002), Acemoglu, Aghion, Bursztyn & Hémous (2012), and Hassler, Krusell, and Olovsson (2021).

function. We employ a Bayesian estimation approach to jointly estimate ϵ and the shock variances. The posterior estimate of ϵ for Germany is 0.03.[5] With a relatively low elasticity of substitution, the price effect will be dominant, implying that higher energy prices will incentivize firms to raise energy efficiency.

At each period t, a fixed amount of R&D investment is allocated to enhance the efficiency of the capital/labor bundle and energy efficiency, where firms choose efficiency growth A_{t+1}/A_t and $A_{e,t+1}/A_{et}$ subject to the technology constraint:

$$G\left(A_{t+1}/A_t, A_{e,t+1}/A_{et}\right) = 0,$$

where G is strictly increasing in both arguments. Thus, the choice to select a high level of one of the input-saving technologies comes at the expense of the other.[6] Once a firm chooses the allocation of R&D investment, it takes the technology levels for A_t and A_{et} as given and chooses levels for k_t, l_t, and e_t. Under the baseline scenario where energy prices are assumed to be 20 percent higher than the pre-pandemic levels in 2028, our simulation results indicate that Germany's energy efficiency by thenis higher by 6 percentage points compared with the counterfactual of a no-shock scenario.

Consumers' Optimization Problem

7. A representative household is assumed to maximize its utility subject to resource and budget constraints. The household derives utility from a stream of consumption units, c_t. It owns a depletable energy resource R, and it supplies one unit of labor l inelastically each period. The problem for the households is to maximize

$$U = \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma} - 1}{1 - \sigma}$$

subject to the resource constraint,

$$\sum_{t=0}^{\infty} e_t = R_0$$

as well as the budget constraint

$$c_t + k_{t+1} = w_t l_t + r_t k_t + p_t e_t$$

[5] The size of the elasticity of substitution is comparable to that for the euro area of 0.04 by Lan et al. (2023) and that for the U.S. of 0.02 by Hassler et al. (2021). There is a typical degree of uncertainty around the estimated parameter.

[6] In our analysis, we assume that the G function exhibits constant returns to scale and is quasi-concave and twice differentiable.

Aggregation

At the aggregate, the economy's planning problem can be written as

$$\max_{\{c_t, k_{t+1}, l_t, e_t, A_{t+1}, A_{e,t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma} - 1}{1-\sigma}$$

subject to the budget constraint,

$$c_t + k_{t+1} = F(A_t k_t^{\alpha} l_t^{1-\alpha}, A_{et} e_t) + (1-\delta) k_t$$

and subject to the technology constraint

$$G\left(A_{t+1}/A_t, A_{e,t+1}/A_{et}\right) = 0,$$

for all t, and with the resource constraint

$$\sum_{t=0}^{\infty} e_t \leq R_0$$

C. Impact of Higher Energy Prices

8. **With the model calibrated for Germany, we simulate the impact of higher energy prices on Germany's potential *growth* and potential *output*.** The model allows technology to respond endogenously to changes in the economic environment and thus save on expensive inputs. With a relatively low calibrated elasticity of substitution between energy and capital-labor inputs, compared with the typical size of the elasticity of substitution between capital and labor, energy price shocks prompt a shift in investment from enhancing capital-labor productivity to enhancing energy efficiency. This leads to both less capital-labor productivity and more energy efficiency relative to the balanced growth path. In the short to medium term, such energy efficiency gains cannot fully offset the adverse price effect and the transitional cost of shifting investment from capital-labor productivity to energy productivity. This in turn lowers potential *growth* and *output* compared with a no-energy shock scenario. Over the long run, however, the economy is expected to adjust and return to the balanced growth path, but the temporary deviation from the balanced path will lead to a permanent output loss.

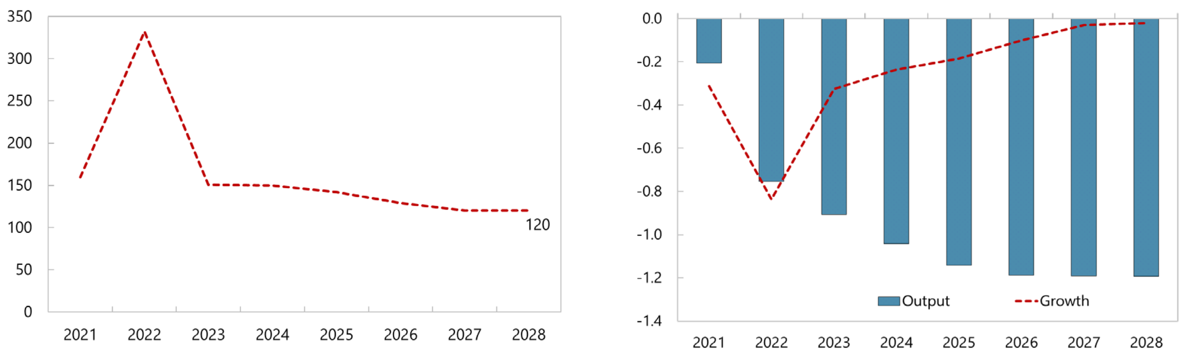
9. **Energy prices that are 20 percent above the 2018–19 average are estimated to reduce Germany's potential output by 1.2 percent in the medium term.** In the scenario where energy prices in Germany (i.e., the consumption share-weighted average of coal, oil, and natural gas prices) are assumed to stay 20 percent above pre-pandemic levels (based on futures prices as of June

2023),[7] the growth of energy efficiency takes off while the growth of capital-labor productivity falls, leading to a decrease in potential growth and output. The largest adverse impact is estimated to have taken place in 2022, when energy prices rose by 232 percent from the 2018–19 average, while the annual incremental impact diminishes over time (Figure 4). By 2028, potential *output* is estimated to be lower by 1.2 percent compared to the no-shock scenario. Meanwhile, the adverse impact on potential growth diminishes to well below 0.1 percentage points by 2028.

Figure 4. Baseline Energy Price Path and Impact on Potential Growth and Output

Price Scenarios
(Index, average 2018/2019=100)

Impact on Potential Growth and Output
(Percent deviation from the no-shock scenario)

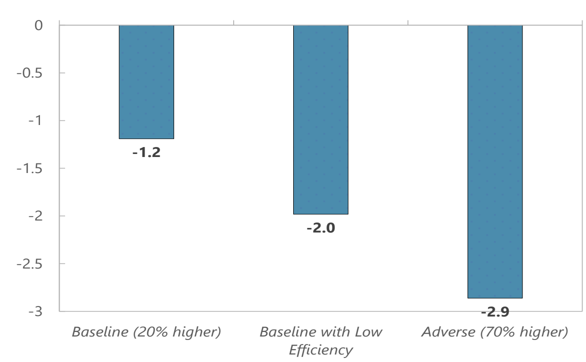


Sources: IMF Staff Estimates.

Source: IMF staff

10. Output losses become larger if energy efficiency is less responsive to energy price changes or if price shocks are greater.[8] When energy prices increase, the directed technical change mitigates the negative economic consequences of high energy prices. However, the effectiveness of this cushioning effect depends on the degree to which energy efficiency responds to changes in energy price. In an alternative scenario where energy efficiency is less responsive to the high energy price shock—i.e., an energy efficiency gain of only around 4 percentage points by 2028, instead of 6 percentage points assumed under the baseline—the level of potential output is estimated to be

Figure 5. Impact of Higher Energy Prices on Potential Output
(Percent deviations from the no-shocks scenario in 2028)



Sources: IMF Staff Estimates

[7] The weight of each energy product is calculated with data on German industries' energy consumption from Eurostat's Energy Balances database.

[8] Our approach has limitations in capturing the multi-sector input-output effects and the potential re-allocation of production across sectors and across countries. These factors could influence the overall impact of higher energy prices on the economy.

2 percentage points lower than that in the non-shock scenario (Figure 5, middle bar). Furthermore, the impact on potential output also depends on the size of energy price shocks. In an adverse scenario where energy prices are assumed to be 70 percent higher than the pre-pandemic level—around the peak of five-year future energy prices, which was observed in the fall of 2022—the estimated reduction in potential output is 2.9 percentage points (Figure 5, right bar).

D. Conclusion and Policy Discussion

11. Permanently higher energy prices could reduce Germany's potential output, but some of the impact is expected to be offset by firms' endogenous response to improving energy efficiency. Under the scenario in which energy prices are above the 2018–19 average by 20 percent, the energy price shock could reduce Germany's potential *output* by around 1.2 percent and potential *growth* by 0.1 percentage points over the medium term, compared to the non-shock scenario. The adverse impact becomes larger if firms' energy efficiency response to price increases is low and/or energy prices turn out to be higher.

12. Policy recommendations. Some decline in Germany's potential output level as a result of higher energy prices is likely unavoidable. However, good policies can help mitigate this loss and avoid exacerbating it. Specifically, it is important to note the following:

- **Price signals are important.** Increased energy efficiency is key to mitigating the adverse effects of the energy price shock. Suppressing price signals by—for example, subsidizing energy prices—could delay improvements in energy efficiency (and the climate transition).
- **Boosting labor and capital productivity remains critical.** Higher labor and capital productivity can help offset output losses from higher energy prices. Government policy can help boost productivity by fostering innovation and human capital development, as discussed in more detail in the 2023 and previous year's Article IV reports.
- **Government interventions can help direct the transition to cleaner energy.** It is important that Germany respond to the energy shock in ways that also support the green transition, given Germany's goals to significantly reduce its CO2 emissions. This can be achieved by continuing to gradually increase carbon pricing while also increasing public investment in renewable energy infrastructure and energy efficiency.

References

Acemoglu, Daron. "Directed technical change." *The Review of Economic Studies* 69, no. 4 (2002): 781-809.

Acemoglu, Daron, Philippe Aghion, Leonardo Bursztyn, and David Hemous. "The environment and directed technical change." *American Economic Review* 102, no. 1 (2012): 131-166.

Hassler, John, Per Krusell, and Conny Olovsson. "Directed technical change as a response to natural resource scarcity." *Journal of Political Economy* 129, no. 11 (2021): 3039-3072.

Lan, Ting, Manasa Patnam, Fred Toscani, and Claire Yi Li. "Energy Price Impacts on Potential Output." *IMF Working Paper*, forthcoming.

"Many industrial companies in Germany cut Gas consumption without curbing production." Ifo Institute. Many Industrial Companies in Germany Cut Gas Consumption without Curbing Production | Press release | ifo Institute.