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Gas Price Caps and Electricity Production Effects in the Context of the Russo-Ukrainian War: Modeling and New Policy Reforms

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Summary:

The merit-order approach in the electricity market, which is in widespread use across the EU27 and the UK, has proven to be somewhat economically problematic in the context of the Russo-Ukrainian war. The massively increased gas prices since summer 2022 – in the context of Russian supply cuts to the EU – has led to an abnormally high electricity price: Using the merit order approach, the price of electricity increases enormously if, as is often the case, gas is the last type of energy still realized in power generation; this leads to artificial increases in returns for all other types of energy providers whose output is used in power generation. Gas price increases by Russia or Russian supply cuts to the EU can increase the price of electricity and also the rate of inflation, as well as depress real income. The electricity price shock can be countered by switching – temporarily – to a modified regulation of the electricity market for a few years with a gas price subsidy in the electricity market. In a macroeconomic analysis, we identify both the output losses and adverse distributional effects of a gas price hike and find that a gas price subsidy is superior in stabilizing output and employment compared to a transfer; it also at least partially addresses certain distributional issues by reducing windfall profits in the electricity market. The study advocates a combination of gas price subsidies only in the electricity market and targeted transfers to households to meet both efficiency and distributional targets. The macro-analysis findings presented herein should be considered carefully, as they could minimize the welfare losses in the EU and the UK. As regards the expansion of renewable energy-based electricity, it is shown herein that the cost-differential between gas-fired power stations and renewable electricity is critical – large cost differentials imply barriers for an expansion of electricity generation from renewables unless there is a price regulation of electricity. There is the potential of an inefficient adjustment path due to nonlinearities. With a proposed narrow gas price cap for the electricity market only, the associated initial deficit related to necessary subsidies is, of course, much smaller than in the case of a general gas price cap.

Zusammenfassung:

Der Merit-Order-Ansatz auf dem Strommarkt, der in der EU27 und im Vereinigten Königreich weit verbreitet ist, hat sich im Zusammenhang mit dem russisch-ukrainischen Krieg als wirtschaftlich problematisch erwiesen. Die seit dem Sommer 2022 massiv gestiegenen Gaspreise – im Zusammenhang mit russischen Lieferkürzungen in die EU – haben zu einem ungewöhnlich hohen Strompreis geführt: Nach dem Merit-Order-Ansatz steigt der Strompreis enorm an, wenn, wie häufig, Gas die letzte Energieart ist, die noch in der Stromerzeugung realisiert wird; dies führt zu künstlichen Renditeerhöhungen für alle anderen Energiearten, deren Output in der Stromerzeugung eingesetzt wird. Gaspreiserhöhungen durch Russland oder russische Lieferkürzungen in die EU können den Strompreis und auch die Inflationsrate erhöhen sowie die Realeinkommen drücken. Dem Strompreisschock kann begegnet werden, indem man – vorübergehend – für einige Jahre zu einer modifizierten Regulierung des Strommarktes mit einer Gaspreissubventionierung im Strommarkt übergeht. In einer makroökonomischen Analyse ermitteln wir sowohl die Produktionsverluste als auch die negativen Verteilungseffekte einer Gaspreiserhöhung und kommen zu dem Ergebnis, dass eine Gaspreissubvention im Vergleich zu einem Transfer besser geeignet ist, Produktion und Beschäftigung zu stabilisieren, und auch bestimmte Verteilungsprobleme zumindest teilweise löst, indem sie Mitnahmeeffekte auf dem Strommarkt verringert. Die Studie spricht sich für eine Kombination aus Gaspreissubventionen nur auf dem Strommarkt und gezielten Transfers an Haushalte aus, um sowohl Effizienz- als auch Verteilungsziele zu erreichen. Die hier vorgestellten Ergebnisse der Makroanalyse sollten sorgfältig geprüft werden, da sie die Wohlfahrtsverluste in der EU und Großbritannien minimieren könnten. Was den Ausbau der Stromerzeugung aus erneuerbaren Energien betrifft, so wird hier gezeigt, dass der Kostenunterschied zwischen Gaskraftwerken und Strom aus erneuerbaren Energien entscheidend ist – große Kostenunterschiede stellen Hindernisse für einen Ausbau der Stromerzeugung aus erneuerbaren Energien dar, sofern es keine Preisregulierung für Strom gibt. Es besteht das Potenzial eines ineffizienten Anpassungspfads aufgrund von Nichtlinearitäten. Bei einer vorgeschlagenen engen Gaspreisobergrenze nur für den Strommarkt ist das damit verbundene anfängliche Defizit im Zusammenhang mit den notwendigen Subventionen natürlich viel geringer als im Falle einer allgemeinen Gaspreisobergrenze.

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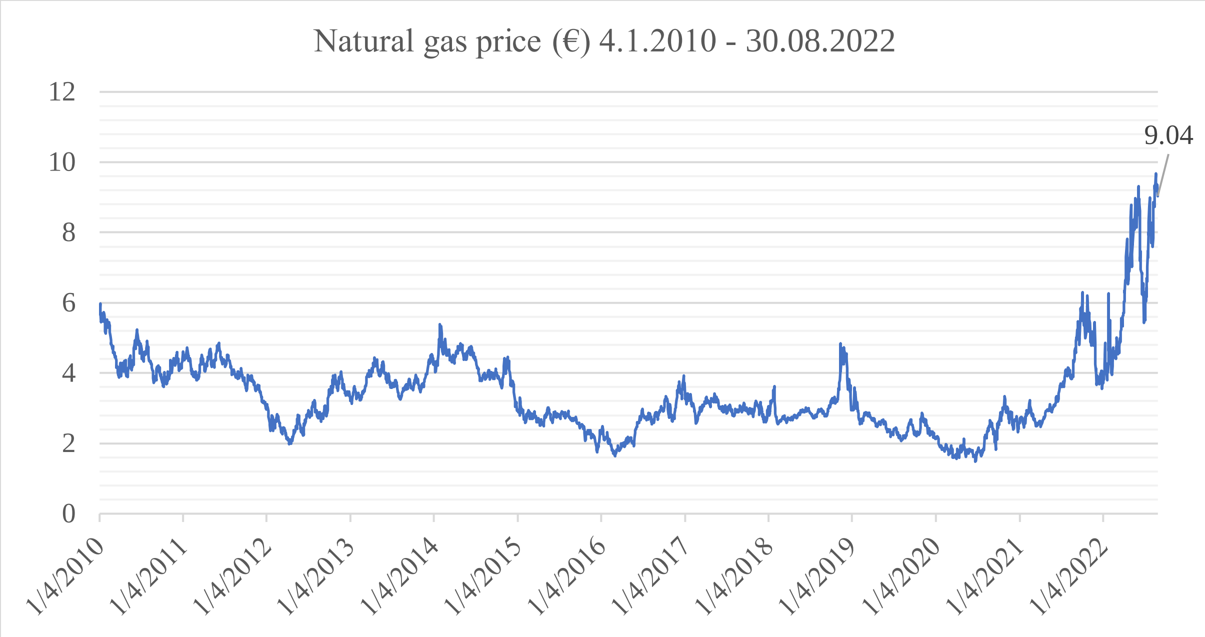
1. Introduction: What is at Stake?

For reasons to do with physics, the electricity market must ensure an equality of supply and demand in the network at all times. Therefore, electricity market regulations in OECD countries are generally such that the supply side adjusts to demand curves that change over the course of the day, week and month; regulatory problems generally occur at the high-voltage and regional/local distribution levels where there are natural monopoly problems (falling marginal costs with increased output from distribution companies) and therefore price regulation is carried out by national regulators – in the EU27 in line with European Union (EU) frameworks. Within the EU27+UK+Norway area, significant amounts of electricity are also imported and exported at times, and in the first half of 2022 - particularly during the summer months - France especially saw uncharacteristically high import volumes, rather than its usual export of electricity to other EU countries. At its core, this was due to the fact that in the summer of 2022, approximately half of France's nuclear power plants were unable to produce electricity or could only produce reduced amounts of electricity (compared to normal output) due to necessary scheduled repairs and because of unusually low river water levels in several parts of the country. Amongst other things, this increased the demand for electricity in Germany, with substantial amounts of electricity being exported to France at times.

In the merit-order approach - as the usual method for determining the electricity supply curve for a specific time window - the rule is that, especially in the case of short-term peaks in demand, gas-fired electricity producers who can react quickly to increases in demand are the last electricity supplier still to gain a foothold on the supply-side: With a low profit margin on the one hand, determining the equilibrium price on the electricity market on the other - due to the relatively low costs of nuclear, coal and renewable energy electricity, this often results in very high profits for the corresponding electricity producers. These high profits (often referred to as "excess profits" in the public debate, which makes the issue sound like a - non-existent - monopoly problem) arise in a market with a homogeneous good, with competition existing at the power generation level. One of the characteristics of the market is that, in the interest of optimal load management or demand timing, electricity distribution companies have entered into contracts with certain industrial companies to offer short-term electricity supply interruptions in return for de facto compensation - visible in the form of a lower electricity price or a rebate.

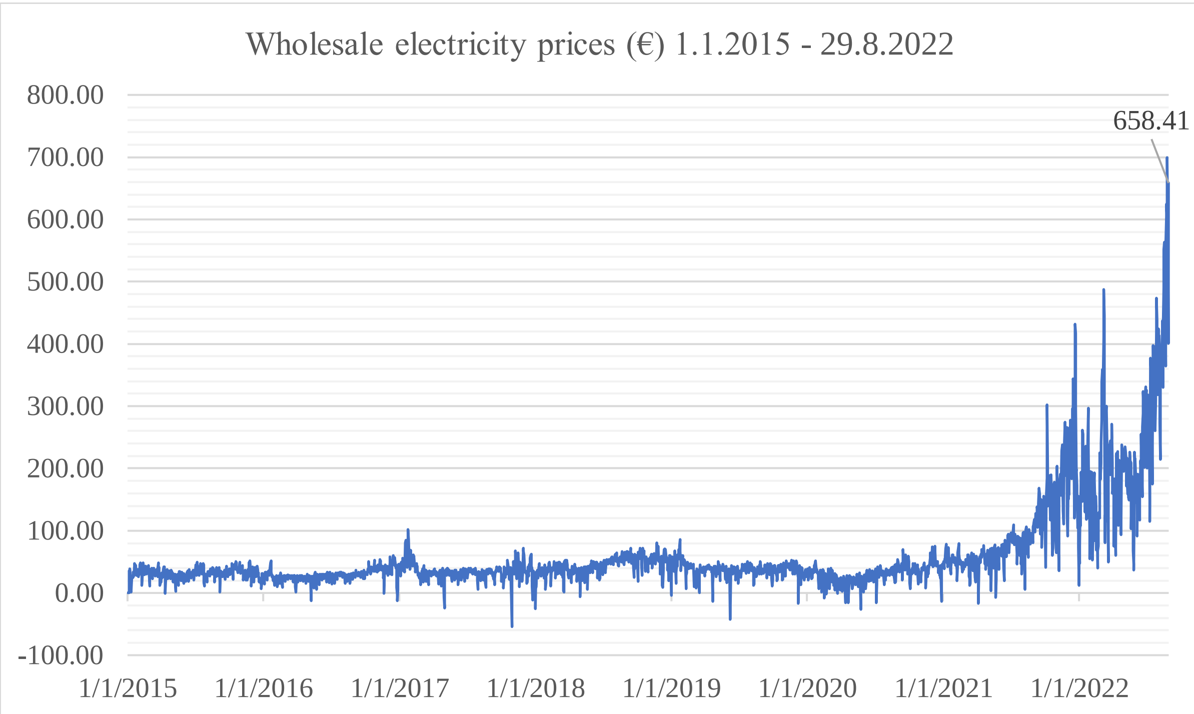
The electricity price in Germany and other EU countries increased very significantly in the first half of 2022, with the electricity and gas price developments running visibly parallel to each other (see Fig. 1 and Fig. 2); in other words, there is a positive correlation. Governments could counter gas price shocks and associated electricity price shocks, in particular, via transfers to private households, whose consumption expenditures can thus be supported; or use subsidies in the area of gas-fired power generation in the electricity market, which depresses the price of electricity and thus makes more production profitable while relieving the burden on private households. Corresponding macro-modeling approaches have been conspicuously absent thus far and such approaches are developed here with a view to determining optimal policy recommendations. In this way, one can analyze, amongst other things, the development of real income, employment, consumption and government deficits in each case for alternative policy interventions: An important contribution to the debate on the rationality of national and EU policies in Europe.

Fig. 1: Gas price development (daily values, wholesale prices) in Germany, 2010-2022



Source: Own representation of data available from finanzen.net, https://www.finanzen.net/rohstoffe/erdgas-preis-natural-gas/historisch accessed 31/08/2022.

Fig. 2: Electricity price development in Germany, 2015-2022 (€ per KWh)



Source: Own calculations and representation of data available from SMARD Electricity Market Data https://www.smard.de/home/downloadcenter/download-marktdaten#!downloadAttributes=%7B%22selectedCategory%22:3,%22selectedSubCategory%22:8,%22selectedRegion%22:%22DE%22,%22from%22:1546297200000,%22to%22:1609541999999,%22selectedFileType%22:%22CSV%22%7D accessed 31/08/2022

From a theoretical point of view, the increase in gas prices significantly drives the development of electricity prices in Germany and other EU countries, with electricity price shocks having to be considered in terms of their effect on industry as well as on private households - ultimately in terms of consumption. In the macroeconomic literature, as in the DSGE macro model, a distinction is usually made between (Ricardian) households that are creditworthy and those whose spending is strictly limited by wage and transfer income. In particular, the macro model aims to illustrate the differences in impact between a gas price subsidy on one hand and the policy option of higher transfers to households on the other.

Beyond the special problems associated with the French energy sector, significant further electricity price increases became apparent in the German electricity market from July 2022, particularly in the form of sharp forward price increases for electricity in 2023. The electricity price for Q1 2023 - if the forward price is an undistorted indicator of the future spot electricity price - will rise to a good six times the price of Q1 2022, which is likely to become a huge burden on private households and many electricity-intensive manufacturing companies.

In Germany, a special incentive regulation has been in place since 2007 for electricity networks in the area of the high-voltage grid and the regional or local distribution grid. The electricity price formation itself via the Leipzig electricity exchange (with the merit-order approach) is classified as unproblematic by Germany's Federal Network Agency (2021) [translation by the authors]:

> *"While competition works among electricity suppliers and electricity generation is marketed via an electricity exchange, electricity and gas networks are among the so-called "natural monopolies" in which competition has only a limited effect or is completely suspended. This is because, as a rule, it does not make economic sense to set up parallel electricity or gas pipeline networks operated by different companies in a given supply area. From a business point of view, too, there is usually no incentive to set up a parallel pipeline structure to compete with an incumbent supplier. However, to ensure that network operators do not make monopoly profits and that the networks are still operated as cost-efficiently as possible, electricity and gas network operators are regulated. In the interests of private consumers, commercial and industrial customers, and energy supply companies, charges for the transmission of electricity and gas must be calculated transparently and appropriately. In incentive regulation, the regulatory authority does not determine the individual network charge (price on the price sheet)."*

However, in 2022 it became clear that the electricity price formation and the electricity generation level in the electricity sector pose a serious problem, mainly due to the Russo-Ukrainian war and the abnormal export behavior of Gazprom, the Russian gas producer and exporter. Gazprom has arbitrarily cut supply volumes to EU countries. This has made it necessary for gas distribution companies in EU27 countries to buy gas on the world market at significantly higher prices than those stipulated in the supply contract with Gazprom.

The merit-order approach to the electricity market, which is widespread in Europe, is proving problematic in the context of the Russo-Ukrainian war. Merit order means that a unit price for electricity is set in an auction model in which the last type of energy still needed to meet demand determines the price for all power plants. In normal times, the merit-order approach is economically sound and provides incentives for the expansion of low-cost energy types, such as renewables (there is, however, one specific problem concerning the expansion of renewables in the merit-order approach if cost differentials between renewable energy power plants and gas-fired power plants, assuming that the latter are the marginal suppliers in the market: See Appendix 1 which suggests that an electricity price cap could reinforce incentives for the expansion of electricity generated from renewable energy sources). However, when a foreign gas supplier with considerable market power in the EU gas market, namely Gazprom, drives up the EU gas price through targeted supply cuts in violation of existing contracts, the merit-order model is characterized by political distorting impulses coming from Russia.

On many days or at many different times of the day, gas proves to be the last energy type still used for power generation in the merit-order approach, which, however, leads to the unusually very high electricity price in the context of the Russo-Ukrainian war or the Russian gas supply restrictions: Due to the war or partial Russian supply boycott shocks, the gas price in the EU has increased enormously since summer 2022. The merit-order approach in the electricity market, which is widespread in the EU27 and the UK, therefore proves to be economically controversial in the context of the Russo-Ukrainian war, as the forward price for gas, which has risen massively since summer 2022 (it is usually a fairly good predictive proxy for the future spot price on the gas market), leads to a very high gas price in the medium term: This also massively increases the price of electricity when the merit-order approach is used; provided, as is often the case, that gas is the last type of energy still realized in electricity generation at certain hours of the day or on certain days. The impression one gets, particularly in Germany, in the summer of 2022 is that policymakers would like to “tax away” the excess profits generated by non-gas-based electricity producers and recycle the revenues to households.

These circumstances lead to quasi-artificially increased returns for all other types of energy used in power generation and, ultimately, to exorbitantly high, medium-term electricity prices for households and business as well as the state. These high returns have nothing to do with a monopoly position on the part of non-gas power producers, which could be used to support the argument for state intervention with regard to “excess profits”, but here such returns are simply an expression of the relatively steep supply curve near the equilibrium quantity.

The following effects result from sudden increases in gas or electricity prices:

- Massively increased excess returns for electricity producers using types of energy other than gas; i.e., electricity from nuclear plants, coal, hydropower and other renewables - the latter being prioritized in Germany according to the German Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz (EEG)*) - are thus always part of the electricity supply. Due to the increasing use of renewables, the merit-order approach could lead to decreasing electricity prices for many years - before 2022 (see, e.g., Sensfuß, 2013). From an economic perspective, renewable electricity production can technically be viewed as reducing the demand for other types of electricity, which amounts to a reduction in the equilibrium price in the electricity market. A short-term expansion of renewable energies on a significant scale in Germany in 2022/23 is not to be expected due to long approval periods; in the medium and long term, however, it is.

- In the event of a massive and sustained increase in the relative price of gas and the relative price of electricity (electricity price/gross domestic product deflator), those production sectors that are relatively gas- or electricity-intensive - e.g., steel and fertilizer production and aluminium production, respectively - will become increasingly unprofitable. These are also capital- and knowledge-intensive sectors of the economy that employ a high proportion of skilled workers.

- The stock of electric cars in the fleets of commercial enterprises or the state as well as of private households will be massively devalued in the event of a massive increase in electricity prices over several years; the purchase of new low-CO2 vehicles of this kind will then drop massively; the stock market value of companies manufacturing electric vehicles will plummet, and some suppliers of electric vehicles will likely exit the market - a medium- or long-term market concentration will then occur. Loan financing of vehicle fleets in companies or for private buyers will become almost impossible with massively increased relative electricity prices. As a result, the planned reduction of CO2 emissions in the transport sector will be fundamentally jeopardized in Germany and the EU.

The massive yield increases of non-gas suppliers in the electricity market in the context of Russian gas supply cuts are distortions - as will be shown below - that should be countered by moving temporarily to a modified, regulation of the electricity market, with the EU and EU member states cooperating swiftly in the re-regulation. In addition, the EU should impose a gas import tariff on Russia (Roeger and Welfens, 2022a), which could significantly lower Gazprom's net supply price, while the state would have additional revenue to partially financially compensate low-income households and the hardest hit small and medium-sized firms. An EU import duty on Gazprom gas supplies should have been agreed and implemented by the EU as early as spring 2022 - but nothing happened here, and so Russia was able to strengthen its strategic position of dominance in the EU gas market by cutting volumes vis-à-vis individual EU states.

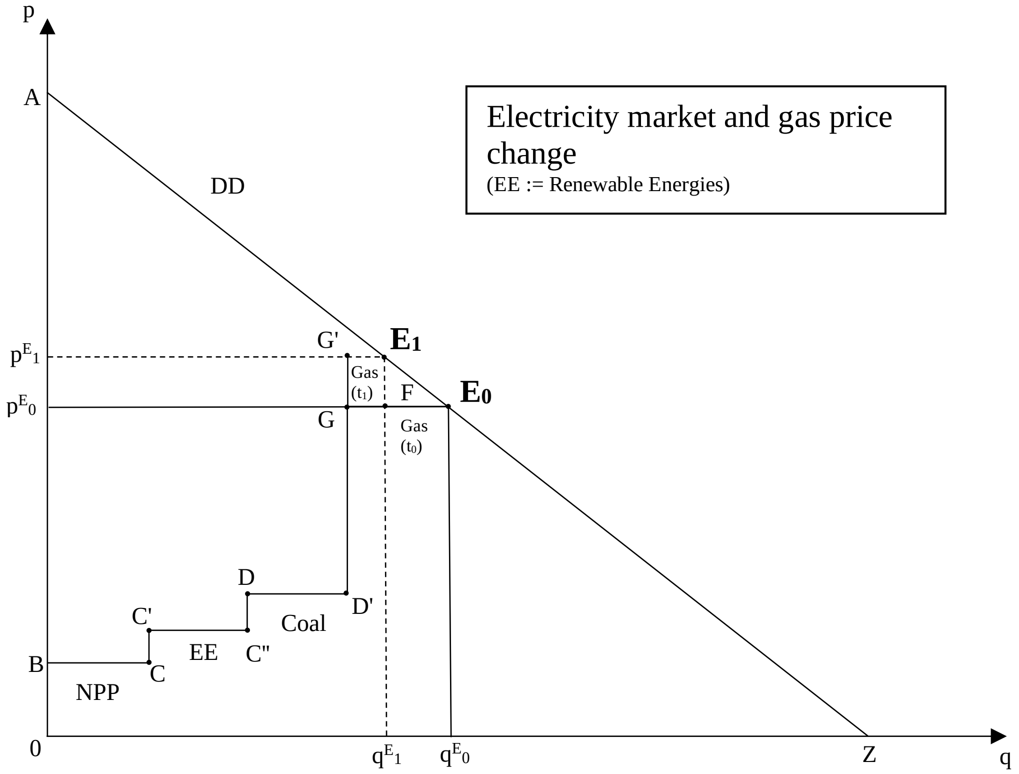
The following analysis briefly addresses the traditional merit-order model in the electricity sector in section 2 and addresses a reasonable policy option to limit electricity price increases in Germany and other EU countries in the third section. In the fourth section, the macroeconomic simulation analysis on gas price subsidy versus increased transfers to households is presented: There are several new findings with respect to key economic variables. The fifth section concludes with policy conclusions. As regards the expansion of renewable energy-based electricity generation, it is shown in Appendix 1 that the cost-differential between gas-fired power stations and electricity generated from renewable energy sources is critical – large cost differentials imply barriers for an expansion of electricity generation from renewable sources unless there is a price cap and price regulation in the electricity market.

2. Traditional Merit-Order Model in the Power Sector

The traditional merit-order approach means that first the suppliers with the lowest marginal costs will offer certain quantities of electricity generation at favorable supply prices for time window X (e.g., 6 a.m. to 7 a.m. the next day); usually renewables-fired power plants, nuclear power plants and coal-fired power plants - which are mostly active in the base load range and where output only be ramped up or down over several hours - followed by the particularly flexible gas-fired power plants which can be started or shut down at short notice. In addition, with intermittent negative or positive demand, there are pumped-storage power plants (negative demand means electricity supply), which buy electricity at relatively low electricity prices to pump water up into the respective pumped-storage lakes, which can then be emptied at short notice during time windows with high electricity prices or used to produce electricity in electricity generators installed below the pumped-storage lake. Disregarding the pumped-storage power plants for simplicity, the following supply curve is obtained as a staircase function, while the demand curve is shown linearly (a demand curve DD is given in Fig. 3; one could also show DD_1 for times of day with low demand and - further to the right of the origin - DD_2 for times of high demand). Looking at the relevant costs for different types of energy, the cheapest supply of electricity supply is provided by nuclear power plants (NPP; the line segment BC represents the corresponding nuclear power supply), renewables (EE) represent the supply of line segment C'C", coal represents DD', and gas represents GE_0 at the origin time with a given gas price. The market equilibrium is described by the point E_0, which is the intersection of the supply and demand curves. The profit corresponds to the area BCC'C "DD'G'p^E_0. A gas price increase in the gas market results in an upward shift in gas-based electricity supply, so that the quantity demanded decreases (to q^E_1) and the market price increases to p^E_1; of course, the profits of non-gas-based electricity producers also increase, namely by the area FE_1 p^E_1 p^E_0 minus a small rectangle (GG'E_1F) which represents profits of gas-fired power plants. As regards the slope of the demand curve (DD) it will be rather steep and price-inelastic in the short term so that a typical gas price increase will be rather high – in contrast to the more long term situation in which the demand curve is rather price elastic.

If a government price cap is set in such a way that the gas price applicable at t_0 also applies at t_1 despite the price increase, there will be more demand for gas because the share of gas-fired electricity generation will increase again, but the electricity price will of course also fall. The government would have to compensate gas producers for the difference between the gas market price and the price cap, i.e., in effect, provide a gas-only subsidy for electricity generation. The frequency with which gas becomes relevant as a marginal supplier source of energy can be reduced by improved electricity demand management – thus far an area of economic policy in Germany and many other EU countries that has seen little activity.

Fig. 3: Merit order model in the electricity sector (NPP= nuclear power plants)



Source: Own representation.

If the gas price rises due to (Gazprom) supply cuts, then with regard to the supply curve, the latter part of the supply curve - assumed to represent gas-fired power plants – is steepened or shifted upward. The market price for electricity in time windows where gas-fired power plants are the last type of electricity producer still considered will rise. However, the following then also applies: The marginal cost curves in all sectors where firms produce with electricity (i.e., all of them) are therefore shifted upward, which, in the case of further gas price increases over time, intensifies inflation at least in the short and medium term. At the same time, the equilibrium quantities on the goods markets decline in all markets, which is equivalent to a decline in real income. Thus, in any case, in addition to the real income decline, the gas price increases or inflation impulses generate additional negative welfare effects in parallel with the medium-term decline in real income or consumption levels.

Nonlinearities in the electricity market can also play a critical role: The exit of certain manufacturing firms and services firms due to extremely high energy costs – occurring in an initial adjustment period - would lead to a permanent decline in total electricity demand at given prices even after the peak electricity price (reflecting the gas delivery shocks in the EU and the UK related to supplies from Russia) has reversed, which means that medium-term and long-run perspectives should also be taken into account. In principle, the relevant mechanism is similar to the historical debate around deindustrialization in response to very high transitory real exchange rate peaks in the early 1980s, whereby a fluctuation of the real exchange rate to above the level which triggered firm exits and then back to the prior level implies permanently lower exports and employment in industrial sector. Baldwin and Krugman (1989), for example, had pointed out that a high initial capital inflow will bring about a strong real appreciation which translates into a worsening of the current account as part of the firms in the export sector are forced to exit the market. This in turn worsens the trade balance in a structural way, partly linked to hysteresis effects, so that there will be a real depreciation in the medium term – the adjustment in the real economy is thus not efficient (the Plaza Accord of 1985 helped to correct the massive $ appreciation of about 60 per cent in the period 1980-85: there was a 50 per cent depreciation in the years 1985-87). A similar problem seems to be relevant in the context of the gas price shocks of 2022 in the EU and the UK, but here it is primarily the electricity and the gas markets which are decisive.

Thus, the popular perception – in the context of the ongoing climate policy debate - in part of the policy community that the higher electricity prices rise, the better, is quite misleading since the Russo-Ukrainian war should be considered a transitory (although large) shock to energy markets in OECD countries. If many innovative firms in industry exit the market, thereby shifting the electricity demand curve to the left in the short term, this would be bad for both growth and green progress in the long run. In such a setting, bankruptcy laws could be temporarily adjusted and expanded government guarantees for knowledge-intensive, innovative firms with liquidity problems should be adopted. If such firms would exit markets in the manufacturing industry sector, there would be a permanent downward shift of the expansion path of the production potential and possibly also a slower technological progress rate in the long run; for Germany in particular this would mean a unwelcome de-industrialization shock.

Only in the long term will a comprehensive broad substitution of Russian gas by gas from other countries be possible. The rise in the relative price of electricity increases employment in the short term through the inflationary increase effect (Phillips curve effect), insofar as there is a positive employment effect due to the increased real wage rate reduction that has occurred and the uncertainty effect of consumers and investors does not dominate as a negative macroeconomic effect; the latter is to be expected in the medium term, which will reduce demand for electricity beyond the initial decline caused by the relative price increase.

Demand for electric vehicles, including hybrid vehicles, will decline due to the actual and expected rise in electricity prices - an effect that will only be partially compensated for temporarily in Germany by purchase pull-forward effects in view of the expiring subsidy for hybrid vehicles. Insofar as a supplier such as Tesla allows free electricity refueling at company-owned charging stations, a decline in sales especially for this brand is likely to be rather limited for the time being; assuming that Tesla has made long-term purchases of electricity. However, in the longer term, even a supplier like Tesla will then either want to charge for some or all of the electricity, or the brand's electric car prices will increase accordingly, reducing demand for (Tesla) electric cars.

3. New Regulatory Approach in the Context of the Russo-Ukrainian War

The task for state regulation of natural monopolies or of certain sectors is to create conditions similar to competition or to achieve optimal capacity utilization and optimal expansion of capacities over time – and, from the point of view of dynamic efficiency, to also realize a high innovation dynamic. Naturally, special attention must be paid to incentive effects. This is especially true at the network level, including network transmission charges, where regional monopolies may play a problematic role (for these aspects in the context of Scandinavian countries and the problem of regulatory capture, see Appendix 1).

From a macroeconomic perspective, one regulatory approach is important in the exceptional situation of the Russo-Ukrainian war, and that is in the field of electricity generation. Here, the state can lower the equilibrium price - on a monthly average - in the electricity market by lowering the price of gas for electricity generation, thus making more production profitable. This is countered by a financing requirement arising from the need for the state to compensate the gas generating companies for the difference between the market price and the level of the gas price cap; here, there may be the problem of an increase in the deficit ratio for the state, but the direct deficit-increasing effect of subsidy expenditures is countered by an expansive macroeconomic production effect due to the reduced electricity prices (welfare gains for private households from the cheaper electricity are added; a negative welfare effect results from possibly increasing CO_2 emissions). Incidentally, it cannot be ruled out that a large supplier of coal-fired or nuclear power may strategically reduce the volume offered in the hope that this will result in gas becoming a marginal supplier input in the electricity supply curve, which ultimately promises a higher electricity price; monitoring this is a task for investigations by the competition supervisory authorities.

As far as the regulation of electricity generation is concerned, or in relation to preventing abnormally high electricity prices in the context of the Russo-Ukrainian war, it should be kept in mind that very sharply increased electricity prices in equilibrium reflect a changed market situation - in this case, reduced Gazprom export volumes to the EU in 2022. However, the question also arises as to whether demand peaks during the course of the day cannot be better managed in the electricity market than has been the case to date; however, this will reduce the frequency of gas-based electricity producers acting as marginal suppliers or reduce the volume of gas required for electricity generation; the latter will cause the gas price in Germany or the EU to fall. In the first half of 2022, 15 percent of electricity generation in Germany was based on gas-fired power generation, which was still slightly above the figure for 2021. Gas demand during the course of the day can be changed within the framework of existing and, if necessary, new contracts between electricity distribution companies and companies with flexibility with regard to the usage of electricity in production over time.

The state can promote demand-smoothing pilot models that could also use the Internet for this purpose - albeit also with digital security risks (more investment must be made in digital security here). In this way, it should be possible to significantly reduce the role of gas-fired power generation; in other words, to also reduce the price of gas and thus, in turn, the price of electricity. The announcement of such pilot projects, which help to reduce demand in the peak morning and evening hours, should already push down price change expectations on the gas and electricity markets.

Finally, there remains the possibility that the German federal government (other EU countries) and the states subsidize gas prices for electricity generation in order to lower electricity prices for households and businesses and also to avoid otherwise very high "excess profits" of non-gas-based electricity producers. With a fixed gas price for electricity generation, the state should pay gas-based electricity producers the difference between the gas price cap and the market price as a subsidy - similar to the model already practiced in Spain in the summer of 2022 with EU permission, which slowed the rise in electricity prices in Spain. In Spain's case, the gas price cap for electricity generation was initially set at €40/MWh in May 2022, which will increase in 2023 in €5 incremental steps every month to reach €70/MWh by the end of 2023 (Enerdata, 2022; Banco de Espana, 2022 – also showing inflation effects of electricity prices on inflation). In Spain, the difference between the market price and gas price cap is paid by about 40 percent of households and 70 percent of firms with a regulated electricity tariff, with gas representing 20 percent of electricity generation in Spain; on 31st August 2022, the wholesale electricity price stood at €193/MWh, in France at €636, in Italy at €661, and in Germany at €571; in Spain, however, customers with a regulated electricity tariff still paid €263/MWh (Handelsblatt, 2022) - with a subsidy from the state, the effective electricity price would be lower.

This gives rise to a state aid scrutiny problem at the EU level. Therefore, apart from the two already existing exemptions for a gas price cap in Spain and Portugal, it is necessary to achieve a preliminary consensus across the EU for such a solution. With a view to the EU internal gas and electricity markets, it would make sense for as many EU countries as possible to introduce a gas price cap for electricity generation for a transitional period - at a similar level - so that distortions in the EU internal market are minimized. It is worth noting here, amongst other things, that Spain's EU electricity exports increased significantly after the introduction of the state electricity rebate.

If, as an alternative policy, a surtax was to be levied on the high profits of power generators, this would constitute sectoral tax discrimination without any objective reason from the point of view of legislation in Germany; it would probably not stand up in court. For this reason, a surtax might be worth considering only under certain condition. Looking at a macro model is thus crucial for a simulation analysis of alternative policy interventions in the energy markets.

4. A Macroeconomic Model with an Electricity Sector and Gas Prices

Here, a standard open economy macro model is used to analyze alternative policy options in the energy sector (electricity, gas) and determine the macroeconomic effects of various intervention measures. The domestic economy produces a good which is an imperfect substitute for goods produced abroad, i.e., imported goods. Since we want to take into account how specific characteristics of the electricity sector amplify the effects of gas price hikes, we have added a simple electricity sector. There are firms using domestic sources and firms using foreign sources for electricity production. Some electricity producers use domestic resources as inputs, and some electricity produces use imported resources as inputs. The electricity market is organized in accordance with the standard a merit-order system, which means that the marginal supplier (gas-fired power station with the highest cost and offer price, respectively) is setting the price for the whole market. It is also assumed that the electricity market is fully competitive and effectively regulated, i.e., marginal suppliers do not make a profit in equilibrium. Gas is a marginal source for electricity production (with a share of 15%). Nevertheless, gas imports are important, since in the short run there are limited possibilities to replace gas by domestic input substitutes. Moreover, we assume in the model that the supply shortage/price hike for gas lasts for 2 years, the time necessary to establish alternative supply chains (e.g., new LNG terminals) for gas. We further assume that electricity is an essential complementary factor for production and consumption of firms and households, i.e., the elasticity of substitution between electricity and other factors in production and consumption is small.

On the demand side we distinguish between two types of households, namely households which receive profits, wage and transfer income and which have access to financial markets and dispose of savings on one hand, and households which only receive income from wages and transfers and which in addition are liquidity constrained (LC=liquidity constrained), on the other.

This model allows one to look at various dimensions of a gas price shock. In particular, we can distinguish between a supply and demand channel and we can look at various distributional aspects of a gas price hike. On the supply side, an increase of gas prices raises the cost of production and reduces the productivity of other production factors, in particular labour, with repercussions for real wages and employment. On the demand side, the price increase in combination with limited options to substitute electricity strains the budgets of households and reduces the demand for domestic goods. This is especially true for LC households which have limited abilities to smooth consumption by varying savings. Finally, due to the organization of the electricity market, the gas supply shock gives rise to windfall profits in the electricity sector. Windfall profits accrue to a fraction of the household sector. Thus, the gas price shock has additional distributional effects.

We use the model to compare two alternative policies. We consider transfer policies with the aim of stabilizing the income of LC households. This is largely the policy advocated by many EU governments. Policies can differ by the way transfer spending is financed. We consider two financing options, namely deficit financing and financing via a tax on the windfall profits of firms operating in the electricity market. A second option we consider is a subsidy on gas inputs for gas-fired power stations. This policy is equivalent to a price cap on electricity where only the marginal supplier (here, gas-fired power stations) is compensated for the difference between the market price and the capped price. We will argue in this paper that the subsidy is an interesting policy option since, in contrast to the transfer policy, it also addresses the production efficiency issues implied by the gas price hike.

Calibration

Parameters are chosen such that the model can replicate key medium-term ratios of the German economy, such as the employment rate, the degree of openness, the government share as well as important government expenditure and revenue components. On the trade side, we distinguish between the imports of final goods which can be used for domestic consumption and the import of gas which is used as an input for electricity production in gas-fired power stations. One important parameter in the current discussion is the share of liquidity constrained households which we set to 40 percent of all private households (see Bach and Knautz (2022)). A more detailed discussion on parameter selection can be found in Clemens and Roeger (2022). A novel feature in the model is the electricity market. Electricity is modelled as complementary in production and consumption with an elasticity of substitution of 0.1 (see Bachmann et al. (2022) for a recent discussion). Concerning energy production, we assume that domestic sources for electricity production (i.e., coal, nuclear power stations, and renewables) can cover 85 percent of electricity needed at the baseline in fixed supply, while gas-fired power stations are the marginal supplier in the electricity market. It is also assumed that the electricity market is effectively regulated and gas prices are set by a merit-order system, i.e., the marginal supplier sets the price equal to marginal cost. Electricity production[1] (as a percent of GDP) is assumed to be 2 percent in the baseline, with a gas share of 15 percent. Industry and private households consume 75 percent and 25 percent, respectively. Since we are focussing on the peculiarities of the electricity market, we neglect the effects of gas price increases for heating and as an intermediate input in production.

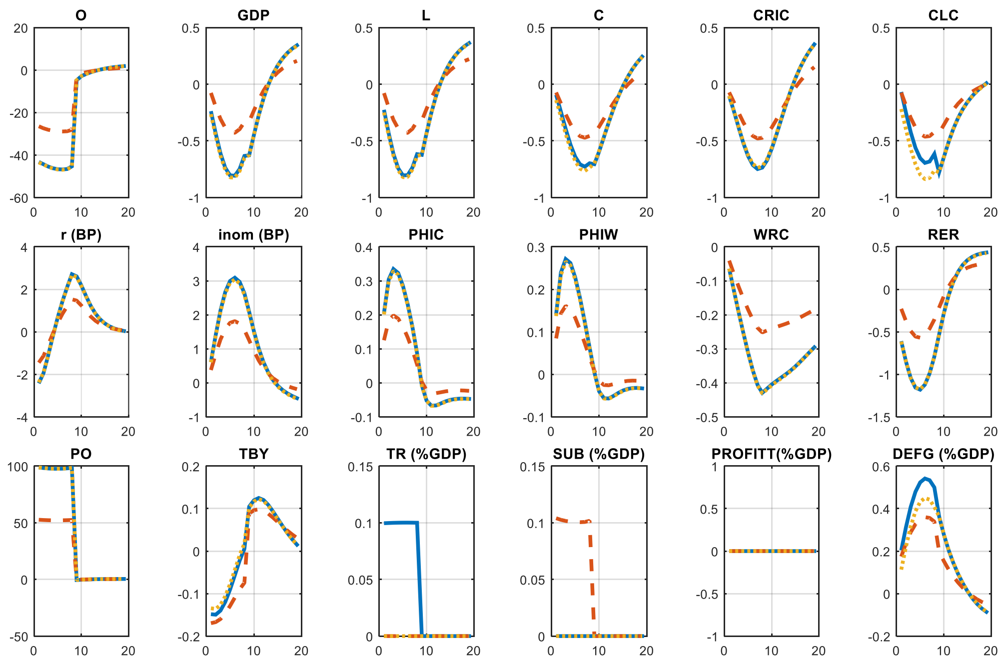
Scenarios

The starting point of our analysis is a baseline scenario with a gas price increase of 100 percent over a period of 2 years and no policy intervention. Against this baseline scenario, various fiscal policy options are compared. The first option considered is a policy of transfers to households, in the order of magnitude of 0.1 percent of GDP. Both the option of transfers to all households and transfers to LC households only are examined. In a third scenario, we consider a subsidy on imported gas of 25 percent for gas-fired power stations. Under our assumption of efficient regulation, this limits the gas (and therefore also the electricity) price increase to 50 percent. Given the gas share in electricity production, this amounts to a gas price subsidy of about 0.1 percent of GDP as well. This makes both measures comparable in budgetary terms. We further assume that both fiscal measures are financed via government deficit.

[1] Without cost for the electricity grid

In the remainder of this section we provide some additional sensitivity analysis. In particular, we compare deficit-financed transfers to transfers financed by a tax on windfall profits of domestic electricity firms.

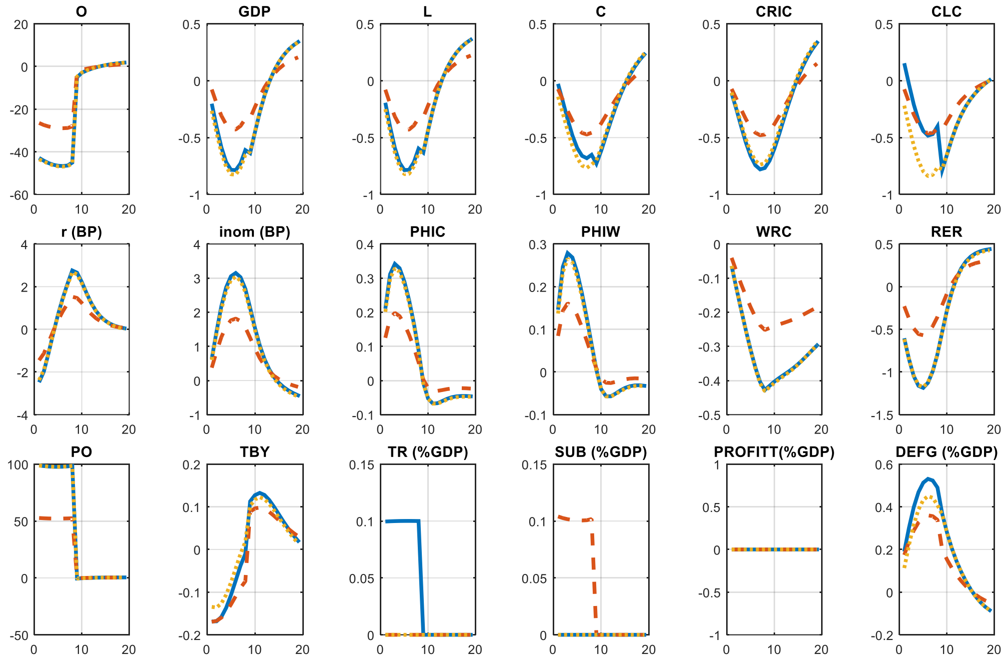
Fig. 4: Lump sum transfer vs. subsidy



No Policy Transfers Subsidies

Note: *O: gas imports; GDP: GDP (baseline prices); L: employment; C: total private consumption; CRIC: consumption (financially unconstrained HHs); CLC: consumption (liq. Constrained HHs), r: real interest rate; inom (nom interest rate); PHIC: quarterly consumer price inflation (incl. VAT); PHIW: quarterly wage cost inflation; WR real wage costs; WRC: real consumption wage; RER: real exchange rate (-: appreciation) PO: gas price (relative to domestic producer prices); TBY: trade balance to GDP ratio; TR: transfers to HH (% of GDP) SUB: subsidy to domestic gas power station (% of GDP); PROFITT: surprise profit tax revenues (% of GDP); DEFG: primary government deficit (% of GDP).*
Source: Own representation.

Fig. 5: Transfer to LC households only vs. subsidy



Source: Own representation.

Baseline scenario (no policy response):

The gas price shock by itself leads to a substantial reduction in the demand for gas (imports) of nearly 50 percent. This significant reduction occurs despite a low short run price elasticity for electricity of 0.1. Electricity usage falls by about 10 percent, but since the domestic supply of electricity is fixed, the 10 percent decline is entirely due to a fall of imported gas. The gas price increase has negative effects on supply and demand in the domestic economy. Since electricity is an input in production, an electricity price increase raises production costs and reduces labour productivity (i.e., an efficiency loss). On the demand side, the limited possibilities for consumers to substitute electricity reduces consumption (also of domestic goods). Liquidity constrained households cannot smooth consumption and therefore suffer larger consumption losses[2]. This negatively affects GDP and employment. The cost effect of an electricity price increase leads to inflationary pressures and a wage price spiral which continues beyond the duration of the gas price shock.

Subsidy to gas-fired power stations:

The subsidy to the electricity sector can substantially mitigate the negative impact of the gas price shock and in particular stabilizes (real) wages and employment. The subsidy targets both the negative impact of the gas price hike on production efficiency by constraining electricity costs in production and thereby mitigating a fall of labour productivity. This stabilises the fall of real wages and employment. The subsidy also corrects further distributional effects by

[2] Our model underestimates the consumption loss of liquidity constrained households since we do not take into account that low-income households spend a larger share of their income on energy.

reducing surprise profits of domestic electricity producers, received by high income households. Another interesting aspect of the subsidy is the large multiplier, which is above one[3]. This multiplier is due to a strong leverage effect. The government can lower the cost of electricity production by subsidizing just 15 percent of production. As consequence, the budgetary cost of subsidy are minimal.

One may add here an additional aspect – not covered in the simulation. If there is a lower inflation rate associated with a subsidy policy benefitting gas-fired power stations, the volatility of relative goods market prices will typically be lower (as often in reality) – as a lower inflation rate reinforces the signalling quality in goods markets – and therefore additional positive output effects, reflecting efficiency gains, may be expected.

Transfers:

As can be seen from Figures 4 and 5, the transfer policy mainly stabilises demand and corrects distributional effects of the gas price increase. In the case of a lump sum transfer, the distributional impact is limited in the sense that LC consumption falls more compared to the subsidy. However, the transfer policy - which is targeted - is more supportive to LC consumption than the subsidy.

Policy Mix:

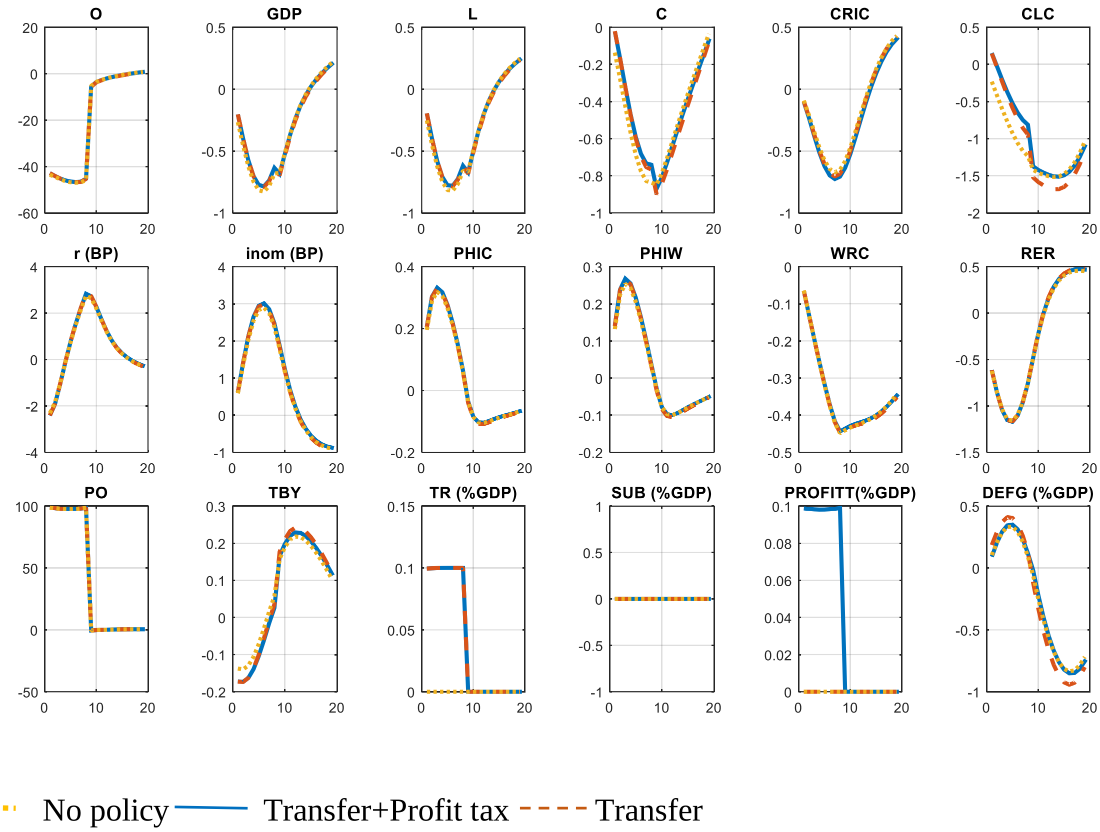
Comparing the effects of a subsidy and a transfer shows that the subsidy mainly corrects the production inefficiency while the transfer corrects adverse distributive effects. This suggests that a policy mix of the two instruments can correct both the efficiency and distribution distortion simultaneously. Given the low budgetary cost of the subsidy government can count on the revenue gearing effects of this instrument.

Extensions

This section provides information on two interesting additional cases. First, we discuss the effects of a transfer policy financed by windfall taxes of non-gas electricity producers. Second, we look at the sensitivity of the production subsidy by allowing for an endogenous gas import price response.

[3] As a consequence of higher economic activity (relative to the no policy baseline) there is also an increased demand for electricity and therefore for gas. This may induce further price increases for gas and reduce the multiplier. See the appendix for a discussion.

Fig. 6: Transfers to LC households only (windfall profit tax financed) vs. a subsidy

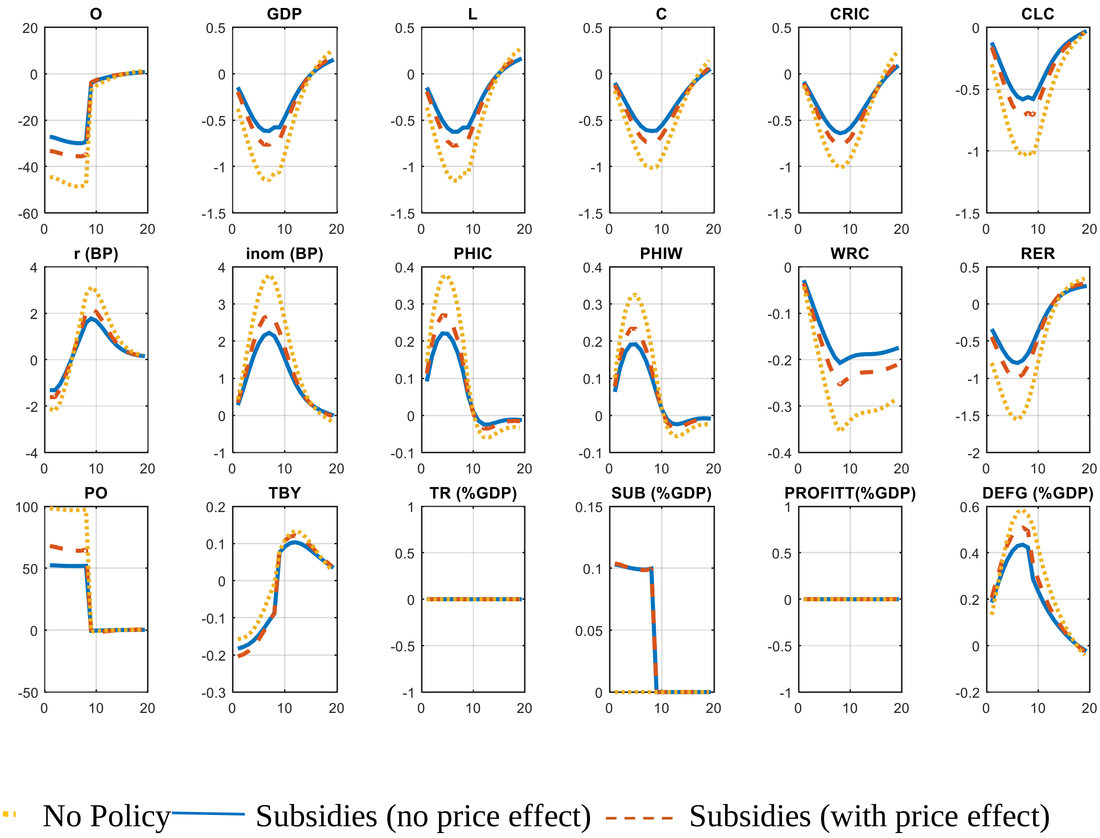


Source: Own representation.

As can be seen from Figure 6, a (windfall) profit tax does not have additional stabilizing effects and only additional marginal distributive effects compared to an increase in transfers alone. It does however affect government deficit dynamics[4]. It reduces the deficit over the period in which the policy is in place and requires a smaller surplus in the following period. For Ricardian households the profit tax shifts tax financing to the current period but does not substantially alter the present discounted value of taxes[5]. Since LC households also pay taxes, the surprise profit tax increases their net income since the profit tax can be used to finance the deficit.

[4] In contrast to the previous scenarios the government debt rule was invoked after five years in order to clearly show the budgetary cost of the two policy measures. In this experiment we keep the debt rule active from the first period onwards in order to show how the profit tax alters deficit dynamics.
[5] It would be completely neutral if only Ricardian households would pay taxes.

Fig. 7: Transfers to LC households only vs. a subsidy (with price elastic gas price)



Source: Own representation.

Figure 7 shows that the subsidy multiplier is negatively affected by the demand responsiveness of gas import prices. Here we assume an elasticity of the gas price w. r. t. gas demand of 0.5, this keeps the gas price about 30% higher. This reduces the multiplier proportionally and increases inflation.

5. Conclusions and Policy Options

In this analysis we have identified both efficiency and distributional issues associated with a gas price hike. We have analyzed how alternative policies can correct for price distortions in production and consumption and mitigate negative distributional effects. We have looked at two policies, namely a subsidy to gas-fired power stations and transfers to households. We find that the subsidy primarily corrects the price distortion in production and consumption and has therefore a substantial multiplier effect and helps to stabilize GDP, employment and the real wage. It has some direct distributional effects since it limits windfall profits which accrue to higher income households and it has indirect distributional effects since it limits the rise of energy price inflation. In contrast, a transfer has a very small multiplier, since it affects consumption of the two households in different directions. That there is a small GDP multiplier is due to the fact that LC households have a higher marginal propensity to consume. However, the same amount of government expenditure devoted to compensating lower income and liquidity constrained households achieves greater consumption stabilization for low income households. We further show that a transfer policy in combination with a tax on windfall profits does not change the result on transfers substantially, since a windfall profit tax mainly shifts the tax burden of higher income households from the future to the present.

Our analysis shows that in order to achieve two policy targets it is advisable to use a combination of two instruments, in this case both a subsidy/price cap and a transfer. As regards the gas price cap, it should be targeted at the electricity market only as this minimizes the gas subsidies required and has positive macroeconomic effects as well as a positive welfare effect on households through lower electricity prices. In contrast to a general gas price cap – such a broad cap would require subsidies about six times as high as would be needed in the case of a selective gas price cap applying solely to gas-fired power stations in Germany - the approach suggested is an efficient policy strategy to cope with the energy crisis in Europe and to minimize (or even avoid) a recession. An output increase in the EU plus the UK would also contribute to a positive transatlantic economic impulse for the US and other countries. Potential extra subsidies for gas-intensive industries should be rather limited in order to let the price mechanism work, but it would also be inadequate to force firms to fully adjust to the exceptional massive gas price hikes caused by Gazprom's cuts to gas exports in 2022. In the medium term, relative gas prices can be expected to fall from a peak level in early September 2022.

With a proposed narrow gas price cap for the electricity market only, the associated initial deficit related to necessary subsidies is, of course, much smaller than in the case of a general gas price cap. The economic leverage of a narrow gas price gap is the higher the smaller the share of gas (relative to the overall gas volume) used in the electricity sector.

However, one should highlight here the challenge posed by isolated national strategies on the part of EU countries, which would not be consistent – countries applying a subsidy to the gas and electricity markets, respectively, will face lower electricity prices which creates an incentive for higher electricity exports (as, for example, could already observed in summer 2022 when Spain introduced its national gas price cap for gas-fired power stations). Ideally, all EU countries should adopt very similar or even identical strategies. The respective national shares of gas in power generation will bring slight differences in the desired policy intervention.

If transfers should be subsidized by some form of sectoral windfall profit – here, for the electricity sector – there could be two key obstacles: One challenge is that the European Commission would have to give a green light for such subsidies in the electricity sector; a second challenge would be that firms would explore legal options in order to get a court ruling which could declare sectoral windfall profit taxation as being discriminatory and illegal.

The EU27 - whose electricity market also includes links to the respective markets in the UK, Norway and Switzerland (and, to a smaller extent, Ukraine) - would be well advised to start negotiations in particular with the United Kingdom which has already imposed a windfall profit tax on the energy sector which includes – in contrast to the debate in Germany and Spain – multinational fossil fuel energy companies. Thus far, the UK has not considered earmarking a large share of the additional tax revenues generated for the subsidization of gas-fired power companies, rather the extra revenues are recycled as higher transfers to households.

As the simulations have shown, a certain policy mix of both subsidies and transfers could be attractive in a macroeconomic perspective. However, as regards avoiding distortions in the EU single market the European Commission would be wise to encourage EU member countries to come up with a policy mix in each country which at the bottom line would not undermine the EU single market as a whole and thus create additional negative welfare effects.

Therefore, government intervention in the form of a gas price subsidy in the electricity market (and only there) – possibly in combination with transfers to households - is preferable. Based on the analysis presented herein, the EU should quickly allow individual EU member states to adopt a wider range of regulation in the electricity sector. The three most important measures which should be enabled by the EU as a matter of some urgency are:

- Subsidizing gas-fired power generation to lower the price of electricity.
- The demand profile in the electricity market, which fluctuates during the course of the day, should be reduced by additional contracts with companies during peak load times: As a result, less gas is then used for monthly electricity generation and the gas price can then fall in parallel with the electricity price.
- Similar policy mix approaches should be adopted in EU countries so as not to create distortions in the EU single market.

The Roeger-Welfens duopoly model for the EU gas market (Roeger and Welfens, 2022a) shows that the net offer price (price before import duty) of Gazprom gas supplies from Russia can be reduced by an EU gas import duty. In this case, the tariff revenues will not be sufficient to compensate for the welfare losses of customers through gross price increases in the gas market; but a substantial compensation of the welfare losses is at least achievable. However, it cannot be ruled out that Russia would respond by setting gas exports to the EU to zero, which would correspond to a political decision to harm the EU; but not to the normally assumed Gazprom profit maximization strategy (with certain politically set volume limits on exports). If Russia were to set gas exports to the EU or Germany to zero, even larger quantities of gas would have to be flared in Russia than was the case in the summer of 2022 – economically pointless and harmful to the climate.

If the proposed measures achieve a trend towards a normalization of the relative electricity price, a medium-term increase in the share of newly registered electric vehicles in vehicle registrations will be achievable; this applies to Germany as well as to other EU countries as well as Norway and the UK. An economic slump can be minimized or even avoided completely by reducing electricity prices for companies and households in Germany and the EU. Russian foreign exchange earnings from gas exports to the EU will be reduced, namely via an EU gas import tariff or a comprehensive gas export boycott imposed by Russia itself on the EU. For its part, the EU should then work to ensure that Greece-registered oil tankers no longer carry more than 50 percent of Russia's oil exports by sea, as they did in the first half of 2022.

The very large gas and electricity price increases from the first half of 2022, positively invoked by some economists, do not make sense per se, even if increased relative prices for gas and electricity do, of course, reduce fossil fuel consumption in a way beneficial to the climate - but not in an efficient way. For this, one should rely on a broadened EU CO2 Emissions Trading System, as is also applied in some other OECD countries, nationally or regionally (Welfens, 2022); an international integration of national CO2 emissions or allowance trading systems, for instance in the G20 context, is also desirable in this context.

It is up to policymakers in Brussels and the EU member states to temporarily change the existing approach of merit-order pricing in the electricity market under the special circumstances of the Russo-Ukrainian war; and to do so in such a way that the price of gas and electricity will fall. In this context, a changed market regime is urgently recommended for Germany and other EU countries, but also for the UK. One can only encourage policymakers to implement a swift and appropriate regime change in the electricity sector. Insofar as the necessary subsidy payments to gas-fired power generators increase the government deficit in the short term, it should be pointed out, with a view to compliance with the debt brake in Germany enshrined in the German Basic Law, that the braking effect of the proposed gas price cap on the price of electricity means an economic expansion effect (relative to the status quo situation) and can thus be expected to have tax revenue-increasing effects.

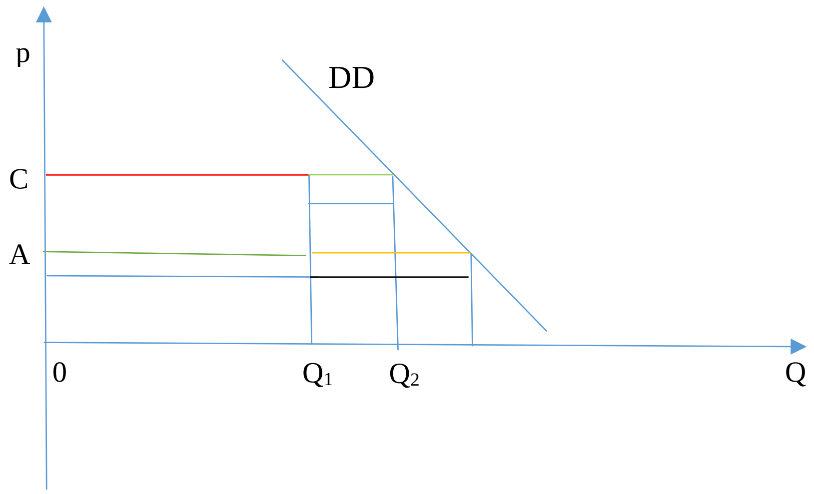
A special problem has become visible in Poland where the government has been quite hesitant to buy additional gas in the world market at rather high prices in summer 2022. This policy approach is risky and could require in the winter 2022/23 that other EU countries would have to supply additional gas to Poland during a national emergency situation. EU countries are entitled to support by partner countries in an energy crisis, but such assistance will come at considerable prices and at high political cost if the government itself is responsible for a national lack of buying sufficient energy quantities international markets (appendix 4).

With a view to future research, one could imagine a more differentiated macro model – possibly also an explicit multi-country model. Without a careful analysis and the inclusion of the macroeconomic effects on important economic variables, policymakers in the EU and the UK will hardly be able to make an optimal decision on the issues raised in the energy market(s) of the EU countries in 2022. It is therefore important to pay careful attention to the analysis findings presented herein, as they can assist policymakers in minimizing the significant welfare losses in Europe that would otherwise result from Russia’s decisions to cut its gas supply.

Appendix 1: The Merit Order System and a Subsidy/Price Cap

This appendix discusses some key issues related to the merit-order approach in the electricity market in the context of our simple model of the electricity market. Of particular interest is the question of whether or not a subsidy for the marginal supplier or a price cap has negative incentive effects for increasing supply for the more cost-efficient producers. We will argue in this section that one must differentiate between high and low cost differentials between the two producers and that, in the case of a high cost differential, there is no incentive for the low-cost producer – which could be renewable energy-based electricity generation - to replace the high-cost producer.

Fig. A1: Electricity market with a low- and high-cost producer



Source: Own representation.

Figure A1 shows the electricity market which is characterized by a high- and low-cost supplier. The low-cost supplier produces the amount Q_1, while the high-cost supplier produces quantity (Q_2-Q_1). The demand curve for electricity is given by the downward sloping schedule DD.

The cost-efficient producer could supply (with a 'normal' profit, granted by the regulator, which is given by the green and blue line) at price A, while the marginal supplier must charge price C. This yields a high windfall profit for the efficient supplier given by the area between the red and green line. In the case that an efficient producer would expand production, she would forego the high windfall profit for an extra normal profit given by the area between the orange and black line.

Notice that the incentive to expand production of the low-cost producer requires relatively small cost differentials and are further enhanced by a high price elasticity of (electricity) demand. However, given the high complementarity between electricity and production it is unlikely that the latter condition is satisfied. Since the marginal cost of renewable energy electricity production is very low and the cost of gas-fired power stations are high, there is a problem for the expansion of renewables in a free market competition (merit-order approach), namely that the expansion of renewable energy-based electricity production could be rather modest; this holds here under the assumption that gas-fired power stations are the marginal suppliers in the electricity market.

The introduction of CO2 certificates paradoxically weakens the incentives for renewable energy-based electricity production to the extent that such production is represented by large firms which will act in a strategic way in the electricity market. The CO2 allowance price will not affect the offer price of renewables-based electricity producers, while the cost/offer price of gas-fired power stations (and of coal-based power stations) would increase; hence the cost-differential will rise and - without price regulation - the expansion of renewables would paradoxically be impaired.

A price cap or a subsidy would increase the incentive for replacing the high cost producer since it would reduce the windfall profit under the status quo.

Further dynamic inefficiencies (related to non-linearities) from high gas prices - not considered in our analysis – could result from firm exits. If so, policies preventing persistent very high prices would have additional benefits.

Appendix 2: The Model

The model presented in this paper is a slight extension of the model developed by Clemens and Roeger (2022). This appendix provides a brief overview of the model structure and focusses on discussing the extension, namely the electricity market, in more detail. The model used is a fairly standard small open economy DSGE model. There are monopolistically competitive upstream producers indexed by $i\epsilon(0,1)$ which supply a final goods producer with intermediate goods X_{it}. The final goods producer uses a CES technology to transform the intermediates into a final good Y_t , which is sold to downstream consumer goods producers C_t^I , to the government G_t, a domestic electricity producer $E_t^{D,I}$and to consumers in the Rest of the World EX_t. The equilibrium condition for final goods is given by

$$Y_t = C_t^I + G_t + E_t^{D,I} + EX_t$$

The upstream intermediate good X_t is produced with a CES production function with labour and electricity as input. The downstream consumption good C_t is produced by a two level CES technology. In a first stage consumption goods producers combine domestic and foreign final goods to a CES aggregate. In a second stage this aggregate is combined with electricity to produce the consumption good. We assume that domestic and foreign final goods are substitutes with an EoS>1, while the final goods inputs and electricity are complements with elasticity of substitution $\sigma = 0.1$. (identical in intermediate and consumption good production). Both monopolistically competitive upstream and downstream producers - apart from the technology constraint - also face a Rotemberg type price adjustment friction, which gives rise to an upstream and downstream Phillips curve.

Electricity market

A novel feature in this model is the electricity market. Electricity demand E_t is given by the respective electricity demand of the consumption goods sector and the intermediate goods sector

$$E_t = s^{E,C} {P_t^{E,C}}^{-\sigma} C_t \ + s^{E,X} {P_t^{E,X}}^{-\sigma} X_t$$

where $P_t^{E,C}$ and $P_t^{E,C}$ is the price of electricity relative to the respective output price in the two sectors. There are two different suppliers of electricity, namely gas fired power stations and non-gas producers of electricity. Domestic gas fired power stations transform imported gas into electricity, using a linear technology

$$E_t^G = A_t^G G_t$$

The price for imported gas is given by P_t^G and domestic gas fired power stations are price takers in the world market for gas. This determines the electricity price, whenever gas is used for producing electricity.

$$P_t^E = \frac{1}{A_t^G} P_t^G$$

The domestic electricity price fluctuates one to one with the world market price for gas (expressed in domestic currency).

Non gas electricity providers use the domestic final good $E_t^{D,I}$ to produce electricity. In contrast to gas fired power stations which can adjust supply to any demand within a given period, domestic electricity can only supply a fixed baseload, i. e. their capacity is fixed in the short and medium term (up to a technology term which essentially summarises exogenous weather conditions). Here we think of nuclear power stations and renewables. In order to simplify notation we assume that the technology term is equal to one. Thus the electricity baseload is given by $E_t^{D,I}$ and the unit cost for producing non-gas electricity is equal to price for final goods P_t^Y.

We mimic the merit order market design in the electricity market by assuming that gas fired power stations are the marginal producers, which can adjust supply to any demand period by period while the baseload is provided by domestic non gas producers. In addition we assume a perfectly regulated electricity market. Thus marginal cost of gas fired power stations generally determines the market clearing price. In all our scenarios we assume a sufficiently high world market price for gas such that

$$P_t^E > P_t^Y$$

which generates a surprise profit equal to

$$\Pi_t^{E,D} = (P_t^E - P_t^Y)E_t^{D,I}.$$

The profit is received by domestic Ricardian households.

International dimensions

Concerning trade and international financial markets we assume that the domestic economy is exporting the domestic final good and importing the foreign final good. Both goods are substitutes. In addition, the domestic economy is importing gas at an exogenously given world market price (in foreign currency). On the financial side we assume that there is an internationally traded bond, which is a nearly perfect substitute for domestic bonds, thus interest parity holds nearly exactly. In addition we assume a flexible exchange rate and monetary policy is determined by a Taylor rule, both domestically and abroad.

Appendix 3: Early Network Regulation in Selected Scandinavian Countries

In the Scandinavian countries of Finland, Sweden and Norway (Viljainen et al., 2004) as well as in the Netherlands and the UK (and the United States; see Vogelsang, 2002), different types of incentive regulation in the electricity sector have been common in earlier decades for high-voltage transmission lines on the one hand and regional as well as local distribution system operators on the other. As already stated in the classic analysis paper by Averch and Johnson (1962), rate-of-return regulation has proven to be a problematic approach in the long run: The state or the regulator allows a maximum return on capital, with firms reporting relevant cost data to the regulator. This creates a problematic incentive problem for the regulated companies, namely to realize unnecessarily high levels of capital investment (including, if necessary, the purchase of particularly luxurious cars for management). After all, the capital employed is the benchmark for the maximum return on capital, which ultimately corresponds to indirect price regulation. Therefore, efficiency losses are to be expected in the medium and long term with this regulatory regime for the power grids.

A particular problem of sectoral regulation is regulatory capture (Stigler, 1971; Peltzman, 1976), whereby “revolving door effects” - i.e., the transition of employees from the regulated sector to the regulatory authority as new experts - can lead to the de facto capture of the regulatory authority by the regulated industry itself; the careers of the senior experts of a regulatory authority can also end in a regulated firm (for various mechanisms of regulatory capture, see Dal Bó, 2006). The regulated sector can then in effect influence the development of regulations that are particularly favorable to it, while at the same time arguing to the outside world that it is being regulated very extensively if returns are high. The quality of the regulator and the expertise available for it to draw on are very important in any type of regulation.

The Scandinavian countries mentioned above created an integrated electricity market relatively early on - with exports and imports of electricity within the framework of a pooled market at the wholesale level - but implemented different regulatory approaches in each case. According to EU regulations, transmission and distribution charges should be set in such a way that the national regulatory authorities in the electricity sector ensure charges that are non-discriminatory on the one hand and cost-based on the other. Therefore, it is not only electricity prices that are important for electricity generation, but also the network charges in the transmission sector (e.g., high-voltage lines) and at the local and regional distribution level.

In the electricity and telecommunications network sectors in the US and some EU countries, price cap regulations have initially applied to individual service offerings, and later to a package of service offerings - in order to provide incentives for innovation (on the telecommunications sector, see Welfens and Graack, 1996; for the electricity sector, see Viljainen et al., 2004; Welfens, 2007; Welfens and Keim, 2006). For such price regulation, one needs a forecast of the inflation rate - called the ‘X factor’ - on the one hand and the respective sectoral productivity progress rate on the other, with the latter ‘Y factor’ then yielding the relative price reduction target in percent for the current period.

A particular problem for regulators in estimating productivity progress is that, of course, the companies themselves hold the all-important cost data; by contrast, authorities can only make their decision on the basis of an engineered top-down or bottom-up cost model of the regulated companies. In this context, both in the telecommunications sector (following EU fixed network and service deregulation) in Germany and other EU countries, the focus over time has not been on the actual costs of service provision, but on the costs of efficient service provision. This should increase the pressure for innovation and diffusion in the regulated sectors, and also make market exit possible in principle. Thanks to modern data envelopment analysis (DEA), it is often possible to clarify efficiency issues in regulated sectors or networks, but also in unregulated sectors.

If one looks for early Scandinavian approaches to electricity regulation in the grid sector (here there is the problem of natural monopolies; i.e., decreasing marginal and average costs), a look at early regulatory approaches in Finland, Sweden, and Norway is particularly interesting. Finland's electricity regulation focused on "reasonable electricity prices" and the efficiency of distribution companies in the electricity sector. Electricity prices at the distribution level were covered by ex post rate-of-return regulation, and cost efficiency at the distribution level is determined by DEA analyses; on the part of the regulator, until 2005, investigations were conducted only when excessive prices were suspected. In subsequent years, the regulatory approach was modified - also to better comply with EU requirements. If excessive prices are identified by the regulator, the "excess profits" must be returned to customers in the subsequent period; and incidental losses can be deferred to the following regulatory period.

In Norway, efficiency analyses for distribution system operators were performed by a DEA approach. A revenue growth cap was set for the regulated companies; ex ante. Efficiency benchmarking based on the DEA analyses, which look at individual electricity companies in comparison and identify an efficiency frontier (representing top efficiency), lead to pressure to adapt or to innovate and improve efficiency for those companies that do not achieve top efficiency. The efficiency frontier must be reached by these firms in the medium term, as part of a multi-year adjustment program. Finally, the Norwegian regulatory system applies a bandwidth return regulation, with a minimum return on capital of 2% on the one hand and a maximum return on capital of 20% as a bandwidth (Grammeltvedt, 2003). In the event that profits exceed the upper limit, the "excess profit" must be returned to customers in the form of future price reductions.

Sweden has long pursued yardstick regulation - based on a comparison of companies - with a hypothetical efficient company or network acting as the yardstick; this regulatory approach is called the Network Performance Assessment Model (NPAM). Power quality is included through power outage rates or outage costs, looking at the difference between actual and expected outage costs.

One important point of such regulation concerns the inclusion of the cost of capital or the valuation of the capital employed. In Finland, this was based on the replacement costs in the network area, in Norway on a corrected book value, and in Sweden on the replacement costs of a hypothetical efficient network. Here, the legislator must provide a clear delimitation of the capital employed and a meaningful concept of capital valuation.

Appendix 4: Polish Problems in Buying Gas from New Sources

In a kind of refusal to accept significantly higher gas prices, Poland apparently had not realized any gas purchases by the end of August 2022, for example from Norway, after Russia's supply freeze in June 2022. The Polish government had relied on Norwegian suppliers as an alternative to Gazprom in view of a new Poland-Denmark-Norway gas pipeline and an existing Polish terminal for liquefied natural gas (LNG); without timely gas purchases by Poland, a situation looms in which other EU countries, especially Germany, would have to supply Poland with substitute gas in the event of a winter emergency, which is likely to provoke a political crisis within the EU - here the European Commission is urgently called upon to remind Poland of its gas purchasing obligations.

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